



Invasive Marine and Estuarine Animals of the Gulf of Mexico

by Gary L. Ray

PURPOSE: New species of estuarine and marine animals are inadvertently or intentionally introduced into the waters of the United States every year (Figure 1). Various referred to as introduced, nonindigenous (NIS), alien, nonnative, or exotic species, most pose little or no threat; however, a few have the potential to disrupt local ecosystems, fisheries, and human infrastructure. Such invasions directly impact the mission of the U.S. Army Corps of Engineers (USACE) through its responsibilities for construction and maintenance of harbors, ports, and waterways; erosion control; management of water resources; and wetland and coastal habitat restoration. The general biology and ecology of invasive estuarine and marine animals have been described in previous reports (Carlton 2001, Ray 2005). This report is part of a series describing the biology and ecology of known invasive estuarine and marine animals in the major geographic regions of the United States. Invasive animals of the Gulf of Mexico are described and examples of species posing a specific threat to USACE activities are identified.

BACKGROUND: Invasive species are officially defined as "alien species whose introduction does or is likely to cause economic or environmental harm to human health" (Executive Order 13112, Federal Register (1999)). Any species removed from its native range has the potential to become invasive. This is because within its normal range, predation, disease, parasites, competition, and other natural controls act to keep population levels in check (Torchin et al. 2003, Wolfe 2002). Once released from these controls species abundances have the potential to reach levels that interfere with or displace local fauna. Such effects may occur immediately, after some period of delay, or never be realized at all depending on the characteristics of the individual species and the conditions into which it is introduced.



Figure 1. Example of an invasive species, the green-lipped mussel, *Perna viridis* (image courtesy of U.S. Geological Survey (USGS))

Lists of estuarine and marine nonindigenous species are often dominated by mollusks, crustaceans, and polychaete worms; however, this may reflect their ease of identification and detection rather than the degree to which they are representative. Ultimately it is an issue of an organism's biological characteristics (e.g., reproductive capacity, growth rate) and not its taxonomic affinities that determine if it becomes invasive. Successful invaders tend to be abundant over a large range in their native region, have broad feeding and habitat preferences, wide physiological tolerances, short generation times, and high genetic variability (Erlich 1989, Williams and Meffe 1999). Despite the fact that we can identify these characteristics, predicting which species pose the greatest threat

20050926 108

remains problematic since many species possess these characters, most are not obvious in their native range, and the opportunities for introduction and subsequent likelihood of survival are difficult to assess. The situation is further complicated by difficulty in distinguishing invaders from species with naturally wide distributions and those that are cryptogenic, that is, species whose original distributions are uncertain.

Predicting which habitats are likely to be invaded is much simpler. Invaded habitats tend to have low natural diversity, relatively simple (low-connectance) food webs, and a history of recent natural or anthropogenic disturbance (Williams and Meffe 1999). Estuaries and sheltered coastal areas are among the most invaded habitats, presumably due to the fact that they are naturally disturbed, low-diversity systems and are historically centers of anthropogenic disturbance associated with navigation, industrial development, and urbanization.

Species are introduced by a variety of different mechanisms; however, most estuarine and marine species introductions are associated with shipping (Ruiz et al. 2000). Species capable of attaching to hard surfaces may be transported on ship hulls, navigational buoys, floatation devices, anchors, chains, ropes, and flotsam or jetsam (Carlton 2001). During the heyday of wooden-hulled ships, wood-borers (e.g., shipworms) and species associated with "dry" ballast such as stones, rock, sand, or other materials were frequently introduced (Carlton and Hodder 1995). Presently, the largest single source of shipping-related introductions is ballast water (Carlton 1985, Lavoie et al. 1999). Ballast water is taken on board vessels for a variety of purposes related to ship maneuverability and control (Carlton et al. 1995). Animals suspended in the water column or present in bottom sediments are taken in and then introduced to a new location when the ballast is pumped out.

Recently, concerns have also been raised regarding introductions of fish, invertebrates, and "live" rock from the aquarium trade (Padilla and Williams 2004, Weigle et al. 2005). The lionfish *Pterois volitans* may have been introduced to Atlantic waters when a private aquarium was demolished in the Miami area in 1992 during Hurricane Andrew (Hare and Whitfield 2003). Other introductions may result from accidental release of animals, inappropriate disposal of packing material by restaurants serving live seafood, and by the live bait industry. Many species have been deliberately introduced to develop new fisheries. For example, the Atlantic striped bass *Morone saxatilis* has been introduced both outside its normal geographic range and in nonnative habitats (e.g., reservoirs) in much of the United States.

METHODS: As indicated in the official definition, invasive species are nonindigenous or alien to the region in which they are found. This does not mean that all NIS are invasive but rather that invasives constitute a subset of NIS. A list of known invasive species within the Gulf of Mexico was created by querying NISBase, a national database of nonindigenous species (NIS) listings maintained by the Smithsonian Institution (<http://www.nisbase.org/nisbase/index.jsp>). Part of the National Exotic Marine and Estuarine Species Information System (NEMESIS), this database permits simultaneous searches of multiple NIS listings. Searches return up to 300 species and include links to individual species' fact sheets and collection data. Queries were performed by state and included searches of the United States Geological Survey's Nuisance Aquatic Species (NAS) database (<http://nas.er.usgs.gov/>), the Chesapeake Bay Exotic Marine and Estuarine Species Information System database, and the Nonindigenous Species in the Gulf of Mexico database (<http://nis.gsmfc.org/>). The resulting lists were amended as necessary after comparison with

individual state NIS listings and other reports (Table 1), then edited to include only estuarine and marine species (Appendix A). Cryptogenic species were not included in the list. Species known to be invasive or suspected of having the potential to become invasive are discussed.

Additional NIS information specific to the Gulf of Mexico can be found in U.S. Environmental Protection Agency (USEPA) (2000), Gossett and Lester (2004), as well as the management plan for the state of Louisiana (Louisiana Aquatic Invasive Species Task Force 2004).

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

Benson et al. 2001
Gossett and Lester 2004
Louisiana Aquatic Invasive Species Task Force 2004
Texas Parks and Wildlife 2004
USEPA 2000
U.S. Geological Survey (USGS) 2003

RESULTS: Listings for the Gulf of Mexico include 74 nonindigenous estuarine and marine animal species (Table 2). Fishes dominated these lists with 25 species. At least 10 of these species represent deliberate introductions associated with sport fisheries or mariculture operations including herring and shad (*Alosa* spp. and *Dorosoma* spp.), salmon (*Onchorhynchus* spp. and *Salmo salar*), and four-spined stickleback (*Apeltes quadricus*), Atlantic needlefish (*Strongylura marina*), spotted seatrout (*Cynoscion nebulosus*) and Atlantic striped bass. In the case of the spotted seatrout, introduction represents stocking of a nonindigenous habitat (e.g., lakes and reservoirs) rather than placement outside of its native geographical range. An additional 15 fish species represent unintentional releases from aquaria including six species of angelfish (*Pomacanthus* spp.), five species of tang (*Zebrasoma* spp.), the spotted scat (*Scatophagus argus*), the blackbelly triggerfish (*Rhinecanthus verrucosus*), the humpback grouper (*Cromileptes altivelis*), the lionfish (*Pterios volitan*), and the

Table 2
Numbers of South Atlantic NIS by State

Species	FL	AL	MS	LA	TX	Total for Region
Scyphozoans	2	1	1	1		2
Anthozoans	2	2				2
Polychaetes	3	3				3
Bivalves	7				1	8
Gastropods	4			1	1	4
Nudibranchs	2	2				2
Copepods	1			1	3	3
Barnacles	3				1	3
Amphipods	1					1
Isopods	3					3
Tanaids	1					1
Crabs	5	1	1	1	1	7
Shrimp	4				1	4
Bryozoans	2					2
Entoprocts		1				1
Tunicates	2				1	3
Fish	18	4	3	2	7	25
Total	60	14	5	6	16	74

Asian swamp eel (*Monopterus albus*). Only the lionfish and the swamp eel are recognized as species of concern at this time.

Geographical distribution of NIS varies widely among states. Florida has the greatest number of reported NIS, probably reflecting the length of coastline, intensity of human influence (e.g., shipping and industrialization), and the extent of NIS monitoring efforts in this state. Texas has the next-longest coastline and the second largest number of NIS.

DISCUSSION: Species most commonly identified as invasive or listed as of concern in the Gulf of Mexico include Australian spotted jellyfish, *Phylloriza punctata*, green or green-lipped mussel *Perna viridis*, brown mussel *Perna perna*, shipworms, green porcelain crab *Petrolisthes armatus*, lionfish, and Asian swamp eel. Of these species, the biology and ecology of all but shipworms and the swamp eel have been previously described in Ray (2005). In the following sections these results will be briefly summarized.

Potential Threats to Infrastructure.

Perna viridis. *Perna viridis* (Figure 1), a native of the tropical Indo-Pacific, has been collected from Tampa Bay to Charlotte Harbor, Florida and in Kingston Harbor, Jamaica (Buddo et al. 2003). Initially discovered clogging water intake pipes at Tampa Bay power plants (Gulf States Marine Commission 2003a), its planktonic larvae are capable of settling on almost any hard surface. It can foul navigation buoys and ship hulls, interfere with shellfish culture, and displace local fauna. This species could also potentially harbor algal species that produce toxic shellfish poisoning (Buddo et al. 2003). The Brown mussel, *P. perna*, a close relative, is also a potential fouling threat. Native to South Africa, it has successfully invaded South America from Uruguay to the Caribbean (Gulf States Marine Commission 2003b) and is now found in the Gulf of Mexico from Freeport, Texas to Veracruz, Mexico (Hicks and Tunnel 1993, 1995). Slightly smaller than its congener, the brown mussel shares most of its biological characteristics. Its planktonic larvae reside in the water column for up to three weeks, potentially allowing it to invade much of the Gulf of Mexico and the Florida Keys. Like *P. viridis*, it can settle on almost any hard surface and has been reported at jetties, navigational buoys, oil platforms, and natural hard-bottom substrates (Hicks and Tunnell 1995). There are an additional 11 NIS species that can be considered fouling species. Probably introduced on ships' hulls or in ballast water, they include two anthozoans (anemones), three barnacles, two bryozoans, one entoproct, and three tunicates.

Chinese mitten crab. The Chinese mitten crab *Eriocheir sinensis* first appeared as an invasive species in Germany during the early 1900's and has since spread through most of Europe (Clark et al. 1998). It is reported in the United States from Lake Erie, San Francisco Bay, the Columbia River, and the Mississippi Sound. The crabs are catadromous, spending most of their adult life in freshwater, then returning to the sea only to reproduce. They form extensive burrows in riverbanks and levees, thus posing a direct threat to earthen water control structures. Further information on the life history of mitten crabs can be found in Veldhuizen and Stanish (2002), an ANS fact sheet (http://el.erd.usace.army.mil/ansrp/eriocheir_sinensis.htm), and in Ray (2005).

Shipworm. *Lyrodus medilobatus*, a wood-boring bivalve mollusc commonly called a shipworm, is native to the Indo-Pacific. First detected at Cape Canaveral in 1995, it was probably introduced on a fouled ship hull (USGS 2005). Shipworms are tolerant of a wide range of salinities, temperatures, flow conditions, and oxygen concentrations. Dispersed by planktonic larvae, the larvae settle and construct extensive burrow systems in wooden structures (e.g., boat hulls, marinas, docks, and pilings). Cohen and Carlton (1995) report that shipworms caused \$615 million in damage in San Francisco Bay during a 1920's outbreak. Likewise, severe damage was reported in Barnegat Bay, New Jersey and Long Island Sound, New York, after outbreaks of *Teredo. bartschi* associated with increased water temperatures and salinities in power station effluents (Hoagland 1983). Effective control of these pests can be accomplished by chemical treatment (e.g., creosote) or use of alternative materials (Highley 1999).

Potential Threats to Habitat Restoration.

Green porcelain crab. The Green porcelain crab *Petrolisthes armatus* (Figure 2) is a South American and Caribbean species distributed as far north as Georgia and South Carolina. Found in rocky intertidal and tidal creek oyster bar habitats, it is presently undergoing large changes both in its distribution and abundance. This species has reached densities as high as 10,000/m² in South Carolina salt marshes (Lohrer 2001). It is unclear whether this represents a natural range expansion or an inadvertent introduction. Hartman et al. (2001) and Hollebone and Hay (2003) suggest that high abundances of *P. armatus* provide an alternative prey for predators of xanthid crabs. Xanthids are important predators of newly settled oysters; therefore, the increase in porcelain crab abundance may indirectly result in a negative impact on oyster populations. Such an effect obviously has important implications for oyster habitat restoration efforts.

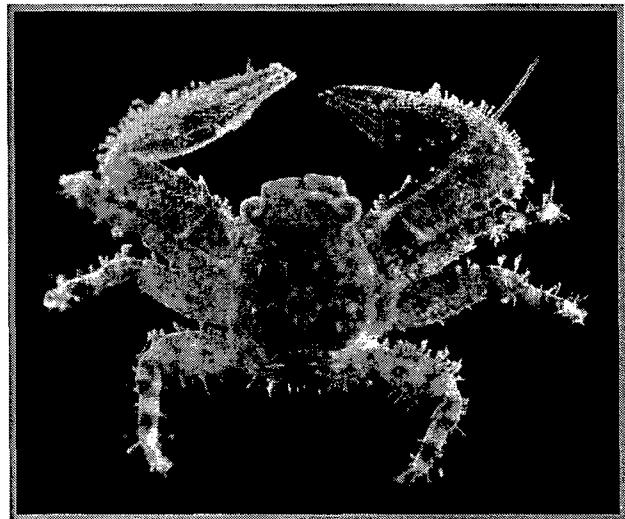


Figure 2. Green porcelain crab, *Petrolisthes armatus* (image courtesy of Southeast Regional Taxonomic Center)

Australian spotted jellyfish. Australian spotted jellyfish *Phylloriza punctata* is presently found in abundance only in the northern Gulf of Mexico, but has been reported as far afield as Brevard County, Florida. This large jellyfish (average adult bell width is 35 cm) can be found in swarms of up to 500,000 in a 150-km² area. Feeding intensively on zooplankton and fish larvae, they may represent a threat to fisheries and fisheries restoration operations. For more information on this species see Fuller (2005a).

Asian swamp eel. The Asian swamp eel *Monopterus albus* is actually not a true eel, but a member of the fish family Synbranchidae. Nocturnal in habit, it burrows as deep as 1.5 m in the bottoms of ponds, streams, rivers, and other freshwater habitats. It can also tolerate both saline and brackish waters. The swamp eel feeds on fishes, worms, crustaceans and other aquatic species.

Marketed as an aquarium species, it may have been introduced accidentally by aquarium release. It is presently found in drainages in South Florida as well as the Tampa Bay region. It may interfere with USACE operations by displacing native species and its extensive burrow systems may contribute to accelerated drying of shallow water bodies. For more information on this species see either the ANSRP website (listed above) or the Gulf States Marine Fisheries Commission NIS fact sheet at <http://nis.gsmfc.org>.

Wood-boring isopods. Two wood-boring isopods reported in the Gulf of Mexico (*Sphaeroma terebrans* and *S. walkeri*) may also affect habitat restoration. The first of these species was probably introduced on the hulls of wooden ships. Now found from Brazil to South Carolina and from Liberia to the Congo (Carlton and Ruckelshaus 1997), it burrows into hard substrates including hard packed sand, and decaying or living wood. There is considerable concern over its potential impact on restoration of mangrove habitat. The isopod burrows into the prop roots of red mangrove (*Rhizophora mangle*), weakening and ultimately destroying them (Rehm and Humm 1973). This not only damages the individual mangrove plant, but leads to undercutting and erosion of exposed sediments. Impact of the introduction of the Southwestern Pacific *S. walkeri* is unknown (Fuller 2005b).

Asian date mussel. Although not presently reported from the Gulf of Mexico, the Asian date mussel *Musculista senhousia* is also of concern in this region. Native from Siberia to the Red Sea, it is now found in Australia, New Zealand, the eastern Mediterranean, and southern France (Crooks 1996). Probably arriving in the United States during introduction of Japanese oysters to the state of Washington in the 1920's, it has since spread to southern California. Its planktonic larvae can remain in the water column as long as 55 days making it a likely candidate for secondary introduction via ballast water. The mussel settles on intertidal or subtidal sand and mud, forming dense beds that can alter both sediment composition and native benthic assemblages (Crooks 1998, Crooks and Khim 1999). Success of seagrass restoration projects can be compromised in heavily infested areas (Reutsch and Williams 1998). Additional information on this species can be found in Ray (2005).

ACKNOWLEDGEMENTS: This report was sponsored by the U. S. Army Engineer Research and Development Center, Vicksburg, MS, under the Aquatic Nuisance Species Research (ANSRP) Program.

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

Ray, G. L. (2005). "Invasive estuarine and marine animals of the Gulf of Mexico," ANSRP Technical Notes Collection (ERDC/TN ANSRP-05-4), U.S. Army Engineer Research and Development Center, Vicksburg, MS. <http://el.erdc.usace.army.mil/ansrp/>

REFERENCES

- Benson, A. J. Fuller, P. L., and Jacono, C. C. (2001). "Summary report of nonindigenous aquatic species in U.S. Fish and Wildlife Service Region 4." United States Geological Survey, Florida Caribbean Science Center. Available online at http://cars.er.usgs.gov/Region_4_Report/R4finalreport.pdf.
- Buddo, D. St. A., Steele, R. D., and D'Oyen, E. R. (2003). "Distribution of the invasive indo-Pacific green mussel, *Perna viridis*, in Kingston Harbour, Jamaica," *Bulletin of Marine Science* 73, 433-441.
- Carlton, J. T. (1985). "Transoceanic and intraoceanic dispersal of coastal marine organisms: The biology of ballast water," *Oceanography and Marine Biology: An Annual Review* 23, 313-374.
- Carlton, J. T. (2001). *Introduced species in U.S. coastal waters: Environmental impacts and management priorities*. Pew Oceans Commission, Arlington, VA. Available online at http://www.pewtrusts.org/pdf/env_oceans_species.pdf.
- Carlton, J. T., and Hodder, J. (1995). "Biogeography and dispersal of coastal marine organisms: Experimental studies on a replica of a 16th century sailing vessel," *Marine Biology* 121, 721-730.
- Carlton, J. T., and Ruckelshaus, M. H. (1997). "Nonindigenous marine invertebrates and algae." *Strangers in paradise. Impact and management of nonindigenous species in Florida*. D. Simberloff, C. Schmitz, and T. C. Brown, ed., Island Press, Washington, DC, 187-201.
- Carlton, J. T., Reid, D. M., and van Leeuwen, H. (1995). *Shipping Study. The role of shipping in the introduction of nonindigenous aquatic organisms to the coastal waters of the United States (other than the Great Lakes) and an analysis of control options*. Report No. CG-D-11-95, The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6.
- Clark, P. F., Rainbow, P. S., Robbins, R. S., Smith, B., Yeomans, W. E., Thomas, M., and Dobson, A. G. (1998). "The alien Chinese mitten crab, *Eriocheir sinensis* (Crustacea: Decapoda: Brachyura), in the Thames catchment," *Journal of the Marine Biological Association of the United Kingdom* 78, 1215-1221.
- Cohen, A. N., and Carlton, J. T. (1995). "Biological study. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta," A report for the United States Fish and Wildlife Service, Washington, DC and the National Sea Grant Program, Connecticut Sea Grant Publication PB96-166525. Available online at <http://www.anstaskforce.gov/sfinvade.htm>.
- Crooks, J. A. (1996). "The population ecology of an exotic mussel, *Musculista senhousia*, in a Southern California bay," *Estuaries* 19, 42-50.
- Crooks, J. A. (1998). "Habitat alteration and community-level effects of an exotic mussel, *Musculista senhousia*," *Marine Ecology Progress Series* 162, 137-152.
- Crooks, J. A., and Khim, H. S. (1999). "Architectural vs. biological effects of a habitat-altering, exotic mussel, *Musculista senhousia*," *Journal of Experimental Marine Biology and Ecology* 240, 53-75.
- Erlich, P. R. (1989). "Attributes of invaders and the invading processes: Vertebrates." Chapter 13, *Biological invasions: A global perspective*. J. A. Drake et al. (ed.), 1989 SCOPE. John Wiley and Sons, Ltd, 315-328. Available online at <http://www.icsu-scope.org/downloadpubs/scope37/scope37-ch13.pdf>.
- Federal Register. (1999). Executive Order 13112 of February 3, 1999—Invasive Species. Federal Register 64, No. 25. Available online at <http://www.invasivespecies.gov/laws/execorder.shtml>.
- Fuller, P. (2005a). *Phyllorhiza punctata*. Nonindigenous Aquatic Species Database, Gainesville, FL, <http://nas.er.usgs.gov/queries/FactSheet.asp?SpeciesID=1192>.

Fuller, P. (2005b). *Sphaeroma walkeri*. Nonindigenous Aquatic Species Database, Gainesville, FL, <http://nas.er.usgs.gov/queries/factsheet.asp?SpeciesID=1084>.

Gossett, L., and Lester, J. (2004). "Galveston Bay invasive species risk assessment final report," Galveston Bay Estuary Program, Galveston, TX. Available online at <http://galvbaydata.org/projects/invasive/invasive.html>.

Gulf States Marine Commission. (2003a) "*Perna viridis* (Linnaeus 1758). *Non-native aquatic species in the Gulf of Mexico and South Atlantic regions*. Available online at <http://nis.gsmfc.org/>.

Gulf States Marine Commission. (2003b) "*Perna perna* (Linnaeus 1758). *Non-native aquatic species in the Gulf of Mexico and South Atlantic regions*. Available online at <http://nis.gsmfc.org/>.

Hare, J. A., and Whitfield, P. E. (2003). *An integrated assessment of the introduction of Lionfish (Pterois volitans/miles complex) to the Western Atlantic Ocean*. National Atmospheric and Oceanographic Administration, National Ocean Service Technical Memorandum CCFHR 1.

Hartman, M. J., Stancyk, S E., and Lohrer, A. M. (2001). "An invasive crab, *Petrolisthes armatus*, as alternative prey in an oyster reef ecosystem." *16th Biennial Conference of the Estuarine Research Federation*, November 4-8, 2001. St. Petersburg Beach, FL. Available online at <http://erf.org/erf2001/>.

Hicks, D. W., and Tunnell, J. W., Jr. (1993). "Invasion of the south Texas coast by the edible brown mussel *Perna perna* (Linnaeus, 1758)," *Veliger* 36, 92-94.

Hicks, D. W., and Tunnell, J. W., Jr. (1995). "Ecological notes and patterns of dispersal in the recently introduced mussel, *Perna perna* (Linne 1758), in the Gulf of Mexico," *American Malacological Bulletin* 11, 203-206.

Highley, T. L. (1999). "Biodeterioration of wood." Chapter 13, *Wood handbook--Wood as an engineering material*. Gen. Tech. Rep. FPL-GTR-113, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI. Available online at <http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch13.pdf>.

Hoagland, K. E. (1983). "Life history characteristics and physiological tolerances of *Teredo bartschi*, a shipworm introduced into two temperate zone nuclear power plant effluents." Hemisphere Publishing Co., Miami Beach, FL, 609-622.

Hollebone, A. L., and Hay, M. E. (2003). "An invasive crab in the South Atlantic Bight; Friend or foe?" *Third International Conference on Bioinvasions*. March 16-19, 2003, La Jolla, CA. Available online at <http://massbay.mit.edu/exoticspecies/conferences/2003>.

Lavoie, D. M., Smith, L. D., and Ruiz, G. M. (1999). "The potential for intracoastal transfer of nonindigenous species in the ballast water of ships," *Estuarine, Coastal and Shelf Science* 48, 551-654.

Lohrer, A. M. (2001). "The threat of invasion in South Carolina estuaries: A focus of exotic decapod crabs." *16th Biennial Conference of the Estuarine Research Federation*, November 4-8, 2001. St. Petersburg Beach, FL. Available online at <http://erf.org/erf2001/>.

Louisiana Aquatic Invasive Species Taskforce. (2004). *State management plan for aquatic invasive species in Louisiana*. Center for Bioenvironmental Research at Tulane and Xavier Universities, New Orleans, LA. Available online at <http://is.cbr.tulane.edu/LouisianaAIS.html>.

Padilla, D. K., and Williams, S. L. (2004). "Beyond ballast water: Aquarium and ornamental trades as sources of invasive species in aquatic ecosystems," *Frontiers in Ecology and the Environment* 3, 131-138.

Ray, G. L. (2005). "Invasive animal species in marine and estuarine environments: Biology and ecology," Technical Report ERDC/EL TR-05-2, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

- Rehm, A., and Humm, H. J. (1973). "*Sphaeroma terebrans*: A threat to the mangroves of Southwestern Florida," *Science* 182, 173-174.
- Reutsch, T. B. H., and Williams, S. L. (1998). "Variable response of native eelgrass *Zostera marina* to a nonindigenous bivalve *Musculista senhousia*," *Oecologia* 113, 428-441.
- Ruiz, G. M., Fofonoff, P., Carlton, J. T., Wonham, M. J., and Hines, A. H. (2000). "Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases," *Annual Review in Ecology and Systematics* 2000, 481-531.
- Texas Parks and Wildlife. (2004). "Prohibited exotic species." Available online at <http://www.tpwd.state.tx.us/fish/infish/regulate/exotics.phtml>.
- Torchin, M. E., Lafferty, K. D., Dobson, A. P., McKensie, V. J., and Kuris, A. M. (2003). "Introduced species and their missing parasites," *Nature* 421, 628-630.
- U.S. Environmental Protection Agency (USEPA). (2000). "An initial survey of aquatic invasive species issues in the Gulf of Mexico region," Invasive Species Focus Team, Gulf of Mexico Program. EPA 855-R-00-003. Available online at <http://nis.gsmfc.org/>.
- U.S. Geological Survey (USGS). (2003). "South Florida restoration science forum website" (<http://sofia.usgs.gov/sfrsf/rooms/species/invasive/intro/>).
- U.S. Geological Survey (USGS). (2005). Nonindigenous Aquatic Species Database, Gainesville, FL. <http://nas.er.usgs.gov>.
- Veldhuizen, T., and Stanish, S. (2002). "Overview of the life history, distribution, abundance, and impacts of Chinese mitten crab *Eriocheir sinensis*." Appendix A, *A draft national management plan for the genus Eriocheir*. Aquatic Nuisance Species Task Force, February 2002, 37-5. Available online at <http://www.anstaskforce.gov/>.
- Weigle, S. M., Smith, L. D., Carlton, J. T., and Pederson, J. (2005). "Assessing the risk of introducing exotic species via the live marine species trade," *Conservation Biology* 19, 213-223.
- Williams, J. D., and Meffe, G. K. (1999). "Nonindigenous species." *Status and trends of the nation's biological resources*. U.S. Geological Service. Available online at <http://biology.usgs.gov/s+t/SNT/index.htm>.
- Wolfe, L. M. (2002). "Why alien invaders succeed: Support for the escape-from-enemy hypothesis," *American Naturalist* 160, 705-711.

NOTE: The contents of this technical note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products.

APPENDIX A: NIS LISTINGS BY STATE FOR THE GULF OF MEXICO

Species	Group	FL	AL	MS	LA	TX
<i>Drymonema dalmatina</i>	Scyphozoan	FL				
<i>Phyllorhiza punctata</i>	Scyphozoan	FL	AL		LA	
<i>Diadumene lineata</i>	Anemone	FL				
<i>Haliplanella lineata</i>	Anemone	FL				
<i>Argulus japonicus</i>	Copepod	FL				
<i>Centrophages typicus</i>	Copepod					TX
<i>Eurytemora affinis</i>	Copepod				LA	TX
<i>Balanus amphitrite</i>	Barnacle	FL				TX
<i>Balanus reticularis</i>	Barnacle	FL				
<i>Balanus trigonus</i>	Barnacle	FL				
<i>Chelura terebrans</i>	Amphipod	FL				
<i>Ligia exotica</i>	Isopod	FL				
<i>Sphaeroma terebrans</i>	Isopod	FL				
<i>Sphaeroma walkeri</i>	Isopod	FL				
<i>Zeuxo maledivensis</i>	Tanaid	FL				
<i>Callinectes bocourti</i>	Crab	FL	AL	MS		
<i>Charybdis helleri</i>	Crab	FL				
<i>Eriocheir sinensis</i>	Crab				LA	
<i>Petrolisthes armatus</i>	Crab	FL				
<i>Platychoirograpsus spectabilis</i>	Crab	FL				
<i>Rhithropanopeus herbstii</i>	Crab					TX
<i>Scylla serrata</i>	Crab	FL				
<i>Macrobrachium olfersi</i>	Shrimp	FL				
<i>Penaeus monodon</i>	Shrimp	FL				
<i>Penaeus stylirostris</i>	Shrimp	FL				
<i>Penaeus vannamei</i>	Shrimp	FL				TX
<i>Lyrodus medilobatus</i>	Bivalve	FL				
<i>Mytella charruana</i>	Bivalve	FL				
<i>Perna viridis</i>	Bivalve	FL				
<i>Perna perna</i>	Bivalve					TX
<i>Pinctada margaritifera</i>	Bivalve	FL				
<i>Rangia cuneata</i>	Bivalve	FL				
<i>Tridacna crocera</i>	Bivalve	FL				
<i>Tridacna maxima</i>	Bivalve	FL				
<i>Littorina littorea</i>	Gastropod	FL				
<i>Melanoides tuberculatus</i>	Gastropod	FL			LA	TX
<i>Myostella myosotis</i>	Gastropod	FL				
<i>Truncatella subcylindrica</i>	Gastropod	FL				
<i>Cuthona oerica</i>	Nudibranch	FL				
<i>Ercolania fuscovittata</i>	Nudibranch	FL				
<i>Boccardiella ligierica</i>	Polychaete	FL				
<i>Hydroides elegans</i>	Polychaete	FL				
<i>Polydora cornuta</i>	Polychaete	FL				

Species	Group	FL	AL	MS	LA	TX
<i>Sunanella sbogae</i>	Bryozoan	FL				
<i>Victorella pavidia</i>	Bryozoan	FL				
<i>Schizoporella unnicornis</i>	Ectoproct		AL			
<i>Botryllus schosseri</i>	Tunicate	FL				
<i>Styela plicata</i>	Tunicate	FL				
<i>Didemnum perlucidum</i>	Tunicate					TX
<i>Alosa aestivalis</i>	Fish					TX
<i>Alosa sapidissima</i>	Fish	FL	AL	MS	LA	TX
<i>Apeltes quadricus</i>	Fish		AL			
<i>Cromileptes altivelis</i>	Fish	FL				
<i>Cynscion nebulosa</i>	Fish					TX
<i>Dorosoma petenense</i>	Fish	FL	AL			TX
<i>Monopterus albus</i>	Fish	FL				
<i>Morone saxatilis</i>	Fish	FL		MS		TX
<i>Oncorhynchus kisutch</i>	Fish					TX
<i>Oncorhynchus tshawytscha</i>	Fish				LA	TX
<i>Pomacanthus annularis</i>	Fish	FL				
<i>Pomacanthus asfur</i>	Fish	FL				
<i>Pomacanthus imperator</i>	Fish	FL				
<i>Pomacanthus maculosus</i>	Fish	FL				
<i>Pomacanthus semicircularis</i>	Fish	FL				
<i>Pomacanthus xanthometopon</i>	Fish	FL				
<i>Pterois volitans</i>	Fish	FL				
<i>Rhinecanthus verrucosus</i>	Fish	FL				
<i>Salmo salar</i>	Fish			MS		TX
<i>Scatophagus argus</i>	Fish	FL				
<i>Strongylura marina</i>	Fish		AL			
<i>Zebrasoma desjardini</i>	Fish	FL				
<i>Zebrasoma flavescens</i>	Fish	FL				
<i>Zebrasoma veliferum</i>	Fish	FL				
<i>Zebrasoma xanthurum</i>	Fish	FL				