A Manual of Previously Recorded Non-indigenous Invasive and Native Transplanted Animal Species of the Laurentian Great Lakes and Coastal United States

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MANUAL DESCRIPTION

This manual presents geographic information by state of occurrence, and descriptions of the socio-economic impact created by the invasion of non-indigenous and native transplanted animal species in the Laurentian Great Lakes and the coastal waters of the United States. It is not a comprehensive literature review, but rather is intended as a primer for those unfamiliar with the socio-economic impacts of invasive aquatic and marine animals. Readers should also note that the information contained in this manual is current as of its publication date. New information and new species are routinely being added to the wider literature base. Most of the information was gathered from a number of web sites maintained by government agencies, commissions, academic institutions and museums. Additional information was taken from the primary and secondary literature. This manual focuses on socio-economic consequences of invasive species. Thus, ecological impacts, when noted in the literature, are not discussed unless a connection to socio-economic factors can be made. For a majority of the species listed, either the impact of their invasion is not understood, or it is not published in sources surveyed. In the species summaries, sources of information are cited except for information from the U.S. Geological Survey's (USGS) Nonindigenous Aquatic Species Database http://nas.er.usgs.gov. This website formed the base information used in creating tables on geographic distribution, and in many of the species summaries provided. Thus, whenever information is given without specific author/source and date citation, it has come from this comprehensive source.

LIST OF WEBSITES PROVIDING EXTENSIVE INFORMATION ON AQUATIC INVASIVE SPECIES

We surveyed a number of sources of information in compiling this compendium. These sources included databases managed by government agencies, commissions or academic institutions/museums. The most comprehensive database for identifying species presented herein, by geographic region, was the United States Geological Survey (USGS) Nonindigenous Aquatic Species (NAS) information resource.

U.S. Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

This database is a repository of spatially referenced biogeographic accounts of nonindigenous aquatic species found in the United States. This repository, located at the Center for Aquatic Resource Studies, is a comprehensive and integrated database. One can obtain information, maps, or issue queries from the NAS database regarding numerous nonindigenous aquatic species. For this report, we generated a preliminary list of coastal invasive species by querying the NAS database (USGS 2004). The database was queried for animals based upon hydrologic units (HUC) and for marine and brackish species only. The returned data were saved in text files and then imported and manipulated in MS Excel. We separated data taken from this site according to geographic area, and exotic and native transplant species are distinguished via color coding as seen in the data tables. These data formed the basis for the tables of this report, although a number of other sources were also used to include a small number of additional species not listed in NAS, and to provide information on the socio-economic impact caused by a number of the invasive species/transplanted natives.

Pam Fuller, Biologist and NAS Program leader, performed the animal database queries for the Great Lakes Region and also answered many questions we had about the database structure and content. She can be reached at pam_fuller@usgs.gov, U.S. Geological Survey, 7920 NW 71st St., Gainesville, FL 32653.

We also used several other databases, listed below.

1. Smithsonian Environmental Research Center (SERC). 2004. Marine Invasion Research Lab, Edgewater, MD. http://www.serc.si.edu/labs/marine_invasions/databases/index.jsp, September 2006.

The Smithsonian Environmental Research Center (SERC) Marine Invasion Research Lab provides access to three databases, AIRD, NEMESIS and NISbase (SERC 2004).

2. World Conservation Union (IUCN). 2006. Invasive Species Specialist Group (ISSG), Global Invasive Species Database, Auckland, New Zealand. http://www.issg.org/database/welcome/, September 2006.

The Global Invasive Species Database was developed by the Invasive Species Specialist Group (ISSG) as part of the global initiative on invasive species led by the Global Invasive Species Program (GISP). The ISSG is part of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). NISbase. The database contains information on species (from micro-organisms to animals and plants) biology and ecology, distribution (native and alien ranges), and impacts worldwide (IUCN 2006).

3. National Invasive Species Information Center, USDA National Agricultural Library
http://www.invasivespeciesinfo.gov/

This site provides opportunity to browse information by geography or by subject, including aquatic species, economic impacts, laws and regulations.

4. Non-Native Aquatic Species in the Gulf of Mexico and South Atlantic Regions Gulf States Marine Fisheries Commission http://nis.gsmfc.org/

This site provides detailed summaries of invasive species, publications and a bibliographic database.

5. Sea Grant National Aquatic Nuisance Species Clearinghouse
http://www.aquaticinvaders.org/

This site provides an on-line library on "research, public policy, and outreach education publications pertaining to invasive marine and fresh-water aquatic nuisance species."

6. Guidebook of Introduced Marine Species of Hawaii. Bishop Museum and the University of Hawaii.
http://www2.bishopmuseum.org/HBS/invertguide/invertintro.htm

This site provides substantial information in the form of species profiles.

7. Aquatic Nuisance Species Task Force site. ANS Task Force.
http://www.anstaskforce.gov/default.php

"The Aquatic Nuisance Species (ANS) Task Force is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990" (from the site).

8. Invasivespecies.gov: a gateway to federal and state invasive species activities and programs. http://www.invasivespecies.gov

This site is currently under construction – users are referred to http://invasivespeciesinfo.gov/ (listed above)

9. National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) site. http://www.glerl.noaa.gov/res/Programs/invasive/, February 2007.

This site provides a "Great Lakes Aquatic Nonidgenous Species List". This list was crossreferenced with the Great Lakes list obtained from NAS.

For some species in this survey, we have included information additional to the databases from the primary, and secondary (review), literature.

MAJOR TAXONOMIC GROUPS OF INVASIVE EXOTIC AND NATIVE TRANSPLANTED SPECIES, AND GENERAL SOCIO-ECONOMIC IMPACTS CAUSED BY THEIR INVASION

Phylum Porifera (sponges)

As a group, the sponges can be considered fouling organisms, although the impact of fouling for many of the species may be modest.

Phylum Ectoprocta (including bryozoans)

As with the sponges (above), bryozoans are commonly considered fouling organisms.

Phylum Coelenterata (Cnideria)

Class Anthozoa (anemones and corals)

As a group anemones are considered fouling organisms, although the impact of fouling in many instances may be modest.

Class Hydrozoa (hydroids and medusae)

This group has economic impact as fouling, and in the mortality some species can impose on economically important commercial resources. Some species also are considered nuisances due to the painful sting they can inflict on humans.

Phylum Rotifera (rotifers)

As a group, invasive rotifers are not known to generate socio-economic Impact

Phylum Gastrotricha (gastrotrichs)

As a group, this phylum is not known to generate socio-economic imact

Phylum Annelida

Class Polychaeta (polychaetes, bristleworms)

The major impact of bristleworms is in fouling, although the impact is probably modest for most species.

Subclass Oligochaeta (earthworms and leeches)

This subclass has little described socio-economic impact.

Phylum Mollusca

Class Bivalvia (bivalves such as mussels, shipworms, clams and oysters)

Bivalves are noted for fouling, and for causing negative impacts on recreationally and commercially important aquatic resources as well as taxa protected under endangered species legislation. The economic impact created

by the introduction of a number of species has been substantial. Shipworms cause economically important damage by destroying wooden structures. Some of the species have the potential to provide economic benefit via aquaculture or by supporting fisheries through natural production once established**.**

Class Gastropoda (snails, slugs and nudibranchs)

This taxonomic group includes species that have caused declines in the abundance of native commercially important resources, have produced bio-fouling problems in municipal water supplies, and have served as vectors of serious human diseases.

Phylum Arthropoda, Subphylum Crustacea

Class Branchiopoda (including the cladocerans)

This group is largely innocuous; however, the species described in the socio-economic impact section of this Manual (strating on page 42) are considered a nuisance by recreational anglers. Their introduction has caused substantial changes in plankton communities, with as yet undetermined possible consequences to the productivity of commercially and recreationally important fish species.

Class Maxillopoda

Subclass Thecostraca (including the barnacles)

Barnacles are fouling organisms that can produce substantial cost in cleaning and maintaining fouled structures.

Subclass Copepoda (the copepods)

The impact of parasitic copepods on socio-economically important fish species is probably modest.

Class Insecta (insects)

Although terrestrial invasive insects have produced substantial, widespread socio-economic impact, aquatic taxa included herein are not noted to do so.

Class Malacostraca

Order Amphipoda (the amphipods)

Very little socio-economic impact is described in the literature for this group.

Order Isopoda (the isopods)

The major problems caused by introduced isopods include fouling and deterioration of wooden structures such as pilings, docks and wooden hulled ships.

Order Decapoda (including lobsters, crabs and shrimp)

Problems caused by exotic decapods include: introducing diseases potentially destructive to native species of commercial importance, and/or humans; reducing the quality of commercially important resources through competitive interactions and predation; becoming a costly nuisance to commercial harvesters through net clogging and destruction; weakening of levees through tunneling activity; and others.

Phylum Chordata

Subphylum Urochordata-Tunicata (the tunicates or sea squirts)

Tunicates are noted for fouling, although in many instances the fouling impact may be modest.

Subphylum Vertebrata

Class Cyclostomata (including the sea lamprey)

Sea lampreys have been blamed for the destruction and loss of commercially and recreationally important fisheries in the Great Lakes, although their exact role versus overfishing in the decline of many species is not clear. Substantial cost and effort is focused on controlling the abundance of this invasive in the Laurentian Great Lakes basin, due to its potential to reduce the productivity of numerous recreationally important fish species, and to prevent successful restoration of locally extinct populations of the lake trout.

Class Osteichthyes (boney fishes)

The introduction and invasion of exotics from this group have created highly valued recreational fisheries, and supported other economically and valuable fisheries by serving as a food base for target species. However, species from this Class have caused the decline or loss of equally or more valued native resources, fouled beaches, power plant intakes and municipal water supplies, introduced destructive diseases into native populations of fishes, and caused other socio-economically important problems.

Class Mammalia

The nutria is the only mammal listed in any of our reference sources. It causes degradation of salt marsh habitat and can destabilize levees and dikes.

NON-INDIGENOUS AND NATIVE TRANSPLANTED SPECIES BY GEOGRAPHIC REGION: DESCRIPTION OF TABLES

The following pages (7-9) present tables listing common and scientific names, taxonomic grouping, and states (or lakes) of occurrence of non-indigenous exotic and native transplanted invasive species.

The tables here are derived from listings in the USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov. This database is the result of extension literature review and is maintained/updated by the USGS; it is the most comprehensive listing of U.S. invasives readily available. The NAS Database species listings provide links to collection maps and listings of collection information including date, site, habitat type (marine, brackish, freshwater) and status (listed as "collected", "failed", "extirpated", or "established"). Pamela Fuller of the USGS searched their database for the Great Lakes region for us, and we search all coastal regions of the U. S. by conducting "queries" of listings for each coastal state. In this compendium species within major taxonomic groupings are alphabetically arranged by common name.

This compendium focuses on the socio-economic consequences of invasive animal species. In the tables of this compendium, we included species listed in the NAS Database from all major animal taxonomic groups for which we could find some examples of socio-economic impacts; thus, even if specific species of invasives do not have a demonstrated socio-economic impact, or one that could be easily projected (which is true of the majority of species listed) but are in a Phylum or Class containing species that do, they are included. Three taxonomic groups, the Rotifera, Insecta and Gastrotricha, are included because they are represented by several or fewer invasive species documented in the literature we reviewed; thus, their inclusion, although socio-economic consequences are not delineated, did not unnecessarily "lengthen" the listings. We chose to exclude taxonomic groupings comprised solely of endoparasites (such as parasitic flukes and tapeworms). We consider these organisms a potential "consequence" of the invasion of free-living organisms rather than a direct invasion by exotic animals. However, parasitic copepods are included in tables where appropriate. This seeming "paradox" is based on inclusion of the Copoepoda in general, as there are free-living members of this group that have descriptions of socio-economic consequences in the literature; inclusion of some copepoda required inclusion of all invasives from that group.

Other protocol used for including/excluding species listings in the NAS Database in this compendium's tables included a specific set of criteria.

1. Species listed as “extirpated” or “failed” (introduction failed) in the NAS database or other sources were excluded from tables, as were species for which all collection entries preceded 1900.

2. If a species was not listed as “established”, and was collected two or fewer times across adjacent states within a region, it is designated with an asterisk (*) in tables of this compendium, thus noting that it represents an infrequent collection that likely has not become established. Species noted as “collected” only once or twice in one state, but showing multiple collection date/site listings or “established” listings for adjacent states are not designated with an asterisk. We do not differentiate between species the NAS Database designated as “established” from those “collected” on multiple dates/sites because original sources of collection information surveyed by the USGS - from Museum collection records to secondary literature references - may not have differentiated between the two designations. Thus, some species listed in the NAS database as “collected” across a number of sites/dates within a state may not be listed as “established” because the original literature did not designate them so, not because of an inability of these taxa to become an enduirng part of the biotic community even with a relatively widespread temporal and spatial invasive occurrence .

3. For coastal regions, (all tables other than Table 1, which covers the Laurentian Great Lakes), only taxa collected/established in either saltwater or brackish water habitats in coastal waters were included in the tables here. Species listed in the NAS Database as freshwater, and collected only in freshwater systems, were excluded. In some instances, species in the NAS Database listed as solely freshwater were collected in coastal/brackish water-estuarine habitats; they are included in the tables here. If after reviewing NAS database collection information and collection maps it was not clear whether a species listed for a coastal state was collected solely in freshwater habitats or, both in freshwater and in brackish/marine coastal waters, the listing is designated with a “?”.

4. A small number of taxa listings in the NAS database included species for a specific state whose native range included adjacent states within the same coastal region. Thus, the presence of these taxa may be more indicative of a ragne extension rather than an invasion. Such species are listed with a “+” in tables here. Since the Niagra River and Niagra Falls served as a natural barrier to movement between Lake Ontario and the upper Laurentian Great Lakes, and since a few taxa native to Lake Ontario produced substantial socio-economic impact once the barrier was breached, no species are designated with a “+” in the Great Lakes table even if native to Lake Ontario. Similarly, species native to either the Atlantic or Gulf Coasts, but listed by the NAS Database as invasive to the other, are not designated with a “+”. Table 3 includes both the South Atlantic and the Gulf of Mexico states because Florida, which has one of the highest diversity of non-indigenous transplants, occurs in both regions. Including Florida in two different tables (one for South Atlantic and one for Gulf of Mexico) would have

been unnecessarily redundant; however, movement from one coastline to the other would more properly represent an invasion than a range extension, thus the "+" designation was not used in this table for such changes in distribution.

The tables in this compendium are coded, with native transplants (species whose native range includes other regions of the U. S.) marked in gray.

To ensure that this document is flexible with regard to future additions, an * is listed in the right hand column of the tables to indicate page location of the description of the socio-economic impact caused by the species' invasion, rather than the page number itself.

Table 1. Invasive Aquatic Animals located in the Great Lakes Region

Highlighted records indicate native transplants. * denotes rare species. ? indicate freshwater, brackish, marine range unknown.

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Protozoan	Gastrotricha	Acineta nitrocrae	suctorian	in Ricciardi 2001 (sites not listed)	
Coelenterates-Hydrozoans	Clavidae	Cordylophora caspia	freshwater hydroid	Lake Erie	*
Coelenterates-Hydrozoans	Olindiidae	Craspedacusta sowerbyi	freshwater jellyfish	Lake Erie	
Ectoprocts	Vasicularidae	Lophopodella carteri	freshwater bryozoan	Lake Michigan	
Annelids-Oligochaetes	Naididae	Ripistes parasita	oligochaete	Lake Huron, Lake Michigan, Lake Superior	
Annelids-Oligochaetes	Tubificidae	Gianius aquaedulcis	oligochaete	Niagara River	
Annelids-Oligochaetes	Tubificidae	Potamothrix bedoti	oligochaete	Lake Michigan	
Annelids-Oligochaetes	Tubificidae	Potamothrix moldaviensis	oligochaete	Lake Michigan	
Annelids-Oligochaetes	Tubificidae	Potamothrix vejdovsky	oligochaete	Lake Michigan	
Annelids-Oligochaetes	Tubificidae	Branchiura sowerbyi	tubificid worm	Lake Erie, Lake Huron, Lake St. Clair	*
Mollusks-Bivalves	Corbiculidae	Corbicula fluminea	Asian clam	Lake Erie, Lake Michigan, Lake Superior	*
Mollusks-Bivalves	Sphaeriidae	Sphaerium corneum	European fingernailclam	Lake Erie, Lake Ontario, Lake Superior	
Mollusks-Bivalves	Sphaeriidae	Pisidium amnicum	greater European peaclam	Lake Ontario, Lake Superior	
Mollusks-Bivalves	Sphaeriidae	Pisidium henslowanum*	Henslow's pea clam	Lake Erie, Lake Michigan (Heard 1962)	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Mollusks-Bivalves	Sphaeriidae	Pisidium supinum	Humpback pea clam	in Ricciardi 2001 (sites not listed)	
Mollusks-Bivalves	Sphaeriidae	Pisidium moitessierianum	pygmy pea clam	Lake Erie, Lake Superior, Lake St. Clair	
Mollusks-Bivalves	Dreissenidae	Dreissena bugensis	quagga mussel	Lake Erie, Lake Michigan, Lake Ontario, Lake St. Clair	*
Mollusks-Bivalves	Dreissenidae	Dreissena polymorpha	zebra mussel	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	*
Mollusks-Gastropods	Viviparidae	Viviparus georgianus*	banded mystery snail	Lake Erie	
Mollusks-Gastropods	Lymnaeidae	Radix auricularia*	big-ear radix	Lake Erie, Lake Huron	
Mollusks-Gastropods	Hydrobiidae	Gillia altilis	buffalo pebble snail	Oneida Lake (Ontario)	
Mollusks-Gastropods	Viviparidae	Cipangopaludina chinensis malleata*	Chinese mysterysnail	Lake Erie, Lake Michigan	*
Mollusks-Gastropods	Valvatidae	Valvata piscinalis	European stream valvata	Lake Erie, Lake Ontario	
Mollusks-Gastropods	Viviparidae	Cipangopaludina japonica	Japanese mysterysnail	Lake Erie	
Mollusks-Gastropods	Bithyniidae	Bithynia tentaculata	mud bithynia or faucet snail	Lake Erie, Lake Michigan, Lake Ontario	*
Mollusks-Gastropods	Hydrobiidae	Potamopyrgus antipodarum	New Zealand mudsnail	Lake Ontario, Lake Superior	*

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Crustaceans-Amphipods	Corophiidae	Corophium mucronatum	an amphipod	Lake St. Clair	
Crustaceans-Amphipods	Gammaridae	Echinogammarus ischnus	an amphipod	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	*
Crustaceans-Amphipods	Gammaridae	Gammarus fasciatus	freshwater shrimp	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior	
Crustaceans-Cladocerans	Cercopagidae	Cercopagis pengoi	fish-hook water flea	Lake Erie, Lake Michigan, Lake Ontario	*
Crustaceans-Cladocerans	Cercopagidae	Bythotrephes longimanus	spiny water flea	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	*
Crustaceans-Cladocerans	Daphniidae	Daphnia lumholtzi	water flea	Lake Erie, Lake Michigan	*
Crustaceans-Cladocerans	Bosminidae	Bosmina maritima	water flea	in Ricciardi 2001 (sites not listed)	
Crustaceans-Cladocerans	Bosminidae	Eubosmina coregoni	water flea	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior	
Crustaceans-Copepods	Temoridae	Eurytemora affinis	calanoid copepod	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Crustaceans-Copepods	Diaptomidae	Skistodiaptomus pallidus	calanoid copepod	Lake Erie, Lake Huron, Lake Ontario, Lake St. Clair	
Crustaceans-Copepods	Cyclopidae	Cyclops strenuus	cyclopoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Cyclopidae	Megacyclops viridis	cyclopoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Ameridae	Nirocra hibernica	harpacticoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Ameridae	Nitocra incerta	harpacticoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Cletodidae	Heteropsyllus cf. nunni	harpacticoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Diosacidae	Schizopera borutzkyi	harpacticoid copepod	in Ricciardi 2001 (sites not listed)	
Crustaceans-Copepods	Argulidae	Argulus japonicus	parasitic copepod	Lake Michigan	
Crustaceans-Copepods	Lernaeopodidae	Salmincola lotae	parasitic copepod	Lake Superior	
Crustaceans-Copepods	Ergasilidae	Neoergasilus japonicus	parasitic copepod	Lake Huron	*
Crustaceans-Crabs	Grapsidae	Eriocheir sinensis	Chinese mitten crab	Lake Erie, Lake Superior	*
Crustaceans-Crabs	Cambaridae	Orconectes rusticus	rusty crayfish	Lake Superior	*
Crustaceans-Shrimp	Mysidacea	Hemimysis anomala	bloody-red shrimp	Lake Michigan (NCRAIS 2007)	*
Platyhelminthes-flatworms	Dugesilidae	Dugesia polychroa	flatworm	Lake Ontario (Mills et al. 1993)	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Insecta	Pyralidae	Acentropus niveus	aquatic moth	Lake Ontario, Lake Erie (Mills et al. 1993)	
Insecta	Erirhinidae	Tanysphyrus lemnae	aquatic weevil	in Mills et al. 1993 (sites not listed)	
Fishes	Clupeidae	Alosa pseudoharengus	alewife	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	*
Fishes	Anguillidae	Anguilla rostrata	American eel	Lake Erie, Lake Huron	*
Fishes	Clupeidae	Alosa sapidissima	American shad	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair	*
Fishes	Salmonidae	Salmo salar	Atlantic salmon	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	*
Fishes	Cyprinidae	Hypophthalmichthys nobilis	bighead carp	Lake Erie	
Fishes	Catostomidae	Ictiobus niger	black buffalo	Lake Huron, Lake Ontario	
Fishes	Clupeidae	Alosa aestivalis	blueback herring	Lake Ontario	
Fishes	Salmonidae	Salmo trutta	brown trout	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Fishes	Esocidae	Esox niger	chain pickerel	Lake Erie, Lake Ontario	
Fishes	Salmonidae	Oncorhynchus tshawytscha	Chinook salmon	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	
Fishes	Salmonidae	Oncorhynchus mykiss irideus	coast rainbow trout	Lake Michigan	
Fishes	Salmonidae	Oncorhynchus kisutch	coho salmon	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	
Fishes	Cyprinidae	Cyprinus carpio	common carp	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	
Fishes	Salmonidae	Oncorhynchus clarkii	cutthroat trout	Lake Huron	
Fishes	Percidae	Gymnocephalus cernuus	Eurasian ruffe	Lake Huron, Lake Michigan, Lake Superior	*
Fishes	Pleuronectidae	Platichthys flesus	European flounder	Lake Erie, Lake Superior	
Fishes	Gasterosteidae	Apeltes quadracus	fourspine stickleback	Lake Superior	
Fishes	Cyprinidae	Notropis buchanani	ghost shiner	Lake Erie, Lake Huron, Lake St. Clair	
Fishes	Clupeidae	Dorosoma cepedianum	gizzard shad	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Fishes	Cyprinidae	Carassius auratus	goldfish	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	
Fishes	Cyprinidae	Ctenopharyngodon idella	grass carp	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario	*
Fishes	Centrarchidae	Lepomis cyanellus	green sunfish	Lake Huron	
Fishes	Salmonidae	Oncorhynchus nerka	kokanee, sockeye	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario	
Fishes	Salmonidae	Salmo salar sebago	landlocked Atlantic salmon	Lake Superior	*
Fishes	Ictaluridae	Noturus insignis	margined madtom	Upper Great Lakes Drainage	
Fishes	Centrarchidae	Lepomis humilis	orangespotted sunfish	Lake Erie	
Fishes	Cobitidae	Misgurnus anguillicaudatus	oriental weatherfish	Lake Michigan	
Fishes	Salmonidae	Oncorhynchus gorbuscha	pink salmon	Lake Erie, Lake Huron, Lake Michigan. Lake Ontario, Lake Superior	*
Fishes	Osmeridae	Osmerus mordax	rainbow smelt	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	*

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Fishes	Salmonidae	Oncorhynchus mykiss	rainbow trout	Lake Erie, Lake Huron, Lake Michigan, Lake Superior, Lake St. Clair	*
Fishes	Characidae	Pygocentrus nattereri	red piranha	Lake Huron, Lake St. Clair	
Fishes	Cyprinidae	Cyprinella lutrensis	red shiner	Lake Michigan	
Fishes	Characidae	Piaractus brachypomus	red-bellied pacu	Lake Huron, Lake Ontario	
Fishes	Centrarchidae	Lepomis microlophus	redear sunfish	Lake St. Clair	
Fishes	Catostomidae	Carpiodes carpio	river carpsucker	Lake Erie	
Fishes	Percidae	Percina shumardi*	river darter	Lake Michigan	
Fishes	Gobiidae	Apollonia melanostomus	round goby	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior	*
Fishes	Cyprinidae	Scardinius erythrophthalmus	rudd	Lake Erie, Lake Ontario	*
Fishes	Percidae	Sander canadense	sauger	Lake Michigan	
Fishes	Petromyzontidae	Petromyzon marinus	sea lamprey	Lake Erie, Lake Huron, Lake Michigan, Lake Superior, Lake St. Clair	*
Fishes	Lepisosteidae	Lepisosteus platostomus	shortnose gar	Lake Michigan	
Fishes	Clupeidae	Alosa chrysochloris	skipjack herring	Lake Michigan	

Table 1 con't. Invasive Aquatic Animals located in the Great Lakes Region

Taxonomic Group	Family	Genus Species	Common Name	Lake	Reviewed below
Fishes	Moronidae	Morone saxatilis*	striped bass	Lake Ontario	*
Fishes	Cyprinidae	Phenacobius mirabilis	suckermouth minnow	Lake Erie	
Fishes	Gasterosteidae	Gasterosteus aculeatus	threespine stickleback	Lake Erie, Lake Huron, Lake Michigan, Lake Superior, Lake St. Clair	
Fishes	Gobiidae	Proterorhinus semilunaris	tubenose goby	Lake Erie, Lake Huron, Lake St. Clair	
Fishes	Poeciliidae	Gambusia affinis	Western mosquitofish	Found in the watersheds of several Great Lakes	*
Fishes	Ictaluridae	Ameiurus catus	white catfish	Lake Erie	
Fishes	Moronidae	Morone americana	white perch	Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake Superior, Lake St. Clair	*
Reptiles-Turtles	Emydidae	Trachemys scripta elegans	Red-eared Slider	Lake Erie	

Notes: Source, USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

Table 2. Invasive Marine and Estuarine Aquatic Animals located from Maine to Virginia

Highlighted records indicate native transplants. * denotes rare species. ? indicate freshwater, brackish, marine range unknown, + indicates range extension

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Coelenterates-Anthozoan	Diadumenidae	Diadumene lineata*	Orange-striped (green) sea anemone	MD	*
Coelenterates-Hydrozoans	Campanulinidae	Blackfordia virginica*	Black Sea jellyfish	VA	
Coelenterates-Hydrozoans	Moerisiidae	Maeotias inexspectata	Black Sea jellyfish	VA	
Coelenterates-Hydrozoans	Olindiidae	Gonionemus vertens	clinging jellyfish	MA	
Coelenterates-Hydrozoans	Clavidae	Cordylophora caspia*	freshwater/ hydroid	MD, NY	*
Coelenterates-Hydrozoans	Bougainvilliidae	Garveia franciscana	hydroid	MD	*
Coelenterates-Hydrozoans	Moerisiidae	Moerisia lyonsi*?		MD, VA	
Ectoprocts	Membraniporidae	Membranipora membranacea	bryozoan	CT, ME, MA, NH, RI	
Ectoprocts	Loxosomatidae	Loxosomatoides laevis		MD	
Entoprocts	Pedicellinidae	Barentsia benedeni	entoproct	MD, MA	
Mollusks-Bivalves	Corbiculidae	Corbicula fluminea	Asian clam	MD, VA	*
Mollusks-Bivalves	Mactridae	Rangia cuneata+	Atlantic rangia	MD, NY	
Mollusks-Bivalves	Teredinidae	Teredo bartschi*	Bartsch	NJ, CT	
Mollusks-Bivalves	Dreissenidae	Mytilopsis leucophaeata	dark false mussel	NY	
Mollusks-Bivalves	Ostreidae	Ostrea edulis*	edible oyster	RI, ME	

Table 2 con't. Invasive Marine and Estuarine Aquatic Animals located from Maine to Virginia

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Mollusks-Bivalves	Cyrenoididae	Cyrenoida floridana+	Florida marsh clam	MD	
Mollusks-Bivalves	Teredinidae	Teredo navalis	naval shipworm	MD	*
Mollusks-Bivalves	Teredinidae	Teredo furcifera*	shipworm	NJ	*
Mollusks-Gastropods	Littorinidae	Littorina littorea	common periwinkle	VA, DE, NJ, NY, CT, RI	
Mollusks-Gastropods	Muricidae	Stramonita haemastoma	Florida rocksnail	MD	
Mollusks-Gastropods	Ellobiidae	Myosotella myosotis	marsh snail	MD	
Mollusks-Gastropods	Truncatellidae	Truncatella subcylindrica	snail	RI	
Mollusks-Gastropods	Muricidae	Rapana venosa	veined rapa whelk	VA	*
Mollusks-Nudibranchs	Tritoniidae	Tritonia plebeia*	European nudibranch	ME, MA	*
Mollusks-Nudibranchs	Tergipedidae	Cuthona perca	Lake Merritt cuthona	MD	
Mollusks-Nudibranchs	Tergipedidae	Tenellia adspersa*	miniature aeolis	VA	
Annelids-Polychaetes	Serpulidae	Ficopomatus enigmaticus*	Australian tubeworm	MD	*
Crustaceans-Amphipods	Gammaridae	Gammarus daiberi*	amphipod	NY	
Crustaceans-Barnacles	Balanidae	Balanus amphitrite	striped barnacle, purple acorn barnacle	MD, NJ, NY, VA	*
Crustaceans-Copepods	Temoridae	Eurytemora affinis	calanoid copepod	VA, MA, NY, MA	
Crustaceans-Crabs	Grapsidae	Hemigrapsus sanguineus	Asian shore crab	CT, ME, MA, NH, NY, RI, MD, NJ, DE, VA	*
Crustaceans-Crabs	Grapsidae	Eriocheir sinensis*	Chinese mitten crab	MD	*

Table 2 con't. Invasive Marine and Estuarine Aquatic Animals located from Maine to Virginia

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Crustaceans-Crabs	Cancridae	Cancer magister*	Dungeness crab	MA	
Crustaceans-Crabs	Portunidae	Carcinus maenas	green crab	CT, DE, ME, MD, MA, NH, NJ, NY, RI	*
Crustaceans-Isopods	Idoteidae	Synidotea laevidorsalis*	isopod	NJ	*
Crustaceans-Isopods	Ligiidae	Ligia exotica	wharf roach	VA, MD, NJ	
Tunicates	Styelidae	Styela clava	Asian tunicate	CT, ME, MA, NH, NY, RI	*
Tunicates	Styelidae	Botrylloides violaceus	orange sheath tunicate	CT, ME, MA, NH, NY, RI	*
Tunicates	Ascidiidae	Ascidiella aspersa*	tunicate	CT, RI	
Tunicates	Perophoridae	Ecteinascidia turbinata	tunicate	VA, MD	
Tunicates	Didemnidae	Diplosoma macdonaldi	tunicate	CT, RI, MA	
Tunicates	Didemnidae	Didemnum cf. lahillei	white crust tunicate	RI, MA, NH, ME	*
Fishes	Salmonidae	Salmo trutta?	brown trout	RI, MA	
Fishes	Salmonidae	Oncorhynchus tshawytscha?	Chinook salmon	NJ	*
Fishes	Salmonidae	Oncorhynchus kisutch?	coho salmon	ME, NH, MA, MD, DE, NH	
Fishes	Salmonidae	Oncorhynchus nerka?	kokanee, sockeye	ME	
Fishes	Salmonidae	Oncorhynchus gorbuscha*?	pink salmon	ME	*
Fishes	Scorpaenidae	Pterois volitans	red lionfish	NJ, NY, RI	*

Table 2 con't. Invasive Marine and Estuarine Aquatic Animals located from Maine to Virginia

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Fishes	Clupeidae	Dorosoma petenense?	threadfin shad	MD	
Fishes	Gasterosteidae	Gasterosteus aculeatus*	threespine stickleback	MA	

Notes: Source, USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

Table 3. Invasive Marine and Estuarine Aquatic Animals located from North Carolina to Texas

Highlighted records indicate native transplants. * denotes rare species. ? indicate freshwater, brackish, marine range unknown.

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Coelenterates-Anthozoan	Dendrophylliidae	Tubastraea coccinea	orange cup coral	FL, LA, TX	
Coelenterates-Anthozoan	Haliplanellidae	Diadumene lineata	orangestriped green anemone	FL	*
Coelenterates-Hydrozoans	Moerisiidae	Maeotias inexspectata*	Black Sea jellyfish	SC	
Coelenterates-Hydrozoans	Clavidae	Cordylophora caspia	freshwater hydroid	FL	
Coelenterates-Scyphozoan	Mastigiidae	Phyllorhiza punctata	Australian spotted jellyfish	AL, FL, LA, MS, TX	*
Coelenterates-Scyphozoan	Cyaneidae	Drymonema dalmatinum	pink meanie	AL, FL, MS, SC	
Ectoprocts	Victorellidae	Sundanella sibogae	bryozoan	FL	
Ectoprocts	Victorellidae	Victorella pavida	bryozoan	FL	
Annelids-Polychaetes	Serpulidae	Hydroides elegans	polychaete worm	FL	
Annelids-Polychaetes	Spionidae	Boccardiella ligerica	spionid worm	FL	
Mollusks-Bivalves	Mactridae	Rangia cuneata	Atlantic rangia	NC	
Mollusks-Bivalves	Mytilidae	Mytella charruana	Charru mussel	FL, GA	*
Mollusks-Bivalves	Tridacnidae	Tridacna crocea*	giant clam	FL	
Mollusks-Bivalves	Tridacnidae	Tridacna maxima*	giant clam	FL	
Mollusks-Bivalves	Gryphaeidae	Hyotissa hyotis	giant coxcomb oyster, honeycomb oyster	FL	
Mollusks-Bivalves	Mytilidae	Perna viridis	green mussel	FL, GA, SC	*
Mollusks-Bivalves	Teredinidae	Lyrodus medilobatus*	Indo-Pacific shipworm	FL	
Mollusks-Bivalves	Mytilidae	Perna perna	Mexilhao mussel	TX	

Table 3 con't. Invasive Marine and Estuarine Aquatic Animals located from North Carolina to Texas

Taxonomic Group	Family	Genus Species	Common Name	States	Page
Mollusks-Bivalves	Pteriidae	Pinctada margaritifera*	Pacific pearl oyster	FL	
Mollusks-Bivalves	Ostreidae	Crassostrea ariakensis	Suminoe oyster	NC	
Mollusks-Gastropods	Littorinidae	Littorina littorea*	common periwinkle	FL	
Mollusks-Gastropods	Ellobiidae	Myosotella myosotis*	marsh snail	FL	
Mollusks-Gastropods	Thiaridae	Melanoides tuberculatus	red-rim melania	FL	*
Mollusks-Gastropods	Truncatellidae	Truncatella subcylindrica	snail	FL	
Mollusks-Nudibranchs	Tergipedidae	Cuthona perca*	Lake Merritt cuthona	FL	
Mollusks-Nudibranchs	Stiligeridae	Ercolania fuscovittata*	nudibranch	FL	
Crustaceans-Amphipods	Cheluridae	Chelura terebrans	amphipod	FL	
Crustaceans-Barnacles	Balanidae	Balanus reticulatus	barnacle	FL	
Crustaceans-Barnacles	Balanidae	Balanus trigonus	barnacle	FL	*
Crustaceans-Barnacles	Balanidae	Balanus amphitrite	striped barnacle, purple acorn barnacle	FL, TX, NC, SC	*
Crustaceans-Barnacles	Balanidae	Megabalanus coccopoma	Titan acorn barnacle	NC, SC, GA, FL, LA	
Crustaceans-Copepods	Temoridae	Eurytemora affinis*	calanoid copepod	SC	
Crustaceans-Copepods	Centropagidae	Centropages typicus	copepod	TX	
Crustaceans-Crabs	Grapsidae	Hemigrapsus	Asian shore crab	NC	
Crustaceans-Crabs	Portunidae	Callinectes bocourti	Bocourt swimming Crab, red blue crab	FL, MS, SC, NC, AL	
Crustaceans-Crabs	Grapsidae	Eriocheir sinensis*	Chinese mitten crab	LA	*
Crustaceans-Crabs	Porcellanidae	Petrolisthes armatus	green porcelain crab	SC, GA, FL	
Crustaceans-Crabs	Portunidae	Charybdis hellerii	Indo-Pacific crab	FL, NC, SC	

Table 3 con't. Invasive Marine and Estuarine Aquatic Animals located from North Carolina to Texas

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Crustaceans-Crabs	Portunidae	Callinectes exasperatus*	rugose swimming crab	GA	
Crustaceans-Isopods	Sphaeromatidae	Sphaeroma terebrans	isopod	FL	
Crustaceans-Isopods	Sphaeromatidae	Sphaeroma walkeri	isopod	FL	
Crustaceans-Isopods	Idoteidae	Synidotea laevidorsalis*	isopod	SC	*
Crustaceans-Isopods	Ligiidae	Ligia exotica	wharf roach	FL, NC, SC	
Crustaceans-Shrimp	Penaeidae	Penaeus monodon	Asian tiger shrimp	FL, GA, SC, AL	*
Crustaceans-Shrimp	Penaeidae	Penaeus stylirostris*	blue shrimp	SC	
Crustaceans-Shrimp	Palaemonidae	Macrobrachium rosenbergil*	Malaysian prawn	MS	
Crustaceans-Shrimp	Nannosquillidae	Pullosquilla litoralis	mantis shrimp	FL	
Crustaceans-Shrimp	Penaeidae	Litopenaeus vannamei	Pacific white shrimp	SC, TX	*
Crustaceans-Tanaids	Tanaidae	Zeuxo maledivensis	tanaid	FL	
Tunicates	Styelidae	Botryllus schlosseri	golden star tunicate	FL	*
Tunicates	Styelidae	Styela plicata	pleated sea squirt	FL	*
Tunicates	Didemnidae	Didemnum perlucidum	white crust tunicate	TX	*
Fishes	Salmonidae	Salmo salar*	Atlantic salmon	NC	*
Fishes	Pomacanthidae	Pomacanthus asfur*	Arabian angel	FL	
Fishes	Cichlidae	Sarotherodon melanotheron	blackchin tilapia	FL	
Fishes	Pomacanthidae	Pomacanthus annularis*	blue ringed angelfish	FL	
Fishes	Pomacanthidae	Pomacanthus xanthometopon*	bluefaced angel	FL	
Fishes	Callichthyidae	Hoplosternum littorale	brown hoplo	FL	
Fishes	Salmonidae	Salmo trutta ?	brown trout	NC	*

Table 3 con't. Invasive Marine and Estuarine Aquatic Animals located from North Carolina to Texas

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Fishes	Balistidae	Rhinecanthus verrucosus*	bursa triggerfish	FL	
Fishes	Pomacanthidae	Pomacanthus imperator*	emperor angelfish	FL	
Fishes	Grammatidae	Gramma loreto	fairy basslet	FL	
Fishes	Serranidae	Cromileptes altivelis	humpback grouper	FL	*
Fishes	Scorpaenidae	Pterois volitans/miles	lionfish	NC, FL	
Fishes	Zanclidae	Zanclus cornutus*	Moorish Idol	FL	
Fishes	Cichlidae	Oreochromis mossambicus?	Mozambiqua tilapia	FL, NC	
Fishes	Acanthuridae	Naso lituratus*	orangespine unicornfish	FL	
Fishes	Ephippididae	Platax orbicularis*	orbiculate batfish	FL	
Fishes	Serranidae	Cephalopholis argus*	peacock hind	FL	*
Fishes	Poeciliidae	Belonesox belizanus	pike killifish	FL	
Fishes	Chaetodontidae	Chaetodon lunula*	Racoon Butterfly	FL	
Fishes	Salmonidae	Oncorhynchus mykiss*?	rainbow trout	AL, TX	
Fishes	Scorpaenidae	Pterois volitans	red lionfish	FL, GA, NC, SC	*
Fishes	Chaetodontidae	Heniochus intermedius*	Red Sea bannerfish	FL	
Fishes	Ancanthuridae	Zebrasoma desjardinii*	sailfin tang	FL	
Fishes	Ancanthuridae	Zebrasoma veliferum*	sailfin tang	FL	
Fishes	Scatophagidae	Scatophagus argus*	scat	FL	
Fishes	Pomacanthidae	Pomacanthus semicirculatus*	semicircle angelfish, zebra angelfish	FL	
Fishes	Acanthuridae	Acanthurus sohal*	Sohal surgeonfish	FL	
Fishes	Tetraodontidae	Tetraodon nigroviridis	spotted green pufferfish	LA	

Table 3 con't. Invasive Marine and Estuarine Aquatic Animals located from North Carolina to Texas

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Fishes	Clupeidae	Dorosoma petenense?	threadfin shad	NC, SC, GA, FL	
Fishes	Characidae	Colossoma or Piaractus sp.	unidentified pacu	FL	
Fishes	Moronidae	Morone chrysops?	white bass	FL, AL	
Fishes	Ancanthuridae	Zebrasoma flavescens*	yellow tang	FL	
Fishes	Pomacanthidae	Pomacanthus maculosus*	yellowbar angelfish	FL	
Fishes	Ancanthuridae	Zebrasoma xanthurum*	yellowtail tang	FL	
Mammals	Capromyidae	Myocastor coypus	nutria	GA, FL, LA	*

Notes: Source, USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

Table 4. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Highlighted records indicate native transplants. * denotes rare species. ? indicate freshwater, brackish, marine range unknown.

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Sponges	Suberitidae	Prosuberites sp.	American Atlantic sponge	CA	
Sponges	Clionidae	Cliona sp.	boring sponge	CA, OR, WA, AK	
Sponges	Halichondridae	Halichondria bowerbanki	Bowerbank's halichondria	CA, OR, WA	*
Sponges	Halichondridae	Hymeniacidon sinapium	Orange sponge	CA	
Sponges	Haliclonidae	Haliclona loosanoffi	Loosanoff's haliclona	CA, OR	
Sponges	Clathriidae	Microciona prolifera	red beard sponge	CA, WA	
Coelenterates-Anthozoan	Diadumenidae	Diadumene cincta	orange anemone	CA	
Coelenterates-Anthozoan	Haliplanellidae	Haliplanella lineata	orangestriped green anemone	CA, OR, WA	
Coelenterates-Anthozoan	Diadumenidae	Diadumene lineata	orange-striped sea anemone	CA, OR, WA	*
Coelenterates-Anthozoan	Diadumenidae	Diadumene franciscana	San Francisco anemone	CA	
Coelenterates-Anthozoan	Diadumenidae	Diadumene leucolena	white anemone	CA, OR	
Coelenterates-Hydrozoans	Tubulariidae	Tubularia crocea	hydroid	CA, OR, WA	
Coelenterates-Hydrozoans	Campanulariidae	Obelia spp.	hydrozoan	WA	
Coelenterates-Hydrozoans	Cladonematidae	Cladonema uchidae	hydrozoan	CA	
Coelenterates-Hydrozoans	Campanulinidae	Blackfordia virginica	Black Sea jellyfish	CA, OR	
Coelenterates-Hydrozoans	Moerisiidae	Maeotias inexspectata	Black Sea jellyfish	CA	
Coelenterates-Hydrozoans	Corynidae	Sarsia tubulosa	clapper hydromedusa	CA, WA	
Coelenterates-Hydrozoans	Clavidae	Clava multicornis	club hydroid	CA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Coelenterates-Hydrozoans	Campanulariidae	Obelia bidentata	doubletoothed hydroid	CA, OR, WA	
Coelenterates-Hydrozoans	Clavidae	Cordylophora caspia	freshwater hydroid	CA, OR, WA	*
Coelenterates-Hydrozoans	Corymorphidae	Corymorpha sp.	hydroid	CA	
Coelenterates-Hydrozoans	Bougainvilliidae	Garveia franciscana	hydroid	CA	*
Coelenterates-Hydrozoans	Campanulariidae	Gonothyraea clarki	hydroid	CA, OR, WA	
Coelenterates-Hydrozoans	Campanulariidae	Obelia dichotoma*	hydroid	CA	
Coelenterates-Hydrozoans	Cladonematidae	Cladonema radiatum		WA	
Coelenterates-Hydrozoans	Moerisiidae	Moerisia sp.		CA	
Coelenterates-Scyphozoan	Mastigiidae	Phyllorhiza punctata	Australian spotted jellyfish	CA	*
Coelenterates-Scyphozoan	Ulmaridae	Aurelia aurita	moon jelly	CA, WA	
Platyhelminthes	Callioplanidae	Pseudostylochus ostreophagus*	flatworm	WA	
Ectoprocts	Nolellidae	Anguinella palmata	ambiguous bryozoan	CA	
Ectoprocts	Bugulidae	Bugula sp.	bugula bryozoan	OR, WA	
Ectoprocts	Bugulidae	Bugula stolonifera	bryozoan	CA, WA	
Ectoprocts	Victorellidae	Victorella pavida	bryozoan	CA	
Ectoprocts	Watersiporidae	Watersipora subtorquata	bryozoan	CA, OR	*
Ectoprocts	Alcyonidioidea	Alcyonidium gelatinosum	bryozoan	CA	
Ectoprocts	Cryptosulidae	Cryptosula pallasiana	bryozoan	CA, OR, WA	*
Ectoprocts	Vesiculariidae	Zoobotryon verticillatum	bryozoan	CA	
Ectoprocts	Vesiculariidae	Bowerbankia gracilis	creeping bryozoan	CA, OR, WA	
Ectoprocts	Membraniporidae	Conopeum tenuissimum	lacy crust bryozoan	CA, OR	
Ectoprocts	Schizoporellidae	Schizoporella unicornis	single horn bryozoan	CA, OR, WA, AK	
Ectoprocts	Alcyonidiiae	Alcyonidium sp.		CA, OR	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Entoprocts	Pedicellinidae	Barentsia benedeni	entoproct	CA, OR, WA	
Annelids-Oligochaetes	Naididae	Paranais frici	tubificid worm	CA, WA	
Annelids-Oligochaetes	Tubificidae	Branchiura sowerbyi	tubificid worm	CA	*
Annelids-Oligochaetes	Tubificidae	Potamothrix bavaricus	tubificid worm	CA	
Annelids-Oligochaetes	Tubificidae	Limnodriloides monothecus	tubificid worm	CA, WA	
Annelids-Oligochaetes	Tubificidae	Tubificoides apectinatus	tubificid worm	CA, WA	
Annelids-Oligochaetes	Tubificidae	Tubificoides brownae	tubificid worm	CA, OR	
Annelids-Oligochaetes	Tubificidae	Tubificoides wasselli	tubificid worm	CA	
Annelids-Oligochaetes	Tubificidae	Varichaetadrilus augustipenis	tubificid worm	CA	
Annelids-Oligochaetes	Tubificidae	Teneridrilus mastix	oligochaete	CA	
Annelids-Oligochaetes	Tubificidae	Tubificoides diazi		OR, WA	
Annelids-Polychaetes	Serpulidae	Ficopomatus enigmaticus	Australian tubeworm	CA	*
Annelids-Polychaetes	Maldanidae	Sabaco elongatus	bamboo worm	CA, WA	
Annelids-Polychaetes	Capitellidae	unknown unknown	capitellid thread worm	OR	
Annelids-Polychaetes	Capitellidae	Capitella capitata	capitellid worm	WA	
Annelids-Polychaetes	Capitellidae	Capitella spp.	capitellid worm	WA	
Annelids-Polychaetes	Capitellidae	Heteromastus filiformis	capitellid worm	CA, OR, WA, AK	
Annelids-Polychaetes	Nereididae	Nereis acuminata*	clam worm	CA	
Annelids-Polychaetes	Phyllodocidae	Eteone sp.	milky paddle worm	OR	
Annelids-Polychaetes	Spionidae	Polydora cornuta	mud worm	CA, OR, WA	
Annelids-Polychaetes	Spionidae	unknown unknown	other Spionid mud worms	OR	
Annelids-Polychaetes	Phyllodocidae	unknown unknown	Phyllodocid paddle worms	OR	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Annelids-Polychaetes	Nereididae	Neanthes succinea	pile worm	CA, OR, WA	
Annelids-Polychaetes	Eunicidae	Marphysa sanguinea	red-gilled Marphysa	CA	
Annelids-Polychaetes	Sabellidae	Manayunkia speciosa	sabellid worm	CA	
Annelids-Polychaetes	Sabellidae	Potamilla sp.	sabellid worm	CA	
Annelids-Polychaetes	Sabellidae	Terebrasabella heterouncinata	sabellid worm	CA	
Annelids-Polychaetes	Spionidae	Boccardiella ligerica	spionid worm	CA	
Annelids-Polychaetes	Spionidae	Marenzellaria viridis	spionid worm	CA	
Annelids-Polychaetes	Spionidae	Pseudopolydora kempi	spionid worm	CA, OR, WA	
Annelids-Polychaetes	Spionidae	Pseudopolydora paucibranchiata	spionid worm	CA, OR, WA	
Annelids-Polychaetes	Spionidae	Streblospio benedicti	spionid worm	CA, OR, WA	
Annelids-Polychaetes	Ampharetidae	Amphicteis floridus		WA	
Annelids-Polychaetes	Dorvilleidae	Ophryotrocha labronica*		CA	
Annelids-Polychaetes	Syllidae	Pionosyllis uraga		WA	
Annelids-Polychaetes	Cirratulidae	Tharyx tesselata		WA	
Mollusks-Bivalves	Veneridae	Gemma gemma	amethyst gemclam	CA, WA	
Mollusks-Bivalves	Corbiculidae	Corbicula fluminea	Asian clam	CA, OR	*
Mollusks-Bivalves	Corbulidae	Corbula amurensis	Overbite clam	CA	
Mollusks-Bivalves	Semelidae	Theora lubrica	Asian semele	CA	
Mollusks-Bivalves	Tellinidae	Macoma balthica	Baltic macoma	CA	
Mollusks-Bivalves	Teredinidae	Lyrodus pedicellatus	blacktip shipworm	CA	
Mollusks-Bivalves	Mytilidae	Mytilus complex	blue mussel	WA	
Mollusks-Bivalves	Teredinidae	Bankia carinata*	carinate shipworm	CA	
Mollusks-Bivalves	Anomiidae	Anomia chinensis	Chinese jingle	OR, WA	
Mollusks-Bivalves	Ostreidae	Crassostrea virginica	eastern oyster	CA, WA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Mollusks-Bivalves	Ostreidae	Ostrea edulis	edible oyster	CA, WA	
Mollusks-Bivalves	Petricolidae	Petricolaria pholadiformis	false angelwing	CA, WA	
Mollusks-Bivalves	Pholadidae	Zirfaea crispata	great piddock		
Mollusks-Bivalves	Mytilidae	Musculista senhousia	green mussel	CA, WA	
Mollusks-Bivalves	Veneridae	Meretrix lusoria	hard clam	CA, WA	
Mollusks-Bivalves	Veneridae	Astralium triumphans	Japanese littleneck	CA, OR, WA	
Mollusks-Bivalves	Laternulidae	Laternula marilina*	littoral spoon clam	OR, CA	
Mollusks-Bivalves	Mytilidae	Mytilus galloprovincialis	Mediterranean blue mussel	CA, OR, WA	*
Mollusks-Bivalves	Teredinidae	Teredo navalis	naval shipworm	CA, OR, WA	*
Mollusks-Bivalves	Veneridae	Mercenaria mercenaria	northern quahog	CA, WA	
Mollusks-Bivalves	Ostreidae	Crassostrea gigas	Pacific giant oyster	CA, OR, WA	
Mollusks-Bivalves	Psammobiidae	Nuttallia obscurata	purple mahogany-clam	WA, OR	
Mollusks-Bivalves	Trapezidae	Neotrapezium liratum	quadrate trapezium	WA	
Mollusks-Bivalves	Mytilidae	Geukensia demissa	ribbed mussel	CA	
Mollusks-Bivalves	Semelidae	Theora fragilis	semele	CA	
Mollusks-Bivalves	Myidae	Mya arenaria	softshell clam	CA,OR, WA, AK	*
Mollusks-Bivalves	Ostreidae	Crassostrea ariakensis	Suminoe oyster	WA	
Mollusks-Bivalves	Arcidae	Arca transversa*	transverse ark	CA	
Mollusks-Bivalves	Pteriidae	Pteria sterna*	wing-oyster	CA	
Mollusks-Bivalves	Tellinidae	Macoma petalum		CA	
Mollusks-Gastropods	Muricidae	Thais clavigera*	rocksnail	WA	
Mollusks-Gastropods	Muricidae	Urosalpinx cinerea	Atlantic oyster drill	CA, WA	*
Mollusks-Gastropods	Muricidae	Rapana thomasiana*	Black sea murex	WA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Mollusks-Gastropods	Melongenidae	Busycotypus canaliculatus	channeled whelk	CA	*
Mollusks-Gastropods	Viviparidae	Cipangopaludina chinensis	Chinese mysterysnail	CA	*
Mollusks-Gastropods	Calyptraeidae	Crepidula fornicata	common Atlantic slippersnail	CA, WA	
Mollusks-Gastropods	Littorinidae	Littorina littorea	common periwinkle	CA, WA	
Mollusks-Gastropods	Calyptraeidae	Crepidula convexa	convex slippersnail	CA	
Mollusks-Gastropods	Calyptraeidae	Crepidula glauca*	convex slippersnail	CA	
Mollusks-Gastropods	Nassariidae	Nassarius obsoletus	eastern mudsnail	CA, WA	
Mollusks-Gastropods	Calyptraeidae	Crepidula plana	eastern white slippersnail	CA, WA	
Mollusks-Gastropods	Turbinidae	Astralium triumphans*	gastropod	CA	
Mollusks-Gastropods	Potamididae	Batillaria attramentaria	Japanese false cerith	CA, WA	
Mollusks-Gastropods	Nassariidae	Nassarius fraterculus	Japanese nassa	WA	
Mollusks-Gastropods	Muricidae	Ceratostoma inornatum	Japanese oyster drill	CA, OR, WA	
Mollusks-Gastropods	Pomatiopsidae	Cecina manchurica	Manchurian cecina	WA	
Mollusks-Gastropods	Ellobiidae	Myosotella myosotis	marsh snail	CA, OR, WA	
Mollusks-Gastropods	Philinidae	Philine auriformis	New Zealand sea slug	CA, OR	
Mollusks-Gastropods	Haliotididae	Haliotis rufescens*	red abalone	WA	
Mollusks-Gastropods	Thiaridae	Melanoides tuberculatus	red-rim melania	CA	*
Mollusks-Gastropods	Muricidae	Ocenebra japonica	rocksnail	WA	
Mollusks-Gastropods	Littorinidae	Littorina saxatilis	rough periwinkle	CA	
Mollusks-Gastropods	Lottiidae	Collisella striata*	Striate limpet	WA	
Mollusks-Gastropods	Pyramidellidae	Boonea bisuturalis	two-groove odostome	CA	
Mollusks-Gastropods	Buccinidae	Neptunea arthritica*	whelk	WA	
Mollusks-Gastropods	Turbinidae	Turbo soronatus coreensis*		WA	
Mollusks-Nudibranchs	Tergipedidae	Catriona rickettsi	nudibranch	CA	
Mollusks-Nudibranchs	Goniodorididae	Okenia plana	flat okenia	CA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Mollusks-Nudibranchs	Tergipedidae	Cuthona perca	Lake Merritt cuthona	CA	
Mollusks-Nudibranchs	Tergipedidae	Tenellia adspersa	miniature aeolis	CA, OR	
Mollusks-Nudibranchs	Eubranchidae	Eubranchus misakiensis*	Misaki balloon aeolis	CA	
Mollusks-Nudibranchs	Cumanotidae	Cumanotus beaumonti	polyp aeolis	WA	
Mollusks-Nudibranchs	Facelinidae	Sakuraeolis enosimensis*	white-tentacled Japanese aeolis	CA	
Mollusks-Polyplacophors	Acanthochitonidae	Acanthochitona achates*	Japanese chiton	WA	
Crustaceans-Amphipods	Ampeliscidae	Ampelisca abdita	amphipod	CA	
Crustaceans-Amphipods	Ampithoidea	Ampithoe longimana*	long-antennaed tube-building amphipod	CA	
Crustaceans-Amphipods	Ampithoidae	Ampithoe valida	amphipod	CA, OR, WA	
Crustaceans-Amphipods	Caprellidae	Caprella mutica	skeleton shrimp	CA, OR, WA	
Crustaceans-Amphipods	Cheluridae	Chelura terebrans	amphipod	CA, WA	
Crustaceans-Amphipods	Corophiidae	Corophium acherusicum	slender tube amphipod	CA, OR, WA	
Crustaceans-Amphipods	Corophiidae	Corophium alienense	amphipod	CA	
Crustaceans-Amphipods	Corophiidae	Corophium herteroceratum	amphipod	CA	
Crustaceans-Amphipods	Corophiidae	Corophium insidiosum	amphipod	CA, OR, WA	
Crustaceans-Amphipods	Corophiidae	Corophium uenoi	amphipod	CA	
Crustaceans-Amphipods	Phoxocephalidae	Eobrolgus spinosus	amphipod	OR, WA	
Crustaceans-Amphipods	Oedicerotidae	Eochelidium sp.		WA	
Crustaceans-Amphipods	Gammaridae	Gammarus daiberi	amphipod	CA	
Crustaceans-Amphipods	Corophiidae	Grandidierella japonica	amphipod	CA, OR, WA	
Crustaceans-Amphipods	Ischyroceridae	Jassa marmorata	tube amphipod	CA, OR, WA	
Crustaceans-Amphipods	Leucothoidae	Leucothoe sp.	amphipod	CA	
Crustaceans-Amphipods	Gammaridae	Melita nitida	amphipod	CA, OR, WA	
Crustaceans-Amphipods	Gammaridae	Melita sp.	amphipod	CA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Crustaceans-Amphipods	Dexaminidae	Paradexamine sp.	amphipod	CA	
Crustaceans-Amphipods	Pleustidae	Parapleustes derzhavini	amphipod	CA, OR, WA	
Crustaceans-Amphipods	Stenothoidae	Stenothoe valida	amphipod	CA	
Crustaceans-Amphipods	Talitridae	Transorchestia enigmatica	amphipod	CA	
Crustaceans-Barnacles	Balanidae	Balanus improvisus	bay barnacle	CA, OR, WA	
Crustaceans-Barnacles	Balanidae	Balanus amphitrite	striped barnacle, purple acorn barnacle	CA	*
Crustaceans-Copepods	Centropagidae	Sinocalanus doerrii	Asian calanoid copepod	CA, WA	
Crustaceans-Copepods	Pseudodiaptomidae	Pseudodiaptomus inopinus	Asian calanoid copepod	CA,OR, WA	
Crustaceans-Copepods	Acartiidae	Acartiella sinensis	Asian copepod	CA	
Crustaceans-Copepods	Oithonidae	Limnoithona sinensis	Asian copepod	CA, OR, WA	
Crustaceans-Copepods	Oithonidae	Oithona sinenesis?	Asian copepod	CA	
Crustaceans-Copepods	Tortanidae	Tortanus dextrilobatus	Asian copepod	CA	
Crustaceans-Copepods	Leuconidae	Nippoleucon hinumensis	Asian cumacean	CA, OR, WA	
Crustaceans-Copepods	Temoridae	Eurytemora affinis	calanoid copepod	OR	
Crustaceans-Copepods	Oithonidae	Oithona davisae	calanoid copepod	CA	
Crustaceans-Copepods	Pseudodiaptomidae	Pseudodiaptomus forbesi	calanoid copepod	CA	
Crustaceans-Copepods	Pseudodiaptomidae	Pseudodiaptomus marinus	calanoid copepod	CA, WA	
Crustaceans-Copepods	Tortanidae	Tortanus sp.	calanoid copepod	CA	
Crustaceans-Copepods	Oithonidae	Limnoithona tetraspina	copepod	CA	
Crustaceans-Copepods	Stephidae	Stephos pacificus	copepod	WA	
Crustaceans-Copepods	Mytilicolidae	Mytilicola orientalis	parasitic copepod	CA, WA	
Crustaceans-Crabs	Grapsidae	Eriocheir sinensis	Chinese mitten crab	CA, WA	*
Crustaceans-Crabs	Xanthidae	Rhithropanopeus harrisii	estuarine mud crab, Harris mud crab	CA, OR	*

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Crustaceans-Crabs	Portunidae	Carcinus maenas	green crab	CA, OR, WA	*
Crustaceans-Crabs	Grapsidae	Eriocheir japonicus*	Japanese mitten crab	OR	
Crustaceans-Crayfish	Cambaridae	Procambarus clarkii	red swamp crayfish	CA	
Crustaceans-Crayfish	Cambaridae	Orconectes virilis	virile crayfish	CA	
Crustaceans-Isopods	Bopyridae	Orthione griffenis	Griffen's isopod	OR, WA	
Crustaceans-Isopods	Anthuridae	Paranthura sp.	isopod	CA	
Crustaceans-Isopods	Cirolanidae	Eurylana arcuata	isopod	CA	
Crustaceans-Isopods	Idoteidae	Synidotea laevidorsalis	isopod	CA	
Crustaceans-Isopods	Janiridae	Iais californica	isopod	CA, OR	
Crustaceans-Isopods	Sphaeromatidae	Dynoides dentisinus	isopod	CA	
Crustaceans-Isopods	Sphaeromatidae	Sphaeroma quoyanum	Burrowing Australian isopod	CA, OR	
Crustaceans-Isopods	Sphaeromatidae	Sphaeroma walkeri*	isopod	CA	
Crustaceans-Isopods	Limnoidae	Limnoria tripunctata	wood boring gribble	CA, OR, WA	
Crustaceans-Isopods	Limnoidae	Limnoria quadripunctata	wood boring gribble	CA	*
Crustaceans-Isopods	Asellidae	Caecidotea racovitzai		WA	
Crustaceans-Mysids	Mysidae	Acanthomysis bowmani	mysid	CA	
Crustaceans-Mysids	Mysidae	Acanthomysis aspera	crab	CA	
Crustaceans-Mysids	Mysidae	Deltamysis holmquistae		CA	
Crustaceans-Ostracods	Sarsiellidae	Eusarsiella zostericola	an ostracod	CA	
Crustaceans-Sea fleas	Nebaliidae	Nebalia sp.	sea flea	CA	
Crustaceans-Shrimp	Alpheidae	Salmoneus gracilipes	snapping shrimp	CA	
Crustaceans-Shrimp	Palaemonidae	Palaemon macrodactylus	Oriental shrimp	CA, OR, WA	
Crustaceans-Shrimp	Palaemonidae	Exopalaemon modestus	Siberian prawn	WA	
Crustaceans-Tanaids	Tanaidae	Sinelobus sp.	tanaid	CA, OR	
Crustaceans-Tanaids	Tanaidae	Sinelobus stanfordi	tanaid	WA	

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Crustaceans-Tanaids	Tanaidae	Tanais sp.	tanaid	WA	
Tunicates	Cionidae	Ciona savignyi	tunicate	CA, WA	
Tunicates	Didemnidae	Didemnum cf. lahillei	white crust tunicate	CA, WA	*
Tunicates	Styelidae	Botrylloides violaceus	orange sheath tunicate	CA, OR, WA, AK	*
Tunicates	Styelidae	Styela clava	Asian tunicate	CA, OR, WA	*
Tunicates	Molgulidae	Molgula manhattensis	common sea grape	CA, OR, WA	
Tunicates	Styelidae	Botryllus schlosseri	golden star tunicate	CA, OR, WA	*
Tunicates	Styelidae	Styela plicata	pleated sea squirt	CA	*
Tunicates	Steylidae	Styela canopus	rough sea tunicate	CA	*
Tunicates	Didemnidae	Diplosoma listerianum	sea squirt	OR	
Tunicates	Cionidae	Ciona intestinalis	Sea vase	CA, WA	*
Fishes	Anguillidae	Anguilla rostrata	American eel	CA	*
Fishes	Clupeidae	Alosa sapidissima	American shad	CA, OR, WA, AK	*
Fishes	Salmonidae	Salmo salar	Atlantic salmon	OR, WA, AK	*
Fishes	Salmonidae	Thymallus arcticus	Arctic grayling	CA	
Fishes	Fundulidae	Lucania goodei	bluefin killifish	CA	
Fishes	Salmonidae	Salvelinus fontinalis?	brook trout	WA	
Fishes	Salmonidae	Salmo trutta?	brown trout	CA, OR	*
Fishes	Gobiidae	Tridentiger trigonocephalus	chameleon goby	CA	
Fishes	Salmonidae	Oncorhynchus masou?	Cherry salmon	WA	
Fishes	Anguillidae	Anguilla anguilla*	European eel	CA	
Fishes	Atherinidae	Menidia beryllina	inland silverside	CA	
Fishes	Cichlidae	Oreochromis mossambicus?	Mozambiqua tilapia	CA	
Fishes	Fundulidae	Lucania parva	rainwater killifish	CA, OR	
Fishes	Gobiidae	Tridentiger bifasciatus	Shimofuri goby	CA	*

Table 4 con't. Invasive Marine and Estuarine Aquatic Animals located on the West Coast including Alaska

Taxonomic Group	Family	Genus Species	Common Name	States	Reviewed below
Fishes	Gobiidae	Tridentiger barbatus	Shokihaze goby	CA	
Fishes	Anguillidae	Anguilla australis*	shortfin eel	CA	
Fishes	Moronidae	Morone saxatilis	striped bass	CA. OR, WA	*
Fishes	Clupeidae	Dorosoma petenense	threadfin shad	CA, OR	
Fishes	Anguillidae	Anguilla sp.?	unidentified eel	CA, OR	
Fishes	Moronidae	Morone chrysops?	white bass	CA, WA	
Fishes	Gobiidae	Acanthogobius flavimanus	yellowfin goby	CA	*
Mammals	Capromyidae	Myocastor coypus?	nutria	OR	

Notes: Source, USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

Table 5. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Highlighted records indicate native transplants. * denotes rare species. ? indicate freshwater, brackish, marine range unknown.

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Sponges	Chalinidae	Sigmadocia (Haliclona) caerulea	blue Caribbean sponge	*
Sponges	Clionidae	Cliona sp.	boring sponge	
Sponges	Niphatidae	Gelliodes fibrosa	gray encrusting sponge	*
Sponges	Suberitidae	Suberites zeteki	Lobate sponge	*
Sponges	Mycalidae	Mycale (Aegogropila) armata	orange keyhole sponge	
Sponges	Mycalidae	Mycale armata	orange sponge	*
Sponges	Mycalidae	Mycale (Zygomycale) parishii	red-brown branching sponge	*
Sponges	Amphilectidae	Biemna fistulosa	sponge	
Sponges	Amphilectidae	Biemna sp.*	sponge	
Sponges	Callyspongidae	Callyspongia cf. diffusa	sponge	
Sponges	Dysideidae	Dysidea arenaria*	sponge	
Sponges	Dysideidae	Dysidea avara*	sponge	
Sponges	Dysideidae	Dysidea cf. arenaria	sponge	
Sponges	Dysideidae	Dysidea cf. avara	sponge	
Sponges	Dysideidae	Dysidea sp. 3*	sponge	
Sponges	Raspailiidae	Echinodictyum asperum	sponge	
Sponges	Heteropiidea	Heteropia glomerosa	sponge	
Sponges	Sollasellidae	Topsentia sp.	sponge	
Sponges	Haliclonidae	Toxiclona sp.*	sponge	

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Sponges	Dysideidae	Dysidea sp.	sponge	
Sponges	Halichondriidae	Halichondria melanadocia	sponge	*
Sponges	Mycalidae	Mycale (Camia) cecilia	sponge	
Sponges	Mycalidae	Neofolitispa unguiculata	sponge	
Coelenterates-Anthozoan	Haliplanellidae	Haliplanella lineata	orangestriped green anemone	
Coelenterates-Anthozoan	Diadumenidae	Diadumene lineata	Orange-striped sea anemone	*
Coelenterates-Anthozoan	Diadumenidae	Diadumene franciscana	San Francisco anemone	
Coelenterates-Anthozoan	Clavulariidae	Carijoa (Telesto) riisei	snowflake coral	*
Coelenterates-Anthozoan	Diadumenidae	Diadumene leucolena	white anemone	
Coelenterates-Anthozoan	Xeniidae	Sarcothelia n. sp.*		
Coelenterates-Hydrozoans	Halocordylidae	Pennaria (Halocordyle) disticha	Christmas tree hydroid	*
Coelenterates-Hydrozoans	Campanulariidae	Obelia bidentata	doubletoothed hydroid	
Coelenterates-Hydrozoans	Sertulariidae	Dynamena crisiodes	hydroid	
Coelenterates-Hydrozoans	Haleciidae	Halecium beanii*	hydroid	
Coelenterates-Hydrozoans	Sertulariidae	Thyroseyphus fruticosus	hydroid	
Coelenterates-Hydrozoans	Campanulariidae	Clytia hemisphaerica	hydroid	
Coelenterates-Hydrozoans	Bougainvilliidae	Garveia humilis	hydroid	
Coelenterates-Hydrozoans	Campanulariidae	Obelia dichotoma	hydroid	
Coelenterates-Hydrozoans	Clavidae	Turritopsis nutricula	hydroid	
Coelenterates-Hydrozoans	Plumulariidae	Antennella secundaria*	thecate hydroid	
Coelenterates-Hydrozoans	Lafoeidae	Anthohebella parasitica*		
Coelenterates-Hydrozoans	Campanulariidae	Clytia latitheca*		
Coelenterates-Hydrozoans	Eudendriidae	Eudendrium sp.*		
Coelenterates-Hydrozoans	Plumulariidae	Halopteris polymorpha*		

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Coelenterates-Hydrozoans	Plumulariidae	Plumularia floridana*		
Coelenterates-Hydrozoans	Plumulariidae	Plumularia strictocarpa		
Coelenterates-Hydrozoans	Sertulariidae	Sertularella areyi*		
Coelenterates-Hydrozoans	Sertulariidae	Sertularella tongensis*		
Coelenterates-Hydrozoans	Sertulariidae	Sertularia ligulata*		
Coelenterates-Hydrozoans	Sertulariidae	Tridentata humferi		
Coelenterates-Hydrozoans	Sertulariidae	Tridentata ligulata*		
Coelenterates-Hydrozoans	Sertulariidae	Tridentata turbinata*		
Coelenterates-Hydrozoans	Kirchenpaueriidae	Ventromma halecioides*		
Coelenterates-Hydrozoans	Syntheciidae	Synthecium megathecum		
Coelenterates-Scyphozoan	Mastigiidae	Phyllorhiza punctata	Australian spotted jellyfish	*
Coelenterates-Scyphozoan	Casseopeidae	Cassiopea medusa	upsidedown jellyfish	*
Coelenterates-Scyphozoan	Ulmaridae	Aurelia sp.		
Ectoprocts	Bugulidae	Bugula dentata	blue-green Bryozoan	
Ectoprocts	Schizoporellidae	Schizoporella errata	branching bryozoan	*
Ectoprocts	Bugulidae	Bugula neritina	brown bryozoan	*
Ectoprocts	Bugulidae	Bugula stolonifera	bryozoan	
Ectoprocts	Bugulidae	Aetea truncata	bryozoan	
Ectoprocts	Watersiporidae	Watersipora edmondsoni	bryozoan	
Ectoprocts	Vesiculariidae	Zoobotryon verticillatum	bryozoan	
Ectoprocts	Vesiculariidae	Amathia distans	bushy bryozoan	*
Ectoprocts	Schizoporellidae	Schizoporella unicornis	single horn bryozoan	
Ectoprocts	Scrupocellariidae	Caberia boryi*		
Ectoprocts	Bugulidae	Caulibugula dendrograpta		
Ectoprocts	Diaperoeciidae	Diaperforma intricata		

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Ectoprocts	Bugulidae	Bugula robusta		
Ectoprocts	Bugulidae	Caulibugula caliculata		
Ectoprocts	Savignyellidae	Savignyella lafonti		
Ectoprocts	Schizoporellidae	Schizoporella cf. errata		*
Ectoprocts	Schizoporellidae	Schizoporella sp.		
Annelids-Polychaetes	Serpulidae	Ficopomatus enigmaticus	Australian tubeworm	*
Annelids-Polychaetes	Capitellidae	Capitella sp.*	capatellid worm	
Annelids-Polychaetes	Sabellidae	Sabellastarte sanctijosephi	Featherduster worm, Fan worm	*
Annelids-Polychaetes	Chaetopteridae	Chaetopterus sp.	parchment worm	*
Annelids-Polychaetes	Sabellidae	Branchiomma nigromaculata	polychaete worm	
Annelids-Polychaetes	Chaetopteridae	Chaetopterus variopedatus	polychaete worm	
Annelids-Polychaetes	Serpulidae	Hydroides crucigera	polychaete worm	
Annelids-Polychaetes	Serpulidae	Hydroides dirampha	polychaete worm	
Annelids-Polychaetes	Serpulidae	Neodexiospira foraminosa*	polychaete worm	
Annelids-Polychaetes	Nereidae	Nereis areanacoedonta*	polychaete worm	
Annelids-Polychaetes	Spionidae	Polydora nuchalis	polychaete worm	
Annelids-Polychaetes	Spionidae	Polydora websteri*	polychaete worm	
Annelids-Polychaetes	Serpulidae	Pomatoleios kraussi	polychaete worm	
Annelids-Polychaetes	Spintheridae	Spinther japonicus	polychaete worm	
Annelids-Polychaetes	Serpulidae	Hydroides elegans	polychaete worm	
Annelids-Polychaetes	Serpulidae	Salmacina dysteri	serpulid worm	*
Annelids-Polychaetes	Spionidae	Streblospio benedicti*	spionid worm	
Annelids-Polychaetes	Opheliidae	Armandia intermedia		
Annelids-Polychaetes	Capitellidae	Capitella sp. cf. capitata*		

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Annelids-Polychaetes	Serpulidae	Serpula vermicularis		
Annelids-Polychaetes	Phyllodocidea	Eulalia sanguinea		
Annelids-Polychaetes	Serpulidae	Hydroides branchyacantha		
Annelids-Polychaetes	Sabellidae	Sabellastarte spectabilis		
Mollusks-Bivalves	Semelidae	Abra sp. a*	abra	
Mollusks-Bivalves	Hiatellidae	Hiatella arctica	Arctic hiatella	
Mollusks-Bivalves	Teredinidae	Teredo bartschi	Bartsch shipworm	
Mollusks-Bivalves	Teredinidae	Lyrodus pedicellatus	blacktip shipworm	
Mollusks-Bivalves	Ostreidae	Saccostrea glomerata	commercial rock oyster	
Mollusks-Bivalves	Ostreidae	Crassostrea amasa	coral rock oyster	
Mollusks-Bivalves	Ostreidae	Lopha cristagalli	coxcomb oyster	
Mollusks-Bivalves	Ostreidae	Crassostrea virginica	eastern oyster	
Mollusks-Bivalves	Tridacnidae	Tridacna crocea	giant clam	
Mollusks-Bivalves	Tridacnidae	Tridacna gigas	giant clam	
Mollusks-Bivalves	Tridacnidae	Tridacna squamosa	giant clam	
Mollusks-Bivalves	Veneridae	Venerupis philippinarum	Japanese littleneck	*
Mollusks-Bivalves	Chamidae	Chama brassica	jewelbox	
Mollusks-Bivalves	Chamidae	Chama fibula	jewelbox	
Mollusks-Bivalves	Chamidae	Chama lazarus	jewelbox	
Mollusks-Bivalves	Chamidae	Chama pacifica	jewelbox	
Mollusks-Bivalves	Anomiidae	Anomia nobilis	Jingle shell, Saddle oyster	*
Mollusks-Bivalves	Chamidae	Chama macerophylla	Leafy jewelbox	*
Mollusks-Bivalves	Mytilidae	Mytilus galloprovincialis	Mediterranean blue mussel	*
Mollusks-Bivalves	Ostridae	Dendrostrea sandvichensis	oyster	
Mollusks-Bivalves	Ostreidae	Crassostrea gigas	Pacific giant oyster	

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Mollusks-Bivalves	Myidae	Sphenia luticola	Pacific sphenia	
Mollusks-Bivalves	Pteriidae	Pinctada fucata martensi	pearl oyster	
Mollusks-Bivalves	Ostridae	Saccostrea cucullata	rock oyster	
Mollusks-Bivalves	Taredinidae	Bankia bipalmulata*	shipworm	
Mollusks-Bivalves	Teredinidae	Lyrodus affinis	shipworm	
Mollusks-Bivalves	Teredinidae	Teredo furcifera	shipworm	*
Mollusks-Bivalves	Myidae	Sphenia sp. a	sphenia	
Mollusks-Bivalves	Pholadidae	Martesia striata	striate piddock	
Mollusks-Bivalves	Chamidae	Chama elatensis		
Mollusks-Gastropods	Cypraeidae	Cypraea clandestina	cowrie	
Mollusks-Gastropods	Cypraeidae	Cypraea cribraria	cowrie	
Mollusks-Gastropods	Cypraeidae	Cypraea cylindrica	cowrie	
Mollusks-Gastropods	Cypraeidae	Cypraea gaspardi	cowrie	
Mollusks-Gastropods	Cypraeidae	Cypraea hirundo	cowrie	
Mollusks-Gastropods	Cypraeidae	Eurosaria poraria	cowrie	
Mollusks-Gastropods	Cypraeidae	Mauritia depressa	cowrie	
Mollusks-Gastropods	Fissurellidae	Diodora ruppelli	limpet	
Mollusks-Gastropods	Hipponicidae	Hipponix australis	limpet	
Mollusks-Gastropods	Lymnaeidea	Pseudosuccinna columella	mimic lymnaea	
Mollusks-Gastropods	Calyptraeidae	Crucibulum spinosum	spiny cup-and-saucer shell	
Mollusks-Gastropods	Calyptraeidae	Crepidula aculeata	spiny slippersnail	
Mollusks-Gastropods	Muricidae	Vitularia miliaris	spotted vitularia	
Mollusks-Gastropods	Pyramidellidae	Hinemoa indica		
Mollusks-Gastropods	Vermetidae	Eualetes tulipa		
Mollusks-Gastropods	Vermetidae	Vermetus alii		

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Mollusks-Nudibranchs	Tergipedidae	Cuthona perca	Lake Merritt cuthona	
Arthropoda-Pycogonid	Phoxichilidiidae	Anoplodactylus californicus*	sea spider	
Arthropoda-Pycogonid	Phoxichilidiidae	Anoplodactylus digitalis*	sea spider	
Arthropoda-Pycogonid	Callipallindae	Callipallen sp.*	sea spider	
Arthropoda-Pycogonid	Tanystylidae	Tanystylum rehderi*	sea spider	
Arthropoda-Pycogonid	Phoxichilidiidae	Anoplodactylus arescus	sea spider	
Arthropoda-Pycogonid	Phoxichilidiidae	Pigrogromitus timsanus	sea spider	
Crustaceans-Amphipods	Corophiidae	Grandidierella japonica	amphipod	
Crustaceans-Amphipods	Leucothoidae	Leucothoe micronesiae	amphipod	
Crustaceans-Amphipods	Leucothoidae	Paraleucothoe flindersi	amphipod	
Crustaceans-Amphipods	Stenothoidae	Stenothoe valida	amphipod	
Crustaceans-Amphipods	Corophiidae	Corophium insidiosum	amphipod	
Crustaceans-Amphipods	Corophiidae	Ericthonius brasiliensis	amphipod	
Crustaceans-Amphipods	Ischyroceridae	Jassa falcata	amphipod	
Crustaceans-Amphipods	Podoceridae	Podocerus brasiliensis	amphipod	
Crustaceans-Amphipods	Stenothoidae	Stenothoe gallensis	amphipod	
Crustaceans-Amphipods	Corophiidae	Corophium baconi	amphipod	
Crustaceans-Amphipods	Gammaridae	Elasmopus repax	amphipod	
Crustaceans-Amphipods	Isaeidae	Photis hawaiensis*	amphipod	
Crustaceans-Amphipods	Chthamalidae	Chthamalus sp.*	barnacle	
Crustaceans-Amphipods	Corophiidae	Corophium acherusicum	slender tube amphipod	
Crustaceans-Amphipods	Caprellidae	Caprella scaura		
Crustaceans-Amphipods	Aoridae	Grandidierella bispinosa*		
Crustaceans-Barnacles	Balanidae	Balanus reticulatus	barnacle	

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Crustaceans-Barnacles	Chthamalidae	Chthamalus proteus	Caribbean barnacle	*
Crustaceans-Barnacles	Balanidae	Balanus eburneus	Ivory barnacle	*
Crustaceans-Barnacles	Balanidae	Balanus amphitrite	striped barnacle, purple acorn barnacle	*
Crustaceans-Copepods	Pseudodiaptomidae	Pseudodiaptomus marinus	calanoid copepod	
Crustaceans-Crabs	Xanthidae	Panopeus herbstii	Atlantic mud crab	
Crustaceans-Crabs	Portunidae	Callinectes sapidus	blue crab	
Crustaceans-Crabs	Pilumnidae	Pilumnus oahuensis	crab	
Crustaceans-Crabs	Xanthidae	Atergatopsis immigrans	crab	
Crustaceans-Crabs	Grapsidae	Nanosesarma minuta	crab	
Crustaceans-Crabs	Xanthidae	Panopeus pacificus	crab	
Crustaceans-Crabs	Portunidae	Carcinus maenas	green crab	
Crustaceans-Crabs	Pilumnidae	Glabropilumnus seminudus	hairy crab	
Crustaceans-Crabs	Portunidae	Charybdis hellerii	Indo-Pacific crab	
Crustaceans-Crabs	Grapsidae	Pachygrapsus fakaravensis	Polynesian grapsid crab	
Crustaceans-Crabs	Portunidae	Scylla serrata	Serrate swimming crab, Samoan crab, Mangrove crab	*
Crustaceans-Crabs	Majidae	Schizophrys aspera	spider crab	
Crustaceans-Isopods	Sphaeromatidae	Exospaeroma sp. a*	isopod	
Crustaceans-Isopods	Sphaeromatidae	Sphaeroma walkeri	isopod	
Crustaceans-Isopods	Sphaeromatidae	Paracerceis sculpta	isopod	
Crustaceans-Isopods	Pseudozeuxidae	Leptochelia dubia	tanaidacean	
Crustaceans-Isopods	Ligiidae	Ligia exotica	wharf roach	
Crustaceans-Isopods	Limnoriidae	Limnoria tripunctata	wood boring gribble	

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Crustaceans-Isopods	Sphaeromatidae	Exospaeroma sp. *		
Crustaceans-Isopods	Anthuridae	Mesanthura sp.		
Crustaceans-Shrimp	Gonodactylidae	Gonodactylaceus falcatus	a mantis shrimp	
Crustaceans-Shrimp	Penaeidae	Penaeus monodon	Asian tiger shrimp	*
Crustaceans-Shrimp	Penaeidae	Penaeus stylirostris	blue shrimp	
Crustaceans-Shrimp	Penaeidae	Penaeus japonicus	Japanese shrimp	
Crustaceans-Shrimp	Palaemonidae	Macrobrachium rosenbergii	Malaysian prawn	
Crustaceans-Shrimp	Penaeidae	Litopenaeus vannamei	Pacific white shrimp	*
Crustaceans-Shrimp	Gonodactylidae	Gonodactylus aloha	Philippine mantis shrimp	
Crustaceans-Shrimp	Palaemonidae	Macrobrachium lar	Tahitian prawn	
Crustaceans-Tanaids	Paraseudidae	Parapseudes latifrons		
Tunicates	Styelidae	Phallusia nigra	black sea squirt	*
Tunicates	Styelidae	Botrylloides simodensis	orange sheath tunicate	
Tunicates	Steylidae	Styela canopus	rough sea tunicate	*
Tunicates	Didemnidae	Diplosoma listerianum	sea squirt	
Tunicates	Cionidae	Ciona intestinalis	Sea vase	*
Tunicates	Ascidiidae	Ascidia sp. a	tunicate	
Tunicates	Ascidiidae	Ascidia sp. b	tunicate	
Tunicates	Styelidae	Botrylluss sp.	tunicate	
Tunicates	Corellidae	Corella minuta	tunicate	
Tunicates	Pyuridae	Herdmania momus	tunicate	
Tunicates	Pyuridae	Microcosmus exasperatus	tunicate	
Tunicates	Styelidae	Polyandrocarpa sagamiensis	tunicate	
Tunicates	Styelidae	Polyandrocarpa zorritensis*	tunicate	
Tunicates	Polyclinidae	Polyclinum constellatum	tunicate	

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Tunicates	Styelidae	Symplegma brakenhielmi	tunicate	
Tunicates	Styelidae	Symplegma oceania	tunicate	
Tunicates	Styelidae	Symplegma reptans	tunicate	
Tunicates	Styelidae	Eusynstyela aliena	tunicate	
Tunicates	Styelidae	Eusynstyela hartmeyeri	tunicate	
Tunicates	Polyclinidae	Herdmania pallida	tunicate	*
Tunicates	Pyuridae	Herdmania sp.	tunicate	
Tunicates	Styelidae	Polyandrocarpa sp.	tunicate	*
Tunicates	Ascidiidae	Ascidia syndeiensis	tunicate (gray sea squirt)	*
Tunicates	Didemnidae	Didemnum perlucidum	white crust tunicate	*
Tunicates	Didemnidae	Didemnum candidum	white didemnid	*
Fishes	Mullidae	Upeneus vittatus	bandedtail goatfish	
Fishes	Lutjanidae	Lutjanus fulvus	blacktail snapper	*
Fishes	Serranidae	Epinephelus fasciatus	blacktip grouper	
Fishes	Blenniidae	Parablennius thysanius	blenny	
Fishes	Lutjanidae	Lutjanus kasmira	bluestripe snapper	
Fishes	Loricariidae	Ancistrus cf. ?	bristlenose catfish	
Fishes	Serranidae	Cephalopholis urodeta	darkfin hind	
Fishes	Engraulidae	Anchoa compressa	deepbody anchovy	
Fishes	Serranidae	Epinephelus merra	dwarf spotted grouper	
Fishes	Lethrinidae	Lethrinus sp.	emperor	
Fishes	Lutjanidae	Lutjanus sebae	emperor snapper	
Fishes	Blenniidae	Omobranchus ferox	fang-toothed blenny	*
Fishes	Pomacanthidae	Centropyge loricula	flaming angelfish	
Fishes	Clupeidae	Herklotsichthys quadrimaculatus	goldspot herring	*

Table 5 con't. Invasive Marine and Estuarine Aquatic Animals located in Hawaii

Taxonomic Group	Family	Genus Species	Common Name	Reviewed below
Fishes	Pomacanthidae	Apolemichthys xanthopunctatus	goldspotted angelfish	
Fishes	Fundulidae	Fundulus grandis	gulf killifish	
Fishes	Gobiidae	Mugilgobius parvus	helmeted goby	
Fishes	Serranidae	Cromileptes altivelis	humpback grouper	*
Fishes	Lutjanidae	Lutjanus gibbus	humpback snapper	
Fishes	Mugilidae	Valamugil engeli	kanda	
Fishes	Pomacanthidae	Centropyge flavissima	lemonpeel angel	
Fishes	Gobiidae	Mugilgobius cavifrons	mangrove goby	
Fishes	Serranidae	Epinephelus irroratus	Marquesan grouper	
Fishes	Clupeidae	Sardinella marquesensis	Marquesan sardine	*
Fishes	Cichlidae	Oreochromis mossambicus	Mozambiqua tilapia	
Fishes	Serranidae	Cephalopholis argus	peacock hind	*
Fishes	Salmonidae	Oncorhynchus mykiss?	rainbow trout	
Fishes	Pomacanthidae	Pygoplites diacanthus	regal angelfish	
Fishes	Lutjanidae	Lutjanus guttatus	rose snapper	
Fishes	Pomacanthidae	Pomacanthus semicirculatus	semicircle angelfish, zebra angelfish	
Fishes	Serranidae	Epinephelus hexagonatus	star-spotted grouper	
Fishes	Clupeidae	Dorosoma petenense?	threadfin shad	
Fishes	Poeciliidae	Poecilia sp ?	unidentified poecilid	
Fishes	Pomacanthidae	Chaetodontoplus mesoleucus	vermiculated angelfish	

Notes: Source, USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov

SOCIO-ECONOMIC IMPACT OF NON-INDIGENOUS AND NATIVE TRANSPLANTED SPECIES

The following pages (51 to 79) present descriptions of the impact created by specific invasive and native transplanted species. Either the impact was taken directly from the literature surveyed for this manual, or it is an inferred socio-economic impact based on ecological impacts described in the literature. We do not describe ecological impacts unless they have social or economic consequences of importance.

Species are organized by major taxonomic groupings. Within these groups, species occur in alphabetical order of common name.

The USGS website "U.S. Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL http://nas.er.usgs.gov" was the source of a substantial portion of the information provided in this section. Thus, information occurring here without specific citation is from this comprehensive source. Other sources of information presented in this section are cited within the text, with full citations listed in alphabetical order by author/source in the REFERENCES section.

Phylum Porifera (sponges)

Blue Caribbean Sponge (*Sigmadocia caerulea*) – This species was introduced to Hawaiian waters via ship hull fouling. The blue Caribbean sponge is a fouling organism, restricted to shallow waters; it affects structures such as piers and floating docks (Bishop Museum and University of Hawaii).

Bowerbank's halichondria (*Halichondria bowerbanki*) – as with several other invertebrate native transplants (the creeping bryozoan, the lacy crust bryozoan and the single horn bryozoan) and even possibly the rainwater killifish, the Bowerbank's halichondria may have been introduced to the West Coast via purposeful plantings of the Atlantic oyster. Other means of introduction for these invertebrates may also have been via ballast water or ship fouling.

Gray encrusting sponge (*Gelliodes fibrosa*) – a shallow water species restricted in Hawaii to the fouling communities of major island harbors, the gray encrusting sponge is also found on shallow reef patches. It was probably introduced as ship fouling; it fouls pier pilings, floating docks, and ship hulls. This species may be a threat to coral reef patches in protected habitats.

Lobate Sponge (*Suberites zeteki*) – This species is a common fouling organism in Hawaiian harbors, occurring on floating docks, ship hulls, dock pilings, or on mangrove roots. As with other sponges, the lobate sponge was probably introduced to Hawaii as ship fouling.

Orange sponge (*Mycale armata*) – The orange sponge was introduced via ship fouling. This fouling species is restricted to the same habitat/areas as the red-brown sponge (below: Bishop Museum and University of Hawaii 2002).

Red-brown branching sponge (*Mycale parishii*) - In Hawaii, this sponge is mainly restricted on Oahu to structures such as pilings and docks in shallow water of the major harbors, or in dredged channels and artificial lagoons. It is also found on patch reefs in the southeast corner of the Kaneohe bay as well as on floating docks on Coconut Island. This fouling species was most likely introduced to Hawaii via ship hull fouling (Bishop Museum and University of Hawaii 2002).

A Sponge (*Halichondria melanadocia*) – This species' entry to Hawaii probably was via fouling on ship's hull. Like many of the sponges, this is considered a fouling species, although the fouling impact may be modest.

A Sponge (*Hymeniacidon sinapium)* – This sponge is bright orange. Common in the northeast Atlantic and also found in southern California, it has recently turned up in Elkhorn Slough, an estuary in central California. It is thought to be influencing community composition via its filtering activities and limiting soft bottom habitat use of other species by occupying same (Wasson et al. 2001).

Phylum Ectoprocta (including bryozoans)

Branching Bryozoan (*Schizoporella* cf. *errata*) – introduced to Hawaiian islands as ship fouling, this species is an encrusting bryozoan found on hard substrates such as pilings, corral rubble, ship hulls and other surfaces. It is most commonly found in harbors and bays but also on more open shallow water reefs. The branching bryozoan is a member of the fouling community (Bishop Museum and University of Hawaii 2002).

Brown Bryozoan (*Bugula neritina*) – introduced to Hawaii as ship fouling, it now is found throughout the main islands in harbors, bays and shallow reefs. Although it is a fouling species, the impact of fouling is unknown but probably is modest (Bishop Museum and University of Hawaii 2002).

Bushy Bryozoan (*Amathia distans*) – The bushy bryozoan forms soft, bushy growths on hard substrates in shallow waters; it fouls pilings, docks and ship hulls. Occasionally it is found fouling shallow water reefs in protected shorelines. Introduced to Hawaii as ship fouling, the bushy bryozoan is a common fouling species throughout the Hawaiian island, although the impact of its fouling is probably modest (Bishop Museum and University of Hawaii 2002).

A Bryozoan (*Watersipora subtorquata*) – This is a fouling organism commonly on boat hulls. In Japan this species is a noted fouler of oyster culturing operations, thus it is a potential pest to bivalve aquaculture activities.

A Bryozoan (*Cryptosula pallasiana*) – This is another fouling organism. It grows in flat, encrusting sheets on shells, wood, glass, plastic, cement, sea grasses and other surfaces.

A Bryozoan (*Membranipora membranacea*) – This species is found in coastal New England. “This bryozoan has apparently contributed to the defoliation of the kelp bed at Cape Neddick, Maine” (Lambert et al. 1992). It out competes other encrusting growth such as *Electra pilosa* (another bryozoan) and *Obelia geniculata* (a hydroid) (Bermann et al. 1992). Kelps encrusted with *M. membranacea* are more susceptible to fracturing during storms (Berman et al. 1992; Lambert et al. 1992). Heavy encrusting can also affect the abundance and composition of organisms in affected kelp communities (Lambert et al. 1992). The character and composition of New England kelp beds changed dramatically between 1989 and 1991 in conjunction with the increased abundance of *M. membranacea* (Lambert et al. 1992). The sea urchin *Strongylocentrotus droebachiensis*, which supports a commercial fishery, declined in abundance an average of between 20 and 280 per square meter before the invasion to 0.47 per square meter after the invasion (Lambert et al. 1992; from NAS site).

Phylum Coelenterata (Cnideria)

Class Anthozoa (anemones and corals)

Orange-Striped Green Anemone (*Diadumene lineata*) – This is a fouling species of bays and estuaries often found on rocks and debris; hulls of ships; structures such as pilings, buoys and floats; seaweeds; and oyster, clam and mussel shells. This species was either introduced as ship fouling or with commercial oysters in the Hawaiian island chain. Its impact is unstudied but assumed modest (Bishop Museum and University of Hawaii 2002).

Snowflake coral (*Carijoa riisei*) – This coral is a fouling species invasive to the Hawaiian island chain; it is most commonly found on pier pilings or ship wrecks in areas of harbors not exposed to direct sunlight, and on hard surfaces in deeper water reefs. Because of its tremendous rate of growth, its potential to effect on the lucrative black coral industry is particulary worrisome. Snowflake coral has already caused some decline in black coral habitat and colonies in Hawaii. The snowflake coral is native to the western Atlantic from Brazil to Florida (Bishop Museum and University of Hawaii 2002).

Class Hydrozoa (hydroids and medusae)

Australian Spotted Jellyfish, white-spotted jellyfish (*Phyllorhiza punctata*) – The invasion of this species on the West Coast, Hawaii Islands and the Gulf of Mexico may have been due to fouling of ships or other structures while in the polyp stage, or from ballast water. Once in a new region, it can further spread as nektonic medusae due to ocean circulation patterns. Medusae occur annually in coastal waters west of the Mississippi River, indicating this species is well-established in the northern Gulf of Mexico. The Australian spotted jellyfish has had a significant economic impact in the Gulf of Mexico, particularly in the prosecution of shrimp fisheries. Medusae clog shrimp trawls, foul boat intakes, and damage fishing gear. Some evidence suggests that shrimp harvest in Mobile Bay, AL and the Mississippi Sound has been reduced by more than 25% due to this jellyfish (USGS-NAS site). Medusae also can have significant impact on commercially important species, causing very high rates of mortality of early life stages of fishes such as *Anchoa mitchilli* (eggs) and bivalves such as oysters (larvae) through predation, thus reducing the productivity of these commercial taxa.

Upsidedown jellyfish (*Cassiopea medusa*) – This species was introduced to Hawaii as ship fouling or in ballast water. This is a nuisance species, which can inflict a painful sting to people (Bishop Museum and University of Hawaii 2002).

Christmas Tree Hydroid (*Pennaria disticha*) – The Christmas tree hydroid is a common fouling organism introduced via fouling of ship hulls. It will foul other structures such as pilings, buoys and floats. This hydroid will sting humans, causing a mild irritation (Bishop Museum and University of Hawaii 2002).

Freshwater Hydroid (*Cordylophora caspia)* - This colonial hydroid causes fouling problems by clogging intake pipes and screens at power plants. It is more prevalent in freshwater habitats but is also found in euryhaline waters of estuaries (Foulino-Rorem and Indelicato 2005).

Hydroid (*Garveia franciscana*) - First identified in 1902, this species has only recently been found in New England. A fouling organism, its economic impact includes: water-pump failures, increases in cleaning frequency at water inlets, and decreases in efficiency of deoxygenating towers (MIT Sea Grant).

Phylum Annelida

Class Polychaeta (polychaetes, bristleworms)

Featherduster worm (*Sabellastarte spectabilis*) – The featerhduster worm was introduced to Hawaiian waters incidentally as ship fouling. This is a nuisance fouling species, with modest impact.

Parchment worm (*Chaetopterus* sp.) – The parchment worm was introduced to Hawaiian waters via ship hull fouling or ballast water. It is a fouling organism with undescribed and probably modest impact (Bishop Museum and University of Hawaii 2002).

A polychaete (*Ficopomatus enigmaticus*) – This fouling colonial organism is found in intertidal to shallow subtidal habitats on rocks, concrete, and wooden structures including pilings, docks, buoys and boat hulls. It is established in Chesapeake Bay.

Sebellid polychaete *(Terabrasabella heterouncinata*) – This species is known for its unusual technique of settling inside the growing end of the host gastropod's shell. It is thus far a West Coast species that has caused economic losses to abalone culture facilities in California (Kuris and Culver 1999).

Serpulid worm (*Salmacina dysteri*) – This species was probably introduced to Hawaii as ship fouling. This is a fouling species with minimal known impact.

Subclass Oligochaeta (earthworms and leeches)

A tubificid worm (*Branchiura sowerbyi*) - Through its feeding behavior, *B. sowerbyi* can transport large quantities of sediment particles from deep water zones and may enhance solute transport between sediments and overlying water. Potentially, this species can have a large impact on its surroundings, as it can burrow to a depth of 20 cm and after a short period of time move to a new location to build new burrows. Its economic impacts are unclear but it can cause bioaccumulation of toxins.

Phylum Mollusca

Class Bivalvia (bivalves such as mussels, clams and oysters)

Asian Clam (*Corbicula fluminea*) - The most prominent effect of the introduction of this species has been bio-fouling, especially of raw water intake pipes, thus affecting power and water suppliers, and other industries. Clams are drawn into intake pipes, obstructing water flow through condenser tubes, valves and service water systems. They also alter benthic substrate and compete with native species for limited resources.

Brown Mussel (*Perna perna*) – Probably introduced through ballast water release, this species now inhabits waters of the western Gulf of Mexico coast. First reported in Gulf of Mexico in 1990 on the Port Arkansas Jetty, TX, within several years it colonized expansively along the TX coast and into Mexico waters (Gulf States Marine Fisheries Commission 2003a). Survival of larvae requires settlement on a hard substrate. Thus this species is found along rocky shorelines, and on hard structures such as jetties, channel buoys and oil rigs. This species is viewed as a good candidate for commercial cultivation. However, where invasive, it competes with valued native bivalves, and it is a fouling pest, capable of sinking navigation buoys and affecting shipping safety.

Atlantic Oyster Drill (*Urosalpinx cinerea*) – The Atlantic oyster drill occurs in intertidal and shallow subtidal waters of bays and estuaries to a maximum depth of 15 m. It has not caused problems on the West Coast, but has proven to be a major predator of oyster spat on the Atlantic Coast, thus potentially impacting reproductive success of this commercial species.

Charru mussel (*Mytella charruana*) – The charru mussel has been noted in water systems of a power plant in Jacksonville, FL; more recently it has also been found in Mosquito Lagoon, near Kennedy Space Center in East-Central FL. The charru mussel was probably introduced through ballast water releases. Although its current distribution as an invasive is limited to Mosquito Lagoon, it has the potential to cause bio-fouling of intake pipes at power plants.

Green mussel (*Perna viridis*) – The green mussel was possibly introduced through ballast water dumping or as ship fouling. It is typically found in low intertidal estuaries. The green mussel can have commercial importance, and is particularly useful for cultivation as it can reproduce throughout the year. It is a serious fouling organism of power plants. Green mussels have fouled the surfaces of intake condenser tunnels of power plants in Florida, and can cause mechanical damage to pumps. This fouling can reduce the heat transfer efficiency of power plant cooling systems. Mechanical and chemical control methods eliminate this species in enclosed fouling systems of power plants - continuous high-level chlorination is necessary to detach and kill green mussels (Gulf States Marine Fish Commission 2005). It also fouls navigation buoys, and may compete with commercially valuable fisheries such as oysters and native mussels. Controlling the spread of green mussels can be facilitated by inspection of the hulls of large and small vessels before they enter un-infested waters.

Japanese Littleneck Clam (*Venerupis philippinarum*) – This species is found in bays and intertidal areas on muddy sand, mud and buried cobble. It is grown commercially in California and sold as the "Manila clam". This species accounts for about half of the hard-shell clam harvest in Washington, with much smaller harvests in Oregon and California.

Japanese Oyster Drill (*Ocinebrellus inornatus)* – The Japanese oyster drill is a marine snail that was most likely imported from Japan with shipments of Pacific oysters at the turn of the last century. It drills holes through the shell of juvenile oysters to get to the soft flesh of the animal. With the original infestation came the devastation of the already struggling Olympia oyster populations. Today it is considered a major impediment to the re-establishment of Washington state's only native oyster. Taxonomic synonyms include *Ceratostoma inornatum, Ocenebra japonica* and *Ocinebrellus inornatus*. Common name synonyms include Asian drill and Asian oyster drill (ISSG, 2007).

Mediterranean Blue Mussel (*Mytilus galloprovincialis*) – Although impacts in areas of the U. S. where it has become established are not documented, this species has replaced indigenous mussel populations in South Africa. It was introduced into Hawaiian waters as hull fouling when the decommissioned battleship U.S.S. Missouri was transferred from the state of Washington to Pearl Harbor; it also may have been introduced accidentally from the ballast tank of a submarine (NAS site).

Naval Shipworm (*Teredo navalis*) – This is a wood boring species. The naval shipworm can be destructive to any wooden structures in shallow bays and inlets. Shipworms and other bivalve wood-borers cause tens of millions of dollars worth of damage annually to underwater wooden structures (estimated at $25 million in 1961; Castagna, 1961). Chemical treatment such as anti-fouling paints or hard coatings over wood, such as plexiglass, are major means of controlling damage (Castagna 1961).

Overbite Clam (*Corbula amurensis*) – This is an invasive predator of subtidal and intertidal mudflats. This species is believed to have influenced the decline of other invasive species such as the soft-shell clam (*Mya arenaria*) in Suisan Bay area of northern San Francisco Bay. A major concern with the overbite clam is its remarkable filtration capabilities. It is suspected that this mass amount of filtration will lead to tropic level changes in areas it inhabits, as great amounts of plankton are removed from the surrounding water.

Quagga mussel (*Dreissena bugensis*) see also Zebra Mussel – The quagga mussel was introduced into the Great Lakes via released ballast water. The ability of this species to rapidly colonize hard surfaces causes serious economic problems. This bio-fouling organism can clog water intake structures, such as pipes and screens, therefore reducing pumping capabilities for power and water treatment plants. Recreation-based industries and activities have also been impacted: docks, breakwalls, buoys, boats, and beaches have all been heavily colonized. *D. bugensis* is able to colonize both hard and soft

substrata (Mills *et al.* 1996). Thus it is not as restricted to shallow water habitats with harder substrates as is the closely-related invasive zebra mussel.

Its ecological impacts - which may generate substantial socio-economic problems - are as yet unclear due to the limited time scale of North American colonization. However, potential ecological impacts of socio-economic importance may result from the capacity of high densities of this species to filter the water column. Quagga mussels have the capacity to substantially reduce densities of plankton through filter feeding activity (Claxton et al. 1998). Impacts associated with filter feeding include: 1) increasing water transparency, which in turn can cause proliferation of aquatic plants, changing energy transfer through the food web while clogging the water column with vegetation. This can negatively impact boating and other recreational activities; 2) reducing the availability of the zooplankton community as food for early life stages of recreationally important fish species, thus reducing the productivity of these taxa; 3) possibly decreasing reproductive success of bottom-spawning fishes due to egg mortality. Its capacity to foul shells of native species of threatened and endangered bivalves, and ensuing competition for plankton foods may seriously threaten the continued existence of these native taxa. The pseudofeces that are produced accumulate and create a foul environment - as the waste particles decompose, oxygen is depleted, the pH becomes very acidic and toxic byproducts are produced. In addition, quagga mussels accumulate organic pollutants within their tissues to levels more than 300,000 times greater than concentrations in the environment and these pollutants are found in the pseudofeces, which can be passed up the food chain, therefore increasing wildlife exposure to organic pollutants (Snyder *et al.* 1997).

Rock Oyster, leafy jewelbox (*Chama macerophylla*) – This species probably was introduced as hull fouling. Rock oysters attach to hard substrates, including natural rock surfaces and structures such as pilings and ship hulls. This species is considered a "stubborn" fouling organism, which is very difficult to remove from hulls and other structures, often requiring a hammer and a chisel. As of 2002 in Hawaii, it has only been reported in Pearl Harbor. It has been locally abundant on the hull of a floating dock, and in two other nearby collecting stations (Bishop Museum and University of Hawaii 2002).

Saddle Oyster, jingle shell (*Anomia nobilis*) – This invasive inhabits harbors throughout the main islands of Hawaii. This common fouling organism is typically found on hard structures such as floating docks and pier pilings. When abundant it forms stacks multiple animals thick, making its removal difficult (Bishop Museum and University of Hawaii 2002).

Shipworm (*Teredo furcifera*) - first found in Barnegat Bay, NJ, *T. furcifera* is adapted to boring into wood; therefore, it can destroy docks and wooden-hulled boats. This species is well established in warmwater effluents of power plants.

Soft-Shell Clam (*Mya arenaria*) – This Atlantic Coast native is found in upper intertidal, and shallow subtidal zones of bays and estuaries. Where it occurs on the West coast, it provided significant commercial harvests from late nineteenth through mid-

twentieth centuries. Currently on the West Coast the soft-shell clam supports very modest recreational harvests for food and bait.

Zebra mussel (*Dreissena polymorpha*) - The zebra mussel entered the Great Lakes in the 1980s in ballast water of ships from Europe, and is now widely distributed throughout the Great Lakes and most major eastern U. S. watersheds. This species is a fouling organism, clogging water intake and condenser pipes. It also encrusts boat hulls, docks and buoys and fouls shells of native mollusks, including federally endangered species, and spawning grounds of recreationally important fishes such as the walleye (*Zander vitreum*) and smallmouth bass (*Micropterus dolomieui*). Economic impacts include: loss of revenues from industries during closure for cleanout of intake pipes; cost of control in municipal water treatment plants and power plants; local cost of removal from docks and boat hulls (ISSG database). Ecological impacts, as described for the Quagga mussel, may produce long-term economic consequences.

Class Gastropoda (snails, slugs and nudibranchs)

Channeled Whelk (*Busycotypus canaliculatus*) – This species inhabits subtidal and intertidal habitats on mud and sand bottoms. The West Coast population in San Francisco Bay may have come from aquarium enthusiasts or from discards of grocery stocks, or perhaps in shipments of Atlantic oysters. This species does not appear to have serious impact on the West Coast, but within its native range on the Atlantic coast it is a serious predator pest in oyster and clam beds.

Chinese Mysterysnail (*Cipangopaludina chinensis malleata*) – This species is typically found partially buried in the mud or silt of lakes, although it can occur in brackish waters of estuaries. This species was sold in Chinese food markets in San Francisco in the late 1800's. It possibly competes with native snails. "This species can serve as a vector for various parasites and diseases, including serving as "an intermediate host for *Echinocasmus elongatus, E. redioduplicatus, E. rugosus, Euparipium ilocanum, E. recurvatum, Echinostoma macrorchis*, and *E. cinetorchis* which can infect human beings" (Gulf States Marine Fisheries Commission 2005e; Pace, 1973).

European nudibranch (*Tritonia plebeia*) – This nudibranch is found in coastal areas of Maine and Massachusetts. "Although only present in the Gulf of Maine during the Mid-1980s, it had a severe impact on the soft coral, *Alcyoniuum siderium.*" (NAS site).

Mud Bithynia or Faucet Snail (*Bithynia tentaculata*) – The mud Bithynia has been known to infest municipal water supplies in abundance. It was first introduced into the Great Lakes (Lake Michigan) about 1870 and remains abundant in the Great Lakes watershed.

New Zealand mudsnail (*Potamopyrgus antipodarum*) – This mudsnail is a prolific species with the potential to be a bio-fouler at facilities drawing from infested waters. Its tolerance of a broad range of ecological factors makes the possibility of further spread

likely. In moist conditions, this snail can withstand short periods of desiccation (NAS site).

Red-rimmed melania (*Melanoides tuberculatus*) – This species is typically found in shallow slow running water, but is highly salinity tolerant; it has been reported in both fresh and estuarine waters in south Florida in salinities up to 30 ppt. It was introduced by the pet trade industry (Gulf States Marine Fisheries Commission 2003b). This species is a potential human health hazard, because it serves as the vector for the Chinese liver fluke and the Oriental lung fluke. It also carries parasites of waterfowl that can infect mammals.

Veined Rapa Whelk (*Rapana venosa*) – This species is found in subtidal habitats. The veined rapa whelk is a carnivore that consumes other mollusks such as native oysters. It has become a serious pest elsewhere, causing declines and losses of bivalves in the Black Sea. Although specific impacts have not been noted in U. S. waters, there is caution concerning serious impacts on economically important shellfish stocks (Harding 1999; 2000).

Phylum Arthropoda, Subphylum Crustacea

Class Branchiopoda (including the cladocerans)

Spiny water flea (*Bythotrephes longimanus*)- This water flea is found among the zooplankton in the upper water column of large and small temperate lakes, reaching greatest abundance in late summer and autumn; it also can tolerate brackish water. "The first noticeable impact of *Bythotrephes* [is] on fishermen. The tail spines of *Bythotrephes* hook on fishing lines, fouling fishing gear. *Bythotrephes* consume small zooplankton such as small cladocerans, copepods, and rotifers, competing directly with planktivorous larval fish for food" (Berg and Garton 1988, Evans 1988, Vanderploeg et al. 1993). *Bythotrephes* have been implicated as a factor in the decline of alewife (*Alosa pseudoharengus*) in Lakes Ontario, Erie, Huron, and Michigan (Evans 1988). The invasion of *B. longimanus* into the Laurentian Great Lakes has resulted in substantial and sustained decreases in the populations of a number of (mostly cladoceran) native zooplankton species (Barbiero and Tuchman, 2004). The ultimate impact of this change in the plankton community on productivity of recreationally important fish species is unknown. *Bythotrephes* is a food source for fish including yellow perch, white perch, walleye, white bass, alewife, bloater chub, chinook salmon, emerald shiner, spottail shiner, rainbow smelt, lake herring, lake whitefish and deepwater sculpin (Bur et al. 1986, Makarewitz and Jones 1990, Branstrator and Lehman 1996; directly from NAS site).

Fish-hook water flea (*Cercopagis pengoi*)-similar to the spiny water flea (*B. longimanus*), this species is euryhaline and eurythermic. The fish-hook water flea "is a consumer of other zooplankton, competing with other planktivores of the Great Lakes, including the Alewife (*Alosa pseudoharengus*) and Rainbow Smelt (*Osmerus mordax*) (Bushnoe et al., 2003), two species that serve as a major food source for economically

valuable salmonine species. *C. pengoi's* establishment in Lake Ontario in 1998 corresponded with the lowest alewife populations in twenty years (Makarewicz et al., 2001). *C. pengoi* is a nuisance to recreational anglers as it also fouls fishing gear. A 2002 study of the food web impacts of C. pengoi showed that the depth at which *C. pengoi* exists is depleted of small organisms (<0.15 g) (Benoit et al., 2002). The full impact of *C. pengoi* on the food web, and thus on important fish species, has not yet been extensively studied." (NAS site).

Water flea (*Daphnia lumholtzi*)- First found in Lake Michigan in 1997, this species may have negative impacts on ecosystems; however, because of its recent introduction its impacts are not fully understood.

Class Maxillopoda
Subclass Thecostraca (including the barnacles)

Barnacle (*Balanus trigonus*) – This species was introduced into the south Atlantic basin (Brazil) in the 1860s by ships from the Pacific. It possibly was brought into the North Atlantic basin by whaling ships in the mid-1900s (Gulf States Marine Fisheries Commission 2005d). It is a fouling organism found on ship hulls, buoys, and other hard substrates in the water column as well as inflow pipes of desalinization plants. When found in intake pipes, it can cause corrosion of metals and increase maintenance costs. Substantial encrustation of this species on ship hulls increases drag, thus increasing fuel costs.

Caribbean barnacle (*Chthamalus proteus*) – This barnacle was probably introduced into the Hawaii islands via ship hull fouling. It inhabits the high or supra-tidal zones of protected harbors, growing on pier pilings and other structures. It is considered a nuisance fouling organism, which can commonly be seen as hull fouling at and above the water line.

Ivory Barnacle (*Balanus eburneus*) – The ivory barnacle is a common fouling organism in the intertidal fouling community, probably introduced as ship hull fouling. The ivory barnacle is considered a nuisance fouling species that occurs on structures such as ship hulls, buoys, and pilings as well as on oysters and mangrove roots. It is distributed throughout the Hawaiian main islands (Bishop Museum and University of Hawaii 2002).

Striped Barnacle (*Balanus amphitrite*) – The striped barnacle was probably introduced as vessel fouling. This species is a very common member of intertidal fouling community. It can cause serious fouling on structures such as buoys and pilings in harbors and bays, ship hulls, and inflow pipes of desalination plants. This species can cause corrosion of metals and increased maintenance costs. Striped barnacles on ship hulls can increase friction to the point of increased fuel consumption and higher travel costs (Bishop Museum and the University of Hawaii 2002; Gulf States Marine Fisheries Commission 2003e).

Subclass Copepoda (the copepods)

A parasitic copepod (*Neoergasilus japonicus*) – This species has been found in Lake Huron. Host fish include bluegill, carp, channnel catfish, goldfish, green sunfish, fathead minnow, largemouth bass, smallmouth bass, rock bass, yellow perch, and pumpkinseed. The impact of this parasite on populations of valued fish species is probably modest.

Predatory copepods (particularly *Pseudodiaptomus inopinus*) – Several bays and estuaries on the West Coast of the United States have recorded exotic planktonic copepod populations (Cordell and Morrison 1996). San Francisco Bay is perhaps the most affected, with eight known Asian copepods inhabiting the area (Orsi and Ohtsuka 1999). These invaders apparently occupy multiple zones of salinity and trophic levels. Socio-economic impacts may include copepodic predation on the larvae of commercially important marine species.

Class Malacostraca

Order Amphipoda (the amphipods)

Amphipod (*Echinogammarus ischnus*) – This species prefers fresh and brackish shallow waters and hard substrates; is closely associated with zebra mussel colonies. It is most likely to become the dominant amphipod in rocky habitats with moderate current, wave-washed cobble beaches, rubble-armored shorelines, and breakwalls. Interactions between *E. ischnus* and native gammarid species may result in displacement and possible local extinction of native species.

Order Isopoda (the isopods)

An isopod (*Paranthura* sp.) – This species is widely distribution in San Francisco Bay and adjacent bays. This is a wood-boring organism that fouls and can cause deterioration of pilings, wooden hulled ships, and other wooden structures.

An isopod (*Synidotea laevidorsalis*) – This is an estuarine inhabitant from brackish to full seawater. It was most likely introduced as ship fouling. This species fouls piling, buoys and other maritime structures.

Burrowing Australian isopod (*Sphaeroma quoyanum*) – The burrows of these isopods have been shown to undermine the steep vertical banks of salt marshes, resulting in large local sediment losses in San Francisco Bay (Levin 2002). Projected and current socio-economic impacts include increased sedimentation, which affects fishing and water quality, shallowing of navigable waterways, and loss of aesthetic values associated with salt marshes.

Wood boring gribble ((*Limnoria quadripunctata*) – a boring isopod that can cause deterioration of wood structures, such as piers.

Order Decapoda (including lobsters, crabs and shrimp)

Asian Tiger Shrimp, Jumbo Tiger Prawn (*Penaeus monodon*) – This species has been collected by commercial shrimpers along the East coast of the U. S. to Florida, and the Gulf of Mexico. This species was probably released by commercial aquaculture facilities; it may not be established as reproducing populations. Juveniles are found in estuarine waters and mouths of rivers, while adults are found in deeper coastal waters over soft substrates in depths up to 110 meters. Exotic viruses, bacteria and fungi carried by this species may pose a threat to native penaeid shrimp (Gulf States Marine Fisheries Commission 2003d).

Asian shore crab (*Hemigrapsus sanguineus*)- *Hemigrapsus* was first recorded in the United States at Townsend Inlet, Cape May County, New Jersey in 1988 (Balabam 2001). This species is now well established and exceptionally abundant along the Atlantic intertidal coastline of the United States from Maine to North Carolina (MIT Sea Grant). It is actively breeding and expanding within its nonnative range. It has the potential to affect populations of native crab species such as blue crab and rock crab, the non-native green crab, as well as other shellfish such as the American lobster and fish. This potential impact on native species may be a result of direct predation or competition for a food source. Recent trends indicate numbers of shore crabs are steadily increasing while native crab populations are declining. This opportunistic omnivore may also threaten shellfish aquaculture operations (NAS site). Most occurrences of this species in the U. S. do not seem to represent reproducing populations.

Bloody-red shrimp (*Hemimysis anomala*) – This freshwater shrimp species was forst found in the Great Lakes in November 2006. The National Center for Research on Aquatic Invasive Species lists it as established with multiple reproducing populatins in the Great Lakes (NCRAIS 2007). Nothing is known about the impact this species might ultimately have as an invasive, but a similar species from the same Order (Mysidacea), the opossum shrimp *Mysis relicta*, caused disruptons in the make-up of plankton communities when purposely introduced as a forage species into lakes in the western U. S. This indirectly caused a decline in growth, abundance and mean size at capture of a number of recreationally important salmonid species in those systems (Nesler and Bergersen 1991).

Chinese mitten crab (*Eriocheir sinensis*) – This is a catadromous species, adults migrating to reproduce in salt water and juveniles and sub-adult life stages occurring in subtidal, estuarine and adjacent freshwater systems. This species seems to be established in the U. S. only in the San Francisco Bay system. Mitten crabs can be transported in ballast water. However, due to this species being considered a delicacy in Asian food markets, it has been found in carry-on luggage in U. S. international airports, and has been marketed in San Francisco and Los Angeles, so introduction into CA may have been due to purposeful plantings. In Europe, this species causes substantial damage to nets and other commercial fishing gears. When caught in shrimp fisheries of the San

Francisco Bay area, it is a major nuisance to harvesters as it is time consuming to remove the crabs from nets, and it can cause damage to the shrimp, eliminating their value to the fresh bait market. Juveniles burrow into banks and levees in subtidal areas of estuaries; in Europe this behavior has caused considerable damage to the stability of levees. Mitten crabs have impeded fish salvage operations at federal and state water pumping plants in California due to entrainment; in 1998, over 1 million were entrained at one federal facility alone (Veldhuizen and Stanish 1999). This species has also caused reduced flow in cooling water systems of several CA power plants due to entrainment. In the Far East, mitten crabs serve as an intermediate host to lung flukes, including a species that infects humans (Gulf States Marine Fisheries Commission 2003c). Although established populations appear restricted to CA and other West Coast states, it has also been found in Lake Erie.

Green crab (*Carcinus maenas*) – The green crab is common in all types of protected marine and estuarine habitats, protected rocky shores, cobble beaches, sandflats and tidal marshes, from high intertidal zone to 60 meters. On the West Coast of the U. S., it is most often associated with tidal/salt marshes and oyster beds (Washington Department of Fish and Wildlife – no date). Once established on the Atlantic coast of North America, it has been implicated in the decline of soft-shelled clam fisheries of New England *(Mya arenaria*) in the mid-20th century, as well as declines in northern quahog (*Mercenaria mercenaria*) and scallop resources. In Humboldt Bay, CA, the green crab has been implicated in a 40% drop in Manila clam harvests (Washington Department of Fish and Wildlife – no date). Washington State is particularly concerned about its potential to out-compete and predate upon the native Dungeness crab, which supports important commercial and recreational fisheries. It is a pest of cultivated clam culturing activities. Of particular concern is the inadvertent introduction and spread of this species by commercial shellfish transfers.

Harris mud crab, estuarine mud crab (*Rhithropanopeus harrisii*) – The Harris mud crab was introduced from the Atlantic coast/Gulf of Mexico most probably via ballist water release. It inhabits brackish and freshwater systems. This species is a carrier of white spot baculovirus, which can cause disease in other crab species and shrimps. It also has caused fouling of PVC water intakes of personal residences (normally in freshwater areas).

Rusty crayfish (*Orconectes rusticus*) – One sample of this species was collected in Lake Superior in 1999. The rusty crayfish has the potential to compete with native crayfish species for hiding places and also to destroy aquatic plant beds. Rusty crayfish aggression is not limited to other crayfish species – they can also pinch waders and swimmers. Some bathers in heavily-infested lakes have stopped swimming because rusty crayfish in high concentrations occupy swimming areas throughout the day and they fear stepping on them and getting pinched by the crayfishes' large-claws. Disruption and destruction of rooted aquatic vegetation can cause the decline of recreationally important fish species (Li and Moyle 1993; Rosenthal et al. 2006).

Serrated Swimming Crab, Edible Mud Crab (*Scylla serrata*) – This species is an inhabitant of brackish shoreline waters, mouths of rivers and mangrove swamps, most often associated with mud substrates. Purposely introduced, the present status of this species in waters of southeastern and Gulf States is unknown. The serrated swimming crab is a valued human food in Asia. It is host to a parasitic dinoflagellate (*Haematodinium* sp.) that causes "bitter crab disease", which affects the marketability and value of the Tanner Crabs (*Chionoestes bairdi*) in Alaska (Gulf States Marine Fisheries Commission 2003e).

Pacific White Shrimp (*Litopenaeus vannamei*) – The Pacific white shrimp was originally imported for aquaculture; due to its tolerance of a wide range of salinities the it has been cultured in both coastal areas and freshwater ponds in GA, FL, TX and SC, as well as a few inland states. It inhabits muddy substrates from the shoreline to 70 meters (Gulf States Marine Fisheries Commission 2005c). Those found outside of aquaculture facilities are a result of escape or accidental release. Shrimp viruses introduced with this invasive species may pose a threat to penaeid shrimp fisheries along the southeastern Atlantic and Gulf of Mexico states. Viruses include TSV (Aaura Syndrome Virus), white spot virus (WSSV) and IHHN virus – the latter may be responsible for a decline in wild shrimp populations of Mexico's Pacific coast (JSA 1997).

Phylum Chordata

Subphylum Urochordata-Tunicata (the tunicates or sea squirts)

Asian tunicate, Club Sea Squirt (*Styela clava*) – a fouling organism. When in high densities, the Asian tunicate may harm other organisms through competition, or by consuming planktonic larvae, becoming a major nuisance in shellfish aquaculture. In Europe, mussel catches are so covered with this tunicate that they cannot be marketed. The Asian tunicate can severely foul structures, including weighing down floating docks to the point they are difficult to remove from the water. This species is harvested and eaten in parts of its native range, including southern Korea.

Black Sea Squirt (*Phallusia nigra*) – It is common in bays and harbors, attached to any hard substrates including pier pilings and floats. A fouling organism, the black sea squirt probably was introduced as ship hull fouling (Bishop Museum and University of Hawaii 2002).

Chain Sea Squirt, Orange Sheath Tunicate (*Botrylloides violaceus*) – This is a fouling organism. This species is a nuisance due to boat hull fouling.

Gray Sea Squirt (*Ascidia sydneiensis*) – Introduced as ship hull fouling, this species is common in shallow water of bays, attaching to any available substrates such as dead coral, pilings, boat hulls or buoys and floats.

Pleated Sea Squirt (*Styela plicata*) – The pleated sea squirt is a dominant component of the biota of San Diego Harbor. It is a fouling species that has replaced native tunicate species in that system.

Sea Vase (*Ciona intestinalis*) – The sea vase was likely introduced to the West coast via ship fouling. This species fouls pilings, floats, and ship hulls. Although it does not seem to reach the extremely high population densities of the past, it still is quite abundant seasonally in specific areas of the California coast.

Star Sea Squirt, golden star tunicate (*Botryllus schlosseri*) – This is a fouling organism. The star sea squirt grows on boat hulls, buoys, ropes, pilings, and on living organisms such as mussels and eelgrass. It can overgrow and compete with cultured oysters and mussels and increase processing costs for these shellfish. This species has been used in studies of reproduction, development and genetics.

Rough Sea Tunicate (*Styela canopus*) – This species fouls ship hulls.

A Tunicate (*Herdmania pallida*) – This species fouls ship hulls.

A Tunicate (*Polyandrocarpa* sp.) – This species fouls ship hulls.

White Crust Tunicate (*Didemnum* cf. *lahillei*) – This is another fouling organism. The white crust tunicate forms encrusting mats that overgrow a variety of living organisms including oysters, scallops and other economically valuable species. Once introduced, this rapidly expanding species can become a serious fouling organism, covering maritime structures (docks, floats, pilings, moorings, ropes), ship's hulls and large areas of fishing ground; it has encrusted 50-90% of a 100 sqare kilometer area of Georges Bank. In 14 months it covered 100% of the surface of a sunken oil rig off the coast of Texas (NAS site). This species can reach abundance sufficient to threaten commercial fishing, commercial culture of mussels, and other coastal and offshore activities.

White Crust Tunicate (*Didemnum perlucidum*) - "This tunicate has been collected in the Gulf of Mexico off Texas … and has been identified from Pensacola Bay, Florida (SERC, Nemesis Database); however, there is some question as to whether it is indigenous to the Gulf. Even if it is determined to be native to the Gulf, it may still be classified as invasive because of its aggressive nature and ability to rapidly colonize and overgrow artificial structures. Collected from the island of Oahu, Hawaii. In areas where it is abundant, it overgrows other epibionts and smothers them. Lambert (2002) noted that in 14 months, *D. perlucidum* colonized and covered 100% of a sunken petroleum rig off Texas." (all from NAS site).

White didemnid (*Didemnum candidum*) – This is a common colonial ascidian that forms patches or mounds in shallow water; it fouls all substrates including living animals and algae. Introduced as ship's fouling, this species inhabits all of the Hawaiian main islands

Subphylum Vertebrata

Class Cyclostomata (including the sea lamprey)

Sea Lamprey (*Petromyzon marinus*) – The sea lamprey has been considered one of the most deleterious and costly invasives (native transplants) in the United States. This species first entered the Great Lakes via entrance into Lake Ontario in the mid-1800s, probably via the Mohawk Valley River and Erie Barge Canal. Construction of the Welland Canal system allowed passage of this species into the upper Great Lakes in the early- to mid-twentieth century, although it first appeared in these waters decades after the Welland Canal was opened. In Lake Erie, because of the lack of expansive spawning habitat with appropriate clean gravel/rock substrates and optimal water velocities in its tributary streams (due largely to wide-scale damming, and excessive silt loading from agriculture), this species never reached the high densities that it later achieved in the three upper Great Lakes (Trautman 1957; Fuller 1999). Once entering Lake Huron, Lake Michigan, and Lake Superior, the sea lamprey exhibited rapid population expansions, reaching very high densities in just a few generations of reproduction.

Substantial controversy has surrounded the role that the sea lamprey played in the collapse/extinction of a number of native fish species in the Great Lakes, including the lake trout and a number of coregonine species (whitefishes and ciscoes such as the longjaw cisco *Coregonus johannae,* blackfin cisco *C. nigripinnis* and longjaw cisco *C. alpenae*). The loss of these resources happened over several decades, showing patterns that could be explained either by fishing mortality or predation by sea lamprey. The lake trout declined and disappeared sequentially from lake to lake based on distance from Lake Erie; commercial fishing tended to develop in the same manner, with fleets shifting their efforts greater and greater distances from the metropolitan areas of Ohio, southern Michigan and northern Indiana/Illinois as fish stocks declined locally. The sea lamprey entered and expanded throughout the Great Lakes basin in a similar manner, arriving in Lake Superior last due to distance of expansion once successfully traversing the Welland Canal. The same pattern persisted within specific lakes, with local stocks of lake trout disappearing followed by effort of fishing fleets expanding to more distant parts of the lake to fish previously unharvested stocks. Another pattern of loss was seen among the deepwater ciscoes, particularly in Lake Michigan. Among the assemblage of species of this fish group that existed in Michigan, there were sequential lake-wide losses starting with the largest bodied species sequentially through the next largest until the smallest species was all that remained reasonably intact (Judd and Leach 1993). Commercial fishing fleets behave in a way that would produce all of these patterns of loss; however, the manner in which the sea lamprey invaded the upper Great Lakes, and its behavior as a predator that may select larger bodied prey first (the same behavior exhibited by commercial fishing) had supported those researchers that contend the sea lamprey was the major agent causing declines of native species while fishing played a secondary role if any.

Class Osteichthyes (boney fishes)

Alewife (*Alosa pseudoharengus*) – The alewife invaded the Great Lakes via the Welland canal system in the 1940's. The decline and disappearance of lake trout stocks in Lake Huron and Lake Michigan led to an explosive expansion of this species in these water bodies (Judd and Leach 1993). By the 1960s, the alewife had become the most abundant species in biomass in these lakes, often undergoing massive die-offs, littering recreationally important beaches and plugging intake pipes of power plants and municipal water supplies, causing "economic havoc" (Judd and Leach 1993). The alewife was at least in part responsible for the decline of native coregonine species that had supported commercial or recreational fisheries – including the whitefish (Crowder and Binkowski 1983), deepwater cisco and lake herring (the latter also affected by rainbow smelt), and the rainbow smelt due to competition, and egg and larval predation. In Lake Michigan, the decline of yellow perch coincided with the increase in dominance of the alewife; perch did not rebound until the alewife stock declined due to predation by introduced Pacific salmon. The decline of the alewife in Lake Michigan and Huron caused a decline in the quality of the very valuable put-grow-and-take Pacific salmon recreational fishery, as well as potentially affecting success of lake trout restoration, due to a reduction in the forage base of these salmonine predators. Predation by alewives on lake trout fry might also impact success of lake trout restoration programs (Krueger et al. 1995).

American eel (*Anguilla rostrata*) – The American eel was first intentionally released into California waters in 187; it has been released since that time for aquaculture and potential establishment of reproducing populations.

American shad (*Alosa sapidissima*) – This was one the earliest transplants of native fishes from the Altantic to the Pacific coast, after creation of the U. S. Office of the Fish Commissioner in 1871. Current production rates in California are strongly influenced by river flows in systems such as the Sacramento/San Joaquin estuary. Water diversion in that system can lead to loss of larvae to diversion canals, to decreased nursery habitat and declines in food productivity (Ross 1997).

Atlantic salmon (*Salmo salar*) – The Atlantic salmon was stocked extensively on the West Coast in an attempt to establish spawning populations. More recently this species has been intensively "farmed" throughout the Pacific coast of the U. S. and Canada. Although hundreds of thousands of Atlantic salmon have escaped from aquaculture facilities, no reproduction has been reported in West Coast states. Reproduction has been found in British Columbia. This species' introduction to the West Coast led to the establishment of viral hemorraghic disease, a potentially deadly salmonid pathogen particularly in rearing facilities (agency hatcheries and private aquaculture systems).

Bighead carp (*Hypophthalmichthys nobilis*) – The bighead carp was collected in Lake Erie in 2000. Its impacts are unknown. This species is planktivorous and attains a large size.

Blacktail snapper (*Lutjanus fulvus*) – The Hawaiian Division of Fish and Game stocked several species of non-indigenous snappers in the 1950s, including the blacktail, humpback, rose and bluestripe snappers to create new recreational fishing opportunities. The blacktail and bluestripe snappers have since become established throughout the Hawaiian Islands, although the blacktail is not abundant in any locality. The rose snapper never became established, and the humpback, although once considered established, has not been collected in Hawaii since the early 1990s.

Brown Trout (*Salmo trutta*) – first introduced into U. S. waters in the 1880s by the U. S. Office of the Fish Commissioner; since that time this species has been actively propagated and stocked by both federal and state agencies widely through the U. S. The brown trout currently supports economically important recreational fisheries via put-grow-and-take programs and natural production (Fuller et al. 1999; Ross 1997). Although highly valued as a recreational species and widely held to be a successful introduction to North American waters, the brown trout has caused serious problems with native fauna. Where naturally reproducing populations overlap in geographic distribution with the native brook trout (*Salvelinus fontinalis*; a stream-dwelling species), brook trout populations are restricted in habitat to upstream headwaters; the brown trout, via competition for food and space, and possibly predation, has eliminated them from using more productive downstream habitats. Thus the quality and distribution of brook trout fisheries has diminished. It has had similar impact in freshwaters of western U. S. with other native species such as the cutthroat trout, the federally listed golden and Gila trouts, and Dolly Varden (Ross 1997). Potentially the greatest harm caused by the introduction of the brown trout will be the spread of whirling disease in the U. S. Whirling disease, caused by the protozoan parasite *Myxobolus cerebralis*, attacks cartilaginous tissues of the vertebral column and skull of salmonid fishes. If infecting young-of-the-year trout, this disease can cause severe cranial deformity, putting pressure on the brain and spinal cord that leads to behavioral aberrations (expressed as uncoordinated whirling behavior) and death. Whirling disease can generate extremely high mortalities of native North American salmonids, although it does not do so with the European brown trout, its native host. Once thought to be contained to hatchery systems, in a short number of years in the 1990s it was found in a number of watersheds in western U. S. and in New York state. Since its discovery in the wild, whirling disease already has caused the collapse of native/resident trout populations in several western states (Fuller et al. 1999). As yet it potential impact on lake trout is not well understood, but it could affect the success of lake trout restoration in the Great Lakes, as well as salmonine fisheries supported by other species in that system.

Chinook salmon (*Oncorhynchus tshawytscha*) - native to the West Coast of the USA, this species has been stocked in all the Great Lakes. The chinook salmon may compete with native lake trout (*Salvelinus namaycush*), thus impeding the restoration of this important native species to the Great Lakes drainage; it also may impact restoration of Atlantic salmon in Lake Ontario due to competitive interactions (Fuller et al. 1999; NAS site). Evidence strongly suggests that this species has become naturalized in Lake Superior and natural production exceeds hatchery production in terms of sport fish catch (Peck et al. 1999; NAS site). Due to the loss of deepwater predators, particularly the

lake trout, and the dominance of the introduced alewife which served as a substantial forage base, the stocking of Chinook salmon (begun in Lake Michigan in 1967) led to the creation of a very valuable recreational fishery in the Great Lakes, particularly Lakes Michigan and Huron; the Lake Michigan fishery for chinook and coho salmon alone was valued at $150,000,000 by the mid-1980s (Judd and Leach 1993). The growth of this put-grow-and-take fishery (a fishery supported by annual stocking of young fishes, without measurable natural reproduction supplementing the population) is felt to be a major reason for the decline of the nuisance alewife resource in Lake Michigan. However, by the 1990s concern was growing that continued stocking of put-and-take Chinook salmon and other top predators would lead to population collapses of alewife and populations of other forage fish, thus disrupting the food base that supports the economically valuable sport fisheries of the Great Lakes (Jones et al. 1993; NAS site).

Common carp (*Cyprinus carpio*)- Introduced into North American waters from Europe as early as 1831 (Courtenay et al. 1984) this species was propagated and widely distributed in the late 1800s by the U. S. Office of The Fish Commissioner. Its propagation in federal hatcheries was terminated by about 1900 when public enthusiasm turned to criticism because of the carp's tendency to displace native species. It has since become established in freshwater systems in more than 40 states, including the Great Lakes. The common carp has proven to be a nuisance throughout the U. S.; "while foraging, the carp can uproot aquatic vegetation, and can cause marked increased in turbidity due to suspension of bottom substrates" (Ross 1997), thus degrading habitat conditions for native species supporting recreational fisheries.

Eurasian Ruffe (*Gymnocephalus cernuus*) – The Eurasian ruffe was introduced to Lake Superior in the mid-1980's in the ballast water of a trans-oceanic ship, first found in Duluth Harbor of Lake Superior in 1986 (Savino and Kolar 1996). This species competes with native fish for food and habitat; it may have a particular detrimental effect on native yellow perch, *Perca flavescens* (Savino and Kolar 1996). Due to its high reproductive rate and its feeding efficiency across a wide range of environmental conditions, it is a threat to other forage fish species. The Eurasian ruffe is a serious threat to commercial and sport fishing and has the potential to seriously disrupt the delicate predator/prey balance necessary to sustaining a healthy fishery.

Fang-toothed blenny (*Omobranchus ferox*) – This species was probably introduced to Hawaii via ballast water. Although not socio-economically important, this invasive species is somewhat of a pest to people, readily biting them with its large, sharp teeth (NAS site).

Goldspot herring (*Herklotsichthys quadrimaculatus*) – The goldspot herring was introduced to Oahu, Hawaii in 1972, likely by a National Marine Fisheries Service research vessel that carried this species to use as bait while exploring tuna fisheries of the Marshall Islands (NAS site). Fish were presumably dumped into Kewalo Basin, Oahu when the vessel returned to port after completing its cruise. Fishermen believe this species is responsible for stock declines of native baitfish species and silversides.

Grass carp (*Ctenopharyngodon idella*)- The grass carp was first introduced in the US in the 1960's as a biological control of rooted aquatic vegetation. The grass carp was first seen in the Great lakes in the 1980's. Impacts include interspecific competition for food with invertebrates and other fishes, significant changes in the composition of macrophyte, phytoplankton, and invertebrate communities, interference with the reproduction of other fishes, and decreases in vegetation refugia for other fishes.

Humpback Grouper (*Cromileptes altivelis*) – Occurrence in Forida and Hawaii is probably due to aquarium releases. The impact of its introduction is unknown, but it is considered to be "endangered" in its native range by the IUCN.

Marquesan sardine (*Sardinella marquesensis*) – released in Hawaii during research cruises, it is now established on all major islands. The impact of this species is unknown. The Marquesan sardine caused the death of a fishermen in 1975 due to clupeoid poisoning (NAS site).

Pink salmon (*Oncorhynchus gorbuscha*)- This species, introduced periodically in the Great Lakes since the 1880s, has become widely established although not as a dominant member of the fish communities of this system. This species may have displaced native chubs and the lake herring (coregonines) through competition for food, (Fuller et al. 1999). Where established it provides recreational fishing opportunities.

Peacock hind (*Cephalopholis argus*) – An inhabitant of shallow water coral reefs, this species was intentionally introduced to the Hawaiian Islands originally in 1956. By the early 1970s it had spread throughout the Hawaiian islands and had become the target of both commercial and recreational fishing.

Rainbow smelt (*Osmerus mordax*) – The rainbow smelt entered the "upper" four Great Lakes after construction of the Welland canal system provided passage past Niagara Falls. Once established, this species became a principal forage species for the lake trout, also supporting a modest commercial fishery (Judd and Leach 1993). It was the primary prey of salmonines (Pacific salmon and the lake trout) in Lake Huron, and reached a dominant biomass in Lake Erie. The loss of the blue pike in Lake Erie, an endemic species supporting an important commercial fishery into the mid-twentieth century, has been blamed on the combined effects of overfishing and competition with the rainbow smelt. The smelt may also have been partially responsible for the decline of the walleye in Lake Erie, although that species has rebounded in the latter decades of the twentieth century (Ross 1997). The rainbow smelt competes with lake herring (*Coregonus artedii*) for food and may be responsible for the decline of whitefish (*Coregonus* spp.). Its decline in Lake Superior in the later twentieth century is felt to have been due to predation from Pacific salmon and the recovering lake trout stocks.

Red Lionfish (*Pterois volitans*) – This species inhabits reefs from 10 to 175 meters in depth. Liberated into coastal waters of Florida and coastal states possibly by aquarists, by ballast water release, and as escapees from a beachside aquarium during hurricane Andrew in 1992 (Courtenay 1995). Its dorsal and anal spines can inflict a

painful sting by release of a potent venom when handled. The National Centers for Coastal Ocean Science recently completed an integrated assessment of this species. Of particular concern is the potential impact on marine ecosystems of the southeast U.S. and diver-fish interactions (Hare and Witfield 2003).

Round Goby (Apolonia (*Neogobius) melanostomus*) – The round goby invaded the Great Lakes in 1990. The round goby tolerates a wide range of environmental conditions. Its diverse diet that includes dreissenids, its aggressive behavior, its ability to spawn repeatedly throughout the spring and summer, its large size compared with species of a similar benthic lifestyle, and egg predation (Charlebois et al. 2001; Steinhart et al. 2004) may make it a threat to valued recreational fishes such as the smallmouth bass (*Micropterus dolomieui*). It probably served as the major factor in the local extinction of a native species, the mottled sculpin (*Cottus bairdi*) in southern Lake Michigan (Janssen and Jude 2001).

Rudd (*Scardinius erythrophthalmus*) – a recent Great Lakes invader (1989), impacts caused by its introduction are largely unknown in the Great Lakes region. This species is omnivorous and can tolerate eutrophic and polluted waters. It probably competes with native species for food resources.

Shimfuri goby (*Tridentiger bifasciatus*) – The shimfuri goby occurs in marshes and bays. This species has become a dominant member of the fish community in Suisan Bay, California. It may compete with the federally endangered tidewater goby (*Eucyclogobius newberryi*), further threatening its continued existence, if the two come into sympatry (NAS site).

Steelhead Salmon/rainbow trout (*Oncorhynchus mykiss*) – an andromous form of the rainbow trout, steelhead salmon were introduced into the Great Lakes to support recreational fisheries. Self-sustaining populations now exist throughout Great Lakes basin. Steelhead use tributary streams for spawning, and reside as juveniles and adults in the Great Lakes proper (Kocik and Taylor 1996). A species native to the western slope of the Rocky Mountains, the rainbow trout has also been widely introduced into the Great Lakes watershed, and throughout the eastern two-thirds of the U. S. Where introduced, *O. Mykiss* has caused widespread extinction or collapse of local populations of a number of native salmonids, due to competition, predation and introgressive hybridization. In western states this species has displaced federally listed Lahontan cutthroat trout (*O. clarki*), and hybridized extensively with the listed Gila trout (*O. gilae*) and Arizona trout (*O. apache*), and is held responsible for the extinction of the Alvord cutthroat in Arizona (Fuller et al. 1999). Widespread stocking of rainbow trout infected with whirling disease has introduced this deadly parasite (an exotic disease of the European brown trout – see brown trout) into watersheds of more than 20 states (Fuller et al. 1999).

Striped Bass (*Morone saxatilis*) – First introduced into California waters in the late 1870s by the U. S. Office of the Fish Commissioner; it is one of the earliest government introductions of an Atlantic coast/Gulf of Mexico native to the Pacific coast. A highly prized sport fish, the abundance of striped bass in California has been

challenged by water-use patterns. Water withdrawals from the San Joaquin River basin result in changes in salinity in the lower basin that can disrupt striped bass spawning activity, particularly in low flow years (Ross 1997). Diversion-related low flows in that same system can increase mortality of postlarval striped bass in the Sacramento/San Joaquin estuary, possibly doe to loss of estuarine nursery habitat. When abundant, the striped bass can serve as an important source of mortality to Pacific salmon fingerlings due to predation.

Western mosquitofish (*Gambusia affinis*) – Western mosquitofish have had several ecological impacts. Their aggressive and predatory behavior may negatively affect populations of small fish through predation and competition and may actually lead to increases in local mosquito populations by displacing select native fish species regarded as better or more efficient mosquito control agents. Introduced mosquitofish have also contributed to the elimination or decline of populations of federally endangered and threatened species. Mosquitofish are very aggressive, even toward larger fish. They often injure and sometimes kill other species. When these include zooplankton grazers, algal blooms can occur. They are known to prey on eggs, larvae, and juveniles of various fishes, including those of largemouth bass, which is a preferred fish of many anglers. Known socioeconomic impacts thus far seem to be limited to some watersheds of the Great Lakes, rather than the lakes themselves.

White perch (*Morone americana*) – The white perch first gained access to Lake Ontario through the Mohawk River Valley and the Erie Barge Canal, and gained access to Lake Erie (1953) and the upper Great Lakes (Lake Huron 1987) through the Welland Canal (Fuller 1999). This species causes significant egg mortality to native species supporting recreational fisheries such as the walleye and yellow perch; at times, up to 100% of the diet of the white perch is comprised of eggs or one or both of these species (Fuller 1999). In Lake Erie, white perch compete with yellow perch for food, possibly affecting the production dynamics of this species (Parrish and Margraf 1990).

Yellowfin goby (*Acanthogobius flavimanus*) – The yellowfin goby was introduced via the release of ballast water, or possibly as eggs deposited on organisms fouling ship's hulls. It is a dominant species where established in San Francisco Bay and other CA embayments and coastal marshes. This species may be causing declines in native CA fishes, and may eliminate the federally endangered tidewater goby.

Class Mammalia

Nutria, swamp beaver, coypu (*Myocastor coypus*) – The nutria is an aquatic South American rodent that was purposely introduced to the Gulf of Mexico states in the 1930s as a fur producer. Although nutria fur did not develop major economic value, it currently is more important than the native muskrat in Louisiana's fur/trapping industry (Gulf States Marine Fisheries Commission 2005b). Once introduced, the nutria displayed explosive population expansion. Although generally associated with freshwater, this species can also inhabit brackish and coastal salt water habitats. Nutria can cause substantial damage to aquatic vegetation, severely damaging wetlands; the nutria has been implicated in the loss of emergent marsh habitats in the Chesapeake Bay (Haramis 2006). Extensive burrowing behavior can cause damage to the stability of levees. After introduction to the Mississippi Barrier Islands, this species' feeding behavior of digging up and eating roots and rhizomes of sea oats, has threatened the stability of beach dunes. This species carries the nematode *Strongiloides myopotami*, which causes a severe rash called "marsh itch" in humans. The nutria threatens the habitat and survival of rare marsh birds, such as bitterns.

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