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NONINDIGENOUS MARINE SPECIES IN THE GREATER TAMPA BAY ECOSYSTEM

FINAL REPORT

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NONINDIGENOUS MARINE SPECIES IN THE GREATER TAMPA BAY ECOSYSTEM

Literature Review and Field Survey of Tampa Bay
for Nonindigenous Marine and Estuarine Species

Final Report to the Tampa Bay Estuary Program

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Summary
Literature, internet, and museum resources were surveyed for information on nonindigenous species in the greater Tampa Bay ecosystem, Florida. Field surveys were also conducted for confirmation of some species. The greater Tampa Bay ecosystem is here defined as coastal marine and estuarine waters from Anclote Keys to the southern end of Sarasota Bay, including Tampa Bay and all marine-influenced tributaries.

Sixty-five species are discussed in detail. Of these, 41 species are known to occur in the greater Tampa Bay ecosystem, nine species are suspected to be present but not well documented and 15 species are potential or expected invaders from nearby ecosystems. Of the species known or suspected to be present, 12 are cryptogenic in origin. Well-studied groups, including mollusks, chordates (fish and sea squirts), and crustaceans make up the majority of the known invasives. It is probable that continued field surveys would reveal many more nonindigenous and cryptogenic species, particularly among the smaller invertebrates. Known or suspected invasion vectors for invasion of these nonindigenous species include: shipping (ballast water, hull fouling, wet cargo, etc.), fisheries and aquaculture (bait, fishery enhancement, aquaculture escape) and private releases. Many invasions occurred decades or centuries ago, and the modern importance of these vectors is unknown.

We recommend two actions. First, a formal rapid assessment of nonindigenous species in the greater Tampa Bay ecosystem should be conducted. A rapid assessment is a cost-effective means to rapidly expand our database on nonindigenous species in the area, and will help resource managers decide how to allocate funds towards research on impacts from biological invaders. Second, a formal investigation of the importance of different vectors for biological invasion to the region should be undertaken. Such a study is essential for managers and regulators when allocating resources to limit new biological invasions.

Table 1. Known or probable nonindigenous and cryptogenic species in the greater Tampa Bay ecosystem (GTBE), Florida. See text for references.

Latin Name/Common Name	Native Range	Distribution in GTBE
MICROALGAE		
Odontella sinensis Centric Diatom	Indo-Pacific	widespread in plankton
PLANTS		
Hydrilla verticillata Hydrilla	southern Asia	freshwater-oligohaline
Alternanthera philoxeroides Alligatorweed	South America	freshwater-oligohaline
Myriophyllum spicatum Eurasian Watermilfoil	Eurasia, Africa	freshwater-oligohaline
CNIDARIANS		
Cordylophora caspia a colonial hydroid	Ponto-Caspian (Eurasia)	common in nearby lakes suspected from GTBE
Garveia franciscana Pelo de Oso	Pacific?	common in estuarine caves in GTBE, wide salinity range
Diadume lineolata Lined Sea Anemone	East Asia?	widespread in GTBE
FREE-LIVING FLATWORMS		
Taenioplana teredini a predatory flatworm	Indo-Pacific?	recorded from Sanibel Is. suspected from GTBE
Stylochus frontalis Oyster Leech	cryptogenic	widespread in benthic habitats
POLYCHAETE ANNELIDS		
Boccardiella hamata a spionid worm	East Asia?	reported from Tampa Bay distribution unknown
Boccardiella ligerica a spionid worm	Western Europe?	reported from Tampa Bay distribution unknown
Serpula elegans a calcareous tubeworm	Indo-Pacific	reported from Tampa Bay distribution unknown
Ficopomatus enigmaticus a reef-building tubeworm	Australia	reported from Tampa Bay distribution unknown
Mediomastus californicus a capitellid worm	unknown cryptogenic	widespread in GTBE

Table 1. (cont.)

Latin Name/Common Name	Native Range	Status in GTBE
MOLLUSKS		
Melanoides tuberculata Red-rimmed Melania (snail)	Middle East (Eurasia)	oligo-mesohaline
M. turriculus Faune Melania (snail)	Philippines	oligo-mesohaline
Tarebia granifera Quilted Melania (snail)	Southeast Asia	oligo-mesohaline
Siphonaria pectinata Striped False Limpet	Eastern Atlantic? cryptogenic	known from Collier County suspected from GTBE
Perna viridis Green Mussel	Indo-Pacific	widespread in GTBE
Mytilopsis sallei Santo Domingo Falsemussel	Southern Caribbean? cryptogenic	oligohaline
Mercenaria mercenaria Northern Hard Clam	Western Atlantic incl. NE Florida	meso-euryhaline
Corbicula fluminea Asian Freshwater Clam	Eastern Asia	oligohaline-freshwater
Martesia striata Striate Piddock	Indian Ocean? cryptogenic	widespread in GTBE in wood
Bankia fimbriatula Fimbriate Shipworm	South America? cryptogenic	known from Sanibel Is. suspected from GTBE
Lyrodus bipartita a shipworm	Indo-Pacific? cryptogenic	known from Monroe County suspected from GTBE
Lyrodus massa a shipworm	Indo-Pacific? cryptogenic	known from east Florida suspected from GTBE
Teredo clappi a shipworm	Indo-Pacific? cryptogenic	known from east Florida suspected from GTBE
Teredo furcifera a shipworm	Indo-Pacific? cryptogenic	known from east Florida suspected from GTBE
CRUSTACEANS		
Balanus amphitrite Striped Acorn Barnacle	Indo-Pacific	widespread in GTBE eury-mesohaline
Balanus reticulatus an acorn barnacle	Indo-Pacific	widespread in GTBE eury-mesohaline
Balanus trigonus an acorn barnacle	Indo-Pacific	known from GTBE distribution unknown
Sphaeroma terebrans Warty Pillbug	Indo-Pacific	widespread in GTBE in wood
Sphaeroma terebrans Warty Pillbug	Indo-Pacific	eury-mesohaline
Ligia exotica Wharf Roach	eastern Atlantic, Mediterranean	widespread in GTBE wide salinity range
Platychirograpsus spectabilis Saber Crab	Yucatan Peninsula, Mexico	known from local rivers, larvae probably marine
Petrolithes armatus Green Porcelain Crab	east Pacific	abundant in GTBE

BRYOZOANS		
Sundanella sibogae a ctenostome bryozoan	Indo-Pacific?	known from Cedar Key suspected from GTBE
Zoobotryon verticillatum a ctenostome bryozoan	Indo-Pacific? cryptogenic	known from Cedar Key suspected from GTBE
CHORDATES - SEA SQUIRTS		
Styela canopus Rough Sea Squirt	Asia?	known from GTBE distribution unknown
Styela plicata Rough Sea Squirt	Asia?	eury-mesohaline
Botryllus schlosseri Star Ascidian	Europe?	suspected from GTBE
Botryllus niger a colonial sea squirt	unknown	suspected from GTBE
CHORDATES - VERTEBRATES		
Hoplosternum littorale Brown Hoplo	South America	oligohaline-freshwater
Belonesox belizanus Pike Killifish	Central America	mesohaline-freshwater
Cichlasoma cyanoguttatum Rio Grande Cichlid	Mexico, Texas	oligohaline-freshwater
C. urophthalmus Mayan Cichlid	Central America	known from Everglades suspected from GTBE
Oreochromis aureus Blue Tilapia	Africa, Middle East?	mesohaline-freshwater
O. mossambicus Mozambique Tilapia	East Africa	widespread in GTBE wide salinity range
Sarotherodon melanotheron Blackchin Tilapia	West Africa	widespread in GTBE wide salinity range
Tilapia mariae Spotted Tilapia	West Africa	known from Everglades suspected from GTBE
Bufo marinus Marine Toad	Central America	known from GTBE

Table 2. Potential or expected nonindigenous and cryptogenic species in the greater Tampa Bay ecosystem (GTBE), Florida.

Latin Name/Common Name	Native Range	Range near GTBE
VIRUSES AND PROCARYOTES		
IHHNV (no Latin name) Shrimp Virus	unknown	reported in Florida farms but not in wild shrimp
Vibrio cholerae Cholera	unknown	reported from Gulf of Mexico may occur in Florida
MACROALGAE		
Caulerpa brachypus Mini Caulerpa	Indo-Pacific	Caribbean, east Florida
Monosporus indicus filamentous red alga	Indo-Pacific	Pensacola, Florida
NEMATODES		
Anguillicola crassus an eel parasite	Eastern Asia	Texas?
CNIDARIANS		
Phyllorhiza punctata Spotted Jellyfish	Australia	Caribbean, east Florida, northern Gulf of Mexico
Drymonema dalmatinum Purple Sea Mane	Mediterranean	Carribean, northern Gulf of Mexico
MOLLUSKS		
Perna perna Brown Mussel	Africa, Asia	Texas
CRUSTACEANS		
Macrobrachium olfersii Bristled River Shrimp	tropical America	St. Johns River, Miami, northwest Florida
Charybdis hellerii a swimming crab	Indo-Pacific	east Florida
Hemigrapsus sanguineus Asian shore crab	western Pacific	North Carolina expanding south
BRYOZOANS		
Conopeum "*seurati*" a cheilostome bryozoan	Europe? cryptogenic	east Florida
Cryptosula pallasiana a cheilostome bryozoan	unknown	east Florida
Watersipora subovoidea a cheilostome bryozoan	Indo-Pacific? cryptogenic	east Florida
Victorella pavida sea mat	India?	east Florida
VERTEBRATES		
Pterois volitans Red Lionfish	Indo-Pacific	east Florida occasionally estuarine

1. Introduction

Tampa Bay is one of the largest and most diverse estuaries in Florida and the Gulf of Mexico. There is a large human population surrounding the bay and several important regional and international marine ports within the bay. These factors provide the conditions necessary for the introduction of nonindigenous species on a scale comparable to other major estuaries. Compared to other U.S. coastlines, however (Carlton, 1979a, 1979b, 1999a; Mills et al., 2000), the topic of nonindigenous species in the Gulf of Mexico has received limited scientific attention. As an illustration, at the 2001 Marine Bioinvasions conference, held in Louisiana, only 36 of the 165 registered attendees and 9 of 94 presentations were from the Gulf of Mexico and southeastern U.S., despite this being the region hosting the conference (calculated from conference proceedings; Barrett-O'Leary, 2001).

Nonindigenous marine species do occur in Tampa Bay and surrounding waters, and as discussed here, some of these probably have important impacts. A few of these invaders have been noted in the past (Marchand, 1946; Rehm, 1976). On the other hand, some common invaders, such as several species of acorn barnacles, have been ignored or not even recognized as nonindigenous in Florida until recently (Carlton and Ruckelshaus, 1997). The study of biological invasions as a discipline dates only to the 1950s (Elton, 1958), and most prior focus has been in terrestrial and freshwater ecosystems. This is particularly true of Florida, home to many famous pests (Simberloff et al., 1997). The publication dates of most of the references used in this study reflect the recent interest in Florida marine invasions, but this represents a trend in research, not a surge in biological invasions.

The following review is not intended to be a formal *rapid assessment* of the type conducted in several other parts of the United States (e.g. Mills et al., 2000), but to determine whether such an assessment is warranted, what its parameters should be, and what other research or management strategies should be pursued.

1-1. Terminology

The study of biological invasions has gained momentum only in the past several decades. As a consequence, much of the terminology is recent and subject to change. The following lexicon comes from a broad reading of the field of invasion ecology. Useful references include Carlton (1996), Simberloff (1997), and Williams and Meffe (1998).

<u>Nonindigenous</u> is currently preferred by some U.S. federal agencies (e.g. U.S. Geological Survey, 2000) to refer to non-native organisms. This term is synonymous with *non-native*, *invasive*, *alien*, *introduced*, and in most cases, *exotic*. *Feral* usually refers to nonindigenous terrestrial animals that have escaped domestication. The U.S. EPA uses the term *biological pollutant* for a nonindigenous species (Baker and Baker, 1999), although one of the original sources for that term uses *invasive* as a synonym (McKnight, 1993). Baker (1965) used *invasive* as a synonym for *weediness* (i.e. dominance) in terrestrial plants, but this use of the term does not prevail in marine terminology. The opposite of *nonindigenous* is usually simply *native*. We shall use both *nonindigenous* and *invasive* throughout this manuscript as synonyms.

Legal and biological definitions of nonindigenous have differed in the past. The biological definition of a nonindigenous species is any established outside of its actual native range. Range, in this context, is defined narrowly. Thus, white bass (*Morone chrysops*), which are native to east Florida rivers, are nonindigenous to the Florida panhandle (Fuller et al, 1999). The legal definition of "native," however, relies upon political boundaries. Until recently, the white bass was considered "native" anywhere in the United States by federal and state agencies, since it was native to part of the U.S.

Invasion is used narrowly by most invasion ecologists to refer to the full process leading to the establishment of a self-maintaining population of a nonindigenous species. *Introduction* is usually a synonym, but implies human involvement, whereas invasion can include natural invasion (a rarely observed event). Biological invasion includes three phases: *inoculation*, *establishment*, and *range expansion*, but ecologists often lump these phases together as *biological invasion*.

- *Inoculation* is the arrival of *propagules* of a nonindigenous species, and is synonymous with the use of the term *invasion* in the popular press. A propagule is defined as any viable unit capable of growth and eventual reproduction, and may include larvae, seeds, or adults. Many inoculations simply die out (Carlton, 1979a; Carlton and Ruckelshaus, 1997; Williams and Meffe, 1998), but there are no good estimates of the proportion that survive.

- *Establishment* refers to the survival, reproduction, and persistence of a new population of a nonindigenous species. Establishment may not occur even if the species can tolerate the host environment because opportunities for reproduction do not occur. For example, sessile marine animals must settle close enough to each other for sperm and egg, which are short-lived gametes, to meet and produce embryos (Levitan and Petersen, 1995). This implies that small inoculations of planktonic larvae will often fail to result in establishment because they are widely dispersed and the resulting adult population is too dilute to reproduce (Baker et al., 2000).

- *Range expansion* usually follows establishment. If range expansion does not occur, the nonindigenous population is vulnerable to chance events, and may die out. We know of no studies that have established the frequency of such die-outs, but examples are common among freshwater fish (Fuller et al., 1999). Range expansion is usually thought of as dispersal by natural means, i.e. coastal currents. If human agents are involved in the continued spread, these events are considered additional inoculations.

Cryptogenic is used to refer to species for which the native range is uncertain (Carlton, 1996). This happens more often than might be suspected, because biological invasions, even in the marine environment, preceded any of the modern biological sciences by several centuries. In many ecosystems, including Florida, there are species long considered native which turn out to have been introduced long ago. There is a longer list of species for which this might have occurred, but for which there has been no detailed study to determine the true origin. The case of the "Portuguese oyster" is discussed below, in Section 1-3. Invasion Vectors: Hull Fouling.

1-2 Biogeography

The interaction of biology and coastal geography influences both our perception of biological invaders, and the probability of invasion. Nonindigenous species in this report are categorized as *known*, *probable*, *expected*, or *potential* invaders of Tampa Bay. The order of these terms indicates a declining expectation of their presence in Tampa Bay. Here we outline a geographical scheme used for this categorization. Rationale for this scheme is presented in Appendix A.

Tampa Bay is not distinct from adjacent coastal ecosystems. We hereby define the *greater Tampa Bay ecosystem* as coastal and estuarine waters from Anclote Keys (Clearwater Bay) in the north to Philippe Creek (Sarasota Bay) in the south. Tidally influenced tributaries to about 1 ppt salinity are included, as are marine waters to about 5 km offshore. Nonindigenous species known from any portion of the greater Tampa Bay ecosystem are **known invaders**.

The greater Tampa Bay ecosystem lies within a transition zone from tropical to warm temperate coastal ecosystems. This transition zone is hereby designated the *West Florida ecocline*. The northern limit of the West Florida ecocline is Cedar Keys, and the southern limit is Florida Bay, both in Florida. Nonindigenous species recorded from the West Florida ecocline, but not specifically from the greater Tampa Bay ecosystem, are considered **probable invaders**.

Nearby coastal regions may serve as sources of nonindigenous species to the greater Tampa Bay ecosystem. Distance, oceanic currents, and biological barriers may affect the likelihood of invasion, although we are unable to estimate specific probabilities. The northern Gulf of Mexico (Cedar Keys to Texas) and the northwest Caribbean (Florida Keys and southeast Florida to Cape Canaveral, Yucatan to Nicaragua, southwest and northern Cuba, and Jamaica) are considered to be separated by few barriers to marine species from the West Florida ecocline. Nonindigenous species established in these regions are considered **expected invaders** of the greater Tampa Bay ecosystem. Other nearby coastal regions, including the eastern Gulf of Mexico, the eastern Carolinian region (Cape Canaveral, Florida to Cape Hatteras, North Carolina) and the remainder of the Caribbean basin are potential but not certain sources for biological invaders. Nonindigenous species established in these regions are considered **potential invaders** of the greater Tampa Bay ecosystem, unless it is believed that temperature tolerance limits limit their further spread.

1-3. Vectors of Invasion

Carlton (1979a) provided the first comprehensive review of vectors (pathways and means) of human-mediated marine biological invasions, and the following categories of known or potential Tampa Bay vectors are modified from that work. Categories of vectors include: 1) fouling of vessel hulls, 2) dry ballast and cargo, 3) water ballast and other water systems, 4) trade in marine species, including aquaculture 5) deliberate introductions, and 6) drift debris.

1-3.1 Fouling of Vessel Hulls

Fouling is a nautical and industrial term, subsequently adopted by marine ecologists, to refer to marine ecosystems consisting of sessile organisms which attach to or bore into hard substrata, usually artificial. The term is convenient because it includes both attached fauna (epibionts) and boring organisms (infauna). In the broadest use of the term, the hard substrata may be natural or artificial, and crevice-dwelling but otherwise free-living organisms (e.g. flatworms) are also included (Carlton and Hodder, 1995). Human structures greatly increase the availability of hard substrata in the typically muddy environments of estuaries. The economic costs of fouling are high, because the weight or burrowing activity of the organisms can damage structures, clog intakes, slow vessels, etc. The addition of any new fouling species can alter these costs. Fouling has been an issue ever since the ocean became a route for transportation, but the Industrial Revolution changed how and where fouling occurred, so hull fouling as an invasion vector can be divided roughly into *historic* versus *modern* phases.

Historic Hull Fouling

Columbus almost certainly brought eastern Atlantic species to the New World on the hull of the *Santa Maria*, although we do not know whether any survived. Well before Columbus, Portuguese traders rounded Africa to points in the Indian Ocean and beyond. In addition to spices, silk, and new technology, they came back with a host of new species attached to their hulls. This vector has been both reviewed and experimentally tested by Carlton and Hodder (1995), using a replicate 16th century sailing vessel.

One of the species brought back to Europe was the Pacific oyster, *Crassostrea gigas*, which rapidly became abundant on the coasts of the Iberian Peninsula. This was centuries before there were local natural historians to record the marine fauna, so when the time came to apply Linnaeus's new taxonomy, the fact that the oyster was non-native had long since passed out of local knowledge. It was named *C. angulata*, and it was not until the end of the 20th century that molecular genetics finally established that the "Portuguese oyster" was, in fact, native to eastern Asia (Ó Foighil et al., 1998).

The above cautionary tale can probably be retold with more obscure fauna all around the world. Florida has been visited by sailing vessels for 500 years, but by naturalists for less than half that time. Seven wood-boring bivalves, a small sea anemone, and three barnacle species in Florida are known or suspected to be introduced from the Indo-Pacific, but all predate marine biological surveys in the region (Carlton and Ruckelshaus, 1997). The same source also listed ten species of nonindigenous invertebrates in Florida which, to that date, had been considered native by Florida researchers. All of these species could have arrived centuries ago either attached to the hulls of wooden ships, living among attached organisms, or bored into the wood itself. This list of long-resident nonindigenous species is likely to grow with further study.

Modern Hull Fouling
Higher vessel speeds, which sweep away most attached organisms, and antifouling paints have reduced hull fouling on major commercial vessels. Ships that are otherwise protected by antifouling paints may have small areas that lack antifouling paint and are not swept directly by currents (Coutts and Taylor, 2001). Hull fouling is more important to other types of vessels, however. Oceanic barges move slowly, seldom have their hulls serviced, and spend weeks to months in each harbor. A single modern barge can have as much surface area as a fleet of 17th century galleons and support a dense and varied fouling community (Godwin, 2001). There are also thousands of private yachts and fishing vessels based out of the greater Tampa Bay area. Hull maintenance of yachts and fishing vessels is variable, records are spotty, regulations are nonexistent, and movements by these vessels have been implicated in the intracoastal spread of nonindigenous species (Zabin and Wasson, 2001). Hull fouling has taken second stage in recent years to ballast water (see below), and may be underrated by resource managers as a vector for invasions.

1-3.2 Dry Ballast and Cargo
Since ancient times, ships have carried temporary ballast whenever they were not fully laden. Rocks were preferred, but sand was used when rocks were unavailable. The ballast was picked up at one port, and dumped overboard at the next port before taking on a new cargo. Even if there were specific areas for such ballast, some inevitably ended up in or along the edge of the water. A variety of small amphibious organisms, such as shore crabs, maritime isopods, intertidal snails, and maritime plants, were associated with dry ballast. Some of these species were capable of surviving weeks or months in the hold of a vessel, particularly if there was some seawater collected in the bottom with which to moisten delicate body parts. It is not known whether any species invaded Florida in dry ballast, but Carlton (1979a) reported two species – a beach amphipod and a maritime insect – which probably invaded California by this vector.

Modern vessels no longer transport dry ballast, but certain cargos my serve the same function. Building stone, coral rock, ore, or coal stored along the shore may acquire a beach fauna and flora. Logs are often stored in water until shipment and may acquire a variety of marine organisms. Logs from Mexico were the probable vector for the introduction of the saber crab, *Platychirograpsus spectabilis*, to Tampa Bay tributaries in the first half of the 20th century (Marchand, 1946). Dry cargos such as coal and phosphate rock are shipped into Tampa Bay, but modern pollution control practices reduce the chances of these cargos either acquiring or releasing maritime species.

1-3.3 Water Ballast and other Water Systems
In the 20th century, dry ballast was replaced with water ballast in most merchant vessels, as discussed below. With the addition of clean water regulations, ballast water and bilge water were separated. Other water systems include coolant systems and fire-fighting systems. Live wells for bait or seafood are discussed in Section 1-3.4.

Water Ballast

The most important vector of marine invasions in recent years is water ballast of large ships (see Barrett-O'Leary, 1999, for a general review). This vector became common in the latter part of the 20th century, when water ballast began to be stored in tanks or cargo holds separate from bilge water, and when vessel size and speed increased significantly. Vessels over 200 meters long cross the Atlantic in a period of days, carrying thousands of metric tons of exotic seawater pumped from a coastal harbor. Until recently, this ballast was routinely emptied in the destination port, while cargo was being loaded, and this still goes on in some harbors. If the origin and destination harbors were reasonably similar, planktonic organisms in the ballast had an excellent chance of survival. The most notorious invader by this manner was the freshwater zebra mussel, *Dreissena polymorpha*, from river ports in Europe to the Great Lakes (Carlton, 1993), but there is a growing list of estuarine and marine species thought to be introduced by this vector (Carlton and Geller, 1993; Cohen and Carlton, 1997; Wonham et al., 2000; Casale and Welsh, 2001).

Regulatory agencies have agreed upon high seas ballast exchange – pumping coastal ballast out and replacing it with mid-ocean water during the voyage - as the most cost-effective means of reducing the threat from ballast water. The theory behind this strategy is that high-seas pelagic taxa cannot survive in coastal waters, and vice versa. In Chesapeake Bay, for example, nonindigenous species in discharged ballast water that did not match estuarine salinities promptly perished (Smith et al., 1999). A mosaic of compulsory and non-compulsory ballast exchange guidelines have been enacted by nations, states or individual ports (McDowell and Cassel, 2001). The U.S. Coast Guard is the lead agency in the United States in researching levels of compliance (Everett, 2001), but the Smithsonian Estuarine Research Center (Collinetti et al., 2001; Murphy and Ruiz, 2001), and state Sea Grant programs (McDowell and Cassel, 2001) among others, are also involved in industry outreach and education. In Florida, compliance as of 2002 was estimated at about 40% of incoming ships (W. Miller, Smithsonian Estuarine Research Center, unpubl. data).

High seas ballast exchange can reduce the densities of nonindigenous species entering a port, but it cannot actually eliminate the threat with current ship design (Simard et al., 2001; Smith et al., 2001; Taylor and MacKenzie, 2001). Alternative technologies are proposed or are being developed (Tamburri et al., 2001; Waite and Kazumi, 2001), so it is possible that permanent solutions for ballast water as a vector for unwanted biological invaders may soon exist. Until that point, ballast water must be considered a primary source for new species invading Tampa Bay (Barrett-O'Leary, 1999).

Other Water Systems

In modern vessels, bilge (waste water collected from the ship decks) is contaminated with petroleum products, paint, and other potentially toxic substances, and its discharge is regulated by most ports. As a consequence, bilge is kept separate from other water systems. Carlton (1979a) did not consider bilge water to be an important vector for species introduction.

In contrast to bilge, coolant systems and fire-fighting intakes are kept as clean as possible. Residency time is low when these systems are running, and each system is usually small enough that if it is shut off, it can become hypoxic in a few days. As long as the system is running, however, it may become habitat for living organisms. This vector for species introduction is often overlooked, but may be significant (Coutts and Taylor, 2001). Many coolant systems are designed to be flushed with hot water specifically to kill fouling organisms, but this is not always done regularly. In one example, the coolant system of a U.S. Navy submarine transported mussels (*Mytilus edulis*) between Chesapeake Bay and other North Atlantic localities, simply because the skipper had not followed the recommended flushing regime (P. Baker, unpubl. data). There is no evidence that this particular event resulted in biological invasion. Unfortunately, no study has been conducted on the importance of water intake systems as a transport vector, although Carlton (1979a) noted the possibility that such intake systems were responsible for separate decapod crustacean invasions of California and Europe. Thus, water systems of marine vessels must be regarded as a potential vector, but the level of risk cannot be assessed.

1-3.4. Trade in Live Marine Organisms

Live marine organisms have been moved around the world for various purposes, resulting in both deliberate and accidental introductions. Deliberate introductions are discussed separately below. Oysters (*Crassostrea* spp.) were deliberately introduced to western North America from the eastern U.S. and Asia, but with them came a host of species associated with the oyster community, including some serious pests (Carlton, 1979a). Oyster introductions to Florida, if they occurred, are not documented, but aquaculture of other species is a potential vector. Other vectors discussed here include aquarium releases, the live seafood trade, and live bait. All of these are potentially significant vectors because the intent is to provide a favorable environment for the transport of live marine organisms over great distances.

Aquaculture

Florida marine aquaculture gained momentum in the 1990s following restrictions on certain forms of fishing. The most successful species to date has been the northern quahog, or hard clam, *Mercenaria mercenaria* (Colson and Sturmer, 2000). The hard clam is native to the east coast of Florida, but not the Gulf of Mexico (Abbott, 1986), where it is cultured in a field grow-out system. Thus, the large hard clam industry in the Cedar Key and Charlotte Harbor areas represent inoculations of a nonindigenous species. The Florida clam culture industry is aware of risks posed by nonindigenous microorganisms (diseases) brought in via shellfish transfers, and there are management regulations in place to prevent disease introduction, but compliance and effectiveness have not been studied (L. Sturmer, Univ. Florida Extension, *pers. comm.*).

Most aquaculture does not involve field grow-out, but land-based pond culture still presents a risk of escape. In one recent example, a hurricane washed thousands of viable Asian tiger prawns, *Penaeus monodon,* from ponds in South Carolina into the Atlantic Ocean, and individuals were captured as far south as Florida (Carlton and Ruckelshaus, 1997; Poss et al., 2000). As the marine aquaculture industry diversifies, there will be pressure to add new species. Laws that protect endangered native species such as Gulf sturgeon (*Acipenser oxyrhynchus desotoi*) restrict the sale of cultured specimens. Similar non-native species, such as Eurasian sturgeons, however, are not protected if they are cultured in the United States, so market pressures may encourage their introduction for aquacylture (Metcalf and Zajicek, 2001). Marine aquaculture may include ornamental species as well, but other aspects of the marine ornamental trade are discussed below, under Aquarium Releases.

Aquarium Releases

The most noted biological invasion in the Mediterranean Sea in recent years was by an Australian strain of the widespread marine alga, *Caulerpa taxifolia*. The blame for this invasion falls on a public aquarium in Monaco, from which the alga escaped via a flow-through seawater system (Wiedenmann et al., 2001). Ironically, the aquarium was associated with marine conservation groups. Flow-through aquarium systems present the greatest risk of escaped nonindigenous species, but even contained aquaria pose risks if near a body of water. Venomous Indo-Pacific lionfish (*Pterois volitans*) escaped from an aquarium in the Florida Keys during a tropical storm, and were later observed among coral reefs (Courtenay, 1997). Aquarium stores are subject to the same risks, if they are close enough to the water. In Florida, if you cannot build on the waterfront, you can bring the waterfront to you via canals, so many commercial and public establishments are within splash range of seawater. Research facilities may also be vectors of introduction if catastrophic events overwhelm their containment systems.

A more difficult vector to quantify is the deliberate release by aquarium stores or private individuals. Aquarium releases by individuals comprise a major vector for nonindigenous freshwater fish in Florida and the rest of the United States (Courtenay, 1997; Fuller et al., 1999). Deliberate or accidental releases of ornamental plants are blamed for several of Florida's worst freshwater aquatic weeds (Schmitz et al., 1997). To date, no marine plants or algae in Florida can be traced to aquarium releases (Carlton and Ruckelshaus, 1997), and marine fish released by individuals have not yet established breeding populations (Courtenay, 1997).

Live Seafood

In 2001, live lobsters (*Homarus americanus*) shipped from Maine to Oregon arrived by air express, packed in fresh Maine seaweed and 40 species of living invertebrates, none of which occurred naturally in Oregon (J.T. Carlton, Williams College, *pers. comm.*). Express air shipment of live seafood is unregulated with respect to nonindigenous species, and is increasingly accessible. At least one species of snail has been introduced to California by this means (Carlton, 1979a). There is also a history of shipping live seafood overland in large tanks, and there has never been an industry move to quarantine these shipments. A visit to a store or restaurant with live seafood will often reveal some nonindigenous species. The waterfront is a popular locality for seafood restaurants in Florida, so accidental releases may occur. Species introduction risks posed by the seafood trade are probably comparable to those from the aquarium trade.

Live Bait
Live bait species which are shipped significant distances tend to be hardy. They are usually abundant, fast-growing, rapidly reproducing fauna, selected for their ability to survive for hours in a bucket of stale water across a range of temperatures and salinities. Unused animals are often dumped overboard. Live bait animals are usually fish or crustaceans, but may be mollusks or annelid worms. In freshwater, bait releases are thought to be responsible for over 16% of nonindigenous fish species in the United States (Fuller et al., 1999). To someone not in the bait business, it is difficult to visualize how far live species may be shipped merely to be impaled on a fishhook, but until recently, marine worms were regularly shipped from New England to California for just that purpose (Carlton, 1979a). Popular marine bait species in Florida include various species of small fish and shrimp, the origin of which are seldom documented, although there are proposed regulations to change that. To date, there are no known marine introductions of bait species in Florida marine waters, but the topic deserves closer examination.

<u>1-3.5 Deliberate Introductions</u>
There is a long tradition of "improving" fisheries by the introduction of nonindigenous species, either as a fishery target or as forage for target fish. Some introductions were private, but over 44% of the nonindigenous fish species established in the United States arrived by agency-sanctioned introductions (Fuller et al., 1999). The peacock cichlid (*Cichla ocellaris*) in Florida is one such example (Florida Fish and Wildlife Conservation, 2003). Marine fish have also been introduced to the west coast of Florida, including the anadromous American shad (*Alosa sapidissima*), formerly restricted to Atlantic drainages (Fuller et al., 1999). At the time that introduction took place the American shad was legally considered native, since it occurred in other parts of the United States. The American shad does not appear to occur in Gulf of Mexico waters near Florida at this time (D. Parkyn and M. Allen, Univ. Florida, pers. comm.).

Fish make up the majority of deliberate stockings, but other species have also been stocked for fishery improvement. *Mysis relicta*, a freshwater peracarid crustacean, has been introduced to coldwater lakes around the world as a forage species (Lasenby et al., 1986). The softshell clam, *Mya arenaria*, was stocked in Oregon early in the 20th century in hopes of establishing a fishery similar to New England (Edmondson, 1923). Carlton (1979a) records other stockings of marine invertebrates, some of them successful. Northern hard clams were introduced to west Florida estuaries (Woodburn, 1961), and can currently be found in Sarasota Bay and Tampa Bay (W.S. Arnold, *pers. comm.*). The state of Florida's position on marine fishery enhancement by the introduction of nonindigenous species is not clearly stated at this time.

Private introductions with the intent of establishing a species (as opposed to aquarium releases, which are considered accidental) have also occurred in both freshwater and marine environments (Carlton, 1979a; Fuller at al., 1999). By their nature, these introductions are undocumented and often illicit. The largest factor which makes it difficult to successfully introduce a new species to the marine environment – the dilution of the inoculation in a very large environment – also makes it difficult to control once established. Federal law does not regulate the introduction of marine species into coastal environments. Florida statutes on the topic are piecemeal, and do not specifically address marine invertebrates.

<u>1-3.6 Drift Debris</u>
Human debris in the oceans is abundant and well-documented, and may serve as a vector of species invasion. Winston (1982a) reported that a bryozoan, *Electra tenella*, was common on drift plastic, which may travel great distances and disperse species far beyond the range of their larvae. There are comparable natural drift vectors, however, including wood, *Sargassum* seaweed, plant seeds, and pumice (Winston, 1982a; Ó Foighil et al., 1999), all of which can be found on Florida beaches. It is debatable, therefore, whether human debris provides a unique vector or merely augments an existing vector. Likewise, it would be difficult to demonstrate that any nonindigenous species that arrived on human debris could not have also arrived on natural drift material.

2. Materials and Methods

2-1. Study Area – Greater Tampa Bay Ecosystem
The geographical parameters of the greater Tampa Bay ecosystem are as follows: Tampa Bay proper, including tidal tributaries and wetlands; coastal waters north to Anclote Keys (Clearwater Bay) and south to Philippe Creek (Sarasota Bay); inland to the head of saltwater intrusion, and seaward to the limit of state territorial waters, 3 miles (5 km) west of Egmont Key. Rationales for these limits are discussed in Appendix A.

Tampa Bay and tributaries encompass a range of salinities from full seawater in the Gulf of Mexico to freshwater. Many Florida freshwaters have naturally high ionic content, but the ions are different from seawater, and will not support many estuarine species. For the purpose of this report, therefore, *salinity* refers to marine salts. We will not consider tidal freshwater species unless they are also common in at least the *oligohaline* portions of estuaries (salinity > 0.5 ppt). Terminology for salinity zones used in this report are taken from McLusky (1971).

2-2. Survey Methods
The study was conducted through literature surveys, augmented by field surveys. Field surveys were used primarily to confirm the presence or identity of certain taxa.

<u>2-2.1 Literature Surveys</u>
The term "literature" is used loosely here, and includes Internet resources as well as museum collections. The following types of resources were used:

1. peer-reviewed manuscripts in journals and texts
2. graduate theses and dissertations
3. peer-reviewed reports to government agencies and symposium proceedings
   e.g. Sea Grant reports and proceedings
4. museum collections (FLMNH = Florida Museum of Natural History,
   FMRI = Florida Marine Research Institute, BMSM = Bailey-Matthews Shell Museum)

5. non-peer-reviewed government reports and symposium proceedings ("gray literature") e.g. Florida state agency publications
6. Internet databases maintained by known research institutions e.g. Smithsonian Marine Station Species Inventory
7. popular media reports
8. personal communications with persons of known credentials

All of the above resources are prone to error, but in the event of contradictory information, the first four types of sources were weighted more than the last four.

<u>2-2.2 Field Surveys</u>

Field surveys were conducted in conjunction with ongoing research on green mussels, *Perna viridis* (Baker and Baker, 1999). Methods included shoreline and piling surveys at low tide, scrapings from floating piers and buoys, collections of wood, and benthic surveys using scuba divers or benthic grabs. Survey methods were not quantitative, but intended to determine presence or absence of species, and sometimes to confirm identification. Fish and other vertebrates were not sampled. Areas of focus include sites along the main green mussels study axis from the south end of the Skyway (I-275) Bridge to the canal at the head of Safety Harbor, in Old Tampa Bay; a survey of pilings, piers, buoys, and intertidal areas from Clearwater Bay to Boca Ciega Bay; and the Little Manatee River from Camp Bayou to the mouth. Sites at each of these areas were qualitatively examined in 2001-2003. 21 total samples were collected in 2002, and an additional nine samples in 2003. Other sites were sampled on occasion.

2-3. Data Analysis and Presentation

For many of species included in this document, neither their presence in the greater Tampa Bay ecosystem (GTBE), nor their status as native or nonindigenous, was clear. The question of nonindigenous versus native was beyond the scope of this study, except in two cases where we questioned native status for two species previously treated as native. Species were designated **known**, **probable**, **expected**, or **potential** invasive, as discussed in Section 1.2. Biogeography, based on the following process.

<u>2-3.1 Known, Probable, Expected, or Potential Invasives</u>

Step 1. Is the species well documented from the GTBE in the literature, museum collections, or our own surveys? (*Well-documented* is a relative condition, based on the level of documentation for other species.)

Yes..............................species is considered a **known invasive** in the GTBE
No...............................go to Step 2

Step 2. Is the species not well documented from the GTBE, but well-documented from elsewhere in the West Florida ecocline?

Yes..............................go to Step 2A
No...............................go to Step 3

Step 2A. Is the documentation for this species in the West Florida ecocline consistent with it also occurring in the GTBA (e.g. abundant at Cedar Key)?

Yes...............................species is considered a **known invasive** in the GTBE
No................................go to Step 3

Step 3. Is it geographically (based on proximity to the GTBE) *and* physiologically (based on published information) possible for the species to presently occur in the GTBE, at least on an *extralimital* (outside main population) basis?

Yes...............................species is a **probable invasive**
No................................go to Step 4

S*tep 4.* Does the species occur in parts of bioregions adjacent to the west Florida ecocline (northern Gulf of Mexico, northwestern Caribbean) *and* do its physiological tolerances include the GTBE?

Yes...............................species is an **expected invasive**
No................................go to Step 5

Step 5. Is the species well established (large populations, multiple age classes) in bioregions near the GTBE *and* do its physiological tolerances include the GTBE?

Yes...............................species is a **potential invasive**
No................................species is not included in this study

2-3.2 Species Accounts

Selected data for species or groups of similar congeners was presented in the following format.

3-0.0 Common Name (if any)

Class (some taxonomic levels may be omitted or intermediates added)
Order
Family
Genus and species Authority, date, possible synonyms

Range and Vectors of Introduction
In many cases, this information is unavailable, so we provide the best possible estimates and possibilities. This is where we address whether a species is **cryptogenic** (unknown native origin), and whether this species is a **known**, **probable**, **expected**, or **potential invasive** (see above), with a synopsis of evidence.

Description and Biology
Relevant details on the appearance, diet (if applicable), and life cycle are summarized here, and references are provided for further information.

Habitat and Potential Impacts
Habitat is described in terms of types of substrata preferred if sessile, salinity and thermal tolerances if known, and any other parameters relevant to Tampa Bay. Potential impacts is usually an estimate based on literature surveys, and must not be regarded as definitive without empirical evidence.

URLs for more information: if available

3. Results and Species Accounts

Known, probable, expected, or potential nonindigenous or cryptogenic species were found in twelve taxonomic or functional groups. With a few exceptions, nonindigenous species were grouped by phylum or division (Table 3.1).

Table 3.1. Summary of nonindigenous species classified by occurrence in the greater Tampa Bay ecosystem: Known, Probable (Prob.), Expected (Expt.), Potential (Ptnl.), or Cryptogenic (Crypt.). Cryptogenic species may also fall under any of the prior classifications – see text .

		Classification				
Section	**Group**	**Known**	**Prob.**	**Expt.**	**Ptnl.**	**Crypt.**
3-1	Viruses and Prokaryotes	0	0	0	2	0
3-2	Protists & Microalgae	1	0	0	0	0
3-3	Macroalgae	0	0	2	0	0
3-4	Division Magnoliophyta (vascular plants)	3	0	0	0	0
3-5	Phylum Porifera (sponges)	0	0	0	0	0
3-6	Phylum Cnidaria (jellyfish, hydroids, etc.)	1	1	2	0	1
3-7	Phylum Ctenophora (comb jellies)	0	0	0	0	0
3-8	Phylum Platyhelminthes (flatworms)	0	1	0	0	1
3-9	Phylum Nematoda (roundworms)	0	0	0	1	0
3-10	Minor Phyla (Rotifera, Entoprocta, etc.)	0	0	0	0	0
3-11	Phylum Annelida (segmented worms)	4	0	0	0	1
3-12	Phylum Mollusca (gastropods, bivalves)	7	0	0	1	7
3-13	Phylum Arthropoda (crustaceans)	8	0	0	3	0
3-14	Phylum Bryozoa (Ectoprocta)	1	0	0	4	3
3-15	Phylum Echinodermata (sea stars, etc.)	0	0	0	0	0
3-16	Phylum Chordata (sea squirts, fish, etc.)	10	1	1	1	1
Totals		**35**	**3**	**5**	**12**	**14**

Following are brief accounts of nonindigenous or cryptogenic species of importance to the greater Tampa Bay ecosystem. In some cases, two or more closely related species are discussed together. These species accounts are not intended to be comprehensive biological reviews, and for more information, the reader should refer to the references included. In many cases, Internet resources are available, and will be listed at the bottom of the species accounts as Uniform Resource Locators (URLs). The reader should bear in mind the dynamic nature of the Internet; some of these URLs will no longer be accurate by the time you read this, although the information almost always still exists at another URL.

Table 3.2 URLs of broad interest for marine nonindigenous species.

Nonindigenous Species of the Gulf of Mexico Ecosystem -- http://www.gsmfc.org/nis/

U.S. Department of Agriculture Invasive Species -- http://www.invasivespecies.gov/

U.S. Geological Survey Nonindigenous Aquatic Species -- http://nas.er.usgs.gov/

Introduced Marine Species of Hawaii -- http://www2.bishopmuseum.org/HBS/invertguide/

CSIRO Centre for Research on Introduced Marine Pests -- http://crimp.marine.csiro.au/

ISSG Global Invasive Species Database -- http://www.issg.org/database/

3-1. Viruses and Prokaryotes

There are probably more species of viruses and prokaryotes (bacteria and blue-green algae) than all other organisms combined, but they are difficult to sample in natural environments and their ecology is poorly known. Both groups are abundant in ship ballast water (Drake et al., 2001). One virus and one pathogenic bacterium are noted here.

3-1.1 Shrimp Virus (IHHNV) – Potential Invasive

3-1.2 Cholera, *Vibrio cholerae* – Potential Invasive

3-1.1 Shrimp Virus (IHHNV)

Viruses are exclusively parasites and are seldom detected unless they become significant pathogens. The most economically costly marine viruses have probably been diseases of cultured shrimp, particularly of the Indo-Pacific white shrimp, *Litopenaeus* (*Penaeus*) *vannamei* (Sindermann, 1993). An undescribed virus known as Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) has been reported from cultured *L. vannamei* in Florida (Invasive Species Focus Team, 2000), but there is no evidence that it occurs outside of farms. It has been reported from the wild in Mexico, however, where it affected wild stocks, which infers that is occurs across a fairly broad range of salinities (Poss et al., 2000). Given the possibility of escape from aquaculture, we consider IHHNV to be a **potential invasive** in the greater Tampa Bay ecosystem.

URL for more information: http://www.gsmfc.org/nis/

3-1.2 Cholera

Ruiz et al. (2000) and Casale and Welsh (2001) present evidence for the importation of human pathogenic bacteria in ballast water, and a strain of the cholera bacterium (*Vibrio cholerae*) may have been introduced to Florida estuaries (Invasive Species Focus Team, 2000, via pers. comm. with S. McCarthy, Gulf Coast Seafood Lab., U.S. Food & Drug Admin.). Casale and Welsh (2001) and Drake et al. (2001) do not believe that all varieties of marine bacteria are already cosmopolitan. It is not known what strains of cholera are native, so we will consider *V. cholerae* a **potential invasive** in the greater Tampa Bay ecosystem, pending further studies.

URL for more information: http://www.bact.wisc.edu/Bact330/lecturecholera

3-2. Protists and Microalgae

Unicellular algae and protozoa consist of numerous divisions and phyla collectively lumped by some biologists into Kingdom Protista. Some experts believe that the majority of planktonic unicellular taxa are naturally circumglobal in distribution. If that is true, then blooms, or the sudden appearance of high-densities of nuisance species (e.g. red tide organisms), are either rare natural events or caused by human modifications of nutrient cycles (S. Shumway, Univ. Connecticut, *pers. comm.*). Other researchers believe that at least some blooms are the results of transoceanic species introductions (Subba Rao et al., 1994; CRIMP, 2001b). Five marine diatoms are believed to be nonindigenous in the United Kingdom (Eno et al., 2002), and one ship ballast contained 132 species of diatoms (McCarthy and Crowder, 2000). One nonindigenous diatom has been reported from Florida to date (Hill, 2002), and is discussed below.

Forams (Phylum Foraminifera), which include some of the largest unicellular organisms, produce distinctive calcareous skeletons that are often used by petrologists to identify marine sediments. This characteristic permitted researchers to detect the introduction of a foram, *Trochammina hadai*, into San Francisco Bay, California, in the 1980s (McGann and Sloan, 1996). No comparable invasion has been reported for Tampa Bay, but this may be due to lack of long-term records for this taxonomic group.

The study of parasites as nonindigenous species has previously focused on terrestrial agriculture and forestry species. The majority of protistan parasites are thought to have arrived via the deliberate introduction of their hosts (MacKenzie at al., 1985). It is suspected that *Perkinsis marinus* and *Haplosporidium nelsoni*, the protozoan diseases that devastated the Chesapeake and Delaware oyster fisheries after about 1960, were introduced, possibly via the transfer of oysters from the Gulf of Mexico (Sindermann, 1993; Carlton and Mann, 1996). Other experts suspect that the parasites were already present, but became a problem as the result of pollutants or other stressors (A. Wright, Univ. Florida, *pers. comm.*). The rise of marine animal health sciences has produced awareness that marine parasites, like terrestrial crop parasites, can be moved around the world (Sindermann, 1993).

There is no direct evidence of nonindigenous marine parasites in Florida. The Gulf of Mexico Program's Invasive Species Focus Team (2000) has reported seven nonindigenous protozoan parasite species from cultured fish in Florida, but all are freshwater species. High mortalities of marine invertebrates, such as the decline of commercial sponges in the 1970s (Stevely et al., 1978), have occurred in Florida, but these have not been attributed to nonindigenous parasites.

3-2.1 Centric Diatom
Division Bacillariophyta
Class Coscinodiscophyceae
Order Biddulphiales
Family Eupodiscaceae
Odontella (*Biddulphia*) *sinensis* (Greville) Grunow 1884

Range and Vectors of Introduction
O. sinensis was described in East Asia, but the native range may be elsewhere in the Indo-Pacific basin. It was first reported in Europe in 1899, possibly as one of the first ballast water invaders (Eno et al., 2002; Huckle and Marrs, 2003), and now occurs throughout the Atlantic basin (Burone and Baysse, 1985; Gallegos and Hedrick, 2001).

O. sinensis has been reported from all coasts of Florida, including Tampa Bay (Hill, 2002; N.L. Smith, *unpubl. data*; E.J. Phlips and S. Badylak, *unpubl. data*). This species is a **known invasive** of the greater Tampa Bay ecosystem.

Description and Biology
The biology of *O. sinensis* is well known because it is commonly used as a scientific model for chloroplast studies (e.g. Lohman et al., 1997; Lang et al., 1998; Morton, 1998). This species is a barrel-shaped centric diatom, typically found as single cells or in pairs, with spines at either end. Its life cycle is typical of the order, with mostly asexual reproduction alternating with occasional sexual reproduction. The size (80-440 µm along the apical axis) varies with age of a clonal lineage; each successive generation becomes smaller until the next sexual reproductive episode (Lee, 1980; Hasle and Syvertsen, 1996).

Habitat and Potential Impacts
O. sinensis is a marine and estuarine diatom, occurring mainly in coastal waters with salinities above 16 ppt (Gallegos and Hedrick, 2001). It occurs from the tropics to northern Europe (Hong Kong Agriculture, Fisheries and Conservation Department, 2003; Huckle and Marrs, 2003).

O. sinensis can be an abundant species. In China, it sometimes forms nuisance blooms which may deplete the water of oxygen (Hong Kong Agriculture, Fisheries and Conservation Department, 2003), although no direct toxic impacts are known. No blooms of this species have been reported in Florida, and its ecology in this region is poorly known.

URLs for more information:
http://www.appliedvegetationdynamics.co.uk/IAAPwebsite/Marinesppintro2.asp?ID=4,
http://thalassa.gso.uri.edu/plankton/diatoms/genera/odontel/sinensis/sinensis.htm,
http://www.hkredtide.org/

3-3. Macroalgae

Macroalgae include three unrelated divisions: Chlorophyta, or green algae; Phaeophyta, or brown algae (*Sargassum*, kelp, and others); and Rhodophyta, or red algae. All are represented by nonindigenous species in some part of the world.

The recent invasion of the Mediterranean, Australia, and southern California by an Australian strain of the green alga, *Caulerpa taxifolia*, has renewed awareness of marine algae as potential invaders (California Water Control Board, 2001; Cottalorda et al., 2001; Wiedenmann et al., 2001). Notable U.S. examples of marine algal invasions include a green alga, *Codium fragilis*, in the northeastern United States and Canada (Freeman and Smith, 2000; Levin et al., 2002); the giant red alga *Hypnea musciformis* in Hawaii (Russell and Balazs, 1994); and a brown alga, *Sargassum muticum*, introduced to the Pacific Northwest (Waaland, 1977; Carlton, 1979a). All of the above are abundant in their introduced habitats and compete with native species for space, but the potential impacts go beyond that. Some macroalgae contain secondary compounds that inhibit herbivory, particularly by grazers that have not co-evolved with that species (Thibaut and Meinesz, 2001). A dense cover by introduced macroalgae, therefore, would not only inhibit native plants and algae, but might not be edible to native animals.

Caulerpa brachypus, a little-known congener of the infamous *C. taxifolia* (above), is established in east Florida, and is discussed here. The Indo-Pacific red alga *Monosporus indicus* has been reported from the Caribbean (Bucher and Norris, 1995) and the Gulf of Mexico (Ballantine, 1996), and is discussed here. Dawes and van Breedveld (1969) noted 18 new records of algae for west Florida, but there was no way to know whether these were first reports of natives or recent invasions. The red alga *M. indicus* was not listed in a survey of the west coast of Florida by Dawes and van Breedveld (1969).

3-3.1 Mini Caulerpa, *Caulerpa brachypus* - Expected Invasive

3-3.2 Filamentous Red Alga, *Monosporus indicus* - Expected Invasive

Mini Caulerpa
Division Chlorophyta
Class Chlorophyceae
Order Caulerpales
Family Caulerpaceae
Caulerpa brachypus Harv.

Range and Vectors of Introduction
Caulerpa brachypus is native to the tropical and subtropical Indo-Pacific, ranging from Africa to the Philippine and Australia (Cordero, 1977; Sartoni, 1978; Sanderson, 1997). It was first reported in the West Palm Beach area of Florida in 2001, where it was already abundant, but was previously reported from other habitats in the Caribbean (Littler and Littler, 2003; Schrope, 2003). The vector of introduction is unknown; aquarium releases, hull fouling, and ballast water have been suggested. This species has since spread north into the Indian River Lagoon (Schrope, 2003), which is consistent with prevailing coastal currents, but has not yet been reported in west Florida. Given this species' abundance and rapid spread in east Florida, and given hull fouling as a potential vector of dispersal, we consider it an **expected invasive** of the greater Tampa Bay ecosystem.

Description and Biology
Information on the description and biology of *C. brachypus* comes from Cordero (1977), Sartoni (1978), Silva (2002), and Lott (2003). *C. brachypus* has a creeping stolon from which arise erect, paddle-like blades 2-3 cm long. These blades are normally simple, but some forms in the Philippines have bifurcated or trifurcated blades. It superficially resembles some small native seagrasses, but is distinguished from those by the lack of a central leaf vein. A native congener, *C. prolifera*, is larger, with blades up to 15 cm.

Members of the genus *Caulerpa* usually reproduce vegetatively via fragments, and sexual reproduction is seldom observed. In other species studied, the same thallus produces male and female gametes, both of which are flagellated and which fuse to form a zygote with four flagella. The dominant phase is diploid.

Habitat and Potential Impacts
Salinity and thermal tolerances of *C. brachypus* are not reported, but it appears to be limited to high salinity reefs in subtropical to tropical waters (Sartoni, 1978). The reported subtropical distributions in Florida and Australia (Sanderson, 1997; Lott, 2003) are consistent with this species becoming established in parts of the greater Tampa Bay ecosystem.

The impacts of *C. taxifolia* in the Mediterranean are well known, and include competition with native plants and algae and reduction of diversity and biomass of native animals, through the formation of large monospecific meadows (Ceccherelli, 2002). Studies on *C. brachypus* in Florida have begun only recently, but like *C. taxifolia*, this species forms large, monospecific meadows in its introduced range (Schrope, 2003).

URL for more information: http://www.floridaoceanographic.org/brachypus.html, http://www.dep.state.fl.us/southeast/hottopics/caulerpa/caulerpamain.htm#brachypus

3-3.2 Filamentous Red Alga
Division Rhodophyta
Class Rhodophyceae
Order Ceramiales
Family Ceramiaceae
Monosporus indicus Børgesen, 1931

Range and Vectors of Introduction
M. indicus was originally reported from the western Indo-Pacific, but was collected in the eastern Caribbean in 1995 (Bucher and Norris, 1995; Ballantine and Aponte, 1997) and in Hawaii in about 2000 (Hunter et al., 2000). No information is available on vectors of introduction, but filamentous algae may be transported on the hulls of ships (Coutts and Taylor, 2001), and probably reached Florida from the Caribbean. This species apparently has thick-walled spores (Baldock, 1977) which may also aid in ballast water dispersal.

M. indicus was reported in the Dry Tortugas of southern Florida in 1996 (Ballantine, 1996) and on fouling plates in Pensacola, Florida in 2002 (N.L. Smith, *unpubl. data*). Given the recent appearance of this species in the Caribbean basin, its presence in Tampa Bay is not assured, and it was not present in a 2000 study of the Cedar Keys, Florida area (E. Bledsoe, U. Florida, *pers. comm.*). However, since its current distribution brackets Tampa Bay, we consider *M. indicus* an **expected invasive** of the greater Tampa Bay ecosystem.

Description and Biology
The limited information available on the biology of *M. indicus* comes from Baldock (1977), Bucher and Norris (1995), and Ballatine (1996). General information on the family comes from Abbott and Hollenberg (1976) and Lee (1980). In the Caribbean, *M. indicus* appears to be epiphytic on other algae. The color is deep red, and most members of the family seldom exceed 20 cm in length. Professional expertise is required for identification.

The life cycle of members of this order are typical for Rhodophyceae: there is an alternation of sexual and asexual benthic phases distinguishable only at the microscopic level, and the only planktonic phase consists of non-motile, unicellular *tetraspores*. The sexual phase is seldom seen, and has never been reported for *M. indicus*. Unlike most members of the family, the spores are protected by a cell wall.

Habitat and Potential Impacts
M. indicus was reported from artificial fouling substrata in Pensacola Bay (N.L. Smith, *unpubl. data*). Collections in the Caribbean were mostly between 1.5 and 15 m in depth (Bucher and Norris, 1995). The distribution of this species (Sartoni, 1998; Bucher and Norris, 1995; Ballantine and Aponte, 1997; Hunter et al., 2000) suggests it is limited to warm waters of high salinity. No information is available on its potential impacts, but if it is primarily epiphytic, it could shade native species.

3-4. Division Magnoliophyta

True marine vascular plants (Division Anthophyta or Magnoliophyta) capable of prolonged immersion in seawater comprise a short list: seagrasses (Families Potamogetonaceae and Hydrocharitaceae), mangroves (Families Rhizophoracea, Combretacea, and Verbenacea), and salt marsh grasses (Family Poacea). No invasions by fully marine plants have been recorded in Florida, nor are there any suspected cryptogenic species (Carlton, 1975). Invasions by marine plants have been documented elsewhere, however. Seven mangrove species were intentionally introduced to Hawaii (Demopoulos and Smith, 2001). Nonindigenous seagrasses occur in the Mediterranean and on the Pacific coast of North America (Phillips and Meñez, 1988). Nonindigenous salt marsh grasses are considered pests in the western United States (Columbia Pacific Resources Center, 2002). Eelgrass and salt marsh grasses probably invaded the western United States through shellfish transfers (Carlton, 1979a). Seagrasses and other species invaded the Mediterranean via the opening of the Suez Canal (Phillips and Meñez, 1988), a vector that has no comparison in the Western Hemisphere.

Maritime species, or plants which can tolerate temporary saltwater intrusions, make up a much longer list and include important Florida invaders such as Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina* spp.), but these species are properly addressed by upland plant ecologists, and have been reviewed elsewhere (Mytinger and Williamson, 1987; Schmitz et al., 1997).

Some primarily freshwater aquatic plants can also survive in estuaries, but there is disagreement regarding the salinity tolerance of some of these species. The Invasive Species Focus Team of the Gulf of Mexico Program (2000) listed water fern, *Salvinia minima*, and water lettuce, *Pistia stratiotes*, as estuarine species. According to Jacono (2002), however, *S. minima* apparently only drifts into estuaries from freshwater and is killed at salinities above 4-7 ppt, so should probably not even be considered an oligohaline species. Literature reports are unclear whether *P. stratiotes* grows in brackish water or merely survives it for a short period. Our surveys in the greater Tampa Bay ecosystem did not reveal more than occasional drifting *P. stratiotes* specimens in tributaries, despite its abundance in surrounding freshwater. We will leave both of the above species for discussions on freshwater invasives.

Several freshwater plants clearly do occur in estuaries. A native example is widgeongrass, *Ruppia maritima*, which ranges from freshwater to nearly full seawater. At least three nonindigenous freshwater species also occur in estuarine tributaries of Tampa Bay.

Plant species covered here include the following:

3-4.1 Hydrilla, *Hydrilla verticillata* - Known Invasive

3-4.2 Alligatorweed, *Alternanthera philoxeroides* - Known Invasive

3-4.3 Eurasian Watermilfoil, *Myriophyllum spicatum* - Known Invasive

3-4.1 Hydrilla

Class Liliopsida (Monocotyledones), Subclass Alismatiales
Order Hydrocharitales
Family Hydrocharitaceae
Hydrilla verticillata Royle, 1839

Range and Vectors of Introduction

Hydrilla occurs widely in southern and eastern Asia, but the Florida strain appears to be from India or Sri Lanka. Hydrilla has invaded waters in most states in the Southeast and along both coasts. This species was once popular in the aquarium trade, and appeared in Florida in the 1950s as discards from private aquaria (Jacono, 2002).

This species is abundant in freshwater throughout Florida (Jacono, 2002; Ramey and Murray, 2003). We have observed hydrilla in several slow-moving streams and canals entering Tampa Bay at salinities up to 14 ppt. This species is a known invasive of the greater Tampa Bay ecosystem.

Description and Biology

Hydrilla is a submergent macrophyte with slender, branching stems which terminate in small tubers in the sediment. Leaves are small and pointed with saw-tooth margins, and are arranged in whorls along the stem. The plant is rough to the touch when pulled through the hand, which distinguishes it from similar species (Ramey and Murray, 2003).

The hydrilla strain in Florida reproduces asexually by fragmentation or lateral growth. Flowers are produced, but they are female only. Other details of the biology and reproduction of this species are given by Ramey and Murray (2003) and Jacono (2002).

Habitat and Potential Impacts

Ramey and Murray (2003) summarized habitat data for this species. Hydrilla apparently grows only at salinities up to 7 ppt, although it was observed at 14 ppt during this study. Its optimal temperature range is 20-27^{o}C. The monoecious strain over-winters as tubers in Massachusetts and re-grows in the spring. The ability of hydrilla to tolerate low light levels is considered a factor in its competitive edge over native plants.

Impacts are reviewed by Jacono (2002) and Ramey and Murray (2003). If unchecked, hydrilla can dominate a shallow lake, crowd out most native plants and fish, and alter ionic composition of the water. The Southwest Florida Water Management District (2000) budgeted $1.2 million in 2001 for exotic plant control; much of this was for hydrilla. In estuaries, however, impacts are unknown. Ionic effects could be overwhelmed by dominant marine ions. In our observations, hydrilla was locally abundant in Tampa estuaries, but we could not determine whether this represented on-site growth or downstream transport. If the latter, then estuarine impacts of hydrilla would be similar to any other plant species washed downstream in large quantities, i.e. oxygen depletion from decay and smothering or disturbance of benthic fauna (Olaffson, 1988).

URL for more information: http://aquat1.ifas.ufl.edu/

3-4.2 Alligatorweed

Class Dicotyledones

Order Caryophyllales

Family Amaranthaceae

Alternanthera (*Buchholzia*) *philoxeroides* (Martius) Grisebach, 1879

Range and Vectors of Introduction

Alligatorweed is native to tropical and temperate South America, and has been introduced to North America, Australia, and tropical Asia (U.S. Dept. Agriculture, ARS 2002). Starting with Alabama in 1897, this species invaded all Southeast states, plus California and Puerto Rico. The suspected vector for the initial invasion is dry ship ballast (Virginia Dept. Conservation & Recreation, 2002). In Florida it has been reported from most counties across the entire state (U.S. Dept. Agriculture, NRCS, 2002).

Alligatorweed is a **known invasive** from the greater Tampa Bay ecosystem. Vouchered specimens of alligatorweed are recorded from Hillsborough and Pinellas counties, and based on its widespread distribution in Florida (U.S. Dept. Agriculture, NRCS, 2002), it probably occurs throughout suitable habitat in the greater Tampa Bay ecosystem.

Description and Biology

Alligatorweed is variable with wetland and submergent forms. Submergent forms have hollow stems which may be green, white, or pink. Leaves are simple, elliptical, and opposite, up to 10 cm long on long, sparsely branching stems. The small (13 mm), white, composite flowers are born at leaf junctions (Westerdahl and Getsinger, 1988; Ramey and Murray, 2003).

Although alligatorweed produces abundant small flowers, no seedlings have been reported from the United States, and it appears to reproduce asexually in its introduced range (Virginia Dept. Conservation & Recreation, 2002).

Habitat and Potential Impacts

Alligatorweed can grow as a fully submersed plant or be semi-terrestrial in waterlogged soil. It can tolerate “brackish” water, but precise salinity limits are not known. It appears to be most abundant in wet ditches and riparian zones, but can form dense floating mats on water (Westerdahl and Getsinger, 1988; Virginia Dept. Conservation & Recreation, 2002).

Alligatorweed is considered a pest because of its abundance in ditches and waterways, but there is apparently little data on its impacts on native flora or fauna. Dense mats can block waterways and water intakes, and apparently increase mosquito breeding habitat by crowding out insectivorous fish. The ability of alligatorweed to form dense monoculture mats allows it to shade out other taxa, and reduce oxygen levels in water below (Miles, 2002; Virginia Dept. Conservation & Recreation, 2002).

URL for more information: http://aquat1.ifas.ufl.edu/

3-4.3 Eurasian Watermilfoil
Class Dicotyledones
Order Saxifragales
Family Haloragaceae
Myriophyllum spicatum Linn., 1753

Range and Vectors of Introduction
Eurasian watermilfoil is apparently native to much of Eurasia and Africa and has been introduced worldwide. It was not documented in the U.S. until 1942, but is now known to occur in at least 45 U.S. states (Jacono, 2002). This species can reproduce by fragmentation, and such fragments are probably the invasive propagule within North America. The vector of introduction to the United States is unknown, but deliberate introduction is a possibility (Jacono, 2002).

This species is often dominant in the Crystal, Homosassa, and Chassohowitzka, all relatively undisturbed estuaries just north of the greater Tampa Bay ecosystem (Jacono, 2002). Fragments of this species were observed in this study in low densities in the Little Manatee River estuary. This species is a **known invasive** from the greater Tampa Bay ecosystem.

Description and Biology
Eurasian watermilfoil is a submersed and rooted plant, although fragments can survive and grow as well. The stems are long and branching, and have whorls of 3-4 finely divided leaves at regular intervals. When the plants are taken out of the water, the leaves collapse upon the stem; other watermilfoils, which include both native (*M. sibericum*) and introduced (*M. aquaticum*) species, have stiffer leaves that stand out when taken from the water (Westerdahl and Getsinger, 1988; Jacono, 2002).

Eurasian watermilfoil reproduces sexually via emergent flowers, with small fruits 2-3 mm in diameter, but the primary means of reproduction is probably through fragmentation (Westerdahl and Getsinger, 1988).

Habitat and Potential Impacts
This species occurs in lakes and low-energy portions of rivers and estuaries up to 5 m deep. Eurasian watermilfoil is known to occur in “brackish” waters; precise salinity tolerances were not found (Westerdahl and Getsinger, 1988). Its thermal tolerance is wide, encompassing most of the United States (Buczacki, 1995).

Jacono (2002) has reviewed impacts by Eurasian watermilfoil. It is reported to out-compete two native estuarine species: an eelgrass, *Vallisneria americana*, and the southern naiad, *Najas guadalupensis*. High-density monocultures of Eurasian watermilfoil are reported to support lower densities of birds feeding upon the seeds and leaves, and of fish and invertebrates living among the plants, than do native aquatic species. High densities of Eurasian watermilfoil result can result in reduced oxygen, particularly following a die-off.

URL for more information: http://aquat1.ifas.ufl.edu/

3-5. Phylum Porifera – Sponges

Marine sponges (Phylum Porifera) have been introduced in the past to other parts of the world (Carlton, 1979a; Bishop Museum, 2002), but there are no nonindigenous sponges reported in Florida or adjoining regions.

Sponges may not be as adapted to long-distance transport by shipping as many other groups. A study on the hull of a wooden sailing vessel revealed no sponges among the many species successfully transported between localities (Carlton and Hodder, 1995). Many sponges also lack a long-lived larval phase (Ruppert and Barnes, 1994), and are less likely than some other taxa to appear in ballast water (Carlton and Geller, 1993). The vector for those species which were successfully introduced was probably shellfish (oyster) transfer (Carlton, 1979a).

Introduced sponges may interact with Tampa Bay's live bottom communities, which include native sponges (Derrenbacker and Lewis, 1985). Some *Cliona* species, which are destructive to shells and coral, are already native to Florida (Ruppert and Fox, 1988).

3-6. Phylum Cnidaria - Sea Anemones, Hydroids, and Jellyfish

Cnidarians, or coelenterates, include solitary and colonial hydroids, sea anemones, hard and soft corals, and jellyfish. This is a large group with a long lineage, and a large proportion of Florida itself is composed of ancient coral reefs. Modern cnidarians remain economically and ecologically important to Florida, and include the corals of the Florida Keys and other reef areas, the notorious man-o-war jellyfish (*Physalia physalia*), and many other freshwater, coastal, and oceanic species.

Two known invasive cnidarians – a colonial hydroid and a small sea anemone - occur in the greater Tampa Bay ecosystem. Two additional jellyfish have been recently reported in large numbers in the northern Gulf of Mexico or other parts of Florida, and are thus potential invaders of Tampa Bay.

Cnidarian species covered here include the following:

3-6.1 Colonial Hydroid, *Cordylophora caspia* - Probable Invasive

3-6.2 Pelo de Oso, *Garveia franciscana* – Known, Cryptogenic

3-6.3 Lined Sea Anemone, *Diadumene lineata* - Known Invasive

3-6.4 Spotted Jellyfish, *Phyllorhiza punctata* - Expected Invasive

3-6.5 Purple Sea Mane, *Drymonema dalmatinum* - Expected Invasive

3-6.1 Colonial Hydroid
Class Hydrozoa
Order Athecatae
Family Clavidae
Cordylophora caspia (Pallas, 1771), possibly synonymous with *C. lacustris*

Range and Vectors of Introduction
C. caspia is probably native to the Ponto-Caspian basin (Eurasia), but has been introduced to estuaries and freshwater of Europe and eastern North America (Calder, 1971, Slobodkin and Bossert, 1991). It is suspected to have arrived via hull fouling (Slobodkin and Bossert, 1991), and is continuing to spread, probably by the same means (Folino, 2000). There may be two separate estuarine species, *C. caspia* and *C. lacustris* (Folino, 2000).

C. caspia has not been reported from Tampa Bay, but occurs in nearby freshwater (G.L. Warren, *unpubl. data*). Given its estuarine tolerance, it is regarded as a **probable invasive** in the greater Tampa Bay ecosystem.

Description and Biology
C. caspia is an athecate hydroid, forming erect, weakly branched colonies up to 5 cm high. Individual within the colony, or *hydranths*, are less than 1 mm in diameter, not including the tentacles. The colony is supported by a stiff coating (*perisarc*), but the perisarc does not enclose the hydranths. Colonies reported from Florida tend to be small (G.L. Warren, *unpubl. data*), but in some habitats, they can form large dense mats (Folino, 2000).

Pennack (1989), Slobodkin and Bossart (1991) and Folino (2000) reviewed biological information on *C. caspia*. Gametes are produced directly by attached gonophores; there is no medusa stage. During periods of stress this species can revert to undifferentiated, resistant cell masses (*metanonts*) which can subsequently regenerate colonies when conditions improve. This normally occurs during seasonal changes, but may also adapt this species for transport via hull fouling. Colonies grow and sometimes divide asexually. The larval period is not reported, but given that the larvae are non-feeding, is probably brief. Like other hydroids, this species feeds on zooplankton.

Habitat and Potential Impacts
Colonies of *C. caspia* occur in the low intertidal to subtidal on almost any hard substrate, particularly in oligohaline-mesohaline and tidal freshwater portions of rivers. In Chesapeake Bay, it co-occurs with the estuarine clam, *Rangia cuneata*, and the eastern oyster, *Crassostrea virginica* (Calder, 1971). Pennak (1989) reports its optimal salinity at 15 ppt, but both Pennak (1989) and Folino (2000) reported this species as widespread in freshwater. Studies on thermal tolerances have not been conducted.

Folino (2000) has reviewed impacts. *C. caspia* is a common member of the fouling community in areas of low salinity, but tends to go unnoticed until it fouls artificial structures. It can be a pest in water intake systems of power plants, and when abundant, appears to influence the fouling community species composition. It is a known predator on native zooplankton, and thus a potential predator of planktonic oyster larvae.

URL for more information: http://www.marlin.ac.uk/

3-6.2 Pelo de Oso
Class Hydrozoa
Order Athecatae
Family Bougainvilliidae
Garveia franciscana (Torrey, 1902) = *Bimeria tunicata*, *Bougainvillia megas*, others

Range and Vectors of Introduction
G. franciscana was first described in California, but its evolutionary origin is unknown. It is possible that more than one species goes under this name; it occurs mainly in low salinities in Chesapeake Bay and Florida (Calder, 1976; Garman, 1999) but is known mainly from high salinities in the Mediterranean (Morri, 1982). Until further information is available, however, we will assume that all reports of *G. franciscana* are of the same species. *G. franciscana* is also known from South America, where it gets its common name, which translates to “bear fur” (de Rincon and Morris, 2003). The vector of introduction is not reported, but given the lack of planktotrophic larvae, fouling on ship hulls and shellfish transfers are more likely than ballast water. This species is **known** from the greater Tampa Bay ecosystem (Garman, 1999), but is considered **cryptogenic**.

Biology and Description.
G. franciscana forms small, branching colonies up to 7 cm high, supported by a semi-rigid *perisarc*. The perisarc does not enclose the *hydranths*, or feeding portions of the colony, each of which has 6-12 tentacles. Individual hydranths are less than 1 mm long. Female *gonophores* (reproductive components) have bright blue gonads and eggs. Professional expertise is required for identification (Calder, 1971).

Information on the biology of *G. franciscana* comes from Calder (1971; 1976), Morri (1982), and Taylor et al. (1983). The alternating hydroid-medusa life cycle seen in many hydroids is suppressed here; gonophores release *planula* larvae directly. The larval period is not reported, but given that the larvae are non-feeding, is probably brief. Like most hydroids, *G. franciscana* feeds on small zooplankton.

Habitat and Potential Impacts
G. franciscana has an extremely wide salinity tolerance in the United States, and in South Carolina, occurs from oligohaline waters to full seawater (Calder, 1976). Thermal tolerances are not described, but it occurs from at least Maryland to the tropical Atlantic (Taylor et al., 1983; de Rincon and Morris, 2003). In Florida, this species has also been reported from estuarine portions of limestone caves (Garman, 1999).

This species is considered a serious pest by industry. It is an important fouling organism on water intakes of power plants in Chesapeake Bay, resulting in costly anti-fouling treatments (Taylor et al., 1983). In Lake Maracaibo, Venezuela, this species coats metal surfaces and results in corrosion and high economic costs to the petroleum industry (de Rincon and Morris, 2003). Its economic and ecological importance in Florida has not been studied.

3-6.3 Lined Sea Anemone

Class Anthozoa, Subclass Hexacorallia

Order Actinaria

Family Diadumenidae

Diadumene lineata (Verrill, 1869) formerly *Haliplanella luciae*, *Edwardsia lineata*

Range and Vectors of Introduction

This species probably originated in eastern Asia, and arrived in the western Atlantic by at least 1892, probably on vessel hulls. Ting and Geller (2000) concluded from molecular genetic data that *D. lineata* has been introduced many times. It is present in estuaries along all coastlines of the United States (Carlton, 1979a; Carlton and Ruckelshaus, 1997; Bishop Museum, 2002).

In Tampa Bay, this species was present at most sites surveyed in this study, and abundant on artificial structures, mangrove prop roots, and oyster reefs. Although its origin is uncertain, the lined sea anemone is known to be nonindigenous in Florida, and is thus a known invasive of the greater Tampa Bay ecosystem.

Description and Biology

D. lineata is as small sea anemones, with a tentacle spread seldom exceeding 15 mm. The column, visible when the tentacles are retracted, is olive to dark green with numerous yellow to red vertical stripes.

The lined sea anemone can creep slowly, but is essentially sedentary. In its native range, it reproduces sexually, but only asexually reproduction via binary fission has been reported in the U.S. (Fukui, 1991; Ting and Geller, 2000). Its ability to reproduce asexually means that a single individual can start a clonal population.

Habitat and Potential Impacts

Lined sea anemones in Tampa Bay occur intertidally and on floating objects, attached to any hard substrate, across a wide range of salinities. Based on their distribution (Carlton, 1979a), they also have wide thermal tolerances.

Anemones of this family are known predators of larvae of commercially important taxa, including oysters (Steinberg and Kennedy, 1979). Their impact in a population level has never been studied, and these species are not generally considered pests, although this may be for lack of study. As fouling species, they are generally innocuous, because of their small size and soft bodies, but they can be extremely abundant. Given their abundance amid ecologically important oysters, it is not safe to assume that the ecological impacts are minor; we can only classify them as unknown.

URL for more information: http://www2.bishopmuseum.org/HBS/invertguide/index.htm

3-6.4 Spotted Jellyfish
Class Scyphozoa
Order Rhizostomeae
Family Mastigiidae
Phyllorhiza punctata (von Lendenfeld 1884), also known as *Cotylorhizoides pacificus*

Range and Vectors of Introduction
This species is native to Australia and possibly other areas of the Indo-Pacific. Widely distributed in tropical oceans, including parts of the Caribbean, it may have spread on ship hulls during the sessile scyphistoma stage (Garcia, 1990; Larson and Arneson, 1990; Bishop Museum, 2002; Graham and Young, 2002).

P. punctata appeared in Alabama and Mississippi in 2000 (U.S. Geological Survey, 2000), and in east Florida in 2002 (W. Miller, Smithsonian Inst., unpubl. data). The vector of invasion is unknown, but oceanic currents from established populations in the Caribbean have been proposed (Graham and Young, 2002). *P. punctata* has not been found in west Florida, but this distribution gap is probably due to chance, not biological barriers. Given prevailing coastal currents and shipping vectors, we regard *P. punctata* as an **expected invasive** in the greater Tampa Bay ecosystem.

Description and Biology
The medusa stage (jellyfish) of *P. punctata* has a pale, deeply-cupped bell, often with white spots, 10-30 cm in diameter. There are short tentacles and frilled oral arms. The sessile scyphistoma stage resembles a small sea anemone.

Rippingdale and Kelly (1995) and Graham and Young (2002) reviewed the biology of this species. Like most jellyfish, *P. punctata* has an alternating life cycle. The planktonic medusa stage is sexual, and produces a short-lived planktonic planula larva, which settles and metamorphoses into a small scyphistoma. Scyphistomae reproduce asexually by free-swimming buds which develop into more scyphistomae, or by budding of juvenile medusae (*ephyrae*). Medusae can reach sexual maturity in six weeks. *P. punctata* feeds on zooplankton, but Garcia (1990) reports that this species, like other members of the family, obtains some nutrition from endosymbiotic algae (zooxanthellae).

Habitat and Potential Impacts
Like most jellyfish but unlike most members of this order, *P. punctata* swims in the plankton. In Australia, medusae occur in estuaries above temperatures of 10^{o}C and salinities of 20 ppt (Rippingale and Kelly, 1995). Little is known about the habitat of the scyphistoma (Bishop Museum, 2002).

Given the abundance of this species, it has the ability to impact coastal zooplankton communities, including the larvae of commercially important species. Like other jellyfish, it may foul fishing gear, but its stings do not appear to affect humans (Graham and Young, 2002).

URL for more information: http://dockwatch.disl.org/haveyouseen.htm

3-6.5 Purple Sea Mane
Class Scyphozoa
Order Semaeostomeae
Family Cyaneidae
Drymonema dalmatinum Haeckel, 1880

Range and Vectors of Introduction
D. dalmatinum is native to the Mediterranean Sea, and was reported in the Virgin Islands and Puerto Rico in the 1980s (Larson, 1987). In 2000, it appeared in the northern Gulf of Mexico (Graham and Young, 2002; U.S. Geological Survey, 2000). Its method of introduction is unknown, but there is a sessile scyphistoma phase for most jellyfish life cycles, so hull fouling is a possibility. Graham and Young (2002) have suggested this species was brought to the Gulf of Mexico from the Caribbean by coastal currents.

D. dalmatinum is abundant in both parts of the Caribbean and the northern Gulf of Mexico. Its absence in west Florida is probably due to chance, not physiology or lack of vectors. Coastal currents and intracoastal shipping provide natural and human vectors, so we regard *D. dalmatinum* as an **expected invasive** in the greater Tampa Bay ecosystem.

Description and Biology
D. dalmatinum attains a large size (bell to 75 cm in diameter), and has long oral arms for feeding. The color has been described as “Pepto-Bismol pink” (Graham and Young, 2002), and this plus the large size make for easy identification. As for the related lion’s mane jellyfish (*Cyanea* spp.), its stings are painful to some people (Graham and Young, 2002).

The biology of *D. dalmatinum* is poorly known. It feeds on other gelatinous zooplankton, including native jellyfish. Juvenile fish often use this species as a refuge. The general life cycle is presumed to be similar to that of most scyphozoans, including *Phyllorhiza punctata* (see prior entry), but few specifics are known (Larson, 1987; Graham and Young, 2002).

Habitat and Potential Impacts
Little is known about specific habitat requirements of the medusa stage of *D. dalmatinum*, and nothing is known about the sessile scyphistoma stage. This is a coastal pelagic species, which can occur in at least the higher salinity portions of estuaries. Its native Mediterranean habitat is not tropical, so this species may be able to extend its range well beyond the Gulf of Mexico.

Reports from the Caribbean and Alabama indicate that *D. dalmatinum* is capable of episodic population explosions (Larson, 1987; Graham and Young, 2002). Large jellyfish can clog fishing gear, the stings can deter swimmers, and in sufficient numbers, this species may be able to alter plankton dynamics by feeding on native zooplanktivorous jellyfish. It will probably be a nuisance species if it invades Tampa Bay, and may have significant ecological impacts.

URL for more information: http://dockwatch.disl.org/glossary.htm

3-7. Phylum Ctenophora – Ctenophores

Ctenophores consist mostly of gelatinous zooplankton species, and are often mistaken by the layperson for small jellyfish (Cnidaria). Some species are very abundant in coastal ecosystems, including Florida, but there are no documented nonindigenous species in Florida or adjoining regions. *Mnemiopsis leidyi*, or sea walnut (Phylum Ctenophora) is a transparent, thumb-sized species abundant in its native Atlantic habitat. In the past, it was not well studied and considered relatively innocuous. When introduced to the Black Sea, probably via ballast water, the sea walnut became extremely abundant and was implicated in a general fishery collapse of the region (Harbison and Volovik, 1994).

The story of the sea walnut illustrates the limitations of attempting to identify potential nonindigenous species. No one predicted that *M. leidyi* would become an invader, nor that it would become a pest. Nonetheless, its impacts were as great as any marine invader.

3-8. Phylum Platyhelminthes – Flatworms

Phylum Platyhelminthes includes three important parasitic classes – Monogenea, Digenea, and Cestoda (trematodes and tapeworms) – and one mostly free-living class, Turbellaria. A European monogene eel parasite, *Gyrodactylus anguillae*, has been introduced worldwide, probably through trade in live eels (Hayward et al., 2001). It is possible that parasitic flatworms have been introduced to Florida with other species, but this has not been documented.

Turbellarian flatworms are believed to be important predators of many benthic invertebrates, but their small size, soft bodies, and benthic habitat make them extremely difficult to sample. No quantitative studies have examined their role in ecosystems. A flatworm, *Pseudostylochus ostreophagus*, introduced to Washington became an important predator of juvenile native oysters (Woelke, 1956), as did another flatworm, *Stylochus frontalis*, apparently introduced to Jamaica from the Gulf of Mexico (Littlewood and Marsbe, 1990). More recently, a small nonindigenous acoel flatworm, *Convoluta convoluta*, was reported from Maine, where it preyed on juvenile mussels (Rivest et al., 1999, Byrnes and Witman, 2001). Florida has a number of native predatory flatworms, and at least one nonindigenous species. This species, plus one cryptogenic species previously considered native, are discussed here.

3-8.1 Predatory Flatworm, *Taenioplana teredini* - Probable Invasive

3-8.2 Oyster Leech, *Stylochus frontalis* - Known, Cryptogenic

3-8.1 Predatory Flatworm

Class Turbellaria

Order Polycladia

Family Cryptocelididae

Taenioplana teredini Hyman 1944

Range and Vectors of Introduction

T. teredini was first described in Hawaii in 1944, by which time it could have been introduced from elsewhere. It has also been reported in Israel, Panama, and Florida (Prudhoe, 1985). Possibly, it invaded Florida at the same time that Teredo and other cryptogenic shipworms appeared, which could be up to several hundred years ago, in the hulls of wooden ships.

T. teredini has been reported from either side of the Florida peninsula, including Sanibel Island (Riser, 1974), which is within the west Florida ecocline. An ongoing survey of the Indian River Lagoon has yet to report it (Hill, 2002). We regard this species as a probable invasive in the Tampa Bay ecosystem.

Description and Biology

The body of *T. teredini* is elongate compared to other polyclad flatworms, possibly as an adaptation to its life in burrows. It lacks tentacles. The protrusible pharynx (feeding organ) is in the anterior portion of the body, rather than towards the middle as in most polyclads (Prudhoe, 1985). No information is available on color of living specimens.

Nothing is known about the reproduction of this species. There is circumstantial evidence that *T. teredini* preys on shipworms (*Teredo* spp. and *Bankia* spp.) (Prudhoe, 1985).

Habitat and Potential Impacts

This species has been collected from burrows of wood-boring bivalves. There is no information on its salinity or thermal tolerances.

T. teredini is so poorly known that speculation on its ecological impacts is ill-advised. This does not mean there are no impacts, or even that the species is rare, and it may be of great importance within wood-boring communities. Abundance of an unidentified polyclad flatworm in shipworm (*Teredo furcifera*) burrows in the Red Sea correlated with high shipworm mortality (Turner and Johnson, 1971).

3-8.2 Oyster "Leech"
Class Turbellaria
Order Polycladida
Family Stylochidae
Stylochus frontalis Verrill 1893 = *S. inimicus*

Range and Vectors of Introduction
S. frontalis was described from Florida 1931 as *S. inimicus* (Pearse and Wharton, 1938), and has been reported from Taiwan, also as *S. inimicus* (Shu and Lin, 1987). *S. inimicus* is a junior synonym of *S. frontalis* Verrill 1893 (Prudhoe, 1985).

S. frontalis is not naturally cosmopolitan, because it was absent from Jamaica until the 1980s (Littlewood and Marsbe, 1990). If a species occurred naturally in both Taiwan and Florida, the distance from Florida to Jamaica would not present a biological barrier. Thus, barring misidentification or cryptic speciation, this species is probably nonindigenous in either the western Pacific or the Gulf of Mexico. It may have been introduced via shellfish transfers, like other species (Woelke, 1956).

This species is **known** from west Florida (Pearse and Wharton, 1938), although rarely studied, but given the information reviewed above, we cannot be sure it is native to this region. We consider this species to be **cryptogenic**.

Description and Biology
S. frontalis is up to 5 cm long and half as wide, but usually smaller. The color is gray, and the only external features are two small anterior-dorsal tentacles. Like other flatworms, it often goes unnoticed unless seen gliding about the surface of a shell.

Adults are simultaneous hermaphrodites, and small clutches of eggs are brooded. There is a planktonic larval phase of several days, and newly settled juveniles become predaceous immediately (Pearse and Wharton, 1938).

Habitat and Potential Impacts
S. frontalis occurs in estuaries in association with oysters mostly at salinities above 20 ppt. In Florida, in salinities below 20 ppt, *S. frontalis* appears to be replaced by another member of the same family, *Eustylochus meridionalis* (Pearse and Wharton, 1938).

The various oyster "leeches" of Family Stylochidae, including *S. frontalis*, are predators of juvenile commercial bivalves (Pearse and Wharton, 1938; Woelke, 1956; Ingle and Whitfield, 1968; Littlewood and Marsbe, 1990). They are exceptionally difficult to sample in a quantitative manner, because of their shape, size, and soft, sticky bodies, so they are seldom noticed until they reach pest proportions. Native or invasive, *S. frontalis* is an important predator of oysters.

3-9. Phylum Nematoda – Roundworms

Nematodes are diverse and widespread, and there are probably many nonindigenous species in Tampa Bay. There are around 20,000 described species, but estimates of diversity suggest up to 50 times that number of undescribed species. Many species are distinguished only by molecular differences (Pechenik, 2000). One species is discussed below.

3-9.1 Eel Parasite
Class Spiruria
Order Dracunculoidea
Family Anguillicolidae
Anguillicola crassus Kuwahara, Niimi and Hagaki, 1974

Range and Vectors of Introduction

A. crassus is native to eastern Asia, where it is a parasite of the Japanese eel, *Anguilla japonica*. In the 1980s, it was reported in European eels (*A. anguilla*), and in the 1990s, was reported in Texas from wild American eels, *A. rostrata*, suggesting its establishment in the wild. The vector of introduction was transfer of cultured European eels (Poss et al., 2000).

This species is considered established in Texas, but is not reported from other Gulf of Mexico states (Poss et al., 2000; Invasive Species Focus Team, 2000). It is a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology

A. crassus is a typical parasitic nematode, with a white, wrinkled, elongate body up to 70 mm long. It is found in or on the swim bladders of eels (Anguilla), but otherwise requires professional expertise for identification.

The biology and reproduction of *A. crassus* has been reviewed by Poss et al.(2000). Adults infest the swim bladder of their eel host, and pass eggs (up to several thousand per female) through the intestinal tract of the host to the environment. Juveniles occupy an intermediate host, usually a small crustacean, which are in turn ingested by juvenile eels. The parasites migrate to the swim bladder, and there feed on blood. In the laboratory, the life cycle can be completed in 2 months.

Habitat and Potential Impacts

Strictly speaking, the habitat of an internal parasite is its host – in this case, eels of the genus *Anguilla*. *Anguilla*, on the other hand, are catadromous species, occurring in estuaries as juveniles and freshwater as sub-adults (Van Den Avyle, 1984). They have been reported in eels at salinities of 20 ppt (JNCC, 2002).

Impacts in Europe have been reviewed by Poss et al. (2000) and Eno et al. (2002). The parasite apparently does well in eel species besides its native host, and can cause swim bladder rupture and decrease in growth. Wider-scale impacts are speculative at this point. The American eel is not a fishery in the greater Tampa Bay ecosystem.

URLs for more information: http://www.gsmfc.org/nis/,
http://www.jncc.gov.uk/marine/non_native/

3-10. Minor Phyla

The term “minor phyla” is used here to encompass groups typically given brief treatment in general zoology texts (e.g. Ruppert and Barnes, 1994; Pechenik, 2000) due to the small size and limited economic importance of their members. No introduced members of these phyla are considered pests, although this may be due to lack of study. Occasional examples of phyla besides those listed below (e.g. Phoronida, Tardigrada) have been recorded from ship ballast water (Locke et al., 1991; Carlton and Geller, 1993). Members of most minor phyla have probably been transported by humans to new habitats, but are too rare or too poorly studied to have been documented.

3-10.1 Phylum Rotifera – rotifers

Rotifers are microscopic, ciliated animals, either sessile or planktonic, that superficially resemble some ciliate protozoa. They are better studied in freshwater ecosystems than in marine systems (Ruppert and Barnes, 1994), and freshwater introductions have been documented (Hendrik, 2001). Rotifers frequently occur in ship ballast water, but the taxonomic identity of most is unknown (Locke et al., 1991; Carlton and Geller, 1993). The taxonomy and biogeography of marine rotifers are poorly known, and possibly as a consequence, no nonindigenous rotifers have been documented from Florida or adjoining areas.

3-10.3 Phylum Entoprocta - entoprocts

The little-known Phylum Entoprocta (Kamptozoa) is represented by small colonies or individuals, sessile and nearly microscopic. Both the name and general appearance lead to confusion with the better known Phylum Ectoprocta (bryozoans) (Ruppert and Barnes, 1994). Entoprocta contains the invasive species *Barentsia benedeni*, introduced nearly worldwide, and *Loxosomatoides laevis*, introduced to Chesapeake Bay (Carlton, 1979a, 1979b; Wasson et al., 2000; U.S. Geological Survey, 2000). *B. benedeni* can be a locally abundant fouling organism in its introduced range, but no nonindigenous entoprocts have been reported from Florida or adjacent waters.

3-11. Phylum Annelida – Segmented Worms

Polychaeta is one of several classes of segmented worms in Phylum Annelida. Other classes, particularly Oligochaeta, are important fauna of freshwater benthic ecosystems and the soil (earthworms), but are less important in marine ecosystems. In most marine benthic ecosystems, polychaete worms dominate the biomass. They tend to be small and inconspicuous but fulfill many ecological niches, from filter-feeder to predator.

The small and inconspicuous nature of polychaetes has meant that, despite their importance, they receive less study than other major marine groups. Species distribution is poorly known and complicated by *cryptic speciation*, or morphologically identical species (Westheide and Schmidt, 2003). A comparison of polychaete species from California (Blake, 1989) and the Gulf of Mexico (Uebelacker and Johnson, 1984) reveals over two dozen apparently co-occurring species, none of which have been considered nonindigenous in either ocean basin. Some of these probably represent cryptic speciation, some may be truly trans-oceanic species, and some may represent previously unrecognized introductions. Florida may, therefore, host many more nonindigenous polychaetes than those listed here. It is also possible that some of the apparently widespread species discussed below actually represent a cluster of morphologically identical species.

Class Polychaeta is currently undergoing extensive revision. Several former minor phyla have been folded into Class Polychaeta, but the class itself may be broken into multiple classes, pending ongoing molecular research. In the interim, taxonomic levels between class and family (subclass, order, superfamily, etc.) are subject to revision, and will not be used here.

The Pacific spirobid polychaete worm *Neodexiospira forminosa* (Moore & Bush, 1904) has been reported from the Gulf of Mexico (N.F. Smith, *unpubl. data*). Very little is known about this species other than that it has been reported as an early successional species on an artificial reef in Hawaii (Bailey-Brock, 1987). Until further information is available on current distribution and native range, we are unable to discuss the status of this species in the greater Tampa Bay ecosystem.

Five species are discussed here, including one species which we are the first to put forward as cryptogenic. Two closely related species of the genus *Boccardiella* are discussed together.

3-11.1 Mudworms, *Boccardiella hamata* – Known Invasive
Boccardiella ligerica - Known Invasive

3-11.2 Calcareous Tubeworm, *Hydroides elegans* - Known Invasive

3-11.3 Reef-forming Tubeworm, *Ficopomatus enigmaticus* - Known Invasive

3-11.4 Capitellid Worm, *Mediomastus californicus* - Known, Cryptogenic

3-11.1 Mudworms

Class Polychaeta

Family Spionidae

Genus *Boccardiella*, formerly in *Boccardia*, formerly in *Polydora*

Boccardiella hamata (Webster, 1879) = *Boccardia uncata*

Boccardiella ligerica (Ferronniere, 1898) = *Boccardia redeki*

Range and Vectors of Introduction

B. hamata was described from Japan, but has been reported from British Columbia, Chesapeake Bay, and the Gulf of Mexico (Larsen, 1978; Wern, 1985, Kravitz, 1987; Strathmann, 1987; Sato-Okoshi, 2000). *B. ligerica* was described from Europe but has been reported from California, both sides of the South Atlantic, and the Caribbean. Shellfish culture and ballast water are possible vectors of introduction for members of this family (spionids), but dates are unknown (Carlton, 1979a; Blake and Pederson, 1999).

Both species were recorded from Crystal River, Florida in 1984. *B. ligerica* occurred mainly in salinities below 23 ppt, and *B. hamata* mainly in higher salinities, but there was some overlap (Kravitz, 1987). Neither species was recorded in a Tampa Bay benthic survey in 1993-1995 (Karlen et al., 1997), but according to S. Rice (Univ. Tampa, pers. comm.), both do occur in Tampa Bay. Given their abundance at Crystal River, we consider both species to be **known invasives** in the greater Tampa Bay ecosystem.

Description and Biology

Information on *B. hamata* and *B. ligerica* comes from Dean and Blake (1966), Strathmann (1987), and Sato-Okoshi (2000). Both species have unpigmented, segmented bodies a few millimeters long and live in semi-permanent U-shaped burrows. Head tentacles are developed into several large, ciliated palps. There are four small eyes. Professional expertise is required for identification.

B. hamata produce 10-100 pelagic larvae, brooded through part of development. Most spionids exhibit a similar life cycle, so *B. ligerica* may be similar. Both species probably use their palps to feed on suspended particles.

Habitat and Potential Impacts

B. hamata has been reported to bore into bivalve shells (Larsen, 1978), but Sato-Okoshi (2000) states that it actually inhabits pre-existing shell crevices. This discrepancy may actually represent cryptic speciation, known for other polychaetes (Westheide and Schmidt, 2003). *B. ligerica* occurs in a variety of substrata (Kravitz, 1978, Lopez Gappa et al., 2001).

Both *B. hamata* and *B. ligerica* can attain high densities in non-native ecosystems and become dominant members of the benthic infauna (Larsen, 1978; Lopez Gappa et al., 2001). Other spionids are predators of economically valuable molluscan larvae (Breese and Phibbs, 1972; Naylor and McShane, 1997). Despite this, no quantitative studies have linked these or other spionids to overall ecological or economic impacts.

3-11.2 Calcareous Tubeworm
Class Polychaeta
Family Serpulidae
Hydroides (*Eupomatus*) *elegans* (Haswell, 1883) = *H. pacifica*

Range and Vectors of Introduction
This widespread species was originally described as several separate species in Europe, Hawaii, and the eastern Pacific. It is now believed to be native to the Indo-Pacific, and probably spread during the days of sailing vessels, attached to ship hulls (Zibrowius, 1971; Unabia and Hadfield, 1999).

H. elegans has been reported from throughout the Gulf of Mexico (Perkins and Savage, 1975), and was collected from Safety Harbor within Tampa Bay (Zibrowius, 1971), but little information is available about its distribution and abundance in west Florida, where it may be confused with *H. dianthus*, a native congener. It is apparently abundant in east Florida (Walters, 2001). *H. elegans* is a **known invasive** in Tampa Bay, but its abundance is unknown.

Description and Biology
H. elegans is a common fouling species, and forms an irregularly sinuous calcium carbonate tube attached to any of a variety of hard substrata. Members of this genus may also form reef-like structures by growing on each other. The tube, which is white or gray in color, seldom exceeds 3 mm in diameter. The worm lives permanently within this tube, and feeds on plankton via a feathery crown of pale cirri (tentacles). When threatened, the cirri are withdrawn, and the entrance to the tube is blocked by an ornate operculum. The fine structure of this operculum is used for species diagnosis.

H. elegans is an important model for settlement of marine larvae, and its life cycle is well known. Fertilization is external, and larvae are planktonic, becoming competent to settle and metamorphose in 4-5 days at 24-25^{o}C (Carpizo-Ituarte and Hadfield, 1998; McEdward and Qian, 2001). Settling larvae are attracted to bacterial biofilms that develop on recently exposed hard substrata (Unabia and Hadfield, 1999).

Habitat and Potential Impacts
H. elegans occurs on natural or artificial hard surfaces. It has a wide temperature tolerance, but the lower salinity limit for juveniles is between 15 and 20 ppt (Qiu and Qian, 1998).

In tropical harbors around the world, *H. elegans* is considered one of the most costly fouling organisms. It produces a calcareous tube cemented to hard substrata, it occurs in great densities, and it grows rapidly (Unabia and Hadfield, 1999). It is a major pest of aquaculture in China (Zheng and Huang, 1990). No information is available on its impacts in Florida, where the similar congener, *H. dianthus*, also occurs.

3-11.3 Reef-forming Tubeworm

Class Polychaeta

Family Serpulidae

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

Range and Vectors of Introduction

F. enigmaticus is native to Australia, but has since been introduced to New Zealand, western Europe and the Mediterranean, both coasts of the South Atlantic, and both coasts of North America (Dixon, 1981; Davies et al., 1989; Probert, 1993; Bianchi and Morri 1996; Schwindt et al., 2001a; Elkhorn Slough Foundation, 2002). Invasion vectors are unknown, but as a fouling organism, it may be introduced either on vessel hulls or with shellfish transfers for aquaculture.

This species has recently been reported from Tampa Bay, where it is common on test fouling plates (N.F. Smith, *unpubl. data*). This species is a **known invasive** of the greater Tampa Bay ecosystem.

Description and Biology

Like other members of the family, *F. enigmaticus* forms an irregularly sinuous, calcareous tube attached to hard substrata. Reef-like structures are formed by animals growing on each other. The tube, which is white to tan in color, may be 100 mm long but seldom exceeds 3 mm in diameter. The worm lives permanently within this tube, and feeds on plankton via a feathery crown of pale cirri (tentacles). When threatened, the cirri are withdrawn, and the entrance to the tube is blocked by an ornate operculum.

Adults appear to be sequentially hermaphroditic. In England, larvae spent at least one month in the plankton (Dixon, 1981). Settlement is not as well studied as for the related *Hydroides elegans* (see prior entry), but may be similar.

Habitat and Potential Impacts

F. enigmaticus is primarily estuarine and occurs in intertidal to shallow subtidal areas. High densities have been documented in shallow lagoons with very little water exchange and extreme salinity fluctuations, from 1.5-50 ppt (Davies et al., 1989; Bianchi and Morri, 1996; Schwindt et al., 2001a). Thermal tolerances have not been recorded, but this species occurs from Florida to England.

F. enigmaticus is a fouling organism, but is better known for forming reef-like structures in estuaries (Bianchi and Morri, 1996). Circular reefs are formed in Argentina, transforming mud flats into a heterogeneous habitat with secondary impacts on other species (Schwindt et al., 2001a, 2001b). Large areas of Elkhorn Slough, California have been transformed from mud to rocky reef (Elkhorn Slough Foundation, 2002). In South Africa, large encrustations by this species are navigation hazards in coastal waterways. When abundant, *F. enigmaticus* can alter water quality via filter feeding (Davies et al., 1989). No reef-like structures formed by this species have been reported in Tampa Bay. It should be noted that the above impacts occurred in temperate to warm temperate estuaries, so the greater Tampa Bay ecosystem may not be comparable.

URL for more information: http://www.jncc.gov.uk/marine/non_native/default.htm

3-11.4 Capitellid Worm
Class Polychaeta
Family Capitellidae
Mediomastus californiensis Hartman, 1944

Range and Vectors of Introduction
M. californiensis was identified and described in California in 1944, but has since been reported nearly worldwide (Uebelacker and Johnson, 1984; Vargas, 1987; Kalke and Montagna, 1991; Hong and Yoo, 1996; Linero Arana, 1996; Brasil and Da Silva, 2000; Dumbauld et al., 2000; Hilbig and Blake, 2000). No information is available on vectors of possible introduction, but this species is associated with cultured oysters in Washington State (Dumbauld et al., 2000).

M. californiensis is one of many polychaetes with reported transoceanic distributions. These distributions may be natural, they may represent widespread introductions, or they may represent cryptic species (Culter, 1995; Westheide and Schmidt, 2003). We have chosen this species to represent here because extensive infaunal polychaete surveys prior to 1970 failed to report it, but later surveys found it (or morphologically identical species) abundant and widespread in Tampa Bay (Taylor, 1971; Santos and Simon, 1980; Culter, 1995; Karlen et al, 1997). *M. californiensis* is **known** from the greater Tampa Bay ecosystem, but we consider it **cryptogenic** until further information is obtained.

Description and Biology
M. californiensis is a slender segmented worm without tentacles and with reduced parapodia. Maximum size is about 25 mm (Blake, 1989). Professional expertise is required for identification. Despite its widespread distribution, the reproduction and feeding ecology of this species have not been reported. Presumably, it is a deposit feeder like other members of its family (Rudy and Rudy, 1979).

Habitat and Potential Impacts
M. californiensis is infaunal in soft sediments, and tolerates a wide range of both salinities and temperatures, ranging from tropical to cool temperate. Given its tolerance of polluted water bodies (Hilbig and Blake, 2000), it is probably also tolerant of low oxygen levels.

As abundant members of many benthic ecosystems, capitellid worms are presumed to be ecologically important (Rudy and Rudy, 1979), and if nonindigenous, would potentially have a high ecological impact. Unfortunately, energy flow regimes have not been worked out at the species-specific level, so it is impossible to quantify any ecological impacts of this or similar species. This worm is not a fouling organism, so it has no known economic impacts.

3-12. Phylum Mollusca – Snails, Mussels, Clams, and Shipworms
Mollusks comprise one of the largest phyla of animals on Earth, with, by some estimates, over 100,000 described species (Pechenik, 2000). Over three quarters of these are gastropods (snails, slugs, and limpets) and most of the remainder are bivalves (clams, oysters, mussels, and shipworms). Taxonomy and common names, except where noted, follow Turgeon et al. (1998).

Several mollusk species not discussed below merit passing mention. The rapa whelk, *Rapana venosa*, recently invaded Chesapeake Bay, Virginia. This is a large snail which preys on commercially valuable northern hard clams, *Mercenaria mercenaria*. To date, the rapa whelk has not spread from Chesapeake Bay, but its thermal tolerances include most of Florida (Harding and Mann, 1999; Mann and Harding, 2001).

A small salt marsh pulmonate snail, *Myosotella* (*Ovatella*) *myosotis*, was reported by Carlton and Ruckelshaus (1997) to occur in Florida, based on a literature survey. The Florida Museum of Natural History has no Florida specimens in its collection, and we were unable to find it in numerous surveys of greater Tampa Bay ecosystem shorelines. The Gulf of Mexico Program's Invasive Species Focus Team (2000) does not consider this species to be established in Florida, and it will not be discussed further here.

An eolid nudibranch, *Cuthona perca*, which was first described from California, has been reported once in Miami, Florida (A. Benson, *unpubl. data*). No further information on this species in Florida exists.

A mussel, *Mytella charruana*, became abundant in the seawater intakes of a power plant in Jacksonville, but subsequently died out (Lee, 1987; 1998). The Indo-Pacific pearl oyster, *Pinctada margaritifera*, was collected alive in the Florida Keys several times but does not appear to be established (Carlton and Ruckelshaus, 1997). An undescribed species of *Electronoma*, a small member of the pearl oyster family, has become abundant in the southern Caribbean (Borrero and Díaz, 1998). The southern Caribbean is the probable source for North American invasions of brown mussels and green mussels (see below).

Molluscan species covered here include the following:

3-12.1 Red-rim Melania, *Melanoides tuberculata* - Known Invasive
Faune Melania, *Melanoides turriculus* - Known Invasive

3-12.2 Quilted Melania, *Tarebia granifera* - Known Invasive

3-12.3 Striped False-Limpet, *Siphonaria pectinata* – Known, Cryptogenic

3-12.4 Brown Mussel, *Perna perna* - Potential Invasive

3-12.5 Green Mussel, *Perna virdis* - Known Invasive

3-12.6 Northern Hard Clam, *Mercenaria mercenaria* - Known Invasive

3-12.7 Asian Clam, *Corbicula fluminea* - Known Invasive

3-12.8 Santo Domingo Falsemussel, *Mytilopsis sallei* – Known, Cryptogenic

3-12.9 Striate Piddock, *Martesia striata* - Known Invasive

3-12.10 Fimbriate Shipworm, *Bankia fimbriatula* – Probable, Cryptogenic

3-12.11 Lyrodus Shipworms, *Lyrodus bipartita* - Probable, Cryptogenic
Lyrodus massa – Probable, Cryptogenic

3-12.12 Teredo Shipworms, *Teredo clappi* - Probable, Cryptogenic
Teredo furcifera - Probable, Cryptogenic

3-12.1 Red-rim Melania and Faune Melania

Class Gastropoda, Subclass Prosobranchia

Order Neotaenioglossa

Family Thiaridae

Melanoides tuberculata (Müller, 1774) (red-rim melania)

Melanoides turriculus (I. Lea, 1850), possible synonym (faune melania)

Range and Vectors of Introduction

M. tuberculata is asexual throughout most of its range but sexual populations in the Middle East suggest that region as the evolutionary origin (Livshits et al., 1984). *M. turriculus* was described from the Philippines, but Thompson (1999) suspects it to be synonymous with *M. tuberculata*. Both nominal species occur in Florida, Louisiana, and Texas, and the vector for Florida introductions was probably aquarium releases in the 1930s (Warren, 1997; U.S. Geological Survey, 2000).

Both *M. tuberculata* and *M. turriculus* are abundant in estuarine tributaries of Tampa Bay (G.L. Warren, *unpubl. data*), and are thus are **known invasives** in the greater Tampa Bay ecosystem.

Description and Biology

The following information, unless noted otherwise, is for *M. tuberculata*; *M. turriculus* is similar in most respects (U.S. Geological Survey, 2000). Shells are high-spired (to 36 mm in Florida) with about five ribbed whorls in mature specimens, and the operculum has an offset spiral growth pattern. Shells are tan to brown, often with red or rust-colored spots (G.L. Warren, *unpubl. data*).

Melania snails consume detritus and benthic microalgae (but see Lee, 1973) and are mostly nocturnal. Asexual reproduction (parthenogenesis) appears to be the only form of reproduction outside of the Middle East (Livshits et al., 1984). There is a brood pouch in the mantle cavity with up to about 70 offspring. There is no planktonic larval phase, and newly released juveniles are 1-2 mm long (Livshits and Fishelson, 1983).

Habitat and Potential Impacts

The reported habitat for *M. tuberculata* is muddy substrata in freshwater streams (U.S. Geological Survey, 2000), but both species are abundant in Tampa Bay estuaries (G.L. Warren, *unpubl. data*). *M. tuberculata* can reach high densities in Florida mangrove swamps at salinities up to 30 ppt. The thermal tolerance range is about 18-25^{o}C, but *M. tuberculata* can survive cooler temperatures by burrowing, and appears to be tolerant of low oxygen levels (Roessler et al., 1977).

Melania snails are intermediate hosts for important human or wildlife trematode parasites in Asia, as reviewed by U.S. Geological Survey (2000). There are no reports of transmission of human parasites from snails in Florida. High densities of melania snails may impact native detritivores (Roessler et al., 1977), but no studies have quantified this. *M. tuberculata* is a pest on aquatic plants in Hong Kong (Lee, 1973), but not in Florida's ornamental aquatic plant industry (C. Watson, *pers. comm*.).

URL for more information: http://www.gsmfc.org/nis/

3-12.2 Quilted Melania

Class Gastropoda, Subclass Prosobranchia
Order Neotaenioglossa
Family Thiaridae
Tarebia granifera (Lamarck, 1822)

Range and Vectors of Introduction

The quilted melania is described from Southeast Asia, and occurs from India to the Philippines and Japan, although how much of that range is natural has not been investigated. It is established in warmer parts of the United States and Puerto Rico. In Florida, it was introduced in about 1937, probably from Hawaii, via aquarium releases, and is now established in the Tampa and Miami areas (Warren, 1997; G.L. Warren, *unpubl. data*; Poss et al., 2000; Ramey and Murray, 2003).

The quilted melania is a **known invasive** in the greater Tampa Bay ecosystem, and can reach high densities in oligohaline tributaries of Tampa Bay (G. Warren, Florida Fish & Wildlife Conserv. Comm., *unpubl. data*).

Description and Biology

The quilted melania is a drab, high-spired snail up to 35 mm in shell length, but there is high shell variability. The shell is light brown, and is covered with rows of small bumps. It is similar to other introduced melania (see prior entry), and to native *Elimia* snails, but the operculum on the latter have centered spiral growth pattern, while the quilted melania operculum has an off-center spiral (Poss et al., 2000).

Introduced populations of quilted melania appear to be parthenogenic; males have been reported, but seem non-functional. Embryos are brooded in the mantle cavity, and released as juveniles of about 2 mm shell length. Females can reach sexual maturity within 100 days. It appears to be a generalist grazer or detritivore, removing epiphytes and/or detritus from vegetation, but not consuming plants (Poss et al., 2000).

Habitat and Potential Impacts

The quilted melania prefers shallow waters, but otherwise occurs in a wide range of habitats. It tolerates temperatures to 7-10^{o}C. It can tolerate low salinities, and persists in oligohaline portions of estuaries, contrary to some reports (G.L. Warren, *unpubl. data*; Poss et al., 2000).

Poss et al. (2000) have reviewed known and suspected impacts of the quilted melania. In some environments, including Florida, the quilted melania can reach high densities, and can displace native snails. This ability has been used to justify past introductions in which the target species are intermediate hosts for human parasites. The quilted melania may also compete with small detritivorous fishes, although there has been no evidence of impacts on native fish in Florida. The quilted melania itself may also serve as the intermediate host for some flatworm parasites of humans, but this has not been reported in Florida.

URL for more information: http://www.gsmfc.org/nis/

3-12.3 Striped False-Limpet

Class Gastropoda, Subclass Pulmonata

Order Basommatophora

Family Siphonariidae

Siphonaria pectinata (Linnaeus, 1758) = *S. lineolata*

Range and Vectors of Introduction

This species occurs throughout the Mediterranean and North Atlantic basin. Carlton (1992) believes the striped false-limpet is introduced in the western Atlantic, but some authorities disagree, so it should be considered cryptogenic until further work is completed (see Carlton, 1992, for review). If introduced, it was present by the 19th century, and may have come via ship hulls (Carlton, 1992). The striped false-limpet occurs widely on the east coast of Florida and in the Florida Keys (Voss, 1959; FMRI EJ67139, EJXX242, EJ60015).

To date, we have been unable to verify the presence of the striped false limpet in Tampa Bay (these authors, unpubl. data), but large (2-3 cm) specimens have been collected from a pier in Collier County, within the west Florida ecocline (FLMNH 13958), so we consider it to be a **probable** resident of the greater Tampa Bay ecosystem, but **cryptogenic** pending clarification of its native range.

Description and Biology

Florida has few limpet-like snails, and no others in the upper intertidal, so the false-limpet is easily recognizable. It has a cap-like shell, seldom more than about 15 mm long but occasionally up to 30 mm (FLMNH 13958), with radiating stripes.

This species grazes on encrusting microbiota (Voss, 1959; Ruppert and Fox, 1988). A few hundred or thousand eggs are laid in coiled ribbons attached to rocks, like those of sea slugs. There is a brief planktonic larval stage, a primitive character among pulmonates (Voss, 1959).

Habitat and Potential Impacts

In east Florida, the striped false-limpet is restricted mainly to the rocky intertidal, which includes some natural limestone but consists mostly of artificial groins, jetties, concrete piers, and seawalls.

The striped false-limpet is an "urban" species in Florida, in that most of its habitat (rocky intertidal) was created by humans. It is a fouling species in the original sense of the word, but because it is a grazer, it probably reduces more fouling than it causes. Because of its apparent rarity around Tampa Bay, its economic and ecological impacts are probably negligible.

URL for more information: http://www.tpwd.state.tx.us/expltx/eft/gulf/cspecies/limpetfact.htm

3-12.4 Brown Mussel
Class Bivalvia
Order Mytiloida
Family Mytilidae
Perna (*Mytilus*) *perna* (Linnaeus, 1958)

The American Society of Fisheries (ASF) has designated *P. perna* as the "Mexilhao mussel," which is commonly used in Hispanic nations (Turgeon et al., 1998), but most published literature on *P. perna* uses the common name "brown mussel."

Range and Vectors of Introduction
The brown mussel is considered native to Africa and southwest Asia, plus parts of South America, although the latter is also consistent with an introduction by early European explorers. It was introduced to Venezuela in the 1960s, and appeared in Texas in the early 1990s (Hicks and Tunnel, 1993). As for green mussels (see following entry), both hull fouling and ballast water are reasonable vectors of introduction.

This species has not yet been recorded in the Gulf of Mexico from east of Texas, but given its history of invasion, we consider it a **potential invasive** to the greater Tampa Bay ecosystem.

Description and Biology
The brown mussel is superficially similar to the green mussel (below), and to the native tulip mussel, *Modiolus squamosus* (*americanus*). *M. squamosus* is covered with a hairy periostracum which *P. perna* lacks (Crochet et al., 1999). In most regards the biology of *P. perna* is comparable to *P. viridis* (see following entry).

Habitat and Potential Impacts
The brown mussel can tolerate water temperatures as low as 7.5^{o}C for 30 days if previously acclimated to 15^{o}C (Hicks and McMahon, 2002). It tolerates salinities of 15-50 ppt, and in Texas, occurs mainly on artificial substrata in high-salinity portions of bays (Hicks et al., 2001).

Brown mussels in Texas are sometimes abundant but are limited primarily to artificial substrata (Hicks and Tunnel, 1993). Impacts, therefore, would be secondary to the impacts already created by artificial structures.

URL for more information: http://www.gsmfc.org/nis/nis/Perna_perna.html

3-12.5 Green Mussel
Class Bivalvia
Order Mytiloida
Family Mytilidae
Perna (*Mytilus*) *viridis* (Linnaeus, 1758)

The American Society of Fisheries (ASF) uses "green mussel" for *Musculista senhousia*, introduced to the Pacific coast of North America (Turgeon et al., 1998). Most of the literature on *P. viridis* uses "green mussel," however, superceding the ASF use.

Range and Vectors of Introduction
The green mussel is native to Southeast Asia and has been introduced to the South Pacific and the Caribbean. Ballast water and hull fouling are likely vectors, with the southern Caribbean the most likely source of the Tampa Bay population (Coeroli et al., 1984; Agard et al., 1992; Rylander et al., 1996; Benson et al., 2001).

In Florida, green mussels are a **known invasive** in the greater Tampa Bay ecosystem, and are rapidly spreading to the rest of Florida (Fajans and Baker, *in prep*.).

Description and Biology
The green mussel has a green *periostracum* (shell coating), at least at the shell margins, over a white and slightly pearly shell. The green mussel is distinguished from the brown mussel (see prior entry) by the green margins; brown mussels may have green shell areas, but not on the margins. Specimens in Florida may exceed 15 cm in shell length.

Green mussels attach by byssal threads to a variety of hard substrata, and have some mobility, particularly as juveniles. They are filter-feeders. Fertilization is external and there is a planktonic larval phase of 7-10 days (review by Benson et al., 2001). In Florida, green mussels can reach 75-100 mm in one year (Fajans and Baker, *in prep*).

Habitat and Potential Impacts
The following data, unless noted otherwise, are from an ongoing study (Baker and Baker, 1999). Green mussels occur on hard substrata, including artificial structures and other mollusks. Adults may fall off these substrata and persist in soft sediments. Green mussels tolerate full seawater to about 10 ppt, but are most abundant at 18-28 ppt. They are killed by freezing and by prolonged temperatures below 12^{o}C or above 35^{o}C (Fajans et al., *in prep.*).

The green mussel is abundant in Tampa Bay, and adds to pre-existing anti-fouling costs. Costs have been reported, but not quantified, for power plants with seawater intakes (Benson et al., 2001) and U.S. Coast Guard buoys (W. Danzik, U.S. Coast Guard, *pers. comm.*). Green mussels are important fouling organisms in Caribbean mangrove communities (Agard et al., 1992), but in Tampa Bay, green mussels are absent from mangroves, which are important habitat for native oysters (*Crassostrea virginica*). On the other hand, green mussels are abundant on oyster reefs in Tampa Bay, and are correlated with high oyster mortalities. On pilings, green mussels displace oysters to a narrow band in the upper intertidal (Baker at al., 2003).

URL for more information: http://www.fcsc.usgs.gov/greenmussel4.pdf

3-12.6 Northern Hard Clam

Class Bivalvia

Order Veneroida

Family Veneridae

Mercenaria (*Venus*) *mercenaria* (Linnaeus 1758)

The American Fisheries Society uses “northern quahog” for this species (Turgeon et al., 1998), but the common name “hard clam” is applied almost exclusively by Florida’s aquaculture industry (Colson and Sturmer, 2000).

Range and Vectors of Introduction

The northern hard clam occurs along the Atlantic coast of North America from Canada to the Indian River Lagoon of east Florida. Prior to this century, it was not known to have occurred in the Gulf of Mexico, although the closely related species, *M. campechiensis*, does. *M. mercenaria* has been intentionally introduced to several other areas of the world for fishery enhancement (Carlton, 1979a, 1992).

M. mercenaria was deliberately introduced to west Florida, including Sarasota Bay in 1960 (Woodburn, 1961). It has been collected as far south as Sanibel Island (BMSM 25519). This species is a **known invader** of the greater Tampa Bay ecosystem.

Description and Biology

The northern hard clam has a robust, pale shell with a rounded outline. Some individuals, especially those escaped from cultivation, may exhibit rays of color. The shell may exceed 12 cm in length, and the interior usually has some purple near the posterior (siphon) margin. The closely related congener, *M. campechiensis* lacks this purple and usually has concentric ridges on the shell, but these differences can be subtle (Hill, 2002).

The biology of *M. mercenaria* has been reviewed by Eversole (1987) and Roegner and Mann (1991). Fertilization is external and there is a planktonic veliger larva lasting 7-12 days, followed by an active *plantigrade* juvenile with a byssus. Older juveniles lose the byssus, and adult clams are essentially sessile. *M. mercenaria* may live for decades, but in Florida they reach market size (3-4 cm) and sexual maturity in about one year (Colson and Sturmer, 2000). Like most other bivalves, *M. mercenaria* are filter feeders, but no study has been conducted on their ability to modify plankton communities.

Habitat and Potential Impacts

Northern hard clams occur in sand to sandy mud, from the intertidal to subtidal. The upper thermal limit is around 30^{o}C, and the optimal salinity range is 20-35 ppt (Roegner and Mann, 1991).

Given the similarity of *M. mercenaria* to native *M. campechiensis*, its ecological impacts as a nonindigenous species are difficult to assess. The culture of this species in some west Florida communities has been economically important, allowing the transformation of former fishing communities to sustainable aquaculture (Colson and Sturmer, 2000).

URL for more information: http://www.sms.si.edu/IRLSpec/Mercen_mercen.htm

3-12.7 Asian Clam

Class Bivalvia

Order Veneroida

Superfamily Corbiculacea, Family Corbiculidae

Corbicula "*fluminea*" Müller 1774

Range and Vectors of Introduction

Taxonomic difficulties with the *Corbicula* genus has made the origin of the species uncertain, but it is known to have originated somewhere in eastern Asia. Several lineages have been introduced nearly worldwide, but most of these, including those in the U.S., are clonal (Siripattrawan et al., 2000). The species name remains uncertain, but until a better option is provided, we shall follow convention and use *C. fluminea* here. Initial North American introductions were intentional, and further introductions plus the species own dispersal ability have spread it throughout the United States.

C. fluminea is the dominant bivalve in almost all permanent Florida freshwater, including tributaries of Tampa Bay (Blalock-Herod, 2000). It is not normally considered an estuarine species, but its reported tolerances put it in at least the oligohaline range (McMahon, 1991). We observed *C. fluminea* in oligohaline portions of the Little Manatee River, and Grabbe (2001) reported it to 23 ppt in Tampa Bay tributaries, although densities were not reported. *C. fluminea* is a **known invasive** in the greater Tampa Bay ecosystem.

Description and Biology

The biology of *C. fluminea* has been reviewed by McMahon (1991), Blalock-Herod (2000) and Foster et al. (2000). The shell of *C. fluminea* is symmetrically triangular to circular in outline, deeply inflated, and robust in water with abundant calcium, such as in Florida. There is a heavy, smooth periostracum (shell coating), yellow to black, and the interior of the shell may be tinged with purple. *C. fluminea* may be confused with related oligohaline marsh clams, *Polymesoda* spp., but the shell outlines of the latter are not as symmetrical.

C. fluminea reproduces asexually via self-fertilization (Siripattrawan et al., 2000). Larvae are brooded until metamorphosis and released as crawl-away juveniles. In Florida, *C. fluminea* appear to reach maximum size in one year. *C. fluminea* is a filter-feeder, but can consume seston as well as plankton.

Habitat and Potential Impacts

C. fluminea is abundant in most freshwater streams and lakes in Florida, but reaches highest densities ($>1000 \cdot m^{-2}$) in streams (Blalock-Herod, (2000). It is also abundant in tidal freshwater (Grabbe, 2001), and tolerates long-term salinities to 14 ppt (McMahon, 1991). Thermal tolerances include most of the United States and all of Florida (McMahon, 1991).

Studies on ecological impacts have been limited to freshwater. It has been suggested, but never clearly demonstrated, that *C. fluminea* competes with native freshwater bivalves (McMahon, 1991; Blalock-Herod 2000; Foster et al., 2000). High densities of *C. fluminea* can alter plankton biomass and hence water clarity in lakes (Beaver et al., 1991). High densities of *C. fluminea* can clog industrial water intakes (Page et al., 1987).

URL for more information: http://nas.er.usgs.gov/

3-12.8 Santo Domingo Falsemussel

Class Bivalvia

Order Veneroida

Family Dreissenidae

Mytilopsis sallei (Récluz, 1849) = *M. domingensis*

Range and Vectors of Introduction

M. sallei is native to the southern Caribbean, but has been reported from throughout the Caribbean basin, including Florida. This species is on record as an invader in Asia (Karande and Menon, 1975; Morton, 1989). According to other authorities, that invader was actually a congener, *M. adamsi* (Marelli and Gray, 1983); however, *M. sallei* recently invaded Australia (Field, 1999; CRIMP, 2001a). It is a fouling species with planktonic larvae, so hull fouling and ballast water are possible vectors of introduction.

In Florida, *M. sallei* has been reported occasionally in inland waters of the southern peninsula (Marelli and Gray, 1983; G.L. Warren, *unpubl. data*), and in tidal waters of the Hillsborough River, Tampa (BMSM 26211). *M. sallei* is **known** from the greater Tampa bay ecosystem, but its status as a native species is uncertain, so we consider it **cryptogenic**.

Description and Biology

The biology of *M. sallei* has been reviewed by Marelli and Gray (1985) and CRIMP (2001a). Studies in Asia (Morton, 1981) may actually refer to *M. adamsi* (see comments above), but the biology probably differs only in minor details. *M. sallei* resembles the nonindigenous zebra mussel, *Dreissena polymorpha*, and the native falsemussel, *M. leucophaeata*, but the ventral surface is relatively rounded compared to the other species. The shell, which seldom exceeds 3 cm, is variously marked, and may be striped.

Juveniles and adults attach to hard substrate or each other via byssal threads, and may detach and reattach, especially as juveniles. They are filter-feeders. Larvae spend “a few days” in the plankton. Juveniles become mature within a month, at 10 mm.

Habitat and Potential Impacts

M. sallei is reported to tolerate temperatures of 5-40^{o}C, and salinities of 0-50 ppt (CRIMP, 2001a), but these estimates may derive from studies on misidentified *M. adamsi* (see comments above), so details may differ. *M. sallei* attaches to a variety of hard substrata.

The family Dreissenidae includes notorious invaders such as the zebra mussel (Karande and Menon, 1975; Morton, 1981; 1989; Nalepa and Schloesser, 1992), but impacts for one species cannot be used to predict impacts for others. A Florida native, *M. leucophaeata*, invaded Europe a century ago, but is rarely noticed there (Wolff, 1969). *M. sallei* had been reported from Florida for decades (Marelli and Gray, 1983), and has yet to become a pest. On the other hand, this species was recently observed in high densities in a canal near Fort Lauderdale (G.L. Warren, *unpubl. data*).

URL for more information: http://crimp.marine.csiro.au/

3-12.9 Striate Piddock

Class Bivalvia

Order Myoida

Family Pholadidae

Martesia striata (Linnaeus, 1758)

Range and Vectors of Introduction

M. striata is widespread in estuaries and harbors of the Indian Ocean. It also occurs in the tropical Atlantic, and some authorities accepted this distribution as natural (Turner, 1955). Carlton (1992, 1999b) reviewed evidence for global introductions of this species, which we shall accept here, pending further information.

M. striata occurs on both coasts of Florida, although, based on collections in the Florida Museum of Natural History, Pinellas County seems to be the northernmost normal limit of its range in west Florida (FLMNH 17758, 22962). In our observations, it is widespread in the greater Tampa Bay ecosystem. This species is a **known invasive** in the greater Tampa Bay ecosystem.

Description and Biology

The biology of *M. striata* is reviewed by Turner (1955) and Boyle and Turner (1976). *M. striata* is enclosed in a pear-shaped pair of fragile shells, which are themselves totally encased in a permanent burrow. Adults may reach 50 mm in shell length and the anterior ends of the shells have a corduroy-like texture – hence the common name.

M. striata is one of a number of wood-boring mollusks in the related families Pholadidae and Teredinidae. Members of Teredinidae are obligate wood borers, while members of Pholadinidae, including *M. striata*, bore into a variety of hard substrate, including wood (Yennawar et al., 1999). *M. striata* is an obligate filter-feeder, unlike teredinid shipworms, which obtain at least some nutrition from the wood they inhabit. *M. striata* have external fertilization and planktonic larvae, with a planktonic phase of about one month. If temperatures permit, *M. striata* probably breeds throughout the year. Growth is rapid, with sexual maturity achieved in one month after settlement, and full size reached in four months.

Habitat and Potential Impacts

This species occurs in wood and other hard substrata, and larvae, at least, tolerate salinities as low as 10 ppt for a short time, but thrive best at higher salinities (Boyle and Turner, 1976; Yennawar et al., 1999). Thermal tolerances are not known, but this is a primarily tropical and subtropical species.

M. striata is an important pest in harbors, boring not only into wooden structures, but also a variety of other substrata, including synthetic rubber (e.g. boat fenders), masonry, polyvinyl chloride (PVC) piping, and even lead (Satyanarayana Rao and Venu, 1984). Turner (1955) considered it equal to teredinid shipworms in the economic damage it does in many areas. Its impact in Florida, relative to other molluscan and arthropod borers, has not been studied, but this species occurs at high densities in Tampa Bay. *M. striata* is considered a minor pest of oysters in Florida (Ingle and Whitfield, 1968).

3-12.10 Fimbriate Shipworm

Class Bivalvia

Order Myoida

Family Teredinidae

Bankia fimbriatula Moll and Roch, 1931

Range and Vectors of Introduction

B. fimbriatula was described from driftwood in Scotland and is circumtropical in distribution, but best known from tropical South America (Müller and Lana, 1986; Lopes and Narchi, 1993; Carlton, 1999b). This is one of numerous wood-boring species that is suspected to be introduced to the Atlantic basin, although its evolutionary origin remains obscure (Carlton, 1999b).

B. fimbriatula is known from east Florida (FLMNH 178235; Mikkelsen et al., 1995) and Sanibel Island in the west Florida ecocline (Riser, 1970), so we consider it a **probable** resident of the greater Tampa Bay ecosystem, and **cryptogenic** until further work has established its evolutionary origin.

Description and Biology

Unless otherwise noted, the following information is from Turner (1966). *B. fimbriatula* has an elongate, worm-like body occupying a burrow in submerged wood. The shell is reduced to a small pair of valves at the anterior (largest) end of the animal, and at the opposite end is a pair of feather-like calcareous *pallets*. The genus *Bankia* can be distinguished from *Teredo* or *Lyrodus* by the pallets; those in the latter genera are smaller and paddle-like. Species identification generally requires professional expertise. The burrow walls of shipworms are lined with a thin layer of calcium carbonate, especially in larger specimens, which distinguished them from crustacean burrows. In Florida, these burrows can reach 7 mm in diameter (FLMNH 178235).

The nutrition of shipworms is not fully understood. They are believed to be able to filter plankton from the seawater, but they also consume wood with the aid of endosymbiotic bacteria. The relative importance of these two food sources varies during the lifetime of the animal and between species. Many members of the family Teredinidae brood larvae, but it is unclear whether *B. fimbrulatula* does so. There is a planktonic larval phase following brooding. Most shipworms have a long breeding season, and grow and reach sexual maturity rapidly.

Habitat and Potential Impacts

B. fimbriatula occurs in many varieties of wood. Lopes and Narchi (1993) found this species primarily in the subtidal on mangroves in Brasil. Salinity and thermal tolerances are unknown, but this species appears to be primarily tropical.

Since the marine environment generally lacks wood-consuming fungi or insects, shipworms are important marine recyclers, but for the same reason, are destructive to wooden structures and vessels in the marine environment. Specific impacts of *B. fimbriatula* are not well studied, and almost nothing is known of its abundance or importance in Florida.

3-12.11 Lyrodus Shipworms

Class Bivalvia

Order Myoida

Family Teredinidae

Lyrodus bipartita (Jeffreys, 1860)

Lyrodus massa (Lamy, 1923)

Range and Vectors of Introduction

These are two of numerous wood-boring mollusks and pericarid arthropods that only recently have been suspected of being introduced, although their evolutionary origins remain obscure (Carlton, 1999b). Until further fossil or molecular work is done, these species must be considered cryptogenic.

There are no collections of *L. bipartita* in the Florida Museum of Natural History, and the only collection of *L. massa* is from Torch Key, in Monroe County (FLMNH 123196). Mikkelsen et al. (1995) lists *L. bipartita* but not *L. massa* from east Florida. Given the lack of study, it is possible that both have been overlooked, and we consider both species to be **probable** residents of the greater Tampa Bay ecosystem, but **cryptogenic** until further study establishes their evolutionary origins.

Description and Biology

The following information is from Turner (1966) and Turner and Johnson (1971). Both *L. bipartita* and *L. massa* have elongate, worm-like bodies which occupy burrows in submerged wood. The bivalve shell is reduced to a small pair of valves at the anterior (largest) end of the animal, and at the opposite end is a pair of paddle-like calcareous pallets. Species identification generally requires professional expertise. The burrow walls of shipworms are lined with a thin layer of calcium carbonate, especially in larger specimens, which distinguishes them from crustacean burrows.

The nutrition of shipworms is not fully understood. They are believed to be able to filter plankton from the seawater, but they also consume wood with the aid of endosymbiotic bacteria. The relative importance of these two food sources varies during the lifetime of the animal and between species. Members of the genus brood larvae partway through development, but there is also a planktonic larval phase. Most shipworms have a long breeding season and grow and reach sexual maturity rapidly.

Habitat and Potential Impacts

Both of these species live in a variety of woods and occur intertidally to subtidally. Both are primarily tropical, but salinity and thermal tolerances are otherwise unknown.

Since the marine environment generally lacks wood-consuming fungi or insects, shipworms are important marine recyclers, but for the same reason, are destructive to wooden structures and vessels in the marine environment. Specific impacts of *L. bipatritus* or *L. massa* are not well studied, and little is known of their abundance or importance in Florida.

<u>3-12.12 Teredo Shipworms</u>
Class Bivalvia
Order Myoida
Family Teredinidae
Teredo clappi Bartsch, 1923
Teredo furcifera von Martens, 1894

Range and Vectors of Introduction
Teredo clappi was originally described from Key West, Florida, but the actual locality was the keel of a wooden ship (Turner, 1966), so the type specimen itself (USNM 348189) probably originated elsewhere. *Teredo furcifera* was described from Indonesia (Turner, 1966). Both species are circumtropical, and both are considered cryptogenic (Carlton, 1992; 1999b).

There are no collections of either species in the Florida Museum of Natural History (FLMNH), but both species have been reported in east Florida (Turner and Johnson, 1971; Mikkelson et al., 1995). Pending further information, both species will be considered **probable** residents of the greater Tampa Bay ecosystem, but **cryptogenic**.

Description and Biology
The following information is from Turner (1966) and Turner and Johnson (1971). Both *L. bipartita* and *L. massa* have elongate, worm-like bodies which occupy burrows in submerged wood. The bivalve shell is reduced to a small pair of valves at the anterior (largest) end of the animal, and at the opposite end is a pair of paddle-like calcareous pallets. Species identification generally requires professional expertise. The burrow walls of shipworms are lined with a thin layer of calcium carbonate, especially in larger specimens, which distinguishes them from crustacean burrows.

The nutrition of shipworms is not fully understood. They are believed to be able to filter plankton from the seawater, but they also consume wood with the aid of endosymbiotic bacteria. The relative importance of these two food sources varies during the lifetime of the animal and between species. Members of the genus brood larvae partway through development, but there is also a planktonic larval phase. Most shipworms have a long breeding season, and grow and reach sexual maturity rapidly.

Habitat and Potential Impacts
The following information is from Turner (1966) and Turner and Johnson (1971). Both of these species live in a variety of woods and occur intertidally to subtidally. Both are primarily tropical, but salinity and thermal tolerances are otherwise unknown. Both are primarily tropical, but salinity and thermal tolerances are otherwise unknown.

Since the marine environment generally lacks wood-consuming fungi or insects, shipworms are important marine recyclers, but for the same reason, are destructive to wooden structures and vessels in the marine environment. Specific impacts of *T. clappi* or *T. furcifera* are not well studied, and little is known of their abundance or importance in Florida.

3-13. Phylum Arthropoda – Barnacles, Isopods, Crabs, and Others
Arthropods, particularly Subphylum Crustacea, comprise the most diverse group of species in the marine environment, and also produce the greatest number of biological invaders, many of which are probably not yet recognized. In particular, the superorder Pericarida (isopods, amphipods, and tanaids) includes thousands of small coastal species which often difficult to identify, and few of which are well-studied. Many peracarids may be introduced, but few researchers have examined the topic in our region.

Four decapod crustaceans have been reported from or are cultured in peninsular Florida, but do not appear to have established wild populations. Individuals of the large portunid crab, *Scylla serrata*, were reported from southern Florida several times, but a recent survey was unable to locate any specimens (U.S. Geological Survey, 2000). A amphidromous (spawns in estuaries) river shrimp, *Macrobrachium olfersii*, was reported in Florida sever al times between the 1930s and 1960s and may occur in the Florida panhandle (N.F. Smith, *unpubl. data*), but there is no evidence that it currently occurs on the Florida peninsula (Poss et al., 2000; G.L. Warren, *unpubl. data*). The Indo-Pacific tiger prawn, *Penaeus monodon*, escaped from cultivation in South Carolina and was subsequently caught as far south as Florida, but also does not appear to have established a wild population (Carlton and Ruckelshaus, 1997). The Indo-Pacific white shrimp, *Litopenaeus* (*Penaeus*) *vannamei*, is widely cultivated in Gulf of Mexico states and may be established in the southern Caribbean, but has not been reported from regional waters (U.S. Geological Survey, 2000).

The Chinese mitten crab, *Eriocheir sinensis*, was one of the earliest biological invaders to receive serious study. It is a catadromous species, spawning in estuaries but spending most of its life in freshwater (Elton, 1958). This species has invaded Europe and California, and has been collected from the lower Mississippi River, but has not been shown to be established in the Gulf of Mexico (Poss et al., 2000).

An Indo-Pacific tanaid, *Zeuxo maledivensis*, has been reported once from Florida (Sieg and Winn, 1981). *Z. maledivensis* may be established in the greater Tampa Bay ecosystem, but no confirmation exists. An unidentified *Zeuxo* was a significant predator of seagrass seeds in Japan (Nakaoka, 2002), but it is not known whether *Z. maledivensis* consumes seagrass or seagrass seeds. A commensal isopod, *Iais floridana*, had been reported in the nonindigenous *Sphaeroma walkeri* (discussed below) on both coasts of Florida (Kensley and Schotte, 1989; N.F. Smith, *unpubl. data*). *I. floridana* species may be nonindigenous despite having been described from Florida. There is insufficient information on the biology and distribution of either of these species to discuss them further here.

Native wood-boring amphipods of the genus *Limnoria* ("gribbles") occur throughout Florida. *L. pfefferi* and *L. saseboensis* are listed as nonindigenous species established in Florida (Carlton and Ruckelshaus, 1997), but both appear to be limited to the Florida Keys (Kensley and Schotte, 1989; Johnson and Gutzmer, 1990; Kensley et al., 1995). Given that the same authors (Kensley and Schotte, 1989) also surveyed amphipods in non-tropical areas of Florida (Kensley et al., 1995), we feel confident in their ability to locate and identify these species, and doubtful, therefore, that either species occurs in the west Florida ecocline. These isopods may be true tropical species unable to invade the greater Tampa Bay ecosystem due to narrow physiological tolerances.

Two maritime insects of dubious origin were reported in a recent study headed by the Smithsonian Institution (N.F. Smith, *unpubl. data*). The seaside earwig, *Anisolabis maritima* (Dermoptera), native to the Atlantic coast, has been reported from the Gulf of Mexico coasts of Florida, as has a cryptogenic beach fly, *Procanace diannae* (Diptera). Maritime insects are properly discussed by upland ecologists, and will not be covered here.

Arthropod species covered here include the following:

3-13.1 Striped Acorn Barnacles, *Balanus amphitrite* - Known Invasive
Balanus reticulatus - Known Invasive
Balanus trigonus - Known Invasive

3-13.2 Warty Pillbug, *Sphaeroma terebrans* - Known Invasive

3-13.3 Warty Pillbug, *Sphaeroma walkeri* - Known Invasive

3-13.4 Wharf Roach, *Ligia exotica* - Known Invasive

3-13.5 Indo-Pacific Swimming Crab, *Charybdis hellerii* - Potential Invasive

3-13.6 Saber Crab, *Platychirograpsus spectabilis* - Known Invasive

3-13.7 Asian Shore Crab, *Hemigrapsus sanguineus* - Potential Invasive

3-13.8 Green Porcelain Crab, *Petrolithes armatus* - Known Invasive

3-13.1 Striped Acorn Barnacles

Subphylum Crustacea
Class Cirripedia
Order Thoracica
Family Balanidae
Balanus amphitrite Darwin, 1854
Balanus reticulatus Utinomi, 1967
Balanus trigonus Darwin, 1854

Range and Vectors of Introduction

These species are included together here because they are similar in appearance anf sympatric in Florida. All three species are circumtropical but were described from the Indo-Pacific. *B. amphitrite* and *B. reticulatus* are believed to be introduced to the Atlantic basin centuries ago, on the hulls of sailing vessels (Carlton and Ruckelshaus, 1997; Poss et al., 2000), but *B. trigonus* may not have invaded until the 1950s (Zullo, 1992). .

B. amphitrite is well-known from Florida, although seldom noted as nonindigenous in the literature (Carlton and Ruckelshaus, 1997). Our own field data indicates that *B. reticulatus* is the dominant barnacle of central Tampa Bay. *B. trigonus* is better known from the Florida east coast (FMRI EJ74304 and others), but is also reported from the west coast of Florida (N.L Smith, *unpubl. data*) and other parts of the Gulf of Mexico (Poss et al., 2000). We consider all three species to be **known invasives** of the greater Tampa Bay ecosystem.

Descriptions and Biology

Acorn barnacles have hard conical *tests* with four articulating plates at the opening, through which feathery *cirri* protrude to capture food. The test of *B. amphitrite*, up to 15 mm in diameter, is distinguished from most other species by radial (base to apex) purple stripes. *B. reticulatus* also has radial purple stripes, but has concentric ridges perpendicular to the stripes (Bishop Museum, 2002). The test of *B. trigonus* seldom exceeds 8 mm, has concentric purple stripes, and a comparatively triangular opening (Museum Victoria, 2002). Native barnacles (e.g. *B. eburneus*) are smooth and usually lack color. Professional expertise is often required for identification.

Acorn barnacles are simultaneous hermaphrodites and fertilization is internal. Up to several thousand larvae may be produced per individual, and there can be 24 reproductive episodes per year. Larvae are planktonic, followed by settlement and cementation to any hard substratum. Growth is rapid, and sexual maturity is attained in weeks (Poss et al., 2000).

Habitat and Potential Impacts

Acorn barnacles mostly occur in the mid-to-upper intertidal, but also occupy floating objects. They grow most rapidly in currents. All three species occurred mainly in higher salinity areas of Tampa Bay (these authors, unpubl. data), and *B. amphitrite* and *B. reticulatus* are tolerant of freezing air temperatures for brief periods (Poss et al., 2000).

B. amphitrite and *B. reticulatus* are two of the most abundant barnacles in high salinity portions of the greater Tampa Bay ecosystem, and are important fouling organisms. Both species have been in Florida so long that nothing is known about pre-invasion distributions of native barnacles. Competitive displacement of native species may have occurred, but determining this will be difficult. Less is known about the ecology of *B. trigonus*.

URL for more information: http://www2.bishopmuseum.org/HBS/invertguide/, http://www.museum.vic.gov.au/crust/, http://www.gsmfc.org/nis/

3-13.2 Warty Pillbug

Subphylum Crustacea

Class Malacostraca

Superorder Pericarida, Order Isopoda, Suborder Flabellifera

Family Sphaeromatidae

Sphaeroma terebrans Bate, 1866, probably synonymous with *S. destructor*

Range and Vectors of Introduction

S. terebrans is suspected to be native to the Indo-Pacific, and was possibly introduced to the Atlantic basin in the hulls of wooden ships (Carlton and Ruckelshaus, 1997). This species occurs in the Caribbean, Gulf of Mexico, and north to Virginia (Kensley and Schotte, 1989).

S. terebrans occurs on both coasts of Florida, and is a **known invasive** of the Tampa Bay ecosystems (Rehm, 1976; Brooks and Bell, 2001, 2002). *S. destructor*, described from Florida, is probably a synonym (Menzies and Kruczynski, 1983).

Description and Biology

The biology of *S. terebrans* has been reviewed by Kensley and Schotte (1989), Thiel (1999) and Ng and Sivasothi (2001). The species is dorso-ventrally flattened with short antennae, multiple segments and pairs of legs, and posterior paddle-like *uropods*. The maximum size is about 10 mm, and like terrestrial pillbugs, *S. terebrans* can roll into a ball when threatened. Color is yellowish-to-dark brown. This species differs from most other isopods (except *S. walkeri*, see below) in the warty protrusions covering the posterior half of its body.

Like most amphipods, *S. terebrans* broods the young and has no free-living planktonic phase. There may be two reproductive episodes per year, and up to 20 juveniles are produced at a time. Although it bores into wood, *S. terebrans* probably gets its nutrition from bacteria and fungi (Kensley and Schotte, 1989) or via filter-feeding (Si et al., 2002).

Habitat and Potential Impacts

S. terebrans bores into wood in the mid-to-lower intertidal range, and occurs mainly in mangrove prop roots. In its Florida range, it occurs mostly in salinities above 17 ppt (Thiel, 1999), and survives brief exposure to near-freezing temperatures (this study).

The impacts of *S. terebrans* on red mangroves (*Rhizophora mangle*) in Tampa Bay have been the topic of several studies and some debate. Rehm (1976) concluded that *S. terebrans* controls the distribution of red mangroves in Tampa Bay by damaging prop roots. Simberloff et al. (1978), however, suggested that root boring by *S. terebrans* stimulated the growth of prop roots in red mangroves, and was beneficial. Ribi (1981) and Brooks and Bell (2001, 2002) concluded that the impacts were not beneficial, but neither did they strongly impact red mangrove distribution, and Brooks and Bell (2002) contradicted the root-stimulation hyopthesis proposed by Simberloff et al. (1978). All animal populations experience abundance cycles over time, however, and negative impacts on red mangroves may occur in years of peak *S. terebrans* abundance.

3-13.3 Warty Pillbug

Subphylum Crustacea

Class Malacostraca

Superorder Pericarida, Order Isopoda, Suborder Flabellifera

Family Sphaeromatidae

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

Range and Vectors of Introduction

S. walkeri is similar in appearance to *S. terebrans* (see prior entry), but is discussed separately because its habitat and potential impacts differ. *S. walkeri* is probably native to India, and was introduced around the world on ship hulls. It was first reported in Florida in 1943, about the same time it was first observed in several other North American ports (Carlton and Iverson, 1981).

S. walkeri has been reported from both coasts of Florida, and is locally abundant (Carlton and Iverson, 1981; Nelson and Demetriades, 1992). This species is a **known invasive** of the greater Tampa Bay ecosystem.

Description and Biology

The biology of *S. terebrans* has been reviewed by Carlton and Iverson (1981), Scaico (1982) and Ng and Sivasothi (2001). The species is dorso-ventrally flattened with short antennae, multiple segments and pairs of legs, and posterior paddle-like *uropods*. The maximum size is about 10 mm, and like terrestrial pillbugs, *S. walkeri* can roll into a ball when threatened. Color is yellowish-to-dark brown. This species differs from most other Florida isopods (except *S. terebrans*, see prior entry) in the warty protrusions covering the posterior half of its body.

The reproductive biology of *S. walkeri* is poorly known. Like other isopods in this genus (Thiel, 1999), this species presumably produces small numbers of juveniles with no planktonic larvae.

Habitat and Potential Impacts

In its native range, *S. walkeri* occurs in burrows in mangrove prop roots (Radhakrishnan et al. 1987), but Carlton and Iverson (1981) believe that *S. walkeri* merely occupies burrows excavated by other species. In Florida, *S. walkeri* is associated with native reef-building tubeworms such as *Phragmatopoma lapidosa* (Nelson and Demetriades, 1992). This species has fairly broad salinity and thermal tolerances, but thrives only above 25 ppt and 15^{o}C (Scaico, 1982). Carlton and Iverson (1981) reported that this species was rarely observed in estuaries.

Despite its superficial similarities, the impacts of *S. walkeri* in the greater Tampa Bay ecosystem are probably very different from the similar *S. terebrans* (above). *S. walkeri* does not appear to damage mangroves, and it is more stenohaline than *S. terebrans*. On the other hand, *S. walkeri* is one of the most abundant species in clumps of native oysters in the west Florida ecocline (these authors, unpubl. data), and in sabellid worm reefs (Nelson and Demetriades, 1992). This species may alter the abundance of native species or serve as food for benthic predators.

3-13.4 Wharf Roach
Subphylum Crustacea
Class Malacostraca
Superorder Pericarida, Order Isopoda
Family Ligiidae
Ligia exotica Roux, 1828

Range and Vectors of Introduction
"Wharf roach" or "beach roach" are terms applied to several species of *Ligia* throughout the world. *L. exotica* are native to the northeast Atlantic and the Mediterranean basin. They have been introduced to many temperate and tropical harbors around the world, including the western Atlantic (Bishop Museum, 2002). Given their habitat (upper intertidal), dry ballast or cargo is a likely vector for introduction.

This species is a **known invasive** in the greater Tampa Bay ecosystem, and is common in areas with artificial seawalls, piers, and other structures.

Description and Biology
The biology of *L. exotica* has been reviewed by Ruppert and Fox (1988) and Bishop Museum, (2002). Wharf roaches are not related to the terrestrial cockroaches, but are isopod crustaceans, related to terrestrial isopods (sowbugs and pillbugs). They represent a return to the marine environment, and, like terrestrial isopods, will drown if submerged. They are tan or gray in color with black dorsal markings, and have a dorso-ventrally flattened, segmented body up to 38 mm long. There are 12 pairs of walking legs, one pair of visible antenna, and a pair of short, paddle-like uropods at the posterior end.

Wharf roaches are dioecious, and females carry developing young in a ventral brood pouch. There is no free-living larval stage.

Habitat and Potential Impacts
Wharf roaches occupy the supralittoral ("splash zone") throughout the southeastern United States and Gulf of Mexico wherever hard structure exists, including seawalls and jetties. In Florida, the vast majority of this habitat is artificial, making the wharf roach essentially an "urban invader." In our collections, the wharf roach occurred along waters with a wide range of salinities, but not on freshwater bodies.

Wharf roaches are common high intertidal scavengers, and probably help reduce the amount of debris in the upper intertidal (Ruppert and Fox, 1988). While they almost certainly have some impacts in Florida, documentation of such impacts is lacking. There are no documented economic impacts.

3-16.5 Bristled River Shrimp
Subphylum Arthropoda
Class Malacostraca
Order Decapoda, Infraorder Caridea
Family Palaemonidae
Macrobrachium olfersii (Wiegmann, 1836)

Distribution and Vectors
The bristled river shrimp is native to the Atlantic drainages of Central America and South America from Mexico to Brazil. It has been reported from coastal drainages of Texas, Louisiana, Mississippi, and Florida (Holthius and Provenzano, 1970; Horne and Beisser, 1977; White, 1977; Anderson and Fillingame, 1980; Bowles et al., 2000. It was first reported in Florida in the St. Johns River drainage in the 1930s, and the proposed vector was aquatic vegetation from South America (Poss et al., 2000).

Bristled river shrimp have been reported from three drainages in Florida: the St. Johns River in northeast Florida; the highly urbanized Snapper Creek drainage in South Miami; and the Escambia River drainage in the Florida panhandle (Holthius and Provenzano, 1970; Bowles et al., 2000). Although Tampa Bay is bracketed by bristled river shrimp sightings, these sightings are spaced over many decades, this species is described as “not common” (Bowles et al., 2000), and there is no certainty that it does occur in the greater Tampa Bay ecosystem. Thus, we consider the bristled River shrimp to be a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology
The biology and life history of the bristled river shrimp is provided by Dugger and Dobkin (1975), Anger and Moreira (1998), Bowles et al. (2000), and Poss et al. (2000). Members of the genus *Macrobrachium* are large shrimp with two pairs of *chelae* (pincers). The second pair of legs is heavy and generally longer than the rest of the body, not including antennae. Maximum body length, from the telson (anal segment) to the rostrum, is about 90 mm in males. Females are smaller. Native species, including *M. carcinus*, may be much larger, but apart from size, professional expertise is required for identification. The similarity of this species to native species and its cryptic habitat (freshwater vegetation) may account for the lack of reported sightings.

The bristled river shrimp has a life cycle typical of the genus, in which adults live and reproduce in freshwater, but larvae are carried to estuaries, where they metamorphose and then migrate upstream. This ontogenetic habitat migration is known as *amphidromy*. Thus, if this species occurred in the greater Tampa Bay ecosystem, only the larvae and juveniles would be estuarine. Estuaries are probably not essential habitat, as some members of the genus can be reared entirely in freshwater. Females produce several hundred to several thousand larvae. Members of the genus are omnivorous, feeding on plant material, carrion, and any small prey they can capture.

Habitat and Potential Impacts
Adult bristled river shrimp, like other members of the genus, usually occur in freshwater. Adults have been collected in estuaries (White, 1977), but normally, only juveniles and larvae, which can tolerate salinities to 28 ppt, occur in estuaries (Poss et al., 2000). Thermal tolerances are not known, but this species it not known from north of Escambia Bay, Florida (Poss et al., 2000). Given this species long history of barely being detected in Florida, ecological and economic impacts on the greater Tampa Bay ecosystem are likely to be subtle.

URL for more information: http://www.gsmfc.org/nis/nis/Macrobrachium_olfersii.html

3-13.6 Indo-Pacific Swimming Crab

Subphylum Crustacea

Class Malacostraca

Order Decapoda, Infraorder Brachyura

Family Portunidae

Charybdis hellerii (A. Milne-Edwards, 1867) = *C. merguiensis*, possibly *C. vannamei*

Range and Vectors of Introduction

C. hellerii is native to the Indo-Pacific, but has been introduced worldwide, including the Mediterranean, Brazil, and the Caribbean. It was first identified in the Indian River Lagoon and adjacent estuaries of east Florida in 1995, and ballast water is the proposed vector of introduction, probably from established populations in South America (Lemaitre, 1995; Dineen, 2001; Mantelatto and Garcia, 2001). Collections of ovigerous females from east Florida suggest this species has become established there.

This species has not been recorded from west Florida, but given its mobility, is a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology

The biology of *C. hellerii* has been reviewed by Poss et al. (2000), Dineen (2001), and Mantelatto and Garcia (2001). *C. helleri* is a member of the swimming crab family, Portunidae, which includes several native Florida representatives. The last leg on each side is modified to a paddle, used for rapid swimming. Males can reach a carapace width of nearly 80 cm, which is larger than the native blue crab, *Callinectes sapidus*, but adults in the Indian River lagoon are generally much smaller. The carapace is nearly as long as wide, unlike native *Callinectes*, and the carapace lacks the spots typical of native *Ovalipes* species.

Females are reported to produce 20,000 to nearly 300,000 eggs. Larval development is similar to other portunid crabs.

Habitat and Potential Impacts

C. hellerii occurs in a variety of benthic habitat, including coral, but prefers soft substrata – possibly because that is where its prey occurs (Poss et al., 2000). Little information is available on thermal or salinity tolerances.

Florida has several native portunid crabs, including the fairly large blue crab, *C. sapidus*. On one hand, *C. hellerii* may compete with native crabs, and it will certainly prey on native invertebrates, including shellfish. On the other hand, the native range of *C. hellerii* overlaps with the green mussel, *Perna viridis*, already introduced to Tampa Bay (this report). *C. hellerii* may be more adapted to prey on green mussels than are the native predators.

URLs for more information: http://www.gsmfc.org/nis/, http://www.sms.si.edu/IRLSpec/

3-13.7 Saber Crab

Subphylum Crustacea

Class Malacostraca

Order Decapoda, Infraorder Brachyura

Family Grapsidae

Platychirograpsus spectabilis (de Man, 1896) = *P. typicus* and *Aspidograpsus typicus*

Range and Vectors of Introduction

The saber crab is believed to be native to coastal rivers of eastern Mexico. It has also been reported from West Africa (Poss et al., 2000), but there is no information on whether this distribution is natural.

The saber crab was probably introduced to the Hillsborough River of Tampa Bay in the 1930s on logs shipped from Mexico (Marchand, 1946). The Hillsborough River locality may have died out, but this species still occurs in other local rivers (D.K. Camp, *pers. comm.*). This species is a **known invasive** in the greater Tampa Bay ecosystem.

Description and Biology

Males have one enlarged claw (*chela*), and one small; females have two small chelae. On the large chelum of an adult male, there is a backwards-projecting process on the propodus (the large part of the claw), as if a man were to attach a large knife to his elbow. It is this process, or "saber," which gives the crab its common name. The function of the saber is unknown, but may be used in male-male aggression. The carapace reaches a maximum reported width of 48 mm in males (Poss et al., 2000).

Almost nothing is known about saber crabs in their native range, and most of what we know about the biology of this species comes from a single study by Marchand (1946). Saber crabs feed on detritus and algal mats with their small chelae. It is suspected that spawning and larval development occurs in estuaries.

Habitat and Potential Impacts

Adult saber crabs appear to live in tidal fresh or oligohaline (to 3 ppt) water. Marchand (1946) suspected that larval development occurred in saltwater (Marchand, 1946). Saber crabs are shore crabs, and live at or above the water level (Poss et al., 2000). Thermal tolerances are unknown.

Tidal freshwater and oligohaline regions of estuaries are poorly studied ecosystems, possibly because species diversity of these zones are lower than in either freshwater or higher-salinity areas of estuaries (McLusky, 1971). These regions in the greater Tampa Bay ecosystems are heavily urbanized and often modified by dams, channelization, etc. Given our lack of data on the saber crab, and the heavily modified nature of much of their habitat, it is difficult to predict ecological impacts of saber crabs at this time. Economic impacts would likely be related to bank erosion as a consequence of their burrowing, but no such impacts have been reported or studied.

URL for more information: http://www.gsmfc.org/nis/

3-13.8 Asian Shore Crab
Subphylum Crustacea
Class Malacostraca
Order Decapoda, Infraorder Brachyura
Family Grapsidae
Hemigrapsus sanguineus (de Haan, 1835)

Range and Vectors of Introduction
The so-called Asian shore crab, *H. sanguineus* is native to the western temperate and subtropical Pacific. It was noted in New Jersey in 1988, and now extends from Maine to south of Cape Hatteras in North Carolina (U.S. Geological Survey, 2000), which puts it barely into the southeast Atlantic bioregion.

This species may continue to spread south, and its range in the western Pacific suggests that it will survive in Florida. We consider this species a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology
The biology of *H. sanguineus* had been reviewed by Gerard et al. (1999), Lohrer et al. (2000), McDermott, (2000), and Tyrrell and Harris (2000). *H. sanguineus* has a nearly square carapace to 44 mm in width. Males have larger chelae (claws) than females, but right and left chelae are usually equal in size. The legs are moderately hairy, and the carapace color varies, but there are usually red or purple spots on the chelae.

H. sanguineus is omnivorous, and will prey on small intertidal gastropods and crustaceans. Females produce up to 40,000 eggs, which are brooded on the abdomen for 23-25 days. Larvae pass through several planktonic *zoea* stages, followed by a competent-to-settle *megalopa* stage, about 16-31 days following hatching. Juveniles molt about 4 more times in their first month, and reach sexual maturity in their first year. The breeding season is temperature-dependent, and appears to be longer in southern latitudes.

Habitat and Potential Impacts
H. sanguineus is strictly intertidal, and occurs primarily amid boulders; south of New Jersey, this habitat is primarily artificial. It can tolerate salinities as low as 5 ppt for 24 hours, but is mainly restricted to the mouths of estuaries and coastal groins and jetties (Lohrer et al., 2000; McDermott, 2000).

Florida has both native (*Sesarma* spp., *Pachygrapsus transversus*, and *Plagusia depressa*) and introduced (*Platychirograpsus spectabilis*) grapsid shore crabs, in addition to many species of fiddler crab (*Uca* spp.), but none that specialize in boulder habitat. Rocky habitat of this nature in Florida is almost entirely artificial, in the form of groins and jetties, so if *H. sanguineus* invades Florida, its impacts may to be limited to altered ("urban") habitats. In New England, the Asian shore crab consumed native and nonindigenous mollusks (Gerard et al., 1999), and displaced nonindigenous green crabs *Carcinus maenas* (Tyrrell and Harris, 2000).

URL for more information:
http://www.fcsc.usgs.gov/Nonindigenous_Species/Asian_shore_crab/asian_shore_crab.html

3-13.9 Green Porcelain Crab
Subphylum Crustacea
Class Malacostraca,
Order Decapoda, Infraorder Anomura
Family Petrolisthidae
Petrolisthes armatus (Gibbes, 1850) = *P. digitalis*

Range and Vectors of Introduction
The green porcelain crab is a tropical and subtropical species native to the east Pacific from northern Mexico to Peru. It now occurs widely in the tropical Atlantic and Gulf of Mexico, and appeared in Florida in the 1930s (Knott et al., 2000). Since 1994, it has spread north from Florida into Georgia and South Carolina (Knott et al., 2000; South Carolina Department of Natural Resources, 2000).

This species was collected during this study throughout the West Florida ecocline, including in Tampa Bay, so it is a **known invasive** in the greater Tampa Bay ecosystem.

Description and Biology
P. armatus resembles true crabs, but has only six pairs of walking legs instead of eight (the last pair is present, but vestigial). The carapace, which is seldom over 14 mm long, is nearly circular, and the chelae (claws) are large and flat. When handled, *P. armatus* readily autonomizes (drops) its chelae as if it were fragile, hence the common name. The antennae are long, and color is highly variable, but includes green (South Carolina Department of Natural Resources, 2000).

Despite their large chelae, procellanid crabs such as *P. armatus* feed on detritus or on suspended particles that they filter with their feathery mouthparts (Rudy and Rudy, 1979). *P. armatus* have a typical decapod crustacean life cycle; females brood eggs which are released as planktonic *zoeal* larvae. After multiple planktonic stages, they settle as *megalopae*, or post-larvae (Brossi-Garcia and Moreira, 1996).

Habitat and Potential Impacts
Native porcelain crabs that occur in estuaries are usually commensal with worms or other marine animals (Ruppert and Fox, 1988), in contrast to the free-living *P. armatus*. In the Suwannee River estuary, this species appears to be abundant in lower intertidal oyster reefs, in salinities of 17-29 ppt (these authors, unpubl. data). In Brazil, temperatures of 25^{o}C and salinities of 32 ppt were found to be optimal for larval growth (Brossi-Garcia and Moreira, 1996), although adults were found in Tampa Bay at salinities as low as 20 ppt in this study.

In a study in South Carolina, *P. armatus* occurred at 85% of intertidal sites surveyed, in densities up to 22,000 individuals per square meter (South Carolina Department of Natural Resources, 2000). There is evidence from Brazilian populations that *P. armatus* competes for space with other crevice-dwelling invertebrates (Almeida Rodrigues and Yuka Shimizu, 1988).

URL for more information: http://www.dnr.state.sc.us/marine/mrri/shellfish/petro.htm

3-14. Phylum Bryozoa (Ectoprocta) – Moss Animals

Ectoprocts, bryozoans, or moss animals, are abundant but often overlooked members of fouling communities in fresh, estuarine, and marine waters. Individual zooids of the sessile colonies are nearly microscopic, but the colonies may be large. Many colonies are erect and plantlike, hence the common name for the phylum, but most are encrusting, and a few can form coral-like masses. This group is poorly known compared to some, and the geographical origin of many species is obscure. In the Indian River Lagoon of east Florida, nearly 30 of the 38 species recorded are considered cosmopolitan, transoceanic, or amphi-Atlantic (Hill, 2002). Carlton and Ruckelshaus (1997) and Carlton (1999b) consider at least some of these to be nonindigenous, but determining the native ranges of these species will be a daunting task. Among small polychaete annelids, it is known that at least some apparently widespread species actually represent groups of morphologically identical species (Westheide and Schmidt, 2003), and the same may be true for some bryozoans (Winston, 1995). It is possible that a few bryozoans are naturally cosmopolitan, via floating debris, although floating debris as a vector also has a large artificial component in the modern world (Winston, 1982a).

The bryozoans selected here include several known Florida taxa for which the origin has been called into question by other authorities. Further study will probably add new species to this list.

3-14.1 Cheilostome Bryozoan, *Conopeum seurati* - Potential, Cryptogenic

3-14.2 Cheilostome Bryozoan, *Cryptosula pallasiana* - Potential Invasive

3-14.3 Cheilostome Bryozoan, *Watersipora subovoidea* – Potential, Cryptogenic

3-14.4 Ctenostome Bryozoan, *Sundanella sibogae* - Known Invasive

3-14.5 Sea Mat, *Victorella pavida* - Potential Invasive

3-14.6 Ctenostome Bryozoan, *Zoobotryon verticillatum* - Known, Cryptogenic

3-14.1 Cheilostome Bryozoan
Class Gymnolaemata
Order Cheilostomata
Family Membraniporidae
Conopeum "*seurati*" (Canu, 1908)

Range and Vectors of Introduction
Conopeum seurati is a western European species, and was reported from Florida by Winston (1982b). Subsequent to that, some question has been raised as to whether the Florida species is, in fact, the European species, or another which closely resembles it (Winston, 1995) – hence the quotation marks about the species name. *C. seurati* is believed to have been introduced on ship (barge) hulls to the Caspian Sea via inland waterways (Ryland, 1971). The date of introduction to Florida is unknown, but fouling on ships is a likely vector.

This species has not been reported from the greater Tampa Bay ecosystem or in annual benthic invertebrate surveys conducted at Cedar Key, at the north end of the west Florida ecocline (F.J. Maturo, *unpubl. data*). It is abundant, however, in the Indian River Lagoon of east Florida (Hill, 2002), so is considered a **potential** member of the greater Tampa Bay ecosystem, but **cryptogenic** until its taxonomic status and origin are known.

Description and Biology
Unless otherwise noted, biological information for *C. seurati* is provided by Ruppert and Fox (1988), Winston (1995) and Hill (2002). *C. seurati* is an encrusting bryozoan which forms small, lacy, calcified colonies, which are often ribbon-like. The lacy appearance is due to the lack of a calcified frontal wall, or covering, which reveals the outline of each zooid, or colony member. This species is morphologically identical to *C. tenuissimum*, which is considered native, but differs in a few reproductive details. Individual zooids are about half a millimeter in length. Professional expertise is required for identification.

The biology of the congener *C. tenuissimum* is better known than *C. seurati*, and many of the details are probably the same (Dudley, 1973; Winston, 1976). Individual zooids in a colony appear to be hermaphroditic and protandric (males first and females when older). A single zooid produces only one egg at a time, within colonies as young as 20 days old. A *cyphonautes* planktonic larva is produced, but the planktonic duration is not known. The larva settles and metamorphoses into a single zooid, called an *ancestrula*, which buds off subsequent zooids.

Habitat and Potential Impacts
C. seurati occurs mostly at salinities between 4 and 18 ppt in east Florida. It grows on a variety of substrata, including seagrass blades (Hill, 2002).

C. seurati is one of the most common fouling taxa in the Black and Caspian Seas (Ryland, 1971). Invasive *Membranipora membranacea*, in the same family, has invaded New England. *M. membranacea* grows on kelp (*Laminaria* spp.), reducing growth and survival, and facilitating replacement by the nonindigenous green alga *Codium fragile* (Levin et al., 2002). The tendency of *C. seurati* to grow on seagrass in the Indian River (Hill, 2002) suggests possible interference in this system as well, but this question has not been addressed in Florida.

URL for more information: http://www.sms.si.edu/IRLSpec/

3-14.2 Cheilostome Bryozoan
Class Gymnolaemata
Order Cheilostomata
Family Cheiloporinidae
Cryptosula pallasiana (Moll, 1803)

Range and Vectors of Introduction
C. pallasiana is common on both sides of the North Atlantic, in the Mediterranean, and around Australia (Ryland, 1971). Its native range is unknown (Carlton and Ruckelshaus, 1997).

This species has not been reported from the greater Tampa Bay ecosystem, and has not been reported from annual benthic invertebrate surveys conducted at Cedar Key, at the north end of the west Florida ecocline (F.J. Maturo, *unpubl. data*). It is abundant, however, in the Indian River Lagoon of east Florida (Hill, 2002), so is considered a **potential** resident of the greater Tampa Bay ecosystem, but **cryptogenic** until better studied.

Description and Biology
The biology of *C. pallasiana* has been reviewed by Hill (2002). This species is an encrusting bryozoan with a hard surface sometimes raised into frills. The zooids, or colony members, are covered with a calcified frontal wall, which is responsible for the hard surface. Colony color is beige or white, or occasionally pink. Professional expertise is required for identification.

Like other bryozoans, each zooid produces a single embryo; unlike many other bryozoans, embryos do not have special brood pouches (ovicells) but are brooded inside the zooid. Like other bryozoans, it is a filter-feeder, using the ciliated lophophores of each zooid.

Habitat and Potential Impacts
In the Indian River Lagoon of east Florida, this species occupies a variety of hard substrata, natural or artificial, but does not occur on seagrass. It is most abundant in the Indian River Lagoon in winter and tolerates "reduced salinities;" otherwise, little is known of its salinity or thermal tolerances (Hill, 2002).

C. pallasiana is one of the most widespread encrusting bryozoans in seaports. It is a significant fouling organism in the Mediterranean basin, Western Europe, the Atlantic seaboard of the United States, and Australia (Ryland, 1971).

URL for more information: http://www.sms.si.edu/IRLSpec/

3-14.3 Cheilostome Bryozoan
Class Gymnolaemata
Order Cheilostomata
Family Cheiloporinidae
Watersipora (*Cellepora*) *subovoidea* (d'Orbigny, 1852) = *W. cucullata*

Range and Vectors of Introduction
W. subovoidea is cosmopolitan in warm waters, but suspected to be native to the tropical IndoPacific (review in Carlton, 1979a). Since the native range has not yet been determined, this species is considered cryptogenic in Florida. *W. subovoidea* is known to be introduced by ship hulls in the 1950s, however, including to Australia, New Zealand, the Galapagos, and California (Ryland, 1971; Carlton, 1979a).

This species has not been reported from the greater Tampa Bay ecosystem, and has not been reported from annual benthic invertebrate surveys conducted at Cedar Key, at the north end of the west Florida ecocline (F.J. Maturo, *unpubl. data*). It is abundant, however, in the Indian River Lagoon of east Florida (Hill, 2002), so is considered a **potential** resident of the greater Tampa Bay ecosystem, and **cryptogenic** until better studied.

Description and Biology
Although it is one of east Florida's most abundant coastal bryozoans, *W. subovoidea* requires professional expertise for positive identification. It forms thin to ruffled, calcified crusts on a variety of hard substrata, and colonies are black to orange in color. In California, colonies may form lumps 20 cm in diameter (Carlton, 1979a). Individuals, or zooids, within the colony, are slightly less than 1 mm in length. The surface is slightly bumpy compared to many encrusting bryozoans (Hill, 2002).

Like other bryozoans, each zooid produces a single embryo; unlike many other bryozoans, embryos do not have special brood pouches (ovicells) but are brooded inside the zooid (Hill, 2002). Like other bryozoans, it is a filter-feeder, using the ciliated lophophore of each zooid.

Habitat and Potential Impacts
W. subovoidea grows on virtually any hard substratum, including seagrass, and in Florida, is the only organism which overgrows reefs created by a native sabellid worm, *Phragmatopoma lapidosa*. It is tolerant of polluted or otherwise toxic habitats, and is the most common encrusting bryozoan in east Florida.

W. subovoidea is a common and persistent fouling pest, able to grow on some antifouling paints, and it is considered a common fouling pest in some parts of the world (Ryland, 1971). On occasion, colonies may become massive, presenting serious fouling problems (Carlton, 1979a). Its ecological impacts may be greater, though, especially if it is able to overgrow important native species such as seagrasses and sabellid tubeworms (Hill, 2002).

URL for more information: http://www.sms.si.edu/IRLSpec/

3-14.4 Ctenostome Bryozoan
Class Gymnolaemata
Order Ctenostomata
Family Victorellidae (Arachnidiidae)
Sundanella sibogae (Harmer, 1915)

Range and Vectors of Introduction
This species is cosmopolitan in its distribution; the genus name comes from a chain of islands in Indonesia. Carlton and Ruckelshaus (1997) consider it nonindigenous; ship fouling is a likely vector of introduction.

We know of no reports of this species from the greater Tampa Bay ecosystem, but it is annually common at Cedar Key, at the north end of the west Florida ecocline, and has been for over 20 years (F.J. Maturo, *unpubl. data*). It also occurs year-round in the Indian River Lagoon (Hill, 2002), and its distribution thus brackets Tampa Bay. We consider this species a **known invasive** of the greater Tampa Bay ecosystem.

Description and Biology
The biology of *S. sibogae* has been reviewed by Ng and Sivasothi (2001) and Hill (2002). *S. sibogae* forms rubbery, encrusting colonies on a variety of substrata, including seagrass and other sessile organisms. Zooids, or colony members, arise from the colony individually, and are less obviously connected to each other than are many bryozoan colonies. Zooids are large for bryozoans – up to 1.5 mm in height, although the lophophore (ring of feeding tentacles) is under 1 mm in diameter.

Little is known of the reproduction of this species. Other members of Order Ctenostomata brood their larvae and have a short-lived planktonic phase, and almost all bryozoans are filter-feeders.

Habitat and Potential Impacts
Little is known about the ecology of this species. Like other bryozoans, it has the potential to competitively exclude other species or shade photosynthetic organisms. This species has not been noted as a fouling pest of economic importance.

URL for more information: http://www.sms.si.edu/IRLSpec/

3-14.5 Sea Mat
Class Gymnolaemata
Order Ctenostomata
Family Victorellidae
Victorella pavida Kent, 1870 = *V. bengalensis*

Range and Vectors of Introduction
This species is widespread but very scattered (Carlton, 1979a), apparently restricted to freshwater and low-salinity portions of estuaries (Hill, 2002; JNCC, 2002). It was first reported in the eastern United States in the 1920s (Carlton, 1979a), and in the Indian River Lagoon, Florida, in 1982 (Winston, 1982b). Carlton (1979a) suggests that the native range is India, based on circumstantial evidence.

This species has not been reported from the greater Tampa Bay ecosystem, and has not been reported from annual benthic invertebrate surveys conducted at Cedar Key, at the north end of the west Florida ecocline (F.J. Maturo, *unpubl. data*). It occurs, however, in the Indian River Lagoon of east Florida (Winston, 1982b; Hill, 2002), so is considered a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology
V. pavida forms mat-like colonies with a loose consistency. Zooids (colony members) arise as vase-like projections from creeping stolons, and can be up to 1 mm long, although the ring of feeding tentacles (lophophore) is well under 1 mm in diameter. Colonies resembles those of *Bowerbankia*, another ctenostome bryozoan, and professional expertise is required for positive identification ((Winston, 1998; Hill, 2002).

The reproduction of this species is poorly known. Other members of Order Ctenostomata brood their larvae and have a short-lived planktonic phase, and almost all bryozoans are filter-feeders.

Habitat and Potential Impacts
Like most bryozoans, *V. pavida* is sessile, growing on firm substrata. In the Indian River Lagoon, it has been found on seagrass. It occurs primarily in waters of low salinity, and is thus seldom collected in surveys for bryozoans. It has been collected only in “brackish” (no salinity ranges given) areas of the Indian River Lagoon (Hill, 2002), Louisiana (Poirrier and Mulino, 1977) and Cornwall, Great Britain (JNCC, 2002), but occurs in freshwater in Virginia (Winston, 1998). In India, this species occurs in waters of 0-22 ppt, but at different times of the year has different salinity ranges, suggesting multiple strains or cryptic speciation (Ravindranatha Menon and Balakrishnan Nair, 1972). The thermal tolerances are unknown, but it occurs from India to Great Britain.

This species tolerates polluted water and was the dominant fouling organism in storm water discharges around New Orleans, Louisiana (Poirrier and Mulino, 1977). Branscomb (1976) reported that this species successfully out-competed juvenile native barnacles, *Balanus improvisus*, for space in Chesapeake Bay.

URL for more information: http://www.sms.si.edu/IRLSpec/

3-14.6 Ctenostome Bryozoan
Class Gymnolaemata
Order Ctenostomata
Family Vesiculariidae
Zoobotryon verticillatum (Delle Chiaje, 1828)

Range and Vectors of Introduction
Z. verticilatum is cosmopolitan in warm oceans, and Carlton and Ruckelshaus (1997) suggested this species is nonindigenous in Florida.

We know of no reports of this species from the greater Tampa Bay ecosystem, but it is annually present and occasionally abundant at Cedar Key, at the north end of the west Florida ecocline, and has been for over 20 years (F.J. Maturo, *unpubl. data*). It is also abundant in the Indian River Lagoon (Hill, 2002), and its distribution thus brackets the greater Tampa Bay ecosystem. Given this, we consider this species **known** from the greater Tampa Bay ecosystem, merely awaiting documentation, but **cryptogenic** until its origin is further studied.

Description and Biology
Although *Z. verticillatum* is one of the most abundant coastal bryozoans in Florida, it, like most bryozoans, requires professional expertise for identification. *Z. verticillatum* produces erect, branching colonies up to a meter in diameter, composed of thousands of zooids (colony members) (Hill, 2002). Each zooid is less than 1 mm in greatest dimension, and are held together on chitinous branches. There is no calcification of the colony, unlike many marine bryozoans. A lophophore, or crown of ciliated tentacles, protrudes from each zooid and is used for filter-feeding (Hill, 2002).

Sexual reproduction of this species is not well known. In the Indian River lagoon, reproduction seems to be primarily asexual, by fragmentation of colonies. Fragments grow rapidly, and colonies can reach a mater in diameter, but die back annually (Hill, 2002). Like other bryozoans, *Z. verticillatum* is a filter feeder.

Habitat and Potential Impacts
This species is moderately euryhaline, but is most abundant in waters of higher salinity. It is intolerant of cool temperatures, and colonies senesce when the water temperature falls below 22^{o}C. It occupies a variety of natural and artificial substrata in the Indian River Lagoon, including seagrass and mangroves (Hill, 2002).

This species has the highest biomass of any bryozoan in the Indian River Lagoon, and seasonally, one of the highest biomasses for any animal. Winston (1995) suggests that this species is a significant filter feeder. It is also likely to be a successful competitor for space, at least in summer months.

URL for more information: http://www.sms.si.edu/IRLSpec/

3-15. Phylum Echinodermata – Sea Stars, Sea Urchins, and Sea Cucumbers
Phylum Echinodermata includes sea stars, brittle stars, sea urchins, sand dollars, sea cucumbers, and a few other forms. Some are dominant consumers which shape their native ecosystems; examples include the crown-of-thorns sea star (*Acanthaster planci*) and sea urchins (*Strongylocentrotus* spp.) (Carefoot, 1977; Babcock et al., 1994).

Most echinoderm species are stenohaline, or intolerant of reduced salinity, and are thus unlikely to survive in estuaries (Ruppert and Barnes, 1994). Carlton (1979a, 1979b) reported no introduced echinoderms on the west coast of North America, nor does the U.S. Geological Survey (2000) list any for the United States. One nonindigenous sea star (*Asterias amurensis*), however, has become a major benthic predator in southern Australia (CRIMP, 2000; Parry and Cohen, 2001). Echinoderm larvae also occur in ballast water (Locke et al., 1991; Carlton and Geller, 1993), and at least one sea star invaded the Mediterranean Sea following the construction of the Suez Canal (Galil, 2000). The potential impacts of echinoderm introductions are high (Ross et al., 2003).

3-16. Phylum Chordata – Sea Squirts, Fish, Amphibians, and Reptiles
Ascidians, or sea squirts, are studied along with invertebrates by most marine biologists, but are clearly related to other chordates. They have a free-swimming tadpole larva with a stiff dorsal notochord, a trait in common with at least some life stage of virtually all vertebrates. As adults, benthic ascidians are sessile leathery or gelatinous sacs. They may be solitary or colonial, and are important fouling organisms. The compound ascidian, *Didemnum pellucidum*, has been reported from the Florida panhandle (N.F. Smith, *unpubl. data*), but insufficient information on its biology and distribution is available to discuss it further here.

In west Florida, American shad (native to the Atlantic coast of the United States), *Alosa sapidissima*, were introduced in the first half of the 20th century, but do not appear to have persisted. The majority of fish introduced to Florida have been in freshwater, but some of these have successfully invaded estuaries as well (Courtenay, 1997; Heagey et al., 2002). The trahira (*Hoplias malabaricus*), an estuarine-tolerant predatory fish from South America, was established for a few years in the Tampa Bay area, but died out during a cold winter in 1977 (Poss et al., 2000). Estuarine-tolerant nonindigenous fish that have survived will be discussed below.

The Indo-Pacific humpback or panther grouper, *Cromileptes altivelis*, a fully marine species, was collected from Tampa Bay in 1984. There are no recent reports of this species, and it does not appear to be established in Florida (U.S. Geological Survey, 2000).

The best-known introduced amphibian in Florida is the infamous marine toad, *Bufo marinus*, discussed below. The only known marine reptilian invader in Florida is a crocodilian, *Caiman crocodilus*. This species is tolerant of estuarine conditions (Britton, 2002), but in Florida, established populations appear to be limited to freshwater in the Miami area, and have not spread from a small area since the 1960s (Ellis, 1980).

Chordates discussed here include:

3-16.1 Sea Squirts, *Styela plicata* - Known Invasive
Styela canopus – Known Invasive

3-16.2 Star Ascidian, *Botryllus schlosseri* - Known Invasive
Sea Liver, *Botryllus niger* - Known, Cryptogenic

3-16.3 Red Lionfish, *Pterois volitans* - Potential Invasive

3-16.4 Brown Hoplo, *Hoplosternum littorale* - Known Invasive

3-16.5 Pike Killifish, *Belonesox belizanus* - Known Invasive

3-16.6 Rio Grande Cichlid, *Cichlasoma cyanoguttatum* - Known Invasive

3-16.7 Mayan Cichlid, *Cichlasoma urophthalmus* - Probable Invasive

3-16.8 Blue Tilapia, *Oreochromis aureus* - Known Invasive

3-16.9 Mozambique Tilapia, *Oreochromis mossambicus* - Known Invasive

3-16.10 Blackchin Tilapia, *Sarotherodon melanotheron* - Known Invasive

3-16.11 Spotted Tilapia, *Tilapia mariae* - Expected Invasive

3-16.12 Marine Toad, *Bufo marinus* - Known Invasive

3-16.1 Sea Squirts
Subphylum Urochordata
Class Ascidiacea
Order Stolidobranchia
Family Styelidae
Styela plicata (Lesueur, 1823)
S. canopus Stimson, 1852 = *S. partita*

Range and Vectors of Introduction
S. plicata and *S. canopus* occur in all oceans, but the native range of both is probably the Indo-Pacific (Carlton and Ruckelshaus, 1997; Lambert and Lambert, 1998; Lambert, 2001). These species are common on ship hulls, but another possible vector is shellfish transfers (Carlton, 1979a; Lambert, 2001). Both species have been in the Atlantic basin for decades at least, and *S. canopus* was separately described as *S. partita*, a synonym still commonly used.

S. plicata was widespread and abundant in our samples, across a range of salinities from full seawater to about 20 ppt. *S. canopus*, which resembles a small *S. plicata* and may have been overlooked in prior surveys, is also abundant in Tampa Bay (N.L. Smith, *unpubl. data*). Both are **known invasives** of the greater Tampa Bay ecosystem.

Description and Biology
The biology of *S. plicata* and *S. canopus* (as *S. partita*) were reviewed by Plough (1978). *S. plicata* is a large, solitary sea squirt, up to the size of a standard lemon (which it resembles) when mature. The tough tunic is rough and tan in color. When feeding, it is roughly urn-shaped with two conical openings (siphons) at the end away from the substrate; one opening is incurrent, and one is excurrent. If disturbed, *S. plicata* contracts to an amorphous blob. *S. canopus* is similar, but seldom larger than a grape, and somewhat less rough in texture.

Styela species, like most ascidians, have internal fertilization (sperm are shed into the water column and taken up by the female), and the tadpole larvae are brooded until competent to settle. The planktonic phase is short (minutes to hours) and growth is rapid. In Tampa Bay, adults appear in late summer and autumn (this study). Sea squirts are filter feeders. There is limited evidence that *S. plicata* have defensive compounds in their gonads, presumably against larval predation (Pisut and Pawlik, 2002).

Habitat and Potential Impacts
S. plicata is a sessile species occurring on a wide range of substrata in Tampa Bay. Settlement and survival of this species is limited to a fairly narrow zone of the lower intertidal and upper subtidal (Dalby and Young, 1992). *S. canopus* is abundant on fouling plates in Tampa Bay, but little else about its distribution in Florida is known.

Although some benthic fauna may inhibit or crowd out incoming species, *S. plicata* had no detectable effect on settlement of other species in a study conducted in the Indian River Lagoon, east Florida (Young, 1989). Both species are considered fouling pests in harbors or on aquaculture facilities in China (Zheng and Huang, 1990; Huang and Chen, 2002).

URLs for more information: http://home.hetnet.nl/~ascidians/families/styelidae/

3-16.2 Star Ascidian, Sea Liver

Subphylum Urochordata
Class Ascidiacea
Order Pleurogona
Family Botryllidae
Botryllus schlosseri (Pallas, 1766)
Botryllus (*Botrylloides*) *niger* Herdman 1886 = *B. nigrum*

Range and Vectors of Introduction

B. schlosseri was described in Europe but has been reported worldwide (Carlton, 1979a). *B. niger* is reported from throughout the Caribbean (Plough, 1978). Members of this genus have been associated with aquaculture transfers (Carlton, 1979a; Lambert, 2001). Aron and Sole-Cava (1991) have suggested that *B. niger* is actually two sister species, but until we know which we have in Florida, we will use *B. niger* for this study.

Members of the genus *Botryllus* were common in Tampa Bay during this study, but we could not identify species beyond determing that they were not the native *B. planus* (Ruppert and Fox, 1988). *B. niger* but not *B. schlosseri* is recorded from the Indian River Lagoon in east Florida (Hill, 2002); however, based on color, not all of the nonindigenous *Botryllus* in Tampa Bay is *B. niger*. *B. schloesseri* has been reported annually at Cedar Key, at the north end of the West Florida ecocline (F.J. Maturo, *unpubl. data*). We consider both species to be **probable invasives** of the greater Tampa Bay ecosystem, pending further investigation.

Description and Biology

Plough (1978) has reviewed the biology of the genus *Botryllus*. Members of the genus are compound (colonial) ascidians. Individual zooids in a colony each have an incurrent feeding siphon, but the excurrent siphons of a cluster of zooids will open into a common cloaca. This results in a colony of star-like clusters, each about a centimeter in diameter. The colony forms a rubbery sheet occasionally over 1 m in diameter. *B. schlosseri* may be virtually any color, from yellow to black, but *B. niger* is usually black (JNCC, 2002). Identification to the species level requires professional expertise.

Ascidian colonies release sperm but retain eggs, and fertilization is internal. Each cluster of zooids usually produces a single large egg, which is brooded until hatching. The tadpole larva is several mm in length and has a planktonic phase of minutes to hours. The tail of the larva is quickly lost upon settlement. Colonies grow by budding new zooids, and new colonies can form by fragmentation and drift of existing colonies. Colony growth is up to several centimeters per day under ideal conditions but colonies tend to be short-lived, and are killed or stunted by changes in salinity or water temperature.

Habitat and Potential Impacts

Colonial sea squirts are shallow-water fouling organisms, overgrowing a variety of substrata, including seagrass (Ruppert and Fox, 1988). Although abundant in Tampa Bay, they are killed by low salinities; precise salinity and thermal tolerances are not known.

Botryllus species are common fouling organisms, but are relatively easy to remove from industrial surfaces, compared to barnacles, tubeworms, or bivalves. Their primary impacts are biological, when they overgrow seagrass, shellfish, and natural fouling communities. *Botryllus* species are common pests in mariculture, where they overgrow shellfish and culture cages (Lambert, 2001). The impact of nonindigenous *Botryllus* relative to native congeners in Florida is unknown.

URL for more information: http://www.itsligo.ie/biomar/tunicata/BOTSCH.HTM

3-12.3 Red Lionfish

Subphylum Vertebrata

Class Osteichthyes

Order Scorpaeniformes

Family Scorpaenidae

Pterois volitans (Linnaeus, 1758)

Range and Vectors of Introduction

The red lionfish is native to coral reefs in the Indo-Pacific from Japan to Australia. It is one of several similar species sold as ornamentals under a variety of common names, and the ornamental trade is the most likely vector of introduction. A population appears to be established on the east coast of the United States, including east Florida (McDonald, 2002; Whitfield et al., 2002).

Red lionfish have escaped or been dumped in the Florida Keys at least twice, but no population has been previously established (Courtenay, 1997). Prevailing coastal currents would transport larvae away from the west Florida ecocline, but adult fish may, over many generations, migrate around Florida. We consider this species a **potential invasive** of the greater Tampa Bay ecosystem.

Description and Biology

Information about red lionfish is summarized by Whitfield et al. (2002) and Froese and Pauly (2003). The red lionfish has a vividly red-banded body with greatly elongated and elaborate fins, and is similar to other Indo-Pacific members of the genus, also found in the aquarium trade. Gulf of Mexico members of the family (*Scorpaena* spp.) are similar in body shape but lack the elaborate fin rays (Walls, 1975). The dorsal and pectoral fin rays of the red lionfish contain venomous spines used for predator deterrence. The red lionfish can reach 38 cm total length, but is typically 15-30 cm.

Red lionfish are predatory on a variety of smaller fish and free-swimming invertebrates, which they trap with their pectoral fins. They spawn in open water, and larvae are planktonic for up to 40 days. Age at maturity in nature is not reported.

Habitat and Potential Impacts

The red lionfish is a solitary, sedentary reef dweller, and is stenohaline, or intolerant of estuarine conditions, but seems to prefer slightly turbid waters (Amesbury and Myers, 2001). In the Atlantic, individuals survived several days of temperatures as low as 14^{o}C, which is lower than the normal lower limits in their native range (Whitfield et al., 2002).

The invasion of the Atlantic basin by the red lionfish is the first documented invasion of this coastline by an exclusively marine fish in historic times. The lionfish is also a significant addition to a slim roster of highly venomous fish in the southeastern United States. While not as deadly as some members of the family, lionfish envenomation causes severe pain, and the circumstances (e.g. scuba diving) or idiosyncratic reactions may result in death (Findlay, 1971). Whitfield et al. (2002) note that this species uses a form of prey capture (large fins) novel to Atlantic reefs, but admit that estimates of ecological impacts are speculative.

URL for more information: http://www.fishbase.org/Summary/

3-16.4 Brown Hoplo

Subphylum Vertebrata

Class Osteichthyes

Order Siluriformes

Family Callichthyiidae

Hoplosternum littorale (Hancock, 1928)

Range and Vectors of Introduction

The brown hoplo, which goes by many local and trade names, is native to Atlantic drainages of tropical South America (Fuller et al., 1999). The method of introduction is not known, but this species is often found in home aquaria, and has been cultured for food in South America (Froese and Pauly, 2003).

This species was first reported in east Florida, in the St. Johns, St. Lucie, and intervening drainages (Nico et al., 1996; U.S. Geological Survey, 2000). It has since invaded the Hillsborough River and other Tampa area drainages (Ruiz-Carus and Grier, 2003) and is a **known invasive** of the greater Tampa Bay ecosystem.

Description and Biology

The biology of this species has been reviewed by Fuller et al. (1999), Poss et al. (2000), and Froese and Pauly (2003). The brown hoplo is one of the armored catfish, with a stout body covered with overlapping bony plates. Adults are brown in color, but juveniles may be paler. The maximum size reported is about 22 cm (standard length).

The brown hoplo is a nest-breeder. Nests are made of vegetation and mucus bubbles, and the 5000-20,000 eggs are guarded by the male. Sexual maturity is reached in about one year. This species preys on a variety of benthic insects and detritus.

Habitat and Potential Impacts

The brown hoplo can breathe air, and is thus tolerant of poor water conditions such as those found in ditches, and has been collected in salinities of 16 ppt (Nico et al., 1996). Optimal temperatures are estimated to be 18-26^{o}C (Froese and Pauly, 2003), but the brown hoplo occurs both in northern Florida (U.S. Geological Survey, 2000) and in Argentina (Nico et al., 1996), so its thermal tolerances include the entire greater Tampa Bay ecosystem. In its natural range, the brown hoplo is considered a stream-dwelling species (Froese and Pauly, 2003). Potential impacts in its nonindigenous range have not been studied.

URLs for more information http://www.gsmfc.org/nis/, http://nas.er.usgs.gov/

3-16.5 Pike Killifish
Subphylum Vertebrata
Class Osteichthyes
Order Cyprinodontiformes
Family Poeciliidae
Belonesox belizanus Kner, 1860

Range and Vectors of Introduction
The pike killifish is native to the Atlantic slope of Central America from the Yucatan Peninsula to Costa Rica. It has been introduced to southern Florida, where it occurs in fresh and brackish waters (Lorenz et al., 1997; Fuller et al., 1999; Poss et al., 2000). Introductions in south Florida were due to deliberate releases from a research facility, and an introduction in Hillsborough County was probably an escape from the ornamental aquaculture industry (Fuller et al., 1999).

Pike killifish are common, but not abundant, in tidal areas of Tampa Bay to salinities of 28.5 ppt (Heagey et al., 2002), so this species is a **known invasive** in the greater Tampa Bay ecosystem.

Description and Biology
The biology of the pike killifish has been reviewed by Poss et al. (2000), U.S. Geological Survey (2000), Robins (2002), and Froese and Pauly (2003). Pike killifish are the largest members of their family, attaining a standard length of 12 cm. They are slender, and like true pike (Esocidae), have a long jaw and large mouth adapted for preying on other small fish.

Like most members of the family, pike killifish are ovoviviparous livebearers, with typically 100 offspring per reproductive episode. Reproduction occurs throughout the year, and a female can breed about eight times annually. They are piscivorous, particularly on adults and juveniles of other topminnows, but their diet in estuaries has not been studied.

Habitat and Potential Impacts
Pike killifish occupy shallow, weed-filled waters along with their primary prey, other members of the family Poeciliidae. They occur in freshwater and estuaries to 40 ppt (Froese and Pauly, 2003), and in Tampa Bay have recently been collected in salinities of 28.5 ppt (Heagey et al., 2002). The lower lethal temperature limit is near 10^{o}C (Poss et al., 2000).

Pike killifish are effective predators on native poeciliids, including the mosquitofish, *Gambusia holbrooki* (formerly *affinis*), and the sailfin molly, *Poecilia latipinna*. In some areas, it has been shown to significantly reduce *Gambusia* and *Poecilia* populations, particularly if weed cover is reduced (Lever, 1996; Fuller et al., 1999). *Gambusia* is a known and effective predator of mosquito larvae, so the potential exists for cascading effects from the introduction of the pike killifish, such as an increase in disease-bearing mosquitoes.

URL for more information: http://www.gsmfc.org/nis/, http://nas.er.usgs.gov/

3-12.6 Rio Grande Cichlid

Subphylum Vertebrata
Class Osteichthyes
Order Perciformes
Family Cichlidae
Cichlasoma cyanoguttatum (Baird & Girard, 1854) = *Herichthys cyanoguttatus*

Range and Vectors of Introductions

The Rio Grande cichlid is native to Atlantic drainages of northern Mexico and southern Texas (Konings, 1989). It became established in the Tampa Bay area of Florida in the 1940s, possibly as an escapee from ornamental fish farms, and has since been established through aquarium releases or deliberate introductions in several south Florida localities (Fuller et al., 1999).

The Rio Grande cichlid is a **known invasive** of the greater Tampa Bay ecosystem, but its known distribution within the area is limited to Six Mile Creek, an estuary in the city of Tampa, and Lake Seminole in St. Petersburg (Fuller et al., 1999).

Description and Biology

The biology of the Rio Grande cichlid has been reviewed by Konings (1989), Fuller et al. (1999), Poss et al. (2000) and Froese and Pauly (2003). It is variously colored, but distinguished by an even covering of pale speckles over most of its body. The tail is rounded, and like other cichlids, the dorsal fins are fused. The mouth is small compared to similar native fishes. The maximum total length is about 30 cm.

The Rio Grande cichlid is primarily an herbivore, but under some conditions, it consumes some benthic invertebrates, such as snails. Members of the genus *Cichlasoma* seldom construct nests, but attach up to several hundred eggs to clean surfaces of rocks or debris. The hatched fry are guarded by the parents for several weeks, and in the absence of food, the fry will graze on the flanks of the adults, apparently consuming mucus.

Habitat and Potential Impacts

The Rio Grande cichlid is primarily a freshwater river species (Konings, 1989; Froese and Pauly, 2003), but in Florida it occurs in salinities to 13 ppt (Courtenay, 1997). The optimal temperature is reported to be 20-33^{o}C (Froese and Pauly, 2003) but their persistence in Florida indicates an ability to tolerate lower temperatures. Ecological impacts in their nonindigenous range have not been studied.

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.7 Mayan Cichlid
Subphylum Vertebrata
Class Osteichthyes
Order Perciformes
Family Cichlidae
Cichlasoma urophthalmus (Günther, 1862)

Range and Vectors of Introductions
The Mayan cichlid, also known as the orange tiger, is native to the Yucatan Peninsula (Konings, 1989). It is established in Everglades National Park, Florida, and surrounding areas, with individuals recorded as far north as Manatee County. The dates and vectors of invasion are unknown, but this is an ornamental species, and may have escaped or been released from captivity (Lorenz et al., 1997; Fuller et al., 1999).

Manatee County is partially within the greater Tampa Bay ecosystem, but the status of the Mayan cichlid in that county is not known. We consider the Mayan cichlid to be a **probable invasive** in the greater Tampa Bay ecosystem.

Description and Biology
The biology of the Mayan cichlid has been reviewed by Koning (1989), Fuller et al. (1999), Poss et al. (2000), and Froese and Pauly (2003). The Mayan cichlid has about nine striking vertical bars, particularly in adult specimens. The tail is rounded, and like other cichlids, the dorsal fins are fused. The mouth is small compared to similar native fishes. The maximum total length is about 30 cm.

The Mayan cichlid feeds on small fish and invertebrates, but apparently also consumes detritus. Members of the genus *Cichlasoma* seldom construct nests, but attach up to several hundred eggs to clean surfaces of rocks or debris. The hatched fry are guarded by the parents for several weeks, and in the absence of food, the fry will graze on the flanks of the adults, apparently consuming mucus.

Habitat and Potential Impacts
The Mayan cichlid inhabits freshwater marshes and mangrove swamps. It has been observed spawning at 26 ppt in Florida (Fuller et al., 1999), occurs in the Everglades at 25 ppt (Lorenz et al., 1997), and is tolerant of full seawater (Poss et al., 2000). The reported lower temperature limit is 15^{o}C (Poss et al., 2000), which probably limits permanent populations in the greater Tampa Bay ecosystem to springs and other thermal refugia. Impacts on native fishes are predicted, but have not been experimentally studied (Fuller et al., 1999).

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.8 Blue Tilapia
Subphylum Vertebrata
Class Osteichthyes
Order Perciformes
Family Cichlidae
Oreochromis aureus (Steindachner, 1864)

We discourage the widespread use of “Nile perch” for the blue tilapia. “Nile perch” is the globally accepted name for *Lates niloticus* of Family Centropomidae, itself a well-studied biological invader (Lever, 1996). *Tilapia nilotica*, formerly considered a synonym, is a distinct species (Fuller et al., 1999).

Range and Vectors of Introduction
The blue tilapia is native to much of Africa and possibly to the Middle East, although ancient human introductions cannot be ruled out. It has been introduced to tropical and warm temperate regions throughout the world. In the United States, it is established in the Colorado River drainage of Arizona and California, and throughout much of southern Texas and Florida. The blue tilapia is also established in warm water effluent areas in northern states (Fuller at al., 1999).

The blue tilapia is a **known invasive** of the greater Tampa Bay ecosystem and is common in near-shore net fisheries (Fuller et al., 1999)

Description and Biology
The biology of the blue tilapia has been reviewed by Poss et al. (2000), U.S. Geological Survey (2000), and Froese and Pauly (2003). The blue tilapia is slate or metallic blue in color. The dorsal fins are fused and the mouth is small. Maximum total length is about 51 cm.

Blue tilapia are nest-building mouth-brooders, and spawn at temperatures above 20^{o}C. A shallow depression is dug from the sediment for the eggs, but eggs and newly hatched juveniles are taken into the mouth in the presence of potential predators. Females become sexually mature at around 10 cm. The diet consists mainly of algae and detritus.

Habitat and Potential Impacts
The blue tilapia is primarily a freshwater species, but can tolerate estuarine conditions. Actual salinities are not reported in the literature, but this species breeds in “saline” waters of Tampa Bay (Poss et al., 2000). The lower temperature tolerance is 6.2^{o}C in freshwater, but may be slightly lower in estuaries (Lever, 1996; Fuller at al., 1999, Costa-Pierce and Riedel, 2001).

Lever (1996), Fuller et al. (1999) and Costa-Pierce and Riedel (2001) have reviewed impacts of the blue tilapia, although according to Lever (1996) evidence for impacts tends to be anecdotal and sometimes contradictory. Most authorities, and the Florida sports fishing industry, regard the blue tilapia as an undesirable invasive. There is an inverse correlation between blue tilapia abundance and a decline in native fish, but cause-and-effect has yet to be experimentally demonstrated. It is suspected that juvenile blue tilapia out-compete juvenile largemouth bass (*Micropterus salmoides*) for food.

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.9 Mozambique Tilapia

Subphylum Vertebrata
Class Osteichthyes
Order Perciformes
Family Cichlidae
Oreochromis mossambicus (Peters, 1852)

Range and Vectors of Introduction

The Mozambique tilapia is native to the Zambesi and Limpopo river basins in southern Africa. It has been widely introduced to tropical regions around the world as a food fish. In the United States, this species is established in Hawaii, southern California, Arizona, Florida, and possibly in other states. Most stockings were deliberately conducted by state agencies or private concerns (Lever, 1996; Fuller et al., 1999).

The Mozambique tilapia was stocked in Florida in the 1960s. It is a **known invasives** of the greater Tampa Bay ecosystem and is common in near-shore net fisheries (Fuller et al., 1999)

Description and Biology

The biology of Mozambique tilapia has been reviewed by Poss et al. (2000), U.S. Geological Survey (2000) and Froese and Pauly (2003). Mozambique tilapia are gray to olive above, yellow to olive on the sides, and yellow ventrally. The dorsal fins are fused and the mouth is small. Mozambique tilapia may reach 40 cm in total length.

Mozambique tilapia are nest-building mouth-brooders. A shallow depression is dug from the sediment for the eggs, but eggs and newly hatched juveniles are taken into the mouth in the presence of potential predators. Females may become sexually mature in as little as two months, and as small as 6 cm. The diet consists mainly of algae and detritus.

Habitat and Potential Impacts

The Mozambique tilapia is primarily a freshwater species, but has been reported to spawn in full seawater under artificial conditions, and salinity tolerances appear to vary between nonindigenous populations (Poss et al., 2000). The lower temperature tolerance is variously reported, but in any case includes the entire greater Tampa Bay ecosystem (Lever, 1996; Fuller at al., 1999, Costa-Pierce and Riedel, 2001).

Impacts of the Mozambique tilapia have been reviewed by Lever (1996), Fuller et al. (1999), Poss et al. (2000), and Costa-Pierce and Riedel (2001). In a study in Hong Kong, Mozambique tilapia reduced chironomids (midges) and algae biomass. In other Southeast Asian nations, the Mozambique tilapia is valued as a food fish, but is suspected to have lead to a decline in native detritivores, including carp (Cyprinidae) and milkfish (*Channos channos*). There have been few studies on impacts of this species in the United States, but any impacts are predicted to be at least as great in coastal ecosystems as those reported in freshwater ecosystems in other nations (Costa-Pierce and Riedel, 2001).

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.10 Blackchin Tilapia

Subphylum Vertebrata

Class Osteichthyes

Order Perciformes

Family Cichlidae

Sarotherodon melanotheron Rüppell, 1852, many synonyms

Range and Vectors of Introduction

Blackchin tilapia are native to estuaries and lagoons of tropical west Africa. They were experimentally farmed for the ornamental trade in Florida in the 1950s, and apparently escaped from captivity into the Tampa Bay ecosystem by 1959, where they rapidly established a population that persists to this date. From there, they may have been deliberately transferred to other parts of Florida. They have also been introduced to Hawaii (Jennings and Williams, 1992; Fuller et al., 1999).

The blackchin tilapia is a **known invasive** of the greater Tampa Bay ecosystem, and is abundant in some coastal fisheries (Jennings and Williams, 1992; Fuller et al., 1999; Faunce and Paperno, 1999).

Description and Biology

The biology of the blackchin tilapia has been reviewed by Jennings and Williams (1992), Poss et al. (2000), U.S. Geological Survey (2000), and Froese and Pauly (2003). Blackchin tilapia attain a maximum standard length of about 24 cm. They are colorful, with gold to orange dorsally and blue ventrally, and there is a dark spot on the lower side of the mouth. The mouth is small and the dorsal fins are fused.

In Florida, spawning occurs form March to November when temperatures rise above 23^{o}C. They build and defend nests, and shelter eggs and juveniles in their mouth. Average brood size is about 50 eggs, but is dependent on female size. Sexual maturity in females may occur at 7 cm (standard length), which implies the possibility of multiple generations per year. Blackchin tilapia have been reported to feed on detritus and invertebrates, including bivalves.

Habitat Potential Impacts

This species is tolerant of a wide range of salinities, but is more abundant in estuaries than freshwater or full marine environments (Jennings and Williams, 1992). Its lower lethal temperature is around 10.3^{o}C (Costa-Pierce and Riedel, 2001; Poss et al., 2002).

Within portions of Tampa Bay and the Indian River Lagoon in Florida, blackchin tilapia are the second most abundant fish, after native mosquitofish, *Gambusia holbrooki*. Blackchin tilapia comprise up to 90% of the fish biomass in some samples, because of their larger body size (Faunce and Paperno, 1999; Fuller et al., 1999). Whether this abundance has lead to displacement of native competitors (e.g. striped mullet, *Mugil cephalus*) or alteration of the diet of native piscivores, is unknown. There is a small commercial fishery for blackchin tilapia in Tampa Bay (Jennings and Williams, 1992).

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.11 Spotted Tilapia

Subphylum Vertebrata
Class Osteichthyes
Order Perciformes
Family Cichlidae
Tilapia mariae (Boulenger, 1899)

Range and Vectors of Introduction

The spotted tilapia is native to West Africa from the Ivory Coast to Cameroon. It has been introduced to the United States several times, and is established in southern Florida and possibly in isolated localities in the Colorado River basin in Arizona and Nevada. Florida populations, which were first reported in 1974, may be the result of escape from captivity or aquarium releases (Poss et al., 2000; Fuller et al., 1999).

The spotted tilapia occurs in the Everglades and surrounding waters, and throughout the Indian River Lagoon and adjoining coastal systems, and is continuing to spread (Lorenz et al., 1997; U.S. Geological Survey, 2000). Given its ability to live in both freshwater and saltwater, there are no barriers to its spread to the greater Tampa Bay ecosystem, so we consider it an **expected invasive**.

Description and Biology

The biology of the spotted tilapia has been reviewed by Poss et al. (2000), U.S. Geological Survey (2000), and Froese and Pauly (2003). The spotted tilapia can be mistaken for a native sunfish (Family Centrarchidae). The body is silver to olive, and there is a row of 6-7 distinct black dots on the sides, continuing onto the base of the tail. Maximum size is about 31 cm. The spiny and soft dorsal fins are fused, but not a great deal more so than some native sunfish (Centrarchidae). The mouth is smaller than most native sunfish, however.

Spotted tilapia are substrate nest brooders, with both parents guarding the nest. They are believed to breed throughout the year in Florida. Up to 2000 eggs, which are reported to be turquoise in color, are deposited and guarded until some time after hatching. Adults feed on plants, large phytoplankton, and possibly detritus.

Habitat and Potential Impacts

The reported lower lethal limit of the spotted tilapia is 11.2^{o}C, but it can tolerate estuarine conditions to at least 28 ppt (Lorenz et al., 1997; Costa-Pierce and Riedel, 2001).

Spotted tilapia have displaced other cichlids in canals of Florida (Fuller et al., 1999), but since both the other cichlids and the canals were artificially placed, it is hard to use this to predict impacts on natural ecosystems. Impacts on native species have not been documented.

URLs for more information: http://nas.er.usgs.gov/, http://www.gsmfc.org/nis/

3-16.12 Marine Toad

Subphylum Vertebrata
Class Amphibia (Sarcopterygii)
Order Anura
Family Bufonidae
Bufo marinus Linnaeus, 1758 = *B. gigas*

Range and Vectors of Introductions

The marine toad is native to South America and Central America north to Texas. It was deliberately introduced to Australia, Hawaii, the Philippines, and Puerto Rico in the 1920s and 1930s to control insect pests of sugar cane. Early Florida introductions failed, but succeeded in the 1950s (King and Krakauer, 1966; Poss et al., 2000).

This species is a **known invasive** of the greater Tampa Bay ecosystem. Hillsborough County is about the northern limit of its range in Florida (Poss et al., 2000).

Description and Biology

Biology of the marine toad is reviewed by Poss et al. (2000), Cameron (2002), and Western Australia Dept. Agriculture (2002). The marine toad, also known as the giant toad, is significantly larger than native species, and adults attain a snout-vent length of 15 cm or more. It is further distinguished by its large parotid glands on either side of the head, and bony ridges above the eye. Tadpoles are dark dorsally and pale with spots ventrally.

Marine toads breed from spring to autumn. Females lay 8000-50,000 eggs at a time in two long jelly-coated strings. Eggs are black and about 1 mm in diameter. Tadpoles metamorphose into juvenile toads in about a month and a half in Florida, but may take as little as half a month or as long as six months. Adults reach maturity in their second year. Marine toads are predatory on a wide range of smaller animals, but will also eat carrion. The parotid glands produce a cardiac toxin that deters predators.

Habitat and Potential Impacts

The marine toad is a tropical species, and in Florida mostly occurs from the Tampa area southwards. The adults are normally terrestrial in disturbed areas, but must return to the water to breed. Unlike the majority of amphibians, adults can tolerate full strength seawater, and larvae can develop in estuarine water to 15 ppt (Poss et al., 2000; Cameron, 2002).

Reported impacts of cane toads have been reviewed by Poss et al. (2000), Cameron (2002), and Western Australia Dept. Agriculture (2002). Marine toads were an early form of biological control, and one of the best cautionary examples against such practices. Nowhere have they achieved their intended goal of protecting crops from insect pests, but in Australia, southern Florida, and other places, they themselves have become abundant pests, often by consuming beneficial insects such as bees. They are blamed for the decline of native amphibians, but it has not clearly been established whether the mechanism is competition or predation. In Florida, their most noted impacts are as toxic hazards to pets that attack them, but they can also poison humans who handle them.

URLs for more information: http://www.gsmfc.org/nis/, http://www.agric.wa.gov.au/agency/pubns/farmnote/2002/

4. Discussion
4-1. Summary of Results
Sixty five nonindigenous or cryptogenic species were found to have either invaded the greater Tampa Bay ecosystem or to be in a position to do so (Table 3.1). Thirty five species were known both to occur in the greater Tampa Bay ecosystem and to be nonindigenous, and an additional three nonindigenous species were considered to probably occur in the greater Tampa Bay ecosystem. If cryptogenic species are included, the number of known and probable invasives rises to 50 species.

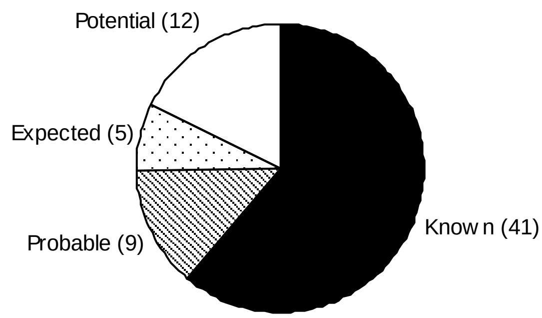

Figure 4.1. Relative abundance of nonindigenous or cryptogenic species which are known to occur, probably occur, are expected to occur, or potentially will occur in the greater Tampa Bay ecosystem.

Three phyla, including Mollusca (snails and bivalves), Chordata (sea squirts and fishes) and Arthropoda (crustaceans) dominate lists of nonindigenous and cryptogenic species in the greater Tampa Bay ecosystem (Fig. 4.2). All three groups are taxonomically diverse and might be expected to dominate species lists in any estuarine system. More intensive surveys of nonindigenous species in other marine ecosystems, however, revealed a greater relative diversity of other taxonomic groups (Carlton, 1979b; Mills et al., 2000; Carlton et al., 2001). We predict that a formal Rapid Assessment Survey (discussed below) of the greater Tampa Bay ecosystem would increase the number of known nonindigenous species, and that most of these new findings would be in groups that are weakly represented in the current study.

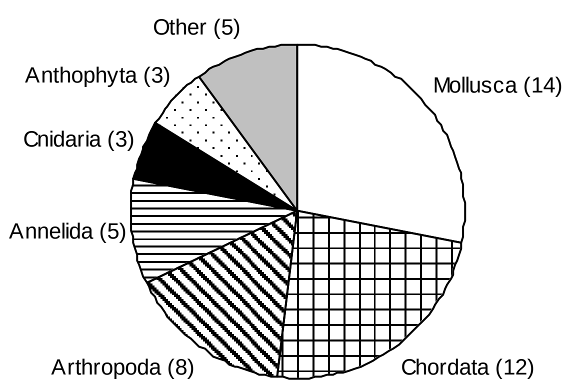

Figure 4.2. Taxonomic distribution of known or probable invasives or cryptogenic species in the greater Tampa Bay ecosystem.

Species richness in estuaries tends to decline from a peak in full marine water towards a minimum number of species at around 5 ppt (oligohaline), and rising thereafter towards freshwater (McLusky, 1971). If one divides the species discussed here by salinity zones of known or expected impact, a different pattern is found for nonindigenous and cryptogenic species. Even including expected and potential invaders to the Tampa Bay ecosystem, species that are mostly restricted to the full marine environment comprised the smallest fraction of the invaders (Fig. 4.3). Euryhaline species, or those with broad salinity tolerances (for example, the green mussel, *Perna viridis*) make up the largest fraction of nonindigenous and cryptogenic species, but there are also many species mostly restricted to oligohaline, or low salinity portions of the estuary. It may be that low-salinity portions of estuaries have more available "niches" to invade than high-salinity areas, or that species adapted to unstable environments make good invaders.

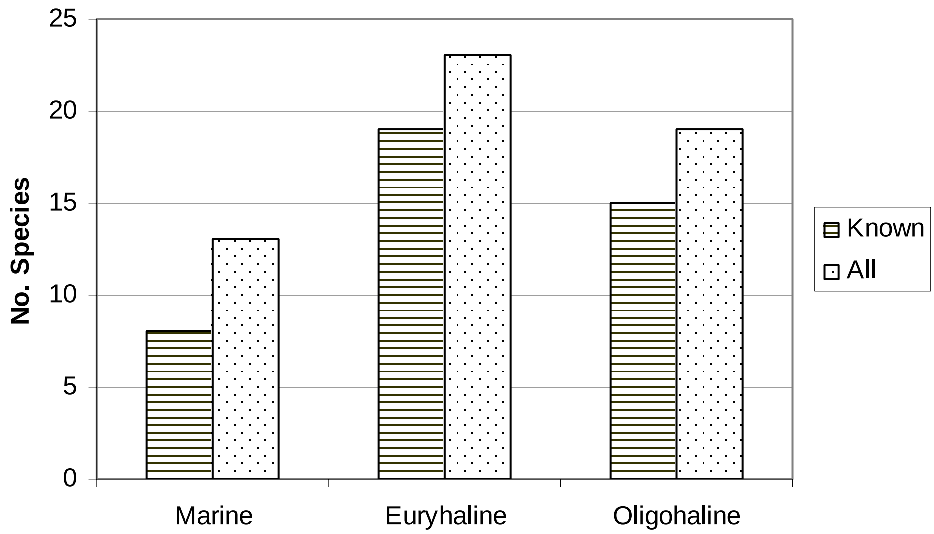

Figure 4.3. Distribution of known and probable nonindigenous and cryptogenic species ("Known") and all probability categories ("All") relative to salinity zones of primary distribution in the greater Tampa Bay ecosystem.

Many of the nonindigenous and cryptogenic species in the greater Tampa Bay ecosystem have impacts locally or in other systems. Industrial impacts (by fouling or boring organisms) and fisheries impacts (including aquaculture) are the best documented. Some nonindigenous species may negatively affect fisheries through disease or fouling of aquaculture facilities, but others, such as certain fish, may themselves provide fisheries. Ecological impacts by nonindigenous species are more often predicted than documented, so we have been conservative in our estimates of species with ecological impacts.

Impacts of nonindigenous species vary between localities. No local impacts have been reported for the hydroid *Garveia franciscana*, but this species is a major industrial pest in Venezuela (Garman, 1999; de Rincon and Morris, 2001). On the other hand, green mussels (*Perna viridis*) have been noted as serious industrial pests several times in Tampa Bay, but not elsewhere (Benson et al., 2001; Werner, 2003; W. Danzik, *pers. comm.*).

4-2. Why are there so many cryptogenic species?

The cryptogenic concept, or the notion that we do not know the native range of a species, is a fairly new idea in ecology (Carlton, 1996). The question generally arises when a single species occurs on both sides of a major biological barrier. For marine species, this can mean opposite coasts of an ocean – for example, Africa and the Caribbean, in the case of the pulmonate limpet *Siphonaria pectinata* – or two different oceans, such as the Indo-Pacific and the Caribbean, in the case of the flatworm *Stylochus frontalis*.

In the past, the scientific community has generally accepted transoceanic distributions as natural, and has developed hypotheses for how such distributions may arise. Turner (1966), for example, proposed that shipworms owe their widespread distribution to driftwood. Scheltema (1973) studied the concept of wide-ranging, or *teleplanic* larvae, which can not only disperse across oceans but carry epifaunal ciliate protozoa with them. Others have pointed to the ancient Tethys Sea, during a period when all tropical oceans were connected, and suggested that species with circumtropical distributions are relics of that time (Plough, 1978; Zullo, 1992).

In a few cases, natural dispersal has been demonstrated as the only reasonable explanation for widespread distribution. For example, the Chilean flat oyster, *Ostrea chilensis*, evolved in New Zealand, but arrived many thousands of years ago in South America, based on recent fossil remains. Thor Heyerdahl's raft aside (Heyerdahl, 1950), the most probable vector during this period of time was adults attached to floating pumice which drifted from New Zealand (Ó Foighil et al., 1999). It is possible that this or other explanations could account for some of the species observed both in Florida and a distant ocean.

There are two more parsimonious explanations for most circumglobal distributions, however. The first possible explanation is that a single species observed in two different oceans is, in fact, two separate but morphologically similar species. Such turned out to be the case with the blue mussel, *Mytilis edulis*, once believed to occur naturally on temperate coastlines around the world. Molecular genetics revealed that the native eastern Pacific species was, in fact, *Mytilus trossulus* (McDonald and Koehn, 1988). Adults of the two mussel species cannot be reliably distinguished, even by experts, and are known as sister species. The sister species scenario has also been demonstrated for some polychaete worms (Westheide and Schmidt, 2003).

The other explanation for a circumglobal distribution is human-mediated biological invasion. As the case of the "Portuguese" oyster reveals (Section 1-3.1), biological invasions between oceans have been going on for centuries. Other supposedly circumtropical distributions, such as the acorn barnacle *Balanus trigonus*, have since come to be considered biological invasions (Zullo, 1992).

In this review, we have taken what we consider a conservative approach; to consider all species of uncertain origin or with cosmopolitan distributions as cryptogenic until proven otherwise. If a cryptogenic species is of no known economic or ecological concern, the issue is academic. If it is considered either harmful or beneficial, management decisions should first address the issue of whether the species is native or nonnative, and thus an evolved or introduced member of the greater Tampa Bay ecosystem. Such information would affect decisions on whether a species is to be mitigated or left to its own devices.

4-3. Recommendations

4-3.1 Rapid Assessment

The purpose of this study was to determine the state of knowledge regarding nonindigenous species in the greater Tampa Bay ecosystem. We have learned that Tampa Bay has many nonindigenous species, but there are probably many more that await detection. Among the species awaiting detection may be well-known pests which have either recently arrived or are established in low numbers. Any plans to manage or exclude nonindigenous species in the greater Tampa Bay ecosystem require complete knowledge of what is already present. Given this, we recommend that a formal Rapid Assessment Survey for nonindigenous and cryptogenic species be conducted in the greater Tampa Bay ecosystem.

Mills et al. (2000) presented a model for a rapid assessment survey conducted in a comparable ecosystem (Puget Sound, Washington). Multiple taxonomic experts were recruited to cooperate in several intensive surveys, distributed across the seasons, each lasting a few days. Information gained included a nearly-complete species list of nonindigenous and cryptogenic species, distributions and relative abundance of these species, and co-occurrence with native species. The taxonomic experts volunteered their time, but were compensated for travel, lodging, etc., and there were additional costs for planning, field surveys, and manuscript preparation time. Nonetheless, the total cost was modest for the amount of information gained. We believe the same is feasible for the greater Tampa Bay ecosystem.

4-3.2 Survey of Invasion Vectors

Ship ballast water has received the greatest attention among modern vectors for marine biological invasions (e.g. Barrett-O'Leary, 1999), and is currently being investigated in the Gulf of Mexico and Tampa Bay by researcher at the Smithsonian Institution and Eckerd College (G.M. Ruiz, *pers. comm*.). As was apparent from the taxonomic survey in this report, however, many different vectors have been responsible for past invasions. Modern awareness, regulations, and technology may have reduced some of these vectors, but not necessarily all. Clearly, prevention is the best way to manage an unwanted biological invader, but effective prevention requires an understanding of the vectors. We recommend that an investigation of potential vectors of biological invasion to the greater Tampa Bay ecosystem be conducted.

An investigation of potential vectors of biological invasions should have multiple phases, the first of which is to determine which potential vectors exist. For example, is dry cargo shipped through Tampa Bay ports in a manner that might allow the invasion of another shore crab species? Does the recreational fishing industry import live bait from other ecosystems? Once the potential vectors have been identified, the following phases would be to quantify their relative importance, which is a product of frequency (number of times nonindigenous species are introduced) and effectiveness (viability of introductions). Carlton and Geller (1993) provided a model for this approach with ship ballast water. Different methods of investigations would be required for different vectors (for example, estimating the importance of private aquarium releases versus the importance of vessel hull fouling).

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Appendix A. Biogeographic Rationale

We will discuss three levels of biogeography and their influence on biological invasions of Tampa Bay: the greater Tampa Bay ecosystem, the West Florida Ecocline, and coastal regions adjacent to West Florida. Citations are all included in Section 5. References.

<u>A-1 Greater Tampa Bay Ecosystem</u>

Tampa Bay is not easily separated, hydrographically or demographically, from adjoining coastal lagoons. We have included these coastal lagoons as part of the greater Tampa Bay ecosystem, as described below. For the remainder of this report, we will refer to biological invasions, or **known invaders**, in the greater Tampa Bay ecosystem, rather than only Tampa Bay.

The greater Tampa Bay ecosystem is here defined to extend from Anclote Keys (Clearwater Bay), south to the southern end of Sarasota Bay. North of the mouth of Tampa Bay are Boca Ciega Bay and Clearwater Bay. These urbanized coastal lagoons are connected to each other and to Tampa Bay by natural coastal channels behind barrier islands. At the north end of Clearwater Bay both coastal urbanization and coastal wave energy decrease, accompanying an ecosystem shift from barrier island lagoons to open, low-energy coastline. To the south, the mouth of Tampa Bay is continuous with Anna Maria Sound and Sarasota Bay. At the southern end of Sarasota Bay there is an artificial channel through mangroves to further coastal estuaries, and a partial osmotic barrier to marine organisms within the Intracoastal Waterway presented by the outflow from Philippe Creek.

The seaward limit of the greater Tampa Bay ecosystem is here defined by the state territorial limits (3 miles, or about 5 km west of Egmont Key) for the purpose of this manuscript. This is a political boundary, but it encompasses most of the estuarine influence caused by the relatively modest freshwater output of Tampa Bay. Inland, we include tidally influenced tributaries of Tampa Bay to about 1.0 ppt concentrations of marine salts.

<u>A-2. West Florida Ecocline</u>

Tampa Bay lies within a transitional zone, or *ecocline* (Whittaker, 1975), between warm temperate and tropical ecosystems. Coastal communities typical of warm temperate ecosystems include oyster reefs and salt marsh, both of which occur in Tampa Bay (Estevez and Mosura, 1985; Baker at al., 2003). Communities typical of tropical coastlines include mangroves, which dominate undeveloped shorelines of Tampa Bay (Estevez and Mosura, 1985), and “live bottom,” or a mixture of gorgonians, sponges, and algae which occur at the mouth of the bay (Derrenbacker and Lewis, 1985). Using these communities, an ecocline can be established with Cedar Key as the northern limit (200 km north of the mouth of Tampa Bay) and Florida Bay as the southern limit (370 km south) (Savage, 1972; Carlton, 1975). South of Florida Bay, coral reefs come up to the shoreline, marking the beginning of a true tropical ecosystem. A similar ecocline, termed a “bioclimatic transition zone,” has been described for the east coast of Florida (Myers, 1986).

Within the West Florida ecocline, it is difficult to establish species distribution limits based on latitude. The greater Tampa Bay ecosystem is near the middle of the ecocline, so annual and interannual variations in temperature may allow some species to occupy Tampa Bay part of the time and not others. For this reason, nonindigenous species recorded from the West Florida ecocline, but not specifically from the greater Tampa Bay ecosystem will be considered **probable invaders**.

A-3. Regional Coastal Systems

Here we discuss the relative potential for biological invasion from several regions adjacent to the West Florida ecocline. These regions include: northern Gulf of Mexico, western Gulf of Mexico, northwest Caribbean, greater Caribbean, and eastern Carolinian. Other biogeographical schemes (e.g. Abbott, 1986; Kelleher et al., 1995) are acknowledged but do not closely match our requirements for a model centered on Tampa Bay.

Northern Gulf of Mexico and Western Gulf of Mexico

The northern Gulf of Mexico is here defined as the region from Cedar Key, Florida (the northern limit of the West Florida ecocline) to the Sabine River, Texas, where the coastline turns south and becomes less estuarine. This region is equivalent to the western half of the Carolinian biological province in some schemes (Abbott, 1986). There is some biological evidence to support separation of biogeographical provinces somewhere along the Texas coast. The southern quahog, *Mercenaria campechiensis,* appears to consist of two Gulf of Mexico populations, separated somewhere along the coast of Texas (Ó Foighil et al., 1996). The nonindigenous brown mussel, *Perna perna*, has persisted in Texas for over a decade (Hicks and Tunnel, 1993; Hicks et al., 2001), but has not spread east, despite prevailing coastal currents in that direction (Pickard and Emery, 1982). In the case of *P. perna*, the dispersal barrier could be either freshwater from rivers (e.g. the Mississippi) or the slightly cooler winter temperatures in the northern Gulf of Mexico. There is some evidence for fish species that the Mississippi River delta serves as a biogeographic barrier or break (Walls, 1975).

No major biological barriers to marine species are known to exist between the northern Gulf of Mexico and the West Florida ecocline, at least east of the Mississippi River plume. Furthermore, the dominant coastal surface currents move towards Florida from west to east (Pickard and Emery, 1982), aiding natural dispersal of invading species. For these reasons, nonindigenous marine species in the northern Gulf of Mexico will be considered **expected invaders** to the greater Tampa Bay ecosystem in this report.

Apparent barriers exist to the eastward dispersal of some nonindigenous species across the Gulf of Mexico (Hicks et al., 2001). Intracoastal shipping could overcome such barriers for many species (Barrett-O'Leary, 1999), but no means has been found to estimate the probability of invasions from these vectors. We can only predict that the *relative* probability of invasion of the greater Tampa Bay ecosystem from the western Gulf of Mexico is lower than from the northern Gulf of Mexico. Nonindigenous marine species in the western Gulf of Mexico will, therefore, be considered as **potential invaders** of the greater Tampa Bay ecosystem.

Northwestern Caribbean and Greater Caribbean
The Northwestern Caribbean is here defined as southwestern and northern Cuba, Jamaica, Central America from about Cancun, Mexico to the Honduras-Nicaragua border, and the Florida Keys and southeast Florida to Cape Canaveral. This is similar to the IUCN marine subregion by the same name, except that the Florida is not included (Kelleher et al., 1995). We included the Florida Keys here because there is evidence that some Florida species, such as the queen conch (*Strombus gigas*) are maintained by larvae carried in marine currents from elsewhere in the northwest Caribbean (Hawtof et al., 1998). These same currents travel north along the east Florida coast to Cape Canaveral, where there is a well-known biogeographic break (Saunders et al., 1986; Reeb and Avise, 1990; Sarver at al., 1992; Hare and Avise, 1998). Earlier biogeographers encompassed all of the Caribbean in a single biogeographic province (Abbott, 1986), but research on *Chione* clams by Roopnarine and Vermeij (2000) support the division of the Caribbean into more than one biogeographic region. As discussed later, this distinction is important for at least one cryptogenic species in Tampa Bay, the falsemussel *Mytilopsis sallei*.

Coastal oceanic currents do not normally flow from any of these regions towards Tampa Bay, but they do flow towards the Florida Keys and southeast Florida. There is heavy coastal traffic between these areas and Tampa Bay, unhindered by open seas or international boundaries. For this reason, plus the proximity of the northwest Caribbean to the West Florida ecocline, we consider nonindigenous species established here as **expected invaders** of the greater Tampa Bay ecosystem, except in cases where narrow thermal tolerances (true tropical species) are likely to prevent establishment in a subtropical estuary.

The greater Caribbean is here defined as the remainder of the Caribbean province or marine bioregion (Abbott, 1986; Kelleher et al., 1995), except for U.S. coastal areas north of Cape Canaveral. Ports in the greater Caribbean provided the majority of international shipping to Tampa Bay that carry ballast from tropical or subtropical estuaries (Barrett-O'Leary, 1999). Molecular genetic evidence suggests that green mussels (*Perna viridis*) invaded Tampa Bay from recently established populations in the southern Caribbean (Benson et al., 2001). On the other hand, the brown mussel (*P. perna*), which has been established for much longer in the same part of the southern Caribbean (Rylander et al., 1996), has yet to invade Florida. Invasion of the greater Tampa Bay ecosystem from the wider Caribbean, therefore, is certainly possible but by no means certain. We therefore consider nonindigenous species from this region to be **potential invaders** of the greater Tampa Bay ecosystem.

East Carolinian
Cape Canaveral, Florida, is recognized as a biogeographic break, and supported by molecular genetic data. Some schemes consider this the eastern portion of the Carolinian province, although the IUCN scheme does not name this subregion. Cape Hatteras, North Carolina, is generally accepted as the northern limit of this bioregion (Abbott, 1986; Saunders et al., 1986; Reeb and Avise, 1990; Sarver at al., 1992; Kelleher et al., 1995; Hare and Avise, 1998). Prevailing marine currents flowing away from Florida,

distance, and relatively colder water all make biological invasion of Tampa Bay from this region less likely than from some other biogeographic regions, but coastal dispersal and shipping are still possible vectors. Nonindigenous species in the east Carolinian province, therefore, will be considered **potential invaders** of the greater Tampa Bay ecosystem.