Aquatic Nuisance Species Report

ANS

An Update on Sea Grant
Research and Outreach Projects 2000

Sea Grant

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This report was prepared by the Ohio Sea Grant College Program for the National Sea Grant College Program. This document is a continuation of earlier research and outreach reports: *Showing Our Mussel* (TB-026), *Zebra Mussel Report: An Update of Research and Outreach* (TB-028) and *Zebra Mussel Update: A 1995 Report of Research* (TB-030). These previous reports document Sea Grant's research and outreach projects related to zebra mussels and Eurasian ruffe (1995 report) and are available on the Ohio Sea Grant web site at ***www.sg.ohio-state.edu/publications/topics/fts-nuisance.html***.

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Whether they're called **aquatic nuisance species**, **exotic species**, or **nonindigenous species**, all of these terms describe the same problem — non-native plants and animals that are invading U.S. waterways. In their own native waters aquatic nuisance species (ANS) may be harmless, but when transplanted to other areas, they compete with native animals and plants for food and habitat, taking over the area. ANS are causing significant ecological and economic problems throughout many areas of the U.S. Species such as zebra mussels, round gobies, Japanese shore crabs, green crabs, Eurasian watermilfoil, purple loosestrife, and Asian clams — to name a few — have been introduced into waterbodies in many areas of the country. Once established, these species have the potential to displace native species, drastically alter aquatic ecosystems, and interfere with business and recreational pursuits.

Most of the time ANS are transported by human activities such as the dumping of ballast water from transoceanic ships, transporting species via recreational boats, and emptying unwanted bait into water. Some species, such as the sea lamprey, entered into the Great Lakes on their own via canal systems. The story of the zebra mussel's invasion of the Great Lakes is now legendary. *Dreissena polymorpha* is presumed to have entered Lake St. Clair in 1985 or '86, having been transported there by transoceanic ships that released contaminated ballast water taken from foreign ports. In 1988 the mussel was officially identified and reported in Lake Erie. Today, according to the Sea Grant National Aquatic Nuisance Species Clearinghouse, the zebra mussel has spread outside the Great Lakes to other states and many inland waters (see distribution map on page 56).

This report includes projects that began on or before March 1998, but does *not* include projects listed in previous editions of this report (1988-1995). However, projects that began during the last report phase and continued past that time frame are included in this update, as well as earlier projects that were not listed in previous reports. As this report went to press, information about Sea Grant ANS projects that began in fiscal years 1999 and 2000 became available. A list of these projects is included in the Appendices beginning on page 219.

Federal Initiatives

In response to the invasion of the Great Lakes by the zebra mussel in the mid 1980s, Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act in 1990 (Public Law 101-646). In 1996 the Act was reauthorized as the National Invasive Species Act (NISA), and included an amendment that called for the development of national voluntary guidelines to prevent the spread of ANS through boating and fishing, and other recreational activities.

On February 3, 1999, President Clinton signed Executive Order 13112 which directed federal agencies to "expand and coordinate their efforts to combat a serious environmental threat: the introduction and spread of plants and animals not native to the United States." The Order created an Invasive Species Council which works in cooperation with a variety of groups including states, tribes, scientists, universities, environmental groups, farm organizations, shipping interests, and the business community.

Sea Grant Aquatic Nuisance Species Research and Outreach Funding Support

Fiscal Year	Total Funds Expended (in millions)	Research	Outreach
1991	$ 1.8	$ 1.3	$ 0.5
1992	$ 2.9	$ 1.9	$ 1.0
1993	$ 2.8	$ 1.0	$ 1.0
1994	$ 2.8	$ 1.8	$ 1.0
1995	$ 2.8	$ 1.5	$ 1.3
1996	$ 3.8	$ 2.4	$ 1.4
1997[1]	$ 4.1	$ 2.8	$ 1.3
1998	$ 1.9	$ 1.7	$ 0.2
1999	$ 3.3	$ 2.4	$ 0.9
2000	$ 3.1	$ 2.2	$ 0.9

[1] Approximately $1.1 million of the 1997 funds were pre-awarded to support 1998 project activities.

Sea Grant's Role

A national program created in 1966, Sea Grant uses research, outreach, and education to make invaluable contributions to the nation in promoting sustainable development in our coastal resources. The National Sea Grant College Program is part of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Sea Grant has been a national leader, responding to the ANS problem with research and outreach projects that have slowed the spread and reduced the ecologic and economic impact of ANS.

Sea Grant researchers are actively working on projects that address problems caused by at least 22 different ANS species (as documented in this report). Sea Grant outreach projects such as the National Aquatic Nuisance Species Clearinghouse, Nationwide Zebra Mussel Training Initiative, Sea Grant Nonindigenous Species site (SGNIS), and others have impacted hundreds of thousands of people in this country and abroad by providing current research results and educational information to inform, combat, and prevent the spread of ANS.

Sea Grant funding for research and outreach projects on aquatic nuisance species is distributed competitively through a national call for proposals with an external peer-review process and by individual Sea Grant programs.

This report documents the results of Sea Grant-funded research and outreach projects on aquatic nuisance species and the possible control or mitigation of these species. Results of Sea Grant research are transferred to the public in the form of outreach programs and materials. This report is a testimony to Sea Grant's efforts to combat aquatic nuisance species.

Contents

Research and Outreach Projects

Sea Grant

All projects are listed in chronological order by starting date.

Research project page numbers appear in black; outreach project page numbers are in blue.

See the Project Index on page 223 for a list of all projects organized by categories.

Contents

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Program Highlights

Only programs that are actively engaged in ANS projects are included in this report.

Contents

Appendices

The Prevention Message

Through Sea Grant research and outreach projects, guidelines have been established to prevent the spread of ANS for any recreational activity associated with water. The following are general preventative guidelines that apply to most recreational activities occurring in marine and inland waters.

- Always thoroughly inspect equipment (boats, trailers, SCUBA gear, anchors, lures) for attached ANS or aquatic vegetation before transporting.
- Always drain water from boat, livewells, and bilges before leaving any water access area.
- Always clean equipment that has been in infested waters before using it in other waters.
- Never use aquatic nuisance species for bait.
- Never transport aquatic nuisance species from one area to another.
- Never release animals or plants (aquarium species, bait, water garden plants) into the wild.
- Never dump live bait or fish into any water area
- Never dip a bait bucket into a water body if it contains water from another lake, stream, river, or other water source.

Prevention methods for the commercial shipping industry are being developed through ballast water projects, as described on page 106.

Research and Outreach Projects

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Research and Outreach Projects on Aquatic Nuisance Species

Sea Grant has funded research and outreach projects related to aquatic nuisance species since 1988. Early projects focused solely on zebra mussels in the Great Lakes region. However because more nonindigenous species have appeared in U.S. waterways, projects now encompass 22 species of flora and fauna and are being conducted by Sea Grant programs in every region. Sea Grant has also funded ballast water initiatives to prevent further introductions.

The following section is organized by species. For each species, research projects appear first and are followed by outreach projects (not all species include both research and outreach projects). Research projects are organized by the six categories used by the ANS Task Force that were originally developed by the Great Lakes ANS Panel in 1990. Outreach projects are organized by content area within the Zebra Mussel and Multi-Species Projects sections.

Projects appear in chronological order by starting date; shared dates are alphabetized by project title. This report includes a description of projects that began on or before March 1998, but does *not* include projects listed in previous editions of this report (1988-1995). However, projects that began during the last report phase and continued past that time frame are included in this update, as well as earlier projects that were not listed in previous reports. As this report went to press, information about Sea Grant ANS projects that began in fiscal years 1999 and 2000 became available. A list of these projects is included in the Appendices beginning on page 219.

For each project, participating Sea Grant programs were requested to submit the following information:

- project title;
- project number (if applicable);
- starting and ending dates;
- principal investigators and affiliation;
- project description, research publications / outreach products; and
- key word list.

The research articles and outreach products included in this report were comprehensive at the time of publication. For information about additional journal or conference proceeding articles, or other information about the studies listed here, contact the sponsoring Sea Grant program. In addition, information about other Sea Grant related publications can be found on the Sea Grant Nonindigenous Species site (SGNIS) at ***www.sgnis.org*** and on the Sea Grant National Aquatic Nuisance Species Clearinghouse (NANSC) site at ***www.cce.cornell.edu/aquaticinvaders/***.

Research Categories

In 1990 the U.S. Great Lakes Nonindigenous Species Coordinating Committee was formed to foster cooperation and collaboration and to develop a coordinated research plan among the six Great Lakes Sea Grant programs, the Great Lakes Environmental Research Laboratory (GLERL) of NOAA, the National Fisheries Research Center-Great Lakes of the U.S. Fish and Wildlife Service (now the U. S. Geological Survey), the Cooperative Institute for Limnology and Ecosystems Research (CILER), the U.S. Environmental Protection Agency, the Great Lakes Commission, the Great Lakes Fishery Commission, the U.S. Coast Guard, and the U.S. Army Corps of Engineers. In 1991, this committee expanded to become the Great Lakes Panel on Exotic Species of the Aquatic Nuisance Species Task Force. Although the research categories listed on the following page were originally developed for zebra mussels, they have become the standard for all ANS research.

Biology and Life History

To predict an ecosystem's response to an invading species, scientists need to understand its life history. Basic biological research into population dynamics, genetics, physiology, behavior, and parasites and diseases of the invader may lead to the discovery of ecologically safe, effective, and inexpensive controls. Further, research on the ecological and environmental tolerances of aquatic nuisance species answers important questions about the geographic limits of their infestation and which native species and habitats are most likely to be affected.

Effects on Ecosystems

Any new organism introduced into an ecosystem can alter or disrupt existing relationships and environmental processes. The invading species can significantly affect populations that are important components of the existing food web, ultimately leading to either overpopulation or the demise of other species. Therefore, it is a high priority to identify and evaluate the effects of an invader at each stage of its life history. Such information helps natural resource managers determine how to minimize the impacts invading organisms have on established biota and habitats.

Socio-Economic Analysis

Invading organisms may introduce disease, concentrate pollutants, contaminate drinking water, or otherwise affect human health. Invading species may also be used as food for domestic animals or fertilizer for gardens and crops. Research in this area must also examine how invading species affect sport, commercial, and tribal fishing industries, the recreation and tourism industry, the shipping and navigation industry, and municipal and industrial water users. These research results become the foundation for sound science-based policy and environmental law, and for useful public education and outreach projects.

Control and Mitigation

Temporary measures may mitigate the effects of invading species, but effective control requires long-term research. Control of aquatic nuisance species may be physical (redesigning water intakes, scraping, filtering), chemical (biocides, antifoulants), biological (parasites, predators), or physicochemical (heat, salinity, pH). To develop selective, effective controls that are ecologically responsible, researchers must determine an invader's physical, chemical, and biological requirements and its physiology, genetic make-up, and behavior.

Preventing New Introductions

Once established in an open aquatic system, most aquatic nuisance species prove impossible to eliminate. While they may eventually be controlled, it is usually expensive, and frequently they have already seriously disturbed or destroyed the ecosystem. Therefore, the prevention of unintended introductions is paramount.

Reducing the Spread of Established Populations

Most aquatic nuisance species are transported and spread by human activities. Scientists may then predict the spread of an invader by analyzing what it requires and can tolerate in its environment and by its dispersal mechanisms. However, dispersal mechanisms and tolerable habitats are usually discovered only as an organism extends its range. Therefore swift action is needed to develop safeguards and international protocols in order to prevent and/or slow the spread of invaders to uninfested areas.

Outreach Categories

Sea Grant outreach projects involve a talented group of extension, communication, and education specialists working together to inform and educate diverse audiences about aquatic nuisance species issues. A network of extension professionals takes ANS research results out of the laboratory and into the field, working with coastal businesses, fisheries, and others to prevent the spread of nonindigenous species. A dedicated corps of communication specialists builds public understanding of ANS issues for informed decision-making. Sea Grant educators bring ANS curricula into schools, using innovative materials to teach students about the problems and solutions needed to address aquatic nuisance species.

Outreach products related to these activities take many forms: newsletters, fact sheets, pamphlets, fliers, curriculum materials, books, reports, posters, displays, information cards, radio and video programs, compact disks, and web sites. Other outreach activities include organizing conferences and producing proceedings, making workshop presentations, conducting surveys, developing monitoring programs, and establishing ANS information centers.

The majority of outreach projects included in this report appear in two sections: Zebra Mussel Outreach and Multi-Species Outreach. Because there are a large number of projects contained in these particular sections, they are organized by the following categories:

Zebra Mussel Outreach Section

- Conferences
- Curriculum Projects
- Gulf of Mexico Region
- Programs for Inland Water Users
- National Zebra Mussel Information Clearinghouse
- Zebra Mussel Training Initiative
- Zebra Mussel Update
- General Zebra Mussel Projects

Multi-Species Projects Outreach Section

- ANS Information Centers
- Boater Surveys
- Exotic Species Day Camp
- Graphics Library
- HACCP Model and ANS
- Sea Grant Nonindigenous Species Site (SGNIS)
- General ANS Projects

Jeffrey Reutter

A Note about Web Sites

Most Sea Grant programs now have ANS information as part of their web sites. ANS web pages that were developed as part of an outreach project are included in the outreach sections. For other on-line ANS resources, access the web pages for the programs in your area (see Inside Back Cover). A "Web of Webs" (WOW) project is being coordinated by the Sea Grant Nonindigenous Species (SGNIS) site. When completed, the WOW site will be a directory to facilitate access to all Sea Grant ANS web pages: *www.sgnis.org/wow.*

Fauna

Alewife, *Alosa pseudoharengus*
Ascidian, *Ciona savignyi*
Asian Copepod, *Pseudodiaptomus inopinus*
Asian Mussel, *Musculista senhousia*
Channeled Apple Snail, *Pomacea canaliculata*
Brown Mussel, *Perna perna*
Eurasian Ruffe, *Gymnocephalus cernuus*
European Green Crab, *Carcinus maenas*
Japanese Shore Crab, *Hemigrapsus sanguineus*
Rapa Whelk, *Rapana venosa*
Round Goby, *Neogobius melanostomus*
Rusty Crayfish, *Orconectes rusticus*
Sabellid Worm, *Terebrasabella heterouncinata*
Sea Lamprey, *Petromyzon marinus*
Spiny Waterflea, *Bythotrephes cederstroemi*
Zebra Mussel, *Dreissena polymorpha*

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ANS

Fauna

For each research and outreach category, projects appear in chronological order by starting date; shared dates are alphabetized by project title. See pages 11 and 12 for a list of project categories.

Brown mussel *(Perna perna)*

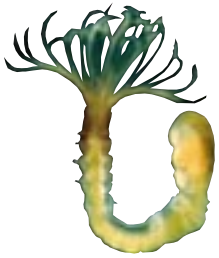
Round goby *(Neogobius melanostomus)*

Channeled apple snail *(Pomacea canaliculata)*

Rusty crayfish *(Orconectes rusticus)*

Alewife *(Alosa pseudoharengus)*

Eurasian ruffe *(Gymnocephalus cernuus)*



Sabellid worm *(Terebrasabella heterouncinata)*

Ascidian *(Ciona savignyi)*

European green crab *(Carcinus maenas)*

Sea lamprey *(Petromyzon marinus)*

Asian copepod *(Pseudodiaptomus inopinus)*

Japanese shore crab *(Hemigrapsus sanguineus)*

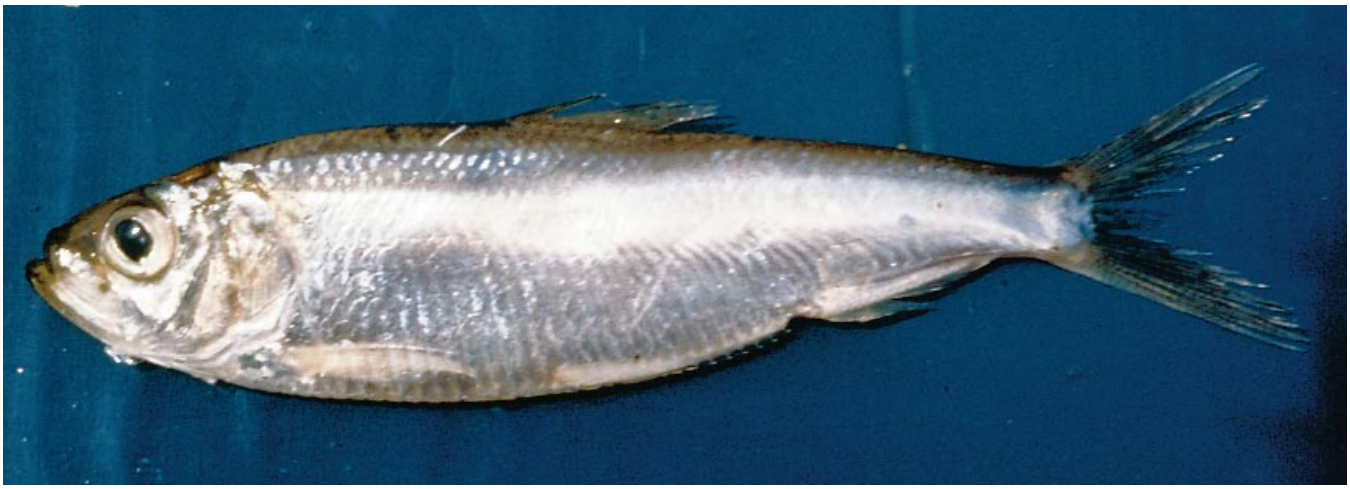
Spiny waterflea *(Bythotrephes cederstroemi)*

Asian mussel *(Musculista senhousia)*

Rapa whelk *(Rapana venosa)*

Zebra mussel *(Dreissena polymorpha)*

Alewife *(Alosa pseudoharengus)*



David Jude

Alewife are native to the Atlantic coast from Labrador to South Carolina. They have invaded the Great Lakes and several other inland states. This small 6-inch fish, possibly native to Lake Ontario, spread to the Great Lakes via the Welland Canal. The species was first reported in Lake Erie in 1931, Lake Huron in 1933, Lake Michigan in 1949, and Lake Superior in 1954. In the Great Lakes the alewife has caused reductions in zooplankton populations and declines of native fish such as whitefish, lake herring, and perch.

Effects on Ecosystems

Key Words
alewife
ecological interactions
nonindigenous

February 1997 – January 1999

The Role of Embayments and Inshore Areas of Lake Ontario as Nursery Grounds for Young-of-Year Alewife and Other Species

New York Sea Grant (Project R / FBM-9)
Lars C. Rudstam and Edward Mills, *Cornell Biological Field Station*
Cliff Schneider, *New York State Dept. of Environmental Conservation*
Ora Johannsson, *Canada Center for Inland Waters*
Robert O'Gorman, *U.S. Geological Survey Biological Resources Division*
Sandra Lary, *U.S. Fish & Wildlife Service*

Presuming that the coastal embayments and inshore areas of Lake Ontario are important nursery grounds for Young-of-Year (YOY) alewife and other fish species, this research emphasized the importance of being aware of the relationship between zooplankton production and fish production in these areas. This research will help management agencies designate appropriate locations for monitoring zooplankton in Lake Ontario and will provide basic information for the continuing efforts to model the dynamics of the alewife populations in the lake.

(see Alewife-related project on page 54)

Alewife *(Alosa pseudoharengus)*

Ascidian *(Ciona savignyi)*

Charles Lambert

Ascidians, or tunicates, also called sea squirts, are invertebrates found in marine environments. Some species form colonies while others are solitary. Ascidians go through a free swimming larval stage before settling on the substrate and were most likely introduced to U.S. waters from the ballast water of ocean-going vessels. Potential impacts include competition with native species for suitable substrate and effects on organisms to which they attach. An example of an introduced ascidian is *Ciona savigny*, which can grow up to 4 inches in southern California waters. This species was introduced into Newport Harbor, California, in the 1920s, where it went unnoticed until 1933. By 1949, it was one of the two dominant ascidians in the bay and has replaced the native solitary species.

Research

Biology and Life History

Key Words
ascidians
nonindigenous
sea squirts
tunicates

October 1996 – September 1998

The Introduction of Nonindigenous Ascidian Species into Southern California Harbors and Marinas

California Sea Grant (Project R/CZ-135)
Charles Lambert and Gretchen Lambert, *California State University - Fullerton*

The project surveyed southern California harbors and marinas for nonindigenous ascidians, *Ciona savignyi* and *Styela clava*. It tested temperature and salinity tolerances of the species, and determined whether abundant numbers produce pharmacologically important compounds.

Publications

Byrd, J. 1998. *Mechanisms of the block to hybridization between the congeneric ascidians* Ciona intestinalis *and* Ciona savignyi. M.S. thesis. Department of Biological Science, California State University, Fullerton.

Hirose, E., G. Lambert, T. Kusakabe, and T. Nishikawa. 1997. Tunic cuticular protrusions in ascidians (Chordata, Tunicata): A perspective of their character-state distribution. *Zoological Science* (Tokyo), 14(4):683-689.

Lambert, C.C., and G. Lambert. 1998. Nonindigenous ascidians in southern California harbors and marinas. *Marine Biology*, 130:675-688.

Ascidian *(Ciona savignyi)*

Asian Copepod *(Pseudodiaptomus inopinus)*

Jeff Cordell

Copepods are tiny crustaceans (about 1/8-inch in length) found in marine, estuarine, and freshwater habitats. Because of their abundance and availability, they form a fundamental link in aquatic food chains by serving as a food source for other invertebrates and small fish, including commercially important fishes. The Asian copepod was discovered in the Pacific Northwest in 1990 and was likely introduced through ballast water discharge. It is now abundant in many estuaries between southern Oregon and central Washington. The full impact of this copepod on native species in not yet known, but it has the potential to alter estuarine food webs that are important to juvenile salmon.

Research

Effects on Ecosystems

Key Words
Asian copepod
estuarine
invasive species
trophic ecology
zooplankton

February 1998 – January 2000

Effects of the Invasive Asian Copepod *(Pseudodiaptomus inopinus)* on Pacific Northwest Estuaries

Washington Sea Grant (Project R/ES-30)
Bruce Frost, Jeffrey Cordell, and Stephen Bollens, *University of Washington*

Pseudodiaptomus inopinus is one of several species of ballast water-introduced Asian copepods (small water-column dwelling crustaceans) that have recently become established in North American estuaries on the western coast. Biological surveys conducted in 1979-80, 1991-92 and 1996 have found that this copepod has become established and abundant in the Columbia River and many smaller coastal estuaries between southern Washington and southern Oregon. The objective of this project was to evaluate the extent and ecological effects of the invasion of the Asian calanoid copepod *Pseudodiaptomus inopinus* in Pacific Northwest estuaries. This study provided valuable new information about (1) the geographical spread of the invasion, (2) seasonal changes in the relative abundance of *P. inopinus* and other assemblage members, and (3) the role of *P. inopinus* in estuarine food webs, including potential effects on juvenile salmon and other commercially important fish and invertebrates. Initial results indicate that although the introduced copepod is consumed by several other types of invertebrates, its reproductive timing precludes it from being available as prey for juvenile salmon.

Publication

Cordell, J.R. 1998. Invasive marine organisms: Asian copepods in Pacific Northwest estuaries. In S. Redman (ed.) *Puget Sound Notes, Puget Sound Water Quality Action Team,* 1:1-4. Washington Sea Grant Publication WSG-TA-00-26.

Asian copepod *(Pseudodiaptomus inopinus)*

Asian Mussel *(Musculista senhousia)*

Jeff Crooks

Dense beds of Asian mussels (raised areas) on a San Diego mud flat.

The Asian mussel is a mollusk that colonizes sand flats, mud flats, marsh channels, and seagrass beds in intertidal and shallow subtidal shore zones. It is found along the California coast and in parts of Europe. This species was first introduced to the Pacific coastline in the 1920s from the ballast water of transoceanic vessels. The mussel is now found from Puget Sound to Baja California, Mexico. The mussels form dense mats bound by byssal threads, pseudofeces, and sediment. Its presence displaces larger, filter feeding clams and mussels, while enhancing populations of small crustaceans and snails.

Jeff Crooks

Research

Effects on Ecosystem

Key Words
Asian mussel
ecological interactions
wetlands

March 1998 – February 2000

Contrasting Effects of Ecosystem Alteration by Two Exotic Wetland Invertebrates

California Sea Grant (Project R/CZ-150)
Lisa Levin, *University of California - San Diego*

This project examined the modification of the physical environment in California bays by two non-native species. The impact of the isopod, *Sphaeroma quoyanum*, and the non-native mussel, *Musculista senhousia*, was investigated.

Publications

Crooks, J.A. 1998. *The effects of the introduced mussel,* Musculista senhousia, *and other anthropogenic agents on benthic ecosystems of Mission Bay, San Diego.* Ph.D. thesis, University of California, San Diego, Scripps Institution of Oceanography, La Jolla, California.

Crooks, J.A. 1999. Life forms from beyond our shores are invading. *San Diego Union Tribune* (January 27, 1999).

Control and Mitigation

Key Words
Asian mussel
nonindigenous

September 1997 – August 1999

Settlement, Survival, Growth, and Reproduction of the Nonindigenous Mussel (*Musculista senhousia*): Effects of Eelgrass

California Sea Grant (Project R/CZ-149)
Susan Williams and Thomas Ebert, *San Diego State University*

This project tested the hypothesis that eelgrass controls the nonindigenous mussel, *Musculista senhousia* by indirectly limiting its phytoplankton food supply. The results will aid regulatory and advisory agencies and private environmental practitioners in determining effective eelgrass planting strategies and setting permit requirements.

Publications

Reusch, T.B.H. and S.L. Williams. 1998. Variable responses of native eelgrass *Zostera marina* to a nonindigenous bivalve *Musculista senhousia. Oecologia,* 113:428-441.

Reusch, T.B.H. and S.L. Williams. 1999. Macrophyte canopy structure and the success of an invasive marine bivalve. *Oikos,* 84:398-416.

Asian mussel *(Musculista senhousia)*

Brown Mussel *(Perna perna)*

David Hicks

The brown mussel was first reported in the Gulf of Mexico in 1990 on the Port Aransas Jetty in Texas. Thought to have been introduced to this region by ballast water released from Venezuelan ships, within four years this mollusk has colonized a distance of 800 miles from the mouth of the Colorado River all the way down to Veracruz, Mexico. The mussels have colonized jetties, navigation buoys, petroleum platforms and other hard substrates along the Texas coast. The mussels are expected to move farther east to the Yucatan penninsula and farther north along the Gulf of Mexico coast. Unlike the zebra mussel's assault on the Great Lakes, so far the brown mussel has been much more elusive, content to increase its population and specimen size with little consequence. Yet, this mussel is capable of causing damage. The expansion and effects of this mussel are currently being monitored in Texas.

Control and Mitigation

Key Words
ballast water
biological control
bivalve
brown mussel
byssal attachment
colonization
dispersal mechanism
nonindigenous
prevention

September 1993 – February 1998

Physiological Tolerances and Nonchemical Control Strategies for the Recently Introduced Macrofouling Brown Mussel *(Perna perna)*

Texas Sea Grant (Project R / ES-23)
John W. Tunnell, Jr., *Texas A&M University - Corpus Christi*

The brown mussel is a known biofouler of raw water-using facilities. The objectives of this project were to detail the mussel's physiological tolerances to the major physio-chemical parameters likely to influence its colonization of North American coastal waters, predict its potential spread in North America, and provide data on which nonchemical control technologies for mussel macrofouling in raw water systems could be based. The data suggest *Perna perna* could eventually inhabit coastal waters from southern Texas to Cape Hatteras, N.C. Models developed in the project can be used in habitat risk assessment, and to design efficacious nonchemical treatments for mussel macrofouling.

Publications

Hicks, D.W., and J.W. Tunnell. 1995. Ecological notes and patterns of dispersal in the recently introduced mussel, *Perna perna* (Linnaeus, 1758), in the Gulf of Mexico. *American Malacological Bulletin*, 11(2):203-206.

Holland, B.S. 1997. Field notes on the southward dispersal of the exotic brown mussel, *Perna perna*, in the western Gulf of Mexico. *Texas Conchologist*, 34(1):1-9.

Holland, B.S., D.S. Gallagher, D.W. Hicks, and S.K. Davis. 1999. Cytotaxonomic verification of a non-indigenous marine mussel in the Gulf of Mexico. *The Veliger*, 42(3):280-282.

Magee, J. 1997. Mussels throwing painless punches at the Texas coast - so far. *Bays Foundation News*, 3(1):1-7.

Maupin, M. 1995. Invasion of the bivalves. *Texas Parks and Wildlife Magazine* (August) pp. 36-37.

McGrath, M. 1997. Monitoring the range expansion of the introduced brown mussel, *Perna perna* (Linnaeus, 1758) along the Texas coast and into bays and inlets. *Texas Conchologist*, 34(1):29.

McGrath, M.E., L.J. Hyde, and J.W. Tunnell. 1998. Occurrence and distribution of the invasive brown mussel, *Perna perna* (Linnaeus, 1758), in Texas coastal waters. Texas Sea Grant Publication TAMU-CC-9801-CCS, Texas A&M University - Corpus Christi.

Serota, T.D., and L.S. Jacks. 1995. Edible brown mussels in coastal waters of Texas. *Aquatic Nuisance Species Digest*, 1(1):6-10.

Brown mussel *(Perna perna)*

Eurasian Ruffe *(Gymnocephalus cernuus)*

Gary Cholwek

The Eurasian ruffe is a small but aggressive fish averaging 4 to 6 inches in length. Native to fresh and brackish waters in portions of Eurasia, it was introduced into Lake Superior's Duluth / Superior harbor area in the mid-1980s in the ballast water of a transoceanic ship. The ruffe's rapid population growth, ability to eat a variety of food, and the lack of native predators create the potential to displace other species in newly invaded areas. The Eurasian ruffe is considered a threat to commercial and sport fishing and has the potential to seriously disrupt the delicate predator-prey balance vital to sustaining a healthy fishery.

Research

Biology and Life History

Key Words
basic biology
colonization
Eurasian ruffe
histology
impact
nonindigenous
population dynamics
reproduction

May 1990 – November 1995

Preliminary Evaluation of Ruffe Reproduction Capabilities in Lake Superior by Histological Examination of Ovaries

Minnesota Sea Grant
Richard Leino, *University of Minnesota - Duluth*

This research project attempted to determine the time, duration, and frequency of spawning by ruffe in the St. Louis River estuary in 1994. Results suggest that different age groups of ruffe spawn somewhat in succession, with older fish ovulating first. As the season progressed, earlier spawners were capable of repeat spawning, probably two or three times before the end of the season. Implications are that in warmer parts of the Great Lakes spawning may be more frequent and there may be greater contributions to spawning by younger ruffe.

Publications

Leino, R.L. and J.H. McCormick. 1997. Reproductive characteristics of ruffe, *Gymnocephalus cernuus*, in the St. Louis river estuary on western Lake Superior: A histological examination of the ovaries over one annual cycle. *Canadian Journal of Fisheries and Aquatic Science*, 54:256-263.

Biology and Life History

Key Words
basic biology
benthos
colonization
diet
dispersal mechanism
ecological interactions
Eurasian ruffe
impact life history
nonindigenous
population dynamics
reproduction

October 1994 – May 1995

Invertebrate Macrobenthos of the St. Louis River: Food Available for Benthophagus Fishes Reproduction

Reproduction and Early Life History of Ruffe *(Gymnocephalus cernuus)* in the St. Louis River, a Lake Superior Tributary

Minnesota Sea Grant
Michael E. McDonald, *University of Minnesota*

The first research project attempted to characterize the benthos community of the St. Louis River estuary and compare benthos available for forage and for those eaten by ruffe. The second related project examined possible interactions among the early life stages of ruffe and other North American percids. Results indicate that the greatest chance of ballast water transport of pelagic larval ruffe is between mid May and July, which will assist fishery managers in developing control methods and ballast water management to prevent the spread of ruffe.

Publications

Brown, W.P., J.H. Selgeby, and H.L. Collins. 1998. Reproduction and early life history of ruffe (*Gymnocephalus cernuus*) in the St. Louis River, a Lake Superior tributary. *Journal of Great Lakes Research*, 24(2):217-227.

June 1995 – May 1998

Geographic Variation and Colonization Patterns of Ruffe *(Gymnocephalus cernuus)* in the Great Lakes: Otolith Signatures and DNA Divergence

Minnesota Sea Grant (Project R / F-30)
George R. Spangler, *University of Minnesota*

Ohio Sea Grant (Project R / NIS-1)
Carol A. Stepien, *Case Western Reserve University*

The research determined that genetic differences between ruffe from the Danube River in Slovakia and ruffe from the Baltic Region of Europe may be large enough to suggest they are separate species. The population from the Danube River appears genetically identical to the North American exotic population. The North American ruffe infestation most likely came from the Danube River region, rather than the St. Petersburg region as previously thought.

Publications

Stepien, C.A., A.K. Dillon, and M.D. Chandler. 1998. Genetic identity, phylogeography, and systematic of ruffe *Gymnocephalus* in North American Great Lakes and Eurasia. *Journal of Great Lakes Research*, 24(2):361-378.

Biology and Life History

Key Words
basic biology
colonization
DNA
dispersal mechanism
Eurasian ruffe
genetics

June 1995 – May 1998

Identification of the Ruffe Oocyte Maturation-Inducing Substance and Characterization of its Receptor

Minnesota Sea Grant (Project R / F-29)
Patrick K. Schoff, Peter W. Sorenson and John Holy, *University of Minnesota - Duluth*

Texas Sea Grant (Project R / F-66)
Peter Thomas, *University of Texas - Austin*

Based on a panel of antibodies developed from ruffe sperm and testis, researchers identified antigens located on the surface of the ruffe sperm, which are likely involved in sperm-egg binding and fertilization.

Publications

Flynn, K., P. Schoff, and J. Holy. 1998. Localization of ruffe testicular antigens by a panel of antibodies. *Journal of Great Lakes Research*, 24(2):379-382.

Biology and Life History

Key Words
antibodies
basic biology
biological control
Eurasian ruffe
nonindigenous
sperm
testis

Eurasian ruffe *(Gymnocephalus cernuus)*

Research

Biology and Life History

Key Words
Eurasian ruffe
exotic
fish
genetics
population structure

September 1997 – August 1998

Genetic Relationships of Ruffe Populations in North America and Eurasia Based on DNA Sequences

Ohio Sea Grant (Project R / NIS-5)
Carol A. Stepien, *Case Western Reserve University*

The purpose of this investigation was to compare DNA sequences of ruffe from the Great Lakes with Eurasian populations in order to assess relative levels of intraspecific variability and to test for distinguishing markers among areas of its present distribution. Specifically this research characterized the genetic structure of the initial ruffe population in the Great Lakes and established groundwork for continued monitoring, provided baseline data for genetic identification of potential future colonization, and determined whether samples from Eurasian regions and North America were genetically similar or different.

Publications

Faber, J.E. and C.A. Stepien. 1997. The utility of mitochondrial DNA control region sequences for analyzing phylogenetic relationships among populations, species, and genera of the percidae. In Kocher, T.D. and C.A. Stepien (eds.) *Molecular Systematics of Fishes*, pp. 129-143. San Diego:Academic Press.

Stepien, C.A., A.K. Dillon, and M.D. Chandler. 1998. Genetic identity, phylogeography, and systematics of ruffe *Gymnocephalus* in the North American Great Lakes and Eurasia. *Journal of Great Lakes Research*, 24(2):361-378.

Stepien, C.A. and T.D. Kocher. 1997. Molecules and morphology in studies of fish evolution. In Kocher, T.D. and C.A. Stepien (eds.) *Molecular Systematics of Fishes*, pp. 1-11. San Diego:Academic Press.

Biology and Life History

Key Words
Eurasian ruffe
exotic
genetic engineering
nonindigenous
morphology

September 1997 – August 1998

Systematic Relationships Among North American Ruffe *(Gymnocephalus cernuus)*, Eurasian Populations, and Related Species Based on Mitochondrial DNA Sequences and Morphology

Ohio Sea Grant (Project R / NIS-109-SG)
Carol A. Stepien and Alison Dillon, *Case Western Reserve University*

Since the Eurasian ruffe's *(Gymnolcephalus cernuus)* introduction to the Lake Superior / St. Louis Harbor region in the mid-1980s, the ruffe population has spread rapidly east to Lake Huron to as far north as Ontario, Canada. This project compared DNA sequences of the ruffe from several Eurasian and North American population areas in order to identify and distinguish genetic types (and possible cryptic species) of *G. cernuus*. Meristic and morphological data were used to compare divergence of genetic types. These data were then compared with the other three members of the genus *Gymnocephalus* (*G. baloni*, *G. schraetser*, and *G. acerina*) in order to test their phylogenetic relationships and gauge species level separations.

Publications

Stepien, C.A., A.K. Dillon, and M.D. Chandler. 1998. Genetic identity, phylogeography, and systematics of ruffe *Gymnocephalus* in the North American Great Lakes and Eurasia. *Journal of Great Lakes Research*, 24(2):361-378.

June 1995 – May 1998

Potential Impacts of Invading Ruffe *(Gymnocephalus cernuus)* on Benthic and Pelagic Ecosystems of the Great Lakes

Minnesota Sea Grant (Project R / F-28)
Carl Richards, Yosef Cohen and Raymond M. Newman, *University of Minnesota - Duluth*
Edward S. Rutherford, *University of Michigan*

Illinois-Indiana Sea Grant (Project R / EC-95-40.1)
Gary A. Lamberti and David M. Lodge, *University of Notre Dame*
Martin B. Berg, *University of Loyola*

Ohio Sea Grant (Project R / NIS-2)
Michael C. Miller, *University of Cincinnati*

This research identified the relationship between ruffe feeding and benthic communities, determined the interactions among native Great Lakes fishes, examined the impacts of ruffe on nutrient cycling, and predicted impacts of ruffe on ecosystems with different physical and trophic conditions within the Great Lakes.

Publications

Fullerton, A.H., G.A. Lamberti, D.M. Lodge, and M.B. Berg. 1998. Prey preferences of Eurasian ruffe and yellow perch: Comparison of laboratory results with composition of Great Lakes benthos. *Journal of Great Lakes Research*, 24(2):319-328.

Effects on Ecosystems

Key Words
basic biology
benthos
ecological interactions
Eurasian ruffe
fish
food preference
impact
nonindigenous

September 1997 – August 1999

The Potential Economic Damages of Ruffe in the Great Lakes

Michigan Sea Grant (Project R / NIS-1)
John P. Hoehn, Frank Lupi, and Sandra S. Batie, *Michigan State University*

The purpose of this study was to provide contemporary estimates of the economic damages that will accrue to recreational anglers as a result of Eurasian ruffe in the Great Lakes.

Publications

Lupi, F. And P.M. Feather. 1998. Using partial site aggregation to reduce bias in random utility travel cost models. *Water Resources Research*, 34(12):3595-3603.

Socio-Economic Analysis

Key Words
benefit-cost analysis
benefits transfer
Eurasian ruffe
fishing
impact
nonindigenous
recreation
travel-cost method

Research

Control and Mitigation

Key Words

basic biology
biological control
ecological interactions
Eurasian ruffe
fish
impact
management
model
nonindigenous
population dynamics
predators

September 1994 – January 1996

A Test in Experimental Management: Applications of Top-Down Predator Control for Pest Management

Minnesota Sea Grant
Gerald L. Hill, *University of Minnesota - Duluth*

Bioenergetics modeling showed that top-down control strategies using fish predators, including northern pike, walleye, smallmouth bass, brown bullhead, and yellow perch, did not control abundance of ruffe in the St. Louis River estuary, Lake Superior. All predators selected four native forage species over ruffe.

Publications

Mayo, K.R., J.H. Selgeby, and M.E. McDonald. 1998. A bioenergetics modeling evaluation of top-down control of ruffe in the St. Louis River, western Lake Superior. *Journal Great Lakes Research*, 24(2):329-342.

Outreach

August 1995 – May 1998

Regional Ruffe Outreach Initiative

Michigan Sea Grant (Project A / FP-4)
John D. Schwartz and Michael Klepinger

Minnesota Sea Grant (Project A / SE-2)
Jeffrey L. Gunderson, Douglas A. Jensen, Mike McLean, Marie E. Zhuikov, and Dale R. Baker

Wisconsin Sea Grant (Project A / AS-36)
Richard Hoops

The Great Lakes Regional Ruffe Outreach Initiative brought scientists together from around the world to investigate the biology, ecology, and management of Eurasian ruffe. The Minnesota and Michigan Sea Grant programs led a regional outreach effort to further the understanding of Eurasian ruffe by sponsoring the first *International Symposium on Biology and Management of Ruffe* in March 1997. The symposium was attended by over 100 scientists, managers, and educators who learned from the world's foremost experts on ruffe. From the symposium, five European researchers published the results of Sea Grant-sponsored research reviews in a special section of the *Journal of Great Lakes Research* (March 1998). Wisconsin Sea Grant disseminated ruffe information through radio programs that were produced and distributed at no charge to roughly 40 radio stations around Lake Superior to raise public awareness about this species in Lake Superior and how to slow its spread. The radio programs succeeded in (1) presenting information about the Eurasian ruffe to people in the Lake Superior region, (2) establishing the Great Lakes Sea Grant network as a credible source of information to radio broadcasters, and (3) establishing Sea Grant communicators as effective and trustworthy partners for outreach projects that involve other Great Lakes management agencies. ***Audience*:** bait and aquaculture businesses, elected officials, general public, government agencies, industry, maritime interests, media, researchers, resource managers students (high school and college), teachers / educators (high school and college).

Products and Presentations

Fact Sheet
Ruffe: A New Threat to our Fisheries (1995, revised 1996). ***Distribution:*** 25,000; ***Audience:*** general public.

Information Card
Ruffe WATCH ID Card (1994, revised 1995 and 1996). ***Distribution:*** Over 150,000;
***Audience*:** general public.

Journal Articles
Special Section on An International Symposium on Eurasian Ruffe (*Gymnocephalus cernuus*): Biology, Impacts, and Control. In *Journal of Great Lakes Research*, 1998, 24(2). (Includes 10 full research papers from Sea Grant sponsored research presented at the Symposium.) ***Distribution:*** 75;
Audience: educators, government agencies, maritime interests, media, researchers, resource managers, students.

Presentation
International Symposium on Biology and Management of Ruffe (March 21-23, 1997). ***Participants*:** 110;
***Audience*:** aquaculture and wild bait harvesters, government agencies, maritime interests, media, researchers, resource managers, sports and commercial fishing representatives, students, teachers.

Proceeding
International Symposium on Biology and Management of Ruffe – Symposium Abstracts (March 1997).
Distribution: 230; ***Audience*:** aquaculture and wild bait harvesters, government agencies, maritime interests, media, researchers, resource managers, sports and commercial fishing representatives, students, teachers.

Radio Programs
Eurasian Ruffe Public Awareness Programs (cassette tapes with accompanying scripts, 1995 and 1997).
***Distribution*:** 80; ***Participants*:** 40; ***Audience*:** managers of radio stations in Wisconsin, Michigan and Minnesota.

General Outreach

Key Words
ballast water
basic biology
biological control
chemical control
colonization
ecological interactions
education programs
Eurasian ruffe
impact
inland lakes/rivers
monitoring
nonindigenous
population dynamics
predators

European Green Crab *(Carcinus maenas)*

Sylvia Yamada

The European green crab is a small shore crab (adults measure about 3 inches across) whose native distribution is along the coasts of the North and Baltic Seas. Although this crustacean is known by the common name of green crab, the shell color can vary from dark, mottled green to orange or red, with yellow patches on the dorsal carapace. The crab is an able and effective forager — capable of learning and improving upon its food-gathering skills. One adult crab reportedly can eat 40 half-inch clams each day and can devour crabs as large as itself. Green crabs also prey on numerous other organisms, making these crabs potential competitors for the food sources of native fish and bird species. The green crab has already invaded numerous coastal communities outside of its native range, including South Africa, Australia, and both coasts of North America. An able colonizer and efficient predator, this small shore crab has the potential to significantly alter any ecosystem it invades. It has been blamed for the collapse of the soft-shell clam industry in Maine.

Research

Biology and Life History

Key Words
colonization
ecological interactions
European green crab
monitoring
nonindigenous
predators

February 1998 – January 2000

Quantifying the Range Expansion and Impacts of the European Green Crab

Maine-New Hampshire Sea Grant (Project R / FMD-510)
Edwin Grosholz, *University of New Hampshire*

In order to determine the abundance of green crabs at several West Coast sites where they are currently established (South Slough / Coos Bay, Elkhorn Slough / Monterey Bay, and Bodega Harbor), sampling and monitoring methods were used to quantify their population distribution. The project also monitored the ongoing range expansion of the green crab along the Pacific Northwest and estimated the abundance of targeted invertebrate populations known to be reduced by green crab predation.

Effects on Ecosystems

Key Words
bivalve
colonization
ecological interactions
European green crab
impact
nonindigenous
population dynamics
predators

February 1998 – January 2000

Potential Impacts of a Nonindigenous Crab on Selected West Coast Commercial Invertebrates

Maine-New Hampshire Sea Grant (Project R / FMD-154)
Edwin Grosholz, *University of New Hampshire*

Washington Sea Grant (Project R / ES-24)
David Armstrong and Gregory Jensen, *University of Washington*
Glen Jamieson, *Fisheries and Oceans Canada*
Gregory Ruiz, *Smithsonian Environmental Research Center*

The recent introduction of *Carcinus maenas* to the West Coast portends substantive ecological impact in estuarine and marine systems. In conjunction with the University of Washington, this project studied how *Carcinus* responsed to two categories of invertebrate prey: the mobile Dungeness crab (*Cancer magister*) and the sessile bivalve. The research gauged the potential ability of this exotic crab to significantly perturb populations of these valued commercial species by direct predation and displacement from habitat. The resultant predator-prey dynamics were quantified as a function of density, tidal elevation, and species mix.

Effects on Ecosystems

Key Words
aquaculture
basic biology
bivalve
ecological interactions
impact monitoring
economic development
European green crab
nonindigenous
population dynamics
predators

October 1998 – May 1999

Experiment to Assess the Implications of Predation by the European Green Crab (*Carcinus meanas*) on Commercially Important Shellfish Species

Oregon Sea Grant (Project R / NIS-07-PD)
Deborah Brosnan and Zasha Bassett, *Sustainable Ecosystems Institute*

The Sustainable Ecosystems Institute worked with Pacific Northwest shellfish growers to assess the impact of the European green crab on different sizes of commercial shellfish (oysters, clams, and mussels) in order to identify the vulnerable sizes of these species.

September 1997 – August 1999

Safety and Efficacy of Green Crab Biological Control

California Sea Grant (Project R / CZ-148)
Kevin Lafferty, *University of California - Santa Barbara*

The objective of this project was to assess methods for the biological control of the European green crab, *Carcinus maenas*, which has the potential to cause losses to oyster, mussel, and clam mariculture industries, in addition to the Dungeness crab fishery.

Control and Mitigation

Key Words
European green crab
nonindigenous
physical control

June 1998 – June 1999

Slowing the Spread of *Carcinus meanas*

Oregon Sea Grant (Project R / NIS-05-PD)
Sylvia Yamada, *Oregon State University*

This project examined methods which would help to identify sites of new invasions of the European green crab.

Publications

Behrens Yamada, S, C. Hunt, and N. Richmond. 1999. The arrival of the European green crab, *Carcinus maenas*, in Oregon estuaries. In *Proceedings of the National Conference on Marine Bioinvasions*, Massachusetts Institute of Technology, Cambridge, MA (January 24-27, 1999).

D. DeDario and M. Zimmerman. 1999. *Mark-Recapture of European Green and Dungeness Crabs in Yaquina Bay, Newport, OR*. Senior Thesis, Department of Fisheries and Wildlife, Oregon State University.

Reducing the Spread of Established Populations

Key Words
aquaculture
basic biology
ecological interactions
European green crab
impact
monitoring
nonindigenous
predators
population dynamics

European green crab *(Carcinus maenas)*

Outreach

General Outreach

Key Words
aquaculture
ballast water
basic biology
biological control
bivalve
chemical control
colonization
dispersal mechanism
ecological interactions
economic development
educational program
European green crab
impact
industry
monitoring
nonindigenous
physical control
population dynamics
predators
prevention
wetlands

October 1997 – February 1998

Green Crab Outreach Program

Oregon Sea Grant (Project M / A-2, RD09)
Robert E. Malouf

Washington Sea Grant (Project R / ES-32)
Andrea E. Copping

This program focused on developing a workshop to inform and mobilize the aquaculture industry, researchers, and resource agencies of the Pacific Northwest on the impending invasion by the European green crab. The project is also producing a book about the spread of the crab that will increase the awareness of the general public regarding the introduction and spread of this species. The document will describe the natural history, patterns, and history of introduction in the U.S., and impacts related to the green crab. ***Audience:*** anglers, aquaculture businesses, elected officials, general public, government agencies, media, recreational boaters, researchers, resource managers, students (intermediate and above), teachers / educators (intermediate and above).

Products and Presentations

Book
A Global Invader: The European Green Crab (forthcoming).
Audience: general public, outreach personnel, scientists.

Fact Sheet
The Green Crab (1998). ***Distribution:*** 5,000;
Audience: aquaculture industry, general public, researchers, resource agencies.

Information Card
The European Green Crab Identification Guide (1998). ***Distribution:*** 8,000;
Audience: aquaculture industry, general public, researchers, resource agencies.

Web Site
Green Crab Web Site: ***seagrant.orst.edu/hot/exotics.html***
Audience: aquaculture industry, general public, researchers, resource agencies, students, teachers.

Workshop
Green Crab: Potential impacts in the Pacific Northwest (1998). ***Participants:*** 150;
Audience: agencies, aquaculture industry representatives, educators, resource managers.

General Outreach

Key Words
aquaculture
basic biology
dispersal mechanism
ecological interactions
economic development
European green crab
impact
monitoring
nonindigenous
population dynamics
predators

September 1997 – February 1999

Monitoring for Green Crabs in Oregon Estuaries

Oregon Sea Grant (Project M / A-2, RD17)
Sylvia Yamada, *Oregon State University*

Dr. Yamada has conducted two courses on field methods for monitoring the spread of the European green crab in Oregon estuaries. She also makes public presentations about the natural history, dispersal mechanisms, and spread of the crab, as well as conducting identification and prevention workshops. ***Audience:*** general public, oyster & shellfish businesses, researchers, resource managers, science center volunteers, students.

Products and Presentations

Presentation
Green Crab Presentation (various presentations throughout the project).
Audience: general public, oyster / shellfish industry, students.

Report
The European Green Crab in Oregon: Results of Student Sampling Projects on the Status of Native Species Prior to the Arrival of the European Green Crab (1998).
Audience: aquaculture, educators, local and state agencies, resource managers, students.

Japanese Shore Crab *(Hemigrapsus sanguineus)*

Robert Cohen

The Japanese shore crab is native to the shores of the Pacific Ocean and has now colonized the East Coast of the United States. The crab was first reported near Cape May, New Jersey in 1988, where it was probably introduced via ballast water from ocean-going ships. Since that time, the crab's range has spread as far north as New Hampshire and as far south as North Carolina. This crustacean typically lives in the intertidal or shallow subtidal zone, where water depth is only a couple of feet at low tide. The crab can often be found under rocks in the intertidal zone during low tide. Adult male crabs can reach over 2.5 inches in body size, measured as the width of the carapace. The Japanese shore crab eats many different types of algae and animals and may displace resident crab populations from rocky intertidal habitats.

Research

Biology and Life History

Key Words
basic biology
Japanese shore crab
nonindigenous

1995 – 1996

Reproductive Timing and Larval Abundance of the Introduced Crab (*Hemigrapsus sanguineus)*

New Jersey Sea Grant (Project R / F-95011D)
Peter Fong, *Gettysburg College*
Eleanor Bochenek, *New Jersey Sea Grant*

This study measured larval abundance of *Hemigrapsus sanguineus* in tidal river areas of New Jersey and correlated the data with temperature, salinity, and pH of the tidal water. Adult populations were also sampled.

Biology and Life History

Key Words
aquaculture
ballast water
basic biology
crustacean, estuary
exotic, fauna
habitat, impact
intertidal, introduced
Japanese shore crab
predators

January 1996 – July 1996

Colonization, Ecological Habitat and Potential Impacts of the Western Indo-Pacific Crab (*Hemigrapsus sanguineus*) in Buzzards Bay, Massachusetts

Woods Hole Oceanographic Institution Sea Grant (Project R / B-136-PD)
Nancy J. O'Connor, *University of Massachusetts - Dartmouth*

Introduction of non-native species to new coastal environments may pose a threat to local biodiversity. Preliminary observations strongly suggest that the Indo-Pacific crab *Hemigrapsus sanguineus* has become established in Buzzards Bay, Massachusetts. This research provided essential ecological information on the preferred habitat and diet of the crab, information necessary to better predict its impact on southeastern New England coastal ecosystems.

Biology and Life History

Key Words
ballast water
basic biology
ecological interactions
Japanese shore crab
nonindigenous

July 1997 – June 1998

Critical Life-History Traits of a Nonindigenous Japanese Shore Crab

Delaware Sea Grant
Charles E. Epifanio and Ana I. Dittel, *University of Delaware*

The introduction of exotic species via ballast water is a major problem worldwide, and as one of the busiest shipping corridors on the East Coast, Delaware Bay is particularly vulnerable. The Japanese shore crab (*Hemigrapsus sanguineus*) represents the first introduction of any crab species in the Middle Atlantic region in modern times. Because its habits are so different from the indigenous crabs of the area, the Japanese shore crab's effects on the local ecosystem are difficult to predict. This project explored the critical early life-history stages of the Japanese shore crab to better determine its potential impacts on the Delaware Bay ecosystem and its potential for dispersal along the coast.

Publications

C. E. Epifanio, A. I. Dittel, S. Park, S. Schwalm, & A. Fouts. 1998. Early life history of *Hemigrapsus sanguineus*, a non-indigenous crab in the Middle Atlantic Bight. *Marine Ecology Progress Series*, 170:231-238.

Japanese shore crab *(Hemigrapsus sanguineus)*

Rapa Whelk *(Rapana venosa)*

Juliana Harding

The rapa whelk is often referred to as the "veined" rapa whelk because of its distinctive shell markings. Native to the Sea of Japan, the rapa whelk is a predatory gastropod that often attacks oysters, clams, and mussels by grating around the area where the two shells meet, rather than boring a distinct hole. The species spread to the Black Sea in the 1940s, then to the Mediterranean, and eventually to the Chesapeake Bay where it was discovered in the summer of 1998. Reaching 5 to 7 inches in length, the whelk has had a serious negative impact on clams and oysters since being introduced to the Black Sea, and there is concern about its possible impact on Chesapeake Bay shellfish.

Outreach

Key Words
ballast water
educational program
monitoring
nonindigenous
predators
veined rapa whelk

1998 – 1999

Veined Rapa Whelk Outreach Program

Virginia Sea Grant
Vicki Clark and Susan Waters, *Virginia Institute of Marine Science*

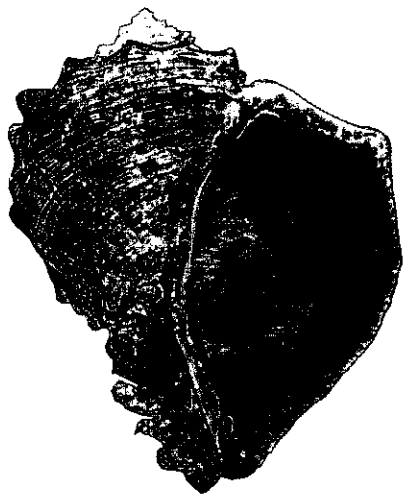
Virginia Sea Grant developed a program to inform the public about the presence of *Rapana venosa* in the Chesapeake Bay. A fact sheet, web site, and presentations were developed for various audiences. ***Audience:*** anglers, commercial fishing and seafood businesses, elected officials, general public, government agencies, maritime interests, media, recreational boaters, resource managers, scientists, students, teachers/educators (middle school, high school, college, and adult students).

Projects and Presentations

Fact Sheet
Veined Rapa Whelk, Rapana venosa, *found in Virginia Waters* (1998). ***Distribution:*** 2,000; ***Audience:*** commercial and recreational anglers, general public, government agencies, industry, scientists.

Presentation
The Rapa Whelk and Ballast Water Invasions in the Chesapeake Bay (1998). Mid-Atlantic Marine Education Association's annual conference, Virginia Beach, VA (October 15-17, 1998). ***Participants:*** 30; ***Audience:*** science educators (classroom, aquarium, science centers).

Web Site
Veined Rapa Whelk Web Site: ***www.vims.edu/fish/oyreef/rapven.html***
Audience: commercial and recreational anglers, general public, government agencies, industry, scientists, students, teachers.



Rapa whelk *(Rapana venosa)*

Round Goby *(Neogobius melanostomus)*

David Jude

Gobies are bottom dwelling fish with a large head, resembling a tadpole, and can grow to be 10 inches. Native to parts of Eurasia, the round goby was discovered in the St. Clair River, the channel connecting Lake Huron and Lake St. Clair, in 1990 and was presumably introduced via ballast water from transoceanic vessels. Since then it has spread to lakes Erie, Michigan, Huron, and Superior and to many rivers including the headwaters of the Illinois River and will likely make its way to the Mississippi River. Although this bottom-dwelling fish likes to eat zebra mussels (an estimated 65 to 70 percent of the round goby's diet consists of zebra mussels), the round goby also eats the eggs and young of native fish, and competes with native fish species, such as sculpins and darters, for food and habitat. Round gobies are thriving in the Great Lakes Basin because they are aggressive, voracious feeders which can forage in total darkness. The round goby takes over prime spawning sites traditionally used by native species, competing with native fish for habitat and changing the balance of the ecosystem. Its cousin, the tubenose goby, appeared for the first time in the St. Clair River in 1990. However, this species – which is endangered in its native habitat in Eurasia – has remained uncommon in the Great Lakes.

Research

Biology and Life History

Key Words
control
exotic
fish
genetics
nonindigenous
round goby
tubenose goby

May 1997 – February 1998

Genetic Characterization of Invasive Gobies in the Great Lakes

Ohio Sea Grant (Project R/NIS-4-PD)
Carol A. Stepien, *Case Western Reserve University*

Since its introduction, the round goby has spread to all five Great Lakes – faster than any previously introduced fish. The research produced baseline data of the round goby (*Neogobius melanostomus*) and the tubenose goby (*Proterorhinus marmoratus*), specifically the number and description of genetic variants, their geographic distribution, and their possible origin(s) in order to compare the genetic variability of these two goby species in the Great Lakes to Eurasian populations.

Effects on Ecosystems

Key Words
bioaccumulation
bivalve
ecological interactions
impact
monitoring
nonindigenous
round goby
zebra mussel

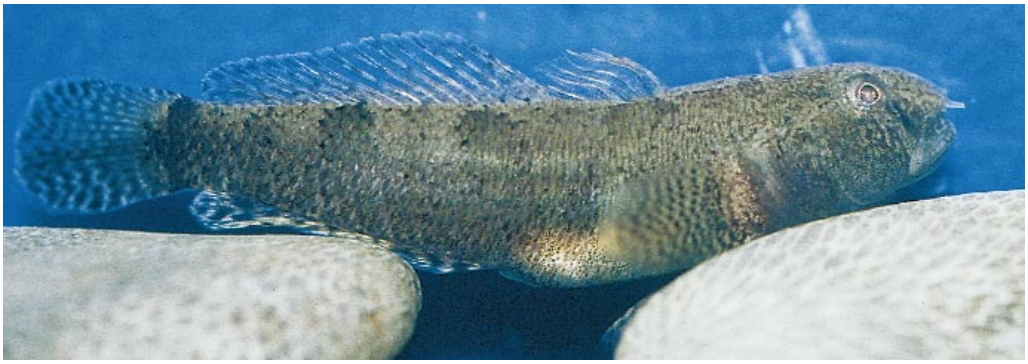
March 1997 – September 1998

Round Gobies and Zebra Mussels: Trophic Interactions Affecting Contaminant Cycling in the Great Lakes

Ohio Sea Grant (Project R/PS-16)
Susan W. Fisher and Paul C. Baumann, *The Ohio State University*

This study examined how polychlorinated biphenyls (PCBs) increase through the food chain. Originally thought to be locked within sediment and safe from dispersion, PCBs are being redistributed by zebra mussels because of their high filtering capacity and tendency to feed on contaminated sediment and algae. Moving from contaminated algae, to zebra mussels, to round gobies, and then to smallmouth bass, PCBs are thought to increase or biomagnify at each trophic level before being consumed by humans or animals. This research sought to answer the question of how much PCB biomagnification occurs at each of these levels. Zebra mussels were tested in laboratory and field settings to confirm that zebra mussels increase in their PCB concentration to approximately 100 parts per billion (ppb) after feeding on contaminated sediment and algae. While PCB concentrations were around 100 ppb in zebra mussels, round gobies' concentrations ranged between 200 to 800 ppb. PCB concentrations in smallmouth bass had the highest increase with ranges between 1100 to 1800 ppb.

Round goby *(Neogobius melanostomus)*



David Jude

Tubenose goby *(Proterorhinus marmoratus)*

September 1997 – August 1999

Invasion Susceptibility and Ecosystem Fragmentation of Great Lakes Coastal River and Lakes by the Newly Introduced Round and Tubenose Gobies

Illinois-Indiana Sea Grant (Project R / ANS-06-97)
David J. Jude, *University of Michigan*
John Janssen, *Loyola University*

This project determined the susceptibility of adjacent connecting water bodies of the Great Lakes to colonization by round and tubenose gobies. It also determined if velocity is potentially limiting to round gobies using a model stream system. Using factorial experiments the research determined what impacts round gobies might have on lentic fish.

Effects on Ecosystems

Key Words
ballast water
control measures
ecological interactions
impact
round goby
tubenose goby

March 1998 – February 2000

Benthic-Pelagic Coupling: Community Responses to Round Goby Predation on Zebra Mussels

Ohio Sea Grant (Project R / NIS-3)
Jeffrey G. Miner and Rex L. Lowe, *Bowling Green State University*

This research determined the extent to which round gobies can reduce zebra mussel abundance and quantified the effects this would have on the benthic macroinvertebrate and periphyton communities through a series of cage manipulations installed at F.T. Stone Laboratory. This research also quantified phytoplankton and zooplankton responses to reduced filtration rate and changes in the ratios of nitrogen and phosphorus available for nutrient cycling.

Effects on Ecosystems

Key Words
algal bloom
community dynamics
control
fish
invading species
nonindigenous
population dynamics
round goby
zebra mussel

March 1998 – February 2000

Round Goby and Mottled Sculpin Spawning Interactions

Illinois-Indiana Sea Grant (Project R / ANS-04-98)
John Janssen and Martin Berg, *Loyola University*

The major goal of this project was to determine whether round gobies interfered with mottled sculpin spawning. Additionally, the researchers compared and contrasted nest site selection in round gobies and mottled sculpins to find ways in which habitats could be modified to minimize round goby reproduction while protecting and enhancing mottled sculpin reproduction.

Effects on Ecosystems

Key Words
exotic species
mottled sculpin
reproduction
round goby
spawning

Round goby *(Neogobius melanostomus)*

Rusty Crayfish *(Orconectes rusticus)*

Jeff Gunderson

The rusty crayfish is a crustacean that has invaded parts of Minnesota, Wisconsin, Ontario, and many other areas. Although native to parts of some Great Lakes states, rusty crayfish have spread to many northern lakes and streams where they cause a variety of ecological problems. Identified in Wisconsin lakes and streams around 1960, and in a Minnesota creek in 1967, rusty crayfish were probably spread by non-resident anglers who brought them north to use as fishing bait. As rusty crayfish populations increased, they were harvested for the regional bait market and for biological supply companies. These activities probably helped spread the species further. Rusty crayfish are an aggressive species that frequently displace native crayfish, reduce the diversity of aquatic plants and invertebrates, and reduce some native fish populations.

Research

Reducing the Spread of Established Populations

Key Words
benthic species
crayfish
hybridization
invasion
nonindigenous

March 1998 – February 2000

Dispersal of Exotic Species in the Great Lakes: Crayfish as a Model System for Benthic Species

Illinois-Indiana Sea Grant (Project R/ES-05-98)
David M. Lodge and Jeffrey L. Feder, *University of Notre Dame*

This project focused on (1) reconstructing the chronology of invasions by all crayfish species into the Great Lakes; (2) using genetic analyses of the regions in Lake Michigan where *O. rusticus* is displacing *O. propinquus*; and (3) predicting the future distribution of *O. rusticus* in the Great Lakes by comparing the environmental requirements of *O. rusticus* (especially substrata) with the characteristics of Great Lakes littoral zones.

Publications

Perry, W.L., J.L. Feder, and D.M. Lodge. 1998. Population dynamics of a hybrid zone accompanying the invasion of the rusty crayfish, *O. rusticus*, in northern Wisconsin. In *Proceedings of the Society for the Study of Evolution*, Vancouver, British Columbia, Canada.

Perry, W.L., J.L. Feder, and D.M. Lodge. 1998. The role of hybridization in the displacement of resident crayfishes by the exotic crayfish, *O. rusticus*. In *Proceedings of the American Society of Limnology and Oceanography and Ecological Society of America Meetings*. St. Louis, MO.

Wilson, K.A., J. Magnuson, D. Lodge, T. Kratz, A. Hill, and W. Perry. 1998. Effects of an omnivorous invader: The sequential invasion of Trout Lake, WI by the rusty crayfish (*Orconectes rusticus*). In *Proceedings of the Ecological Society of America*, Baltimore, MD.

Rusty crayfish *(Orconectes rusticus)*

Sabellid Worm *(Terebrasabella heterouncinata)*

Carolynn Culver

The sabellid worm is a unique parasite-like shell-infesting worm native to South Africa that has devastated California's abalone aquaculture industry. Inadvertently introduced to cultured stocks in the late 1980s, the previously unknown worm – a member of the family sabellidae (a group collectively known as “fan worms”) – is a pest to abalone and many marine snails. Although the meat of the abalone or other host is not affected, its growth slows or virtually ceases often with the shell becoming brittle and grossly deformed. Initially only a pest in California abalone aquaculture facilities, the worm became established in wild black turban snails at an intertidal site in the state. Fortunately, eradication efforts have proved successful in both species. Though industry has learned to manage the pest, concerns over its impact and potential spread remain.

Research

Effects on Ecosystem

Key Words
aquaculture
ecological interactions
impact
industry
monitoring
nonindigenous
prevention
sabellid worm

September 1997 – August 1999

Containment of Sabellid Pests of California Abalone: Assessment of Habitats and Hosts at Risk of Infestation

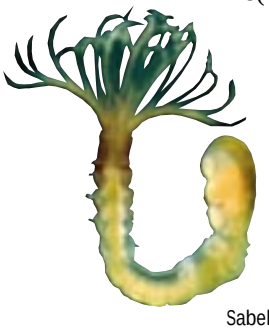
California Sea Grant (Project R/CZ-147)
Armand Kuris, *University of California - Santa Barbara*

The project determined which California habitats and which native California species of mollusk are most at risk for the establishment of the sabellid pest. It further quantified the relationship between sabellid intensity and shell damage, determined the mechanisms of shell damage, and identified the basis for host specificity.

Publications

Culver, C.S., A.M. Kuris, & B. Beede. 1997. *Identification and Management of Exotic Sabellid Pests in California Abalone Aquaculture.* California Sea Grant Publication T-041, La Jolla, CA.

Kuris, A.A. and C.S. Culver. 1999. An introduced sabellid polychaete infesting cultured abalone and its potential to spread to other California gastropods. *Invertebrate Biology*, 118(4): 391-403.



Sabellid worm *(Terebrasabella heterouncinata)*

Sea Lamprey *(Petromyzon marinus)*

U.S. Fish and Wildlife Service

Sea lamprey on a lake trout.

Great Lakes Sea Grant Network
Exotic Species Graphics Library

Sea lamprey mouth.

The sea lamprey was first discovered in Lake Ontario in 1835, Lake Erie in 1921, Lake Huron (1932), Lake Michigan (1936), and Lake Superior (1946). Reproducing populations were found in all of these upper lakes by 1947. This fish with an eel-like body, can range from 12 to 20 inches in length. It attaches to deepwater fish, especially lake trout, for food and indirectly gains transportation that has enabled it to become widely dispersed throughout the Great Lakes. The lamprey injures fish by sucking out the blood, soft tissue, and body fluids of its prey. They remain attached and feed on the fish until they are satiated or until the fish dies. Lake trout, burbot and whitefish populations were devastated by lamprey predation by the early 1940s. Much work to control this parasite in the Great Lakes has been accomplished, but without continued control and research into stream invasions, the populations may once again escalate, damaging the ecosystem.

Research

Control and Mitigation

Key Words
basic biology
biological control
chemical control
dispersal mechanism
hormone
nonindigenous
pheromone
predators
sea lamprey

Sea lamprey *(Petromyzon marinus)*

February 1994 – January 1996

Characterizing the Biochemical Origins and Behavioral Actions of Water-Borne Acids on Sea Lamprey and Other Fish: The Secondary Step in Evaluating Whether Natural Odors Can Be Used in Lamprey Population Control

Minnesota Sea Grant (Project R / F-25)
Peter W. Sorenson and Daniel D. Gallaher, *University of Minnesota*

This research project attempted to determine the olfactory sensitivity of parasitic and adult sea lamprey to chemical compounds, which may serve as important roles as feeding stimulants, migrational cues, and sexual stimulants (pheromones and repellents). Emphasis was on the biological relevance of identified synthetic olfactory stimulants. Results demonstrate that olfactory sense is unique in sea lamprey, suggesting that specific natural attractants may serve as biocontrol agents for sea lamprey. Further study discovered that two novel bile acids released by sea lamprey larvae are likely migratory pheromones, which may have application for biocontrol efforts to attract sea lamprey to spawning areas.

Publications

Li, W. 1994. T*he Olfactory Biology of Adult Sea Lamprey*. Ph.D. Thesis. University of Minnesota.

Li, W., P.W. Sorenson, and D.D. Gallaher. 1995. The olfactory system of migratory adult sea lamprey (*Petromyzon marinus*) is specifically and acutely sensitive to unique bile acids released by conspecific larvae. *Journal of General Physiology*, 105:569-587.

Sorensen, P.W., and W. Li. 1997. Highly independent olfactory receptor sites for naturally occurring bile acids in sea lamprey, *Petromyzon marinus*. *Journal of Comparative Physiology: A Sensory Neural and Behavioral Physiology*, 180(4):429-438.

Control and Mitigation

Key Words
aquaculture
basic biology
nonindigenous
sea lamprey
spawning

April 1996 – March 1998

Regulation of Function in Spermatozoa of the Sea Lamprey (*Pertromyzon marinus*): The First Step in Contraception

Ohio Sea Grant (Project R / A-8)
Konrad Dabrowski and David Stetson, *The Ohio State University*

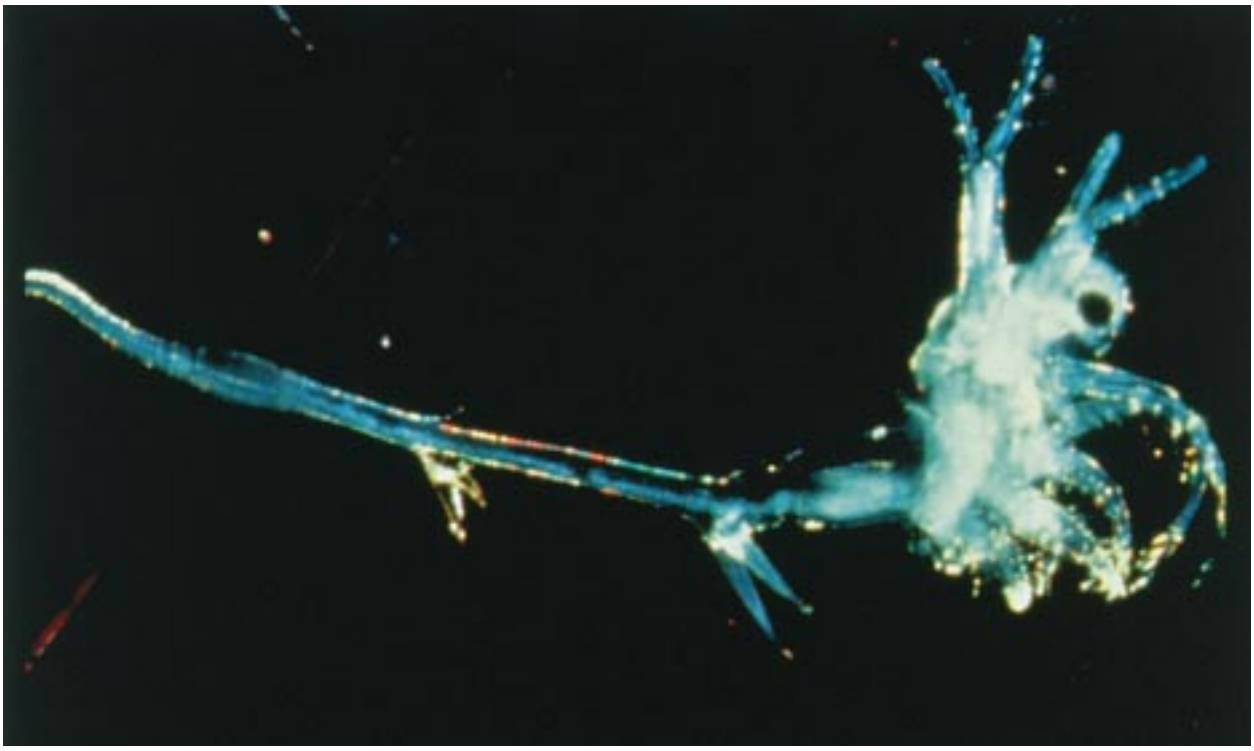
With the opening of the St. Lawrence Seaway, nonindigenous sea lamprey gained access to the Great Lakes, successfully colonized their waters, and caused a devastating impact on fish assemblages. This study examined the morphology of lamprey spermatozoa before and after acrosomal reaction (AR) by scanning and transmission electron microscopy. Besides computer-assisted Sperm Motion Analysis (CASA) used for motility studies, the relationship between the acrosomal reaction and fertilization was evaluated by means of fertilizing batches of eggs with sperm under controlled conditions and with various degrees and mechanisms of AR blocking. This research described the ultrastructure of spermatozoa of the sea lamprey, characterized the nature and regulation of sperm motion, and identified factors able to inhibit sperm motility. It also characterized the sperm acrosomal reaction and its regulation, developed cryopreservation of sea lamprey sperm, tested the effect of a spermicidal agent, and studied sperm proteolytic activity.

Publications

Ciereszko, A., J. Glogowski, and K. Dabrowski. 1999. Fertilization in landlock sea lamprey (*Petromyzon Marinus*): Storage of gametes, optimal sperm / egg ratio, and methods of assessing fertilization success. *Fish Biology*, 56(3):495-505.

Rinchard, J., A. Ciereszko, K. Dabrowski and J. Ottobre. 1999. Effects of gossypol on sperm viability and plasma sex steroid hormones in male sea lamprey, *Petromyzon Marinus*. *Toxicology Letters*, 111(3):189-198.

Spiny Waterflea *(Bythotrephes cederstroemi)*



U.S. Fish and Wildlife Service

The spiny water flea, a small planktivorous crustacean, averages about 1/2 to 1/4-inch in length, of which 70 percent is a long, sharp, barbed tail spine. Native to parts of Eurasia, it was first introduced into the Great Lakes ecosystem in 1984 via ballast water that was discharged into Lake Huron. By 1987 it had spread to all of the Great Lakes and currently infects inland lakes in Michigan and Southern Ontario. Its rapid reproduction, general lack of predators, and direct competition with young fish for food give this species the potential to dramatically alter the food webs of the Great Lakes.

Research

Effects on Ecosystems

Key Words
alewife
bioaccumulation
ecological interactions
impact
nonindigenous
pollution
polychlorinated biphenyls
predators
spiny waterflea
stable isotopes

February 1996 – January 1998

Effect of *Bythotrephes* on PCB Biomagnification in Salmonids

Minnesota Sea Grant (Project R / CL-48)
Deborah L. Swackhammer, *University of Minnesota*

This research project modeled and field validated whether predation of *Bythotrephes* by alewife is causing a bioacccumulation increase in alewife, which is responsible for increases of polychlorinated biphenyls in coho salmon and lake trout in Lake Michigan.

Spiny waterflea *(Bythotrephes cederstroemi)*

Zebra Mussel *(Dreissena polymorpha)*

Great Lakes Environmental Research Laboratory

Zebra mussels cover a Lake Erie beach.

Zebra mussels are small, fingernail-sized, freshwater mollusks native to parts of Eurasia, and were introduced to North America via ballast water from transoceanic vessels. Zebra mussels were first discovered in Lake St. Clair and Lake Erie in 1988 and are a problem throughout the Great Lakes region, and in an increasing number of inland waterways in the United States and Canada. The barnacle-like zebra mussel grows quickly on surfaces such as docks, boat hulls, commercial fishing nets, water intake pipes and valves, native mollusks and other zebra mussels, and even along lake bottoms causing a problem for native fish and mussels, and utility companies. The zebra mussel is a filter feeder, and consumes large quantities of microscopic phytoplankton from the water. This mollusk can alter aquatic food webs dramatically by reducing phytoplankton levels, the source of food for microscopic zooplankton. The zooplankton serve as an important food source for larval and juvenile fish as well as forage fish species that support sport and commercial fisheries. Zebra mussels can also colonize inside water-intake pipes and prevent water from flowing through the pipe, water that is needed for drinking and supplying electricity. This species has greatly altered the Great Lakes ecosystem and economy.

Zebra Mussel Distribution Map (as of July 2000)

Research

September 1995 – August 1997

Facilitation of Exotic Species Information Exchange Between North America and the Former Soviet Union

Wisconsin Sea Grant (Project R / LR-65)
Diana K. Padilla, *University of Wisconsin - Madison*

Two researchers from Belarus spent nine months at the University of Wisconsin-Madison exchanging knowledge about zebra mussel ecology with Sea Grant researchers. The European researchers have extensive experience with the invasive organisms, having studied them for 20 years. The collaboration enhanced the knowledge of both teams.

Publications

Buchan, L.A. and D.K. Padilla. 1999. Estimating the probability of long-distance overland dispersal of invading aquatic species. *Ecological Applications*, 9(1):254-265.

Karatayev, A.Y., L.E. Burlakova and D.K. Padilla. 1997. Effects of *Dreissena polymorpha* (Pallas) invasion on aquatic communities in eastern Europe. *Journal of Shellfish Research*, 16(1):187-203.

Karatayev, A.Y., L.E. Burlakova and D.K. Padilla. 1999. Physical factors that limit the distribution and abundance of *Dreissena polymorpha* (Pallas). *Journal of Shellfish Research*, 17(4):1219-1235.

Molloy, D.P., A.Y. Karatayev, L.E. Burlakova, D. P. Kurandina and F. Laruelle. 1997. Natural enemies of zebra mussels: Predators, parasites and ecological competitors. *Reviews in Fisheries Science*, 5(1):27-97.

Biology and Life History

Key Words
basic biology
biological control
bivalve
colonization
dispersal mechanism
ecological interactions
impact
inland lakes/rivers
monitoring
nonindigenous
population dynamics
prevention
zebra mussel

September 1997 – March 2000

Systematics and Population Genetic Divergences of Invasive Dreissenid Mussels in North America versus Native Eurasian Populations

Ohio Sea Grant (Project R / NIS-108-SG)
Carol A. Stepien, *Case Western Reserve University*

This study provided essential data for testing the dynamics, systematic relationships, and patterns of genetic relationships among the Eurasian and North American zebra and quagga mussel populations. It determined genetic differences between zebra, quagga, and variant mussels and analyzed whether or not intraspecific genetic polymorphisms are defined among geographic regions. Systematic and population relationships were determined among zebra, quagga, profundal-type variants, and outgroup species and additional information relating to the origin of parental stocks were provided.

Publications

Skidmore, J.L. 1999. *Phylogeny of the Family Dreissenidae based on Molecular Markers*. Master's thesis, Case Western Reserve University.

Stepien, C.A, A.N. Hubers, and J. Skidmore. 1999. Diagnostic genetic markers and evolutionary relationships among invasive dreissenoid and corbiculoid bivalves: Phylogenetic signal from Mitochondrial 16S rDNA. *Molecular Phylogenetics and Evolution*, 13:31-49.

Biology and Life History

Key Words
nonindigenous
population dynamics
quagga mussel
zebra mussel

Research

Effects on Ecosystems

Key Words
basic biology
ecological interactions
fouling, impact
invertebrate
metabolism, morphology
mollusks, reef, shell
zebra mussel

September 1994 – June 1997

Population and Energetic Consequences of Zebra Mussel Fouling on Native Gastropod Fauna of Lake Michigan

Illinois – Indiana Sea Grant (Project R / ES-01-94)
J. Ellen Marsden and Daniel W. Schneider, *Illinois Natural History Survey*

The research developed a new technique for measuring the oxygen consumption of snails. Preliminary analysis suggested that physical and chemical characteristics of shells were not responsible for differences in settlement rate on different snail species, and that allogrooming behavior is likely responsible for species-specific differences in settlement. Preliminary studies showed a reduction in consumption rate and a reduction in fecundity in fouled snails.

Effects on Ecosystems

Key Words
gammarus
nonindigenous
quagga mussel
soft substrate
zebra mussel

June – July 1995

Effects of Colonization of Soft Substrate by Zebra and Quagga Mussels

Ohio Sea Grant (Project R / ZM-24-PD)
Maria J. Gonzalez and Scott A. Roush, *Wright State University*

This research documented to what extent zebra mussel colonization on soft substrate areas affected populations of the amphipod *Gammarus*. The research was conducted in the western basin of Lake Erie.

Publications

Dermott R., J. Witt, Y. M. Um and M. J. Gonzalez. 1998. Distribution of the Ponto-Caspian amphipod *Echinogammarus ischnus* in the Great Lakes and replacement of native *Gammarus fasciatus*. *Journal of Great Lakes Research*, 24:442-452.

Gonzalez, M. J. and A. Downing. 1999. Mechanisms underlying amphipod responses to zebra mussel invasions and implications for fish-amphipod interactions. *Canadian Journal of Fisheries and Aquatic Sciences*, 56(4):679-685.

Effects on Ecosystems

Key Words
competition
benthos
bioenergetics
ecological interactions
feeding
fish
inland lakes/rivers
macrophytes
nonindigenous
nutrient
phytoplankton
zebra mussel
zooplankton

June 1995 - August 1997

Trophic Interactions between Zebra Mussels and Larval Fish: Experimental Tests of Competition for Planktonic Resources

Wisconsin Sea Grant (Project R / LR-66)
Mark Sandheinrich, *University of Wisconsin - La Crosse*
William B. Richardson, *U.S. Geological Survey, La Crosse, Wisconsin*

The investigators conducted three outdoor mesocosm experiments to assess the effects of zebra mussels on larval fathead minnows. Zebra mussels reduced growth rates and survival of larval fish. The addition of nutrients (nitrogen and phosphorus) to the mesocosms increased the growth and survival of larval fish; addition of nutrients to treatments containing zebra mussels offset the negative effects of zebra mussels on fish growth by 24 percent. Mixing the water column through aeration increased the growth of zebra mussels but reduced the survival of larval fish by 38 percent. The presence of zebra mussels and water column mixing reduced survival of larval fish by 55 percent relative to treatments without mussels or mixing. Zebra mussels caused larval fish to shift from feeding on zooplakton to feeding on benthic (i.e., bottom dwelling) prey more rapidly. Mixing the water column delayed this effect slightly.

September 1995 – August 1998

Influences of Zebra Mussels on the Distribution and Fate of Coplanar PCB Congeners in the Green Bay Estuary

Wisconsin Sea Grant (Project R/MW-5)
David E. Armstrong, William C. Sonzogni, and Jon B. Manchester, *University of Wisconsin - Madison*

This project examined the influence of zebra mussels on the distribution and fate of polychlorinated biphenyls (PCBs), especially coplanar congeners, and the resulting effects on the toxicity of PCBs in Green Bay. Its specific objectives were to: (1) develop a data set of coplanar PCBs and other congeners in Green Bay, including concentrations in zebra mussels, phytoplankton, zooplankton, sediments and fish; (2) determine whether short-term temporal trends and spatial differences occur in concentration of coplanar PCB congeners in zebra mussels and fish; and (3) assess the influence of zebra mussels on coplanar PCBs by comparing ratios, quantities, and fluxes of coplanar and non-coplanar congeners among compartments of the food web.

Publications

Willman, E.J., J.B. Manchester-Neesvig, and D.E. Armstrong. 1997. Influence of ortho-substitution on patterns of PCB accumulation in sediment, plankton, and fish in a freshwater estuary. *Environmental Science & Technology*, 31(12):3712-3718.

Willman, E.J., J.B. Manchester-Neesvig, C. Agrell, and D.E. Armstrong. 1999. Influence of ortho-substitution homolog group on polychlorobiphenyl bioaccumulation factors and fugacity ratios in plankton and zebra mussels (*Dreissena polymorpha*). *Environmental Toxicology and Chemistry*, 18(7):1380-1389.

Effects on Ecosystems

Key Words
bioaccumulation
ecological interactions
impact
polychlorinated biphenyls
zebra mussel

Charles Ramcharan

September 1995 – August 1999

The Effect of Zebra Mussel Infestation in Inland Lakes on Pelagic Benthic Coupling

Wisconsin Sea Grant (Project R/LR-63)
David N. Edgington, Russell L. Cuhel, and Jerry L. Kaster, *University of Wisconsin - Milwaukee*

This study evaluated the effect of lake characteristics on the success of colonization by the zebra mussel, and examined the potential for zebra mussel infestations to affect the transfer of energy between primary producers and higher trophic levels. Four years of colonization by zebra mussels have not shown detectable effects on general lake water characteristics beyond normal year-to-year variation. However, inshore areas have shown deteriorating "recreational quality" due to zebra mussel concentrations. The linkage of 1998 events characteristic of zebra mussel invasion (e.g., floating algal blooms, slippery rock surfaces, and aquatic weed proliferation) cannot yet be separated from the influence of the strong 1997-98 El Niño event, which substantially affected the seasonal hydrologic cycle of small lakes.

Effects on Ecosystems

Key Words
basic biology
biological control
bivalve
byssal attachment
colonization
ecological interactions
impact
inland lakes/rivers
monitoring
nonindigenous
population dynamics
veliger
zebra mussel

Research

Effects on Ecosystems

Key Words
bioaccumulation
zebra mussel

February 1996 – January 1998

Bioaccumulation of Metals by Zebra Mussels

New York Sea Grant (Project R / CTP-23)
Nicholas S. Fisher, *State Univeristy of New York*

While zebra mussels – which very effectively filter small particles out of the water column (including most phytoplankton) – are ubiquitous and abundant in major freshwater ecosystems in New York and elsewhere, very little is known about their influence on the biogeochemical cycling of metals. Therefore, by evaluating the daily processes and functions of zebra mussels, this research hypothesized that these organisms might also hold great promise as bioindicator organisms for the presence of toxic metals in freshwater systems. Another primary objective of the study was to assess the role of zebra mussels in influencing metal cycling in freshwater ecosystems, with a focus on the upper Hudson River region.

Publications

Roditi, H.A. and N.S. Fisher. 1999. Rates and routes of trace element uptake in zebra mussels. *American Society of Limnology & Oceanography*, 44 (7).

Effects on Ecosystems

Key Words
benthic communities
impact
Lake Erie
nonindigenous
zebra mussel

May 1996 – November 1996

Benthic Invertebrate Communities along Zebra Mussel-Macrophyte Gradients in Lake Erie

Ohio Sea Grant (Project R / ZM-20-PD)
Maria J. Gonzalez, *Wright State University*

This study documented spatial and seasonal abundance patterns of benthic invertebrates in zebra mussel colonies and macrophytes using field and laboratory studies.

Publications

Dermott R., J. Witt, Y. M. Um, and M. J. Gonzalez. 1998. Distribution of the Ponto-Caspian amphipod *Echinogammarus ischnus* in the Great Lakes and replacement of native *Gammarus fasciatus*. *Journal of Great Lakes Research*, 24:442-452.

Gonzalez, M. J. and A. Downing. 1999. Mechanisms underlying amphipod responses to zebra mussel invasions and implications for fish-amphipod interactions. *Canadian Journal of Fisheries and Aquatic Sciences*, 56(4):679-685.

Lloyd Lemmerman

September 1996 – August 1998

Preliminary Field and Laboratory Tests of the Hypothesis that Zebra Mussels Release Phytoplankton Populations from P-Limitation

Ohio Sea Grant (Project R/ER-40-PD)
Robert T. Heath and Conrad E. Wickstrom, *Kent State University*

This research conducted a preliminary test of whether phytoplankton communities in the western basin of Lake Erie (WB-LE), heavily affected by zebra mussels, are released from P-limitation because of the remineralizing activites of zebra mussels. Physiological status of phytoplankton communities at selected sites near and far from dense zebra mussel colonies were surveyed using currently accepted indicators of P-limitation. This study provided information on the current nutritional status of the WB-LE, useful in considering the validity of current management strategies; augmented other investigations of zebra mussels; and provided preliminary data in support of a larger proposal.

Publications

Heath, R.T., X. Gao, C.E. Wickstrom, and D. Cassamatta. 1998. Evidence that zebra mussels (*Dreissena polymorpha*) can remove phytoplankton from P-limitation and can stimulate growth of microcystis, a nuisance cyanobacterium. In *Proceedings of the Eighth International Zebra Mussels and Aquatic Nuisance Species Conference*, Sacramento, CA (March 16-19 1998).

Effects on Ecosystems

Key Words
bivalve
Lake Erie
phosphorus
phytoplankton
zebra mussel

September 1997 – August 1998

Zebra Mussels as Determinants of Benthic Macroinvertebrate Community Composition in Western Lake Erie: A Systematics Approach to Species Responses

Ohio Sea Grant (Project R/NIS-107-SG)
Jeffrey G. Miner, Rex L. Lowe, and Timothy W. Stewart, *Bowling Green State University*

Through integrated use of field experiments, identification of organisms to the species level, and multivariate statistics, this research quantified the effects of zebra mussels and large predators (fish and crayfish) on a benthic macroinvertebrate community in Lake Erie. Results generated contributed to an improved understanding of zebra mussels' effects on community properties and energy flow through aquatic food webs.

Effects on Ecosystems

Key Words
benthic community
Lake Erie
macrophyte
nonindigenous species
zebra mussel

September 1997 – August 1999

A Model of the Lake Michigan-Illinois River Zebra Mussel

Illinois-Indiana Sea Grant (Project R/ANS-04-97)
Daniel W. Schneider, *Illinois Natural History Survey*

The project investigated and modeled the metapopulation dynamics of the zebra mussel in the connected waters of Lake Michigan and the Illinois River. In addition, the research quantified the flux of veligers leaving Lake Michigan and moving downstream in the Illinois River.

Effects on Ecosystems

Key Words
control
Illinois River
Lake Michigan
metapopulation
zebra mussel

Research

Effects on Ecosystems

Key Words
algae clearance
bacterial clearance
basic biology
bivalve
zebra mussel

February 1998 – January 2000

Ciliary Structures on the Gills of Bivalve Mollusks Determine their Ability to Capture Bacterial-Sized Particles: Implications for Distribution, Diet, and Accumulation of Pathogens

Louisiana Sea Grant (Project R / ZM-3)
Harold Silverman, Thomas H. Dietz, John W. Lynn, and Kevin R. Carman, *Louisiana State University*

This research compared the zebra mussel's ability to accumulate pathogens to other bivalves accumulation, and how pathogens are possibly redistributed in the ecosystem.

Publications

Dietz, T.H., D.H. Neufeld, H. Silverman, and S.H. Wright. 1998. Cellular volume regulation in freshwater bivalves. *Journal of Comparative Physiology and Biology*, 168:87-95.

Wilcox, S. and T. H. Dietz. 1998. Salinity tolerance of the freshwater bivalve *Dreissena polymorpha*. *The Nautilus*, 111(4):143-148.

Zheng, H. and T.H. Dietz. 1998. Paracellular solute uptake in the freshwater bivalves *Corbicula fluminea* and *Toxolasma texasensis*. *Biological Bulletin*, 194:170-177.

Effects on Ecosystems

Key Words
ecological interactions
zebra mussel

February 1998 – January 2000

Sustaining Fisheries in a Changing Environment: The Effect of Oligotrophication and Invasion of Dreissenids in Eastern Lake Erie

New York Sea Grant (Project R / C-13)
Edward L. Mills and Lars G. Rudstam, *Cornell Biological Field Station*
Myron Mitchell, *SUNY College of Environmental Science and Forestry*
Donald Einhouse, *New York State Department of Environmental Conservation*

This project determined how changes in nutrient levels and exotic mussels affected the Lake Erie food web and the future of the fish community. This collaborative effort specifically studied the interactions between the amount of smelt produced by the lake; growth rates of predatory fish such as smallmouth bass, walleye and lake trout; and changes in the lake's ability to support fish. Samples were taken between May and October of each year of Lake Erie's food web (benthic animals, phytoplankton, zooplankton and fish) and nutrients in lake water and compared with earlier samples taken before the mussels invaded the lake. In addition, fish stomach samples were compared to earlier data to determine how much fish diets may have changed and how fish growth may be affected.

March 1998 – February 2000

Effects of Zebra Mussels on Benthic Microbial Activity: Field and Laboratory Tests of the Hypothesis that *Dreissena polymorpha* Feeding Activity Increases Benthic Microbial Processes

Ohio Sea Grant (Project R/ER-43)
Robert T. Heath, *Kent State University*
Joseph M. Balczon, *Westminster College*

The study examined the hypothesis that zebra mussels (ZM) increase the importance of benthic microbial communities by providing particulate carbon and nutrients. The researchers (1) studied the responses of benthic microbial communities previously unaffected by ZM feeding in benthic microcosms; (2) tested the hypothesis experimentally in the laboratory by adding particulate organic carbon and particulate organic nutrients into microcosms without ZM to mimic the effects that ZM may have on microbial communities; and (3) also tested the hypothesis experimentally in the field by comparing the responses of benthic microbial communities in ZM-containing enclosures and ZM exclosures.

Effects on Ecosystems

Key Words
algae
bacteria
benthic community
nonindigenous
protozoa
sediment
zebra mussel

March 1998 – February 2000

Spatial Dynamic Modeling of Large Lake Lower Trophic Level Dynamics: Effects of Zebra Mussels and Nutrient Loading

Ohio Sea Grant (Project R/EM-20)
David A. Culver, *The Ohio State University*
Murray N. Charlton, John P. Coakley, and Paul F. Hamblin, *National Water Research Institute*
Mark Loewen, *University of Toronto*

This study (1) tested whether variation in phosphorus and nitrogen loading can explain changes in the seasonal and spatial plankton dynamics of Lake Erie; and (2) determined the relative importance of algal consumption and nutrient excretion by zebra mussels on the function of the Lake Erie plankton.

Publications

Culver, D. 1999. *Ecological Modeling of Lake Erie Trophic dynamics*. White paper prepared for the International Joint Commission on the Great Lakes.

Culver, D., H. Li, and L. Babcock-Jackson. 1999. Lake Erie phytoplankton at the millenium: Nutrients, zebra mussels, and the future. In *Proceedings of the Lake Erie at the Millenium Conference*, University of Windsor, Windsor, Ontario, Canada (April 26-28, 1999).

Effects on Ecosystems

Key Words
aquaculture
contaminant
impact
Lake Erie
model
monitoring
nonindigenous
phytoplankton
phophorus
sediment
vertical transport
zebra mussel
zooplankton

J. Ellen Marsden

Research

Effects on Ecosystems

Key Words
Lake Erie
reef
reproductive habitat
round goby
sidescan sonar
substrate
walleye
zebra mussel

March 1998 – February 2000

Substrate and Zebra Mussels: Controls and Impacts on Fish Reproductive Habitat — Western Basin Reefs

Ohio Sea Grant (Project R/ZM-28)
Scudder D. Mackey, *ODNR Division of Geological Survey*
Kenneth Baker, *Heidelberg College*

This project developed detailed substrate maps of six reefs within the bedrock reef complex of western Lake Erie and determined patterns of zebra mussel coverage of substrate surfaces within and among the six reefs. With the use of sidescan sonar data, the effects of variation in substrate on zebra mussel coverage and on habitat use by fish for spawning and reproduction was assessed. Because of the round goby's arrival and rapid growth, this research also determined potential impacts of the round goby on zebra mussels and habitat use by fish for spawning and reproduction.

Publications

Roseman, E.F., W.W. Taylor, D.B. Hayes, R.C. Haas, D.H. Davies, and S.D. Mackey. 1998. The influence of physical processes on the early life history stages of walleye, *Stizostedion vitreum*, in western Lake Erie. In *Ecosystem Considerations in Fisheries Management: Proceedings of the 16th Lowell Wakefield Symposium*, Anchorage, AK (September 1998).

Socio-Economic Analysis

Key Words
impact
economy
cost benefit
zebra mussel

September 1993 – August 1995

Present and Expected Economic Costs of Zebra Mussel Damages to Water Users with Great Lakes Water Intakes

Ohio Sea Grant (Project R/ZM-12)
Leroy J. Hushak, *The Ohio State University*

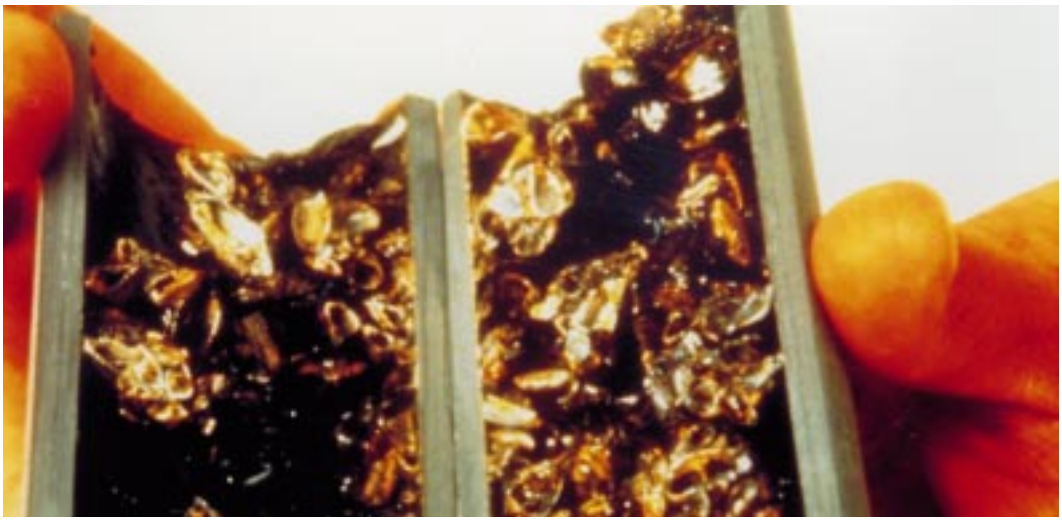
This research surveyed all electric power plants, industrial water users, and municipal water systems which draw water from the Great Lakes to obtain information about the direct costs of the following factors: zebra mussel damages, maintenance due to the infestation of zebra mussels, shutting down facilities for cleaning related to zebra mussel investation, redesigning plants and facilities to cope more effectively with zebra mussels, and research expenses incurred to mitigate zebra mussel damages. The Sea Grant Great Lakes Network and other agencies were surveyed to obtain information on zebra mussel research expenditures. Benefit-cost techniques were used to estimate benefit and cost streams from which to estimate the rate of return to zebra mussel research in developing lower cost zebra mussel control technologies.

Publications

Hushak, L. 1995. The cost of zebra mussel monitoring and control. *Aquatic Nuisance Species Digest*, 1(10):5.

Hushak, L. 1995. *Water User Expenditures on Zebra Mussel Monitoring and Control.* Sea Grant Research Progress Report, Ohio Sea Grant College Program.

Hushak, L. and J. Park. 1999. *Zebra Mussel Controls Costs in Surface Water Using Facilities.* Ohio Sea Grant College Program Technical Summary Report, Publication OHSU-TS-028.



Great Lakes Sea Grant Network Graphics Library

June 1996 – May 1997

Field Testing of a Mechanical Device for the Control of Zebra Mussel Infestation in Water Piping Systems

Ohio Sea Grant (Project R / ZM-27-PD)
Tiao J. Chang, *Ohio University*

The project conducted the field testing of a mechanical device for the control of zebra mussel infestation in water conduits at the Avon Lake Water Plant, Avon Lake, Ohio, and gathered further information for the future installation of a pilot device at the site that was infested by zebra mussels. The device was developed based on the mechanical reduction of dissolved oxygen in the water conduits by a vacuum system, which was successfully tested in the laboratory at Ohio University.

Publications

Chang, T. J. and B. A. Bartrand. 1998. Field testing results of a vacuum device for zebra mussel control in water conduits. In *Proceedings of the Eighth International Zebra Mussel and Aquatic Nuisance Conference* (March 15-18, 1998).

Chang, T.J., M. Hoover, and T.A. Bartrand. 1997. Optimization of a vacuum device for zebra mussel control. In *Zebra Mussels and Aquatic Nuisance Species Control*, pp. 389-398, Boca Raton, FL:CRC Press.

Control and Mitigation

Key Words
monitoring
nonindigenous
physical control
zebra mussel

September 1997 – August 1999

Optimizing Zebra Mussel Control and Preventing Dispersal Through Improved Veliger Detection Using an rRNA

New York Sea Grant (Project R / XG-7)
Sandra Nierzwicki-Bauer, *Darrin Fresh Water Institute*
Clifford E. Kraft, *Cornell University*
Marc Frischer, *Skidaway Institute of Oceanography*

This study developed a genetic probing method whereby water samples could be quickly and simply screened for zebra mussel veligers without the requirement of laborious laboratory procedures. The objectives were to: (1) develop in situ hybridization techniques, using 18S rRNA targeted probes, that were responsive to routine use in typical zebra mussel monitoring programs; (2) determine the usefulness of the 18S rRNA probe for assessing the metabolic activity and viability of veligers; and (3) characterize the use of the Polymerase Chain Reaction (PCR) amplification technique to provide maximum veliger detection sensitivity.

Control and Mitigation

Key Words
genetic probe
veliger
zebra mussel

Research

Preventing New Introductions

Key Words
ballast water, basic biology
bivalve, byssal attachment
colonization, dams
disposal, dispersal mechanism
ecological interactions
economic development
electricity, filters, impact
industry, inland lakes/rivers
nonindigenous
population dynamics
prevention, quagga mussel
recreation, resource managers
surface water users
zebra mussel

September 1997 – August 1999

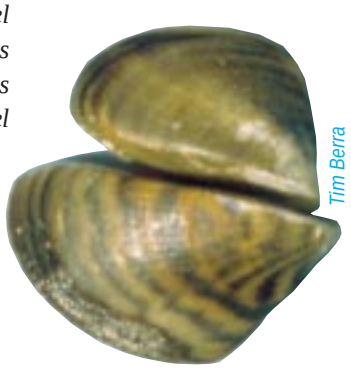
Suitability of Florida Waters to Invasion by the Zebra Mussel (*Dreissena polymorpha*)

Florida Sea Grant (Project E / ZM-3)
Ernest D. Estevez and Don Hayward, *Mote Marine Laboratory*

Using a database and a Habitat Suitability Index (HSI), Florida waters that could be vulnerable to a zebra mussel infestation were identified.

Publications

Howard, D. and Estevez, E. D. 1997. *Suitability of Florida Waters to Invasion by the Zebra Mussel,* Dreissena polymorpha. Mote Marine Laboratory Technical Report No. 495, Sarasota, Florida.


Tim Berra

Reducing the Spread of Established Populations

Key Words
bivalve
colonization
dispersal mechanism
inland lakes/rivers
nonindigenous
recreation
veliger
zebra mussel

September 1994 – August 1997

An Assessment of the Overland Dispersal of Zebra Mussels into North American Lakes

Connecticut Sea Grant (Project R / ES-8)
Ladd Johnson, *Connecticut Sea Grant*

Wisconsin Sea Grant (Project R / LR-62)
Clifford Kraft, *Wisconsin Sea Grant*
James Carlton, *Michigan Sea Grant*

This project examined the potential rate and direction of the overland spread of zebra mussels to North American inland lakes by examining plankton samples and inspecting recreational vessels to assess dispersal mechanisms. Veliger transport in live wells and mussels attached to macrophytes caught on boat trailers and propellers were determined to be the most likely means for overland dispersal of zebra mussels.

Publications

Johnson, L.E. 1995. Enhanced early detection and enumeration of zebra mussel (*Dreissena* spp.) veligers using cross-polarized light. *Hydrobiologia,* 312:139-146.

Johnson, L.E. 1999. Post-establishment spread of the zebra mussel (*Dreissena polymorpha*): Potential mechanisms for the further spread in Ireland. In *Proceedings of the Zebra Mussels in Ireland Conference,* T.K. McCarthy (ed.), National University Galway, Galway, Ireland.

Johnson, L.E. and Carlton, J.T. 1996. Post-establishment spread in large-scale invasions: Dispersal mechanisms of the zebra mussel *Dreissena polymorpha. Ecology*, 77:1686-1690.

Johnson, L.E. and Padilla, D.K. 1996. Geographic spread of exotic species: Ecological lessons and opportunities from the invasion of the zebra mussel *Dreissena polymorpha. Conservation Biology*, 78(1-2):23-33.

September 1996 – August 1998

Ecosystem State Changes in Lake Erie: Expansion of Invading Mussel Assemblages on Soft Substrates

Ohio Sea Grant (Project R/ER-38)
Paul A. Berkman, *The Ohio State University*
David W. Garton, *Indiana University - Kokomo*
John E. Gannon and Gregory Kennedy, *National Biological Survey*
Scudder D. Mackey, *ODNR Division of Geological Survey*

This research project integrated Side Scan Sonar (SSS) and Remotely Operated Vehicle (ROV) surveys along with *in situ* SCUBA collections to interpret and predict the lakewide distribution and abundance of *Dreissena* assemblages on soft substrates in Lake Erie. Specifically, it concentrated on the coverage of *Dreissena* assemblages on different soft-substrate types in Lake Erie; characterized the *Dreissena* assemblages (size frequency, density, and species composition) on different soft-substrate types; assessed the expansion of *Dreissena* assemblages on different soft-substrate types; and predicted the overall soft-substrate distributions and abundances of *Dreissena* assemblages in Lake Erie.

Publications

Berkman, P.A., M.A. Haltuch, E. Tichich, D.W. Garton, G.W. Kennedy, J.E. Gannon, S.D. Mackey, J.A. Fuller, D.L. Liebenthal. 1998. Invading Mussel Beds in Lake Erie. *Nature*, 393:27-28.

Reducing the Spread of Established Populations

Key Words
aquaculture
bivalve
colonization
ecological interactions
impact
Lake Erie
nonindigenous
quagga mussel
remotely operated vehicle
sidescan sonar
soft substrates
zebra mussel

June 1997 – May 1999

Assessment of Active Dispersion by Adult Zebra Mussels, and Consequences for Unionid Mussel Refugia

Connecticut Sea Grant
J. Ellen Marsden, *University of Vermont*

This study quantified rates of adult zebra mussel movement in relation to current under artificial (laboratory) and field conditions, and how zebra mussels are affected by temperature and mussel size. The data helped define areas which zebra mussels may be able to access, that currently are assumed to be protected from mussel colonization. This information will be particularly valuable for programs that target the preservation of native unionids, as it will help define potential refuge habitats for unionids.

Reducing the Spread of Established Populations

Key Words
basic biology
bivalve
byssal attachment
colonization
dispersal mechanism
ecological interactions
impact
nonindigenous
zebra mussel

Fred Snyder

Outreach

For other related projects, see the Multi-Species Outreach Projects section beginning on page 107.

Conferences

Key Words
aquaculture
aquatic nuisance species
ballast water
biological control
ecological interactions
educational program
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
prevention
zebra mussel

1990 – 1999

International Zebra Mussel and Aquatic Nuisance Species Conferences

California Sea Grant, Jodi Cassell
Michigan Sea Grant, John Schwartz
Minnesota Sea Grant, Doug Jensen
New York Sea Grant, Charles O'Neill
Ohio Sea Grant, Fred Snyder
Wisconsin Sea Grant, Allen Miller

In 1990, Ohio Sea Grant hosted the first *International Zebra Mussel Research Conference*. Since its inception, this conference has served as a model that has been repeated annually in both the U.S. and Canada. Renamed the *International Zebra Mussel and other Aquatic Nuisance Species Conference* in 1995 to recognize the impact of other invasive species, the conference has played a significant role in fostering the dissemination of research and education program results among various agencies, states, regions, and countries. (Note: Only the conferences that were hosted by a Sea Grant program are listed below). ***Audience:*** aquaculture, elected officials, fisheries, general public, government agencies, lake associations, mariculture, maritime interests, media, property owners, recreational boaters, researchers, resource managers, utilities.

Products and Presentations

Conferences and Proceedings

International Zebra Mussel Research Conference Proceedings, Columbus, OH (December 5-7, 1990); conference hosted by Ohio Sea Grant. ***Distribution:*** 250; ***Participants****:* 200; ***Audience****:* agencies, government, industry, researchers, students, teachers.

Second International Zebra Mussel Research Conference Proceedings, Rochester, NY (November 19-22, 1991); conference hosted by New York Sea Grant. ***Distribution:*** 250; ***Participants****:* 200; ***Audience****:* agencies, government, industry, researchers, students, teachers.

Fourth International Zebra Mussel Conference Proceedings, Madison, WI (March 7-10, 1994); conference hosted by Wisconsin Sea Grant. ***Distribution:*** 350; ***Participants:*** 300; ***Audience:*** agencies, government, industry, researchers, students, teachers.

Sixth International Zebra Mussel and Other Aquatic Nuisance Species Conference Proceedings, Dearborn, MI (March 5-7, 1996); conference hosted by Michigan Sea Grant. ***Distribution:*** 450; ***Participants:*** 428; ***Audience:*** agencies, government, industry, researchers, students, teachers.

Eighth International Zebra Mussel and Other Aquatic Nuisance Species Conference Proceedings, Sacramento, CA (March 16-19, 1998); conference hosted by California Sea Grant. ***Distribution:*** 400; ***Participants:*** 358; ***Audience:*** agencies, government, industry, researchers, students, teachers.

Ninth International Zebra Mussel and Other Aquatic Nuisance Species Conference Proceedings, Duluth, MN (April 26-30, 1999); conference hosted by Minnesota Sea Grant. ***Distribution:*** 450; ***Participants:*** 394; ***Audience:*** agencies, government, industry, researchers, students, teachers.

1994 – 1995

Gambling with the Threat of Zebra Mussel Invasion in the Mid-Atlantic Conference

New Jersey Sea Grant (lead program), Eleanor A. Bochenek
Delaware Sea Grant, Jim Falk
Maryland Sea Grant, Dan Terlizzi
New York Sea Grant, Charles O'Neill
North Carolina Sea Grant, Barbara Doll
Virginia Sea Grant, Vicky Clark

The conference was held in Atlantic City, NJ on June 1-3, 1994. It was sponsored by the Mid-Atlantic Sea Grant Network (NY, NJ, DE, MD, VA, NC), New Jersey Marine Sciences Consortium, Rutgers Cooperative Extension, National Sea Grant College Program, and Public Service Electric & Gas.
Audience: business / industry, government, lake associations, maritime interests, media, resource managers, utilities.

Products and Presentations

Conference and Proceeding
Proceedings of Selected Papers: Gambling with the Threat of Zebra Mussel Iinvasion in the Mid-Atlantic Conference, Atlantic City, NJ. 1994. (produced by NJ, 1995). ***Distribution:*** 100; ***Audience:*** lake associations, industry personnel, natural resource managers and biologists, water users.

Conferences

Key Words
basic biology
biological control
bivalve
chemical control
coatings
colonization
educational
filters
impact
industry
inland lakes/rivers
monitoring
physical control
prevention
veliger
zebra mussel

August 1995 – July 1999

Videotape and Videoconference Project: Zebra Mussels - Lessons Learned in the Great Lakes: An Overview of Biology, Impacts, Prevention and Control of a Freshwater Invader

Illinois-Indiana Sea Grant (Project A / SE-95-876.1)
Brian K. Miller and Thomas Luba

A panel of experts from this national videoconference offered current information on zebra mussel biology, environmental and economic impacts, and suggested methods for prevention and control. The videos are designed for professionals and interested citizens who are just experiencing or expect a zebra mussel invasion. Zebra mussel research updates and practical help tips are also provided. Case studies show hypothetical situations where zebra mussels exist or are suspected of being a potential problem.
Audience: anglers, bait shop owners, elected officials, freshwater marina owners, general public, government agencies, lake associations, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators, utilities.

Products and Presentations

Videoconference
Zebra Mussels: Lessons Learned in the Great Lakes Region (1997).
Audience: extension educators, resource managers, water users in newly infested areas.

Videos
Zebra Mussels: Lessons Learned in the Great Lakes Region (1997). ***Audience:*** anglers, boaters, extension educators, lake associations, water users in newly infested waters.

*Zebra Mussel Biology: Lessons Learned in the Great Lakes (*1998).
Audience: anglers, boaters, general public, students, water users.

Zebra Mussel Control: Lessons Learned in the Great Lakes (1998).
Audience: industry, municipalities, water users.

*Zebra Mussel Outreach Products: Lessons Learned in the Great Lakes (*1998).
Audience: extension educators.

Zebra Mussel Spread and Impact: Lessons Learned in the Great Lakes (1998).
Audience: anglers, boaters, general public, students, water users.

Conferences

Key Words
ballast water
basic biology
biological control
byssal attachment
dispersal mechanism
ecological interactions
economic development
educational program
electricity
impact
inland lakes/rivers
nonindigenous
population dynamics
prevention
videos
videoconference
zebra mussel


Tim Berra

Outreach

Curriculum Projects

Key Words
aquaculture, ballast water
basic biology, bioaccumulation
biological control
bivalve, byssal attachment
chemical control, coatings
colonization, common carp
curlyleaf pondweed, dams
disposal, dispersal mechanism
ecological interactions
economic development
educational program
electricity, Eurasian ruffe
Eurasian watermilfoil
filters, impact, industry
inland lakes/rivers, monitoring
nonindigenous, pollution
population dynamics, predators
prevention, quagga mussel
recreation, round goby
sea lamprey, rusty crayfish
spiny waterflea
threespine stickleback, veliger
wetlands, zebra mussel

1992 – 1993

Mussel Menace! Zebra Mussels and You: An Instructor's Training Package

Minnesota Sea Grant
Glenn M. Kreag, Jeffrey L. Gunderson, Connie Schwegman, Mike McLean, Gail Tischler, Douglas A. Jensen, Marie E. Zhuikov, Maggie Aitkin, and Alice Tibbetts

This leader training package is designed to teach about the problems posed by zebra mussels and aquatic nuisance species, and how to prevent their spread. The package includes a 16-minute videotape, a slide-audiotape, and a manual, which contains newsletters, contact information, legislation, fact sheets, brochures, cards, posters, and other information on ANS. It is a popular ready-made education program for water resource professionals and many groups such as sporting, conservation, and environmental organizations, and boating and lake associations in the Great Lakes and nationally. ***Audience:*** anglers, business / industry, charter captains, conservation organizations, elected officials, environmental organizations, general public, government agencies, lake associations, maritime interests, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators, utilities.

Products and Presentations

Training Package
Mussel Menace! Zebra Mussels and You (1993). ***Distribution:*** 400;
Audience: boaters, business / industry, conservation and environmental organizations, educators, general public, governments agencies, lake associations, maritime interests, media, recreational boaters, utilities.

Curriculum Projects

Key Words
basic biology
bivalve
colonization
dispersal
mechanism
ecological interactions
educational program
impact
inland lakes/rivers
nonindigenous
prevention
veliger
zebra mussel

1993 – 1998

Educational Resource Package: Invasion of an Exotic Species – Stop the Zebra Mussel!

Virginia Sea Grant
Vicki Clark, *Virginia Institute of Marine Science*

This teaching resource includes a collection of zebra mussel fact sheets and other resources focusing on zebra mussel biology and the ecological and economic problems created by zebra mussels. It also features group problem-solving activities that allows students to predict the risk of invasion and establishment of zebra mussels in a variety of Virginia lakes and rivers by analyzing water quality information and other data from research projects. ***Audience:*** students (grades 8-12), teachers / educators (grades 8-12).

Products and Presentations

Educational Material
Invasion on an Exotic Species: Stop the Zebra Mussel! (1994). ***Distribution:*** over 1,000 since 1994 (in VA); 100 distributed through NJ Sea Grant (1995-1998); ***Audience:*** students and educators in grades 8 - 12.

August 1994 – July 1995

Zebra Mussel Education Project: The Traveling Trunk

Illinois-Indiana Sea Grant (Project A / SE-08-94)
Robin G. Goettel

The Zebra Mussel Mania Traveling Trunk was developed to fill a void in aquatic nuisance species information targeted toward young people. The hands-on curriculum includes experiments, games, and stories along with a kit filled with scientific apparatus, sample zebra mussel / native mussel shells, videos, posters, and student worksheets and pre-tests / post-tests. In 1995, The Traveling Trunk was available at 30 lending centers nationwide (expanded to 37 in 1998) and has been used by teachers in grades 2-12 integrating subjects of science, math, social studies, language arts, and cultural arts. ***Audience:*** students (grades 3-8), teachers / educators (grades 3-8).

Products and Presentations

Chart
Zebra Mussel Life Cycle (1995). ***Distribution:*** 120; ***Audience:*** educators.

Fact Sheet
Crazy Creature (1995, revised 1998). ***Distribution:*** 4000; ***Audience:*** educators.

Curriculum Guides
Teacher Resource Portfolio on Zebra Mussels and other Aquatic Exotics (1995).
Distribution: 37; ***Audience:*** educators.

Zebra Mussel Mania Curriculum Guide (1995). ***Distribution:*** 37; ***Audience:*** Educators.

Curriculum Projects

Key Words
basic biology
colonization
ecological interactions
educational program
Eurasian ruffe
impact
industry
nonindigenous
population dynamics
round goby
sea lamprey
spiny waterflea
zebra mussel

August 1995 – July 1997

An Intensive Marketing Effort to Provide the Zebra Mussel Traveling Trunk and Curriculum Materials to Educators Across the Nation

Illinois-Indiana Sea Grant (Project A / SE-95-77.4)
Robin G. Goettel

Minnesota Sea Grant (Project A / SE-4; A / SE-D)
Michael McLean, Douglas A. Jensen, Jeffrey L. Gunderson, Dale R. Baker, Alice Tibbets, and Marie E. Zhuikov

To further zebra mussel education both in the Great Lakes region and throughout the U.S., the Illinois-Indiana and Minnesota Sea Grant College programs developed unique educational science resource kits known as "Traveling Trunks" that inform youth of the biology, spread, and impacts of zebra mussels and other nonindigenous aquatic species. Both Sea Grant programs maximized use of these educational trunks through a joint publicity brochure that identified lending centers, content information, prices, and background on curriculum content. In addition Illinois-Indiana and Minnesota Sea Grant conducted in-service training presentations and independent and joint demonstrations at national and regional meetings for teachers and environmental educators. ***Audience:*** general public, government agencies, lake associations, students (grades 3-8), teachers / educators (grades 3-8).

Products and Presentations

Brochure
Two Traveling Trunk Adventures: Exotic Aquatics and Zebra Mussel Mania Traveling Trunks (1997).
Distribution: 12,000; ***Audience:*** teachers and educators (formal and non-formal).

Curriculum Guides
Teacher Resource Portfolio on Zebra Mussels and other Aquatic Exotics (1997). ***Distribution:*** 49;
Participants: 37 Lending Centers in U.S. and Canada; **Audience:** educators and students.

*Zebra Mussel Mania Curriculum Guide (*1997). ***Distribution:*** 60; ***Audience:*** educators and students.

Curriculum Projects

Key Words
basic biology
biological control
colonization
ecological interactions
educational program
Eurasian ruffe
Eurasian watermilfoil
impact
industry
nonindigenous
population dynamics
predators
prevention
purple loosestrife
recreation
round goby
rusty crayfish
sea lamprey
spiny waterflea
veliger
wetlands
zebra mussel

Outreach

Gulf of Mexico Region

Key Words

aquaculture
ballast water
basic biology
bivalve
chemical control
Chinese tallow
coatings
colonization
dispersal mechanism
ecological interactions
educational program
electricity
grass carp
hydrilla
impact
industry
inland lakes/rivers
monitoring
nonindigenous
nutria
physical control
recreation
risk assessment
veliger
water hyacinth
wetlands
zebra mussel

September 1997 – August 1999

Gulf of Mexico Region Project Relative to Invasions of Zebra Mussels and other Nonindigenous Nuisance Species

Lousiana Sea Grant - lead program (Project A / ZM-4)
Michael Liffmann and Marilyn Barrett-O'Leary

Mississippi-Alabama Sea Grant (Project A / O-26)
William Hosking and C. David Veal

Florida Sea Grant (Project A / ZM-2)
Marion Clarke

Texas Sea Grant (Project A / F-9)
Mike Hightower

The major purpose of this project was to convey the concept of nonindigenous species and make it a familiar word. In addition, this project provided audiences with ways to reduce dispersal and control invasion in the Gulf of Mexico region. By working together as a region while each concentrating on separate target audiences, the Sea Grant Programs in the Gulf of Mexico Region have been able to reach most of the groups in the area who are key dispersers and targets for invasion. ***Audience:*** aquaculturists, anglers, business / industry, elected officials, general public, government agencies, inland navigation management maritime interests, media, motorists trailering boats into region, ports, recreational boaters, researchers, resource managers, students (K-8), surface water using industries, teachers / educators (K-8), utilities.

Products and Presentations

Note: The primary program contact is given for each product, if applicable.

Display

Exotic Invaders Display "Ocean Commotion" event at Louisiana State University (October 1998, LA).
Participants: 6,000; ***Audience:*** children and teachers.

Fact Sheets

Could Your Boat and Motor be in Trouble? Maybe! (1998, FL).
Distribution: 15,000; ***Audience:*** boaters.

Don't Release Non-native Species! Aquarium Hobbyists (1998, FL).
Distribution: 20,500; ***Audience:*** aquarium hobbyists, government agencies, shop owners.

Don't Release Non-Native Species! Water Gardeners (1998, FL; MS-AL).
Distribution: 20,500; ***Audience:*** homeowners, landscape companies.

Invasion of Zebra Mussels (1995, LA).
Distribution: 1,000; ***Audience:*** general public.

Zebra Mussels - A Florida Perspective (1998, FL).
Distribution: 7,000; ***Audience:*** boaters and anglers, general public, media, surface water users.

The Zebra Mussel and Bait Fish Aquaculture (1997, LA).
Distribution: 500; ***Audience:*** aquaculturists.

The Zebra Mussel and Catfish Aquaculture (1997, LA).
Distribution: 500; ***Audience:*** aquaculturists.

The Zebra Mussel and Crawfish Aquaculture (1997, LA).
Distribution: 500; ***Audience:*** aquaculturists.

The Zebra Mussel and Hybrid Striped Bass Aquaculture (1997, LA).
Distribution: 500; ***Audience:*** aquaculturists.

The Zebra Mussel and Tilapia Aquaculture (1997, LA).
Distribution: 500; ***Audience:*** aquaculturists.

Information Cards
Keep Our Waters Free of Zebra Mussels (1996, LA).
Distribution: 1000; ***Audience:*** anglers and recreational boater.

Zebra Mussel Alert (1998, LA). ***Distribution:*** 900; ***Audience:*** anglers, boaters, resource managers.

Instructional Booklets
Controlling Zebra Mussels In Brown Water Commercial Vessels (1998, LA). ***Distribution:*** 300;
Audience: port engineers and maintenance foreman associated with the inland navigation industry.

Sampling for Zebra Mussels in Industrial Facilities (1997, LA).
Distribution: 100; ***Audience:*** industry technicians.

Magazine
Texas Shores: Corporate Raiders of Nature (July 1998 special issue). ***Distribution:*** 6,000;
Audience: general public, educators, industry, state and federal agencies, researchers, resource managers.

Newsletters
Southern Region Zebra Mussel Newsletter (1995-1997, LA); formerly known as *Lower Mississippi Valley Zebra Mussel Newsletter* (replaced by the *Zebra Mussel Newsletter*, below). ***Distribution:*** 600 per issue;
Audience: all groups interested in zebra mussel distribution and control, primarly regional subscribers.

Zebra Mussel Newsletter (published biannually, LA).
Distribution: 2000 per issue; ***Audience:*** industries and other groups with zebra mussel infestation.

Pamphlet
Aquatic Nuisance Species in Alabama (1998, MS-AL).
Distribution: 3,000; ***Audience:*** General public.

Poster
Ballast Water Management: The Right Thing to Do (1999, MS-AL).
Distribution: 9,000; ***Audience:*** commercial shippers, U.S. Coast Guard.

Presentations
The Gulf of Mexico Sea Grant Plan for Deterring Distribution of Nonindigenous Species, Houston, TX, (May 1998). ***Participants:*** 40; ***Audience:*** government and advocacy group officials.

Potential Environmental and Economic Impacts of Nonindigenous Species on American Transoceanic Ports, American Association of Port Authorities Annual Conference, Houston, TX (October 7, 1998).
Participants: 40; ***Audience:*** port management.

Zebra Mussels and Other Aquatic Nuisance Species (1998, MS-AL).
Participants: 200 during five presentations; ***Audience:*** general public, high school students.

Reports
Introduction of Nonindigenous Species Focus Team Meeting (1998, LA). ***Distribution:*** 78;
Audience: environmental groups, researchers, resource managers, state and federal regulatory agencies.

Potential Environmental and Economic Impacts of Nonindigenous Species on Gulf of Mexico Transoceanic Ports (1998, LA). ***Distribution:*** 10; ***Audience:*** ports along the Gulf of Mexico.

Shrimp Virus Management Workshop/Aquaculture Management Recommendations (1998, LA).
Distribution: 95; ***Audience:*** commercial shrimpers, environmental groups, fish farmers, maritime industry, researchers, resource managers, shrimp farmers, state and federal regulatory agencies.

Summary of the Aquatic Nonindigenous Species Workshop for the Gulf of Mexico (1998, LA).
Distribution: 90; ***Audience:*** educators, environmental groups, maritime industry, researchers, resource managers, state and federal regulatory agencies.

Radio Broadcasts
Zebra Mussel Awareness: Low powered radio broadcasts at I-95; 1300 am and I-75; 1600 am (1997-1999, FL). ***Audience:*** Motorists.

Outreach

Programs for Inland Water Users

Key Words
colonization
dispersal mechanism
educational program
inland lakes/rivers
monitoring
nonindigenous
population dynamics
prevention
quagga mussels
recreation
veliger
zebra mussel

June 1995 – August 1999

Early Detection of Zebra Mussels in Midwestern Inland Lakes by Citizen Monitors

Michigan Sea Grant (Project A / FP-4)
John D. Schwartz

Minnesota Sea Grant (Project A / SE-2C)
Jeffrey L. Gunderson, Douglas A. Jensen, Michael McLean, and Dale R. Baker

Wisconsin Sea Grant (Project A / AS-36)
Clifford Kraft

The project provided training and sampling kits in 1996 and 1997 for volunteers who worked on different lakes in Michigan, Minnesota, and Wisconsin. The quality and quantity of samples collected by the citizen volunteers was consistent with that of work done by Sea Grant personnel and demonstrated the potential utility of having samples collected by volunteers. ***Audience:*** anglers, elected officials, environmental learning centers, general public, government agencies, lake associations, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators, utilities.

Products and Presentations

Note: The primary program contact is given for each product, if applicable.

Fact Sheet
Zebra Mussel Watch Citizen Network Guide (1996, MN). ***Distribution:*** 180; ***Audience:*** agencies, anglers, boaters, environmental learning centers, lake associations, shoreland property owners, students, teachers / educators.

Map and Report
Zebra Mussel Distribution in the Inland Waters of Michigan's Lower Peninsula (produced quarterly since 1996, MI). ***Distribution:*** 5,000; ***Audience:*** lake associations, media, researchers, teachers / educators.

Presentation
Volunteers for Minnesota's Zebra Mussel Detection Program, North American Lake Management Society Meeting (Minneapolis, MN, 1996). ***Participants:*** 790; ***Audience:*** agencies, anglers, boaters, environmental learning centers, lake associations, shoreland property owners, students, teachers / educators.

Volunteers for Minnesota's Zebra Mussel Detection Program, Shoreland Volunteer Workshop (1996). ***Participants:*** 120; ***Audience:*** agencies, anglers, boaters, environmental learning centers, general public, lake associations, shoreland property owners, students, teachers / educators.

Specimen Sets
Detecting Zebra Mussels: A Monitoring Program for Citizens (MN).
Distribution: 600 sets of 4 specimens; ***Audience:*** agencies, anglers, boaters, environmental learning centers, lake associations, shoreland property owners, students, teachers / educators.

Training Manuals
Detecting Zebra Mussels: A Monitoring Program for Citizens (1996, MI).
Distribution: 55 in MI; 5 in MN; ***Participants:*** number unavailable for MI; 35 in MN;
Audience: agencies, environmental learning centers, lake associations, teachers / educators.

Video
Detecting Zebra Mussels: A Monitoring Program for Citizens (1996, MI). ***Distribution:*** 50 in MI; 10 in MN ;
Audience: agencies, environmental learning centers, lake associations, teachers / educators.

August 1995 – July 1997

Outreach Education Program for Inland Water Users

Illinois-Indiana Sea Grant (Project A / SE-95-77.4)
Brian Miller

Michigan Sea Grant (Project A / FP-4)
John Schwartz and Michael Klepinger

Ohio Sea Grant (Project A / ZM-1)
Leroy Hushak and Fred Snyder

This main object of this program was to develop a conference for industries and personnel responsible for the control of zebra mussels in industrial facilities. The workshops consisted of a 1-day, low-cost, conference that used a case study format to maximize the exchange of practical methods for "living with zebra mussels." The body of knowledge assembled from these conferences has helped minimize costs incurred by industry in newly-infested areas around the country. ***Audience:*** elected officials, government agencies, lake assocations, property owners, recreational boaters, researchers, resource managers, utilities, water using industries

Products and Presentations

Zebra Mussel Conference for Inland Water Users (1995 -1997 by OH and IL-IN). ***Participants:*** 200 total; ***Audience:*** facility supervisors, equipment engineers and suppliers, policy-makers.

Zebra Mussels in Michigan: Implications for Municipal/Industrial Water Users (1996 -1997). ***Participants:*** 300 total; ***Audience:*** facility supervisors, equipment engineers and suppliers, policy-makers.

Maran Hilgendorf

Programs for Inland Water Users

Key Words
basic biology
byssal attachment
chemical control
coatings
dams
disposal
electricity
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
zebra mussel

Outreach

Programs for Inland Water Users

Key Words
aquatic nuisance species
basic biology
byssal attachment
coatings
ecological interactions
impact
inland lakes/rivers
monitoring
nonindigenous
prevention
recreation
zebra mussel

September 1997 – August 1999

Zebra Mussel Workshops for Inland Water Users: Prevention and Protection through Education

Illinois-Indiana Sea Grant - lead program (Project A / SE-(ANS)-07-97)
Pat Charlebois

Michigan Sea Grant (Project A / NIS-3)
John Schwartz and Michael Klepinger

Minnesota Sea Grant (Project A / SE-14)
Douglas A. Jensen

This project developed slide presentations on zebra mussel biology and spread, monitoring for veligers, protection of small intakes and recreational equipment, and outreach tools on zebra mussels and other aquatic nuisance species. The workshops allowed delivery of this information directly to water users and resource managers, and allowed personal interaction between Sea Grant and its constituents. ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters, resource managers

Products and Presentations

Note: The primary program contact is given for each product, if applicable.

Presentations

Aquatic Exotics in Inland Lakes: Prevention and Protection (1998-1999, IL-IN).
Participants: 200; ***Audience:*** anglers, general public, lake associations, property owners, recreational boaters, resource managers.

Controlling Inland Lake Biological Pollution (1997- 1998, MI).
Participants: 250; ***Audience:*** lake property owners, policy-makers.

Detecting Zebra Mussels: A Monitoring Program for Citizens (PowerPoint presentation, 1999, MN).
Audience: agencies, anglers, boaters, general public, lake associations, shoreland property owners, students, teachers / educators.

Slide Packages

Aquatic Exotics in Inland Lakes: Prevention and Protection (1998, IL-IN).
Distribution: 20; ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters, resource managers.

Aquatic Exotics in Inland Lakes: Outreach Tools (1998, IL-IN).
Distribution: 20; ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters, resource managers.

*Detecting Zebra Mussels: A Monitoring Program for Citizens (*1997, revised 1998, MI).
Distribution: 6; ***Audience:*** lake property owners, boaters, policy-makers.

Inland Lake Weed Harvesters: Part of the Solution to Biological Pollution (1998, MI).
Distribution: 6; ***Audience:*** commercial macrophyte harvesters, lake property owners, policy-makers.

The Spread of Zebra Mussels to Inland Lakes: Implications and Actions (1998, MI).
Distribution: 6; ***Audience:*** lake property owners, boaters, policy-makers.

Workshop

Detecting Zebra Mussels: A Monitoring Program for Citizens (1999, MN).
Audience: agencies, anglers, boaters, general public, lake associations, shoreland property owners, students, teachers / educators.

September 1995 – September 2000

The National Zebra Mussel and Aquatic Nuisance Species Information Clearinghouse

New York Sea Grant (Project A / EEP-4)
Charles R. O'Neill, Jr. and Dale R. Baker

The mission of the National Zebra Mussel and Aquatic Nuisance Species Clearinghouse is to: facilitate and coordinate sharing of zebra mussel and other aquatic nuisance species information among all levels of university, government, and private industry researchers throughout North America; serve as a high-profile national and international nexus for linking aquatic nuisance species researchers with similar interests; provide continuity to the timely dissemination of findings of zebra mussel and other aquatic nuisance species research; facilitate technology transfer between zebra mussel and aquatic nuisance species researchers and end user audiences; focus attention on the need for additional research and outreach to enhance the fight against zebra mussels and other aquatic nuisance species; and, compile, maintain, and provide access to North America's most extensive scientific / technical libraries on zebra mussels and other aquatic nuisance species via the World Wide Web. ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, lake associations, maritime interests, media, property owners, recreational boaters, researchers resource managers, students (K-12, undergraduate, graduate, post graduate), teachers / educators (K-12, undergraduate, graduate, post graduate), utilities.

Products and Presentations

Library

National Zebra Mussel & Aquatic Nuisance Species Clearinghouse Technical Collection Library.
Distribution: 3,706 items (since January 1995; the library has been in existence since 1991 and is continually updated); ***Audience:*** business / industry, commercial fishers and recreational anglers, commercial navigation, drinking water treatment utilities, elected officials, general public, government agencies, lake associations, media, power plants, property owners, recreational boaters, researchers, resource managers, students, teachers / educators.

Newsletter

Dreissena! (published bi-monthly since 1990).
Distribution: 18,344 (since January 1995); ***Audience:*** business / industry, commercial fishers and recreational anglers, commercial navigation, drinking water treatment utilities, elected officials, general public, government agencies, lake associations, media, power plants, property owners, recreational boaters, researchers, resource managers, students, teachers / educators.

Zebra Mussel Distribution Map

North American Range of the Zebra Mussel and the Quagga Mussel.
Distribution: 17,217 (since January 1995); ***Audience:*** business / industry, commercial fishers and recreational anglers, commercial navigation, drinking water treatment utilities, elected officials, general public, government agencies, lake associations, media, power plants, property owners, recreational boaters, researchers, resource managers, students, teachers / educators.

Web Site

National Zebra Mussel & Aquatic Nuisance Species Clearinghouse Web Site:
www.cce.cornell.edu/aquaticinvaders/
Audience: business / industry, commercial fishers and recreational anglers, commercial navigation, drinking water treatment utilities, elected officials, general public, government agencies, lake associations, media, power plants, property owners, recreational boaters, researchers, resource managers, students, teachers / educators.

National Zebra Mussel Information Clearinghouse

Key Words
aquatic nuisance species
aquaculture, Asian clam
ballast water
basic biology
bioaccumulation
biofouling
biological control
bivalve, blueback herring
blue mussel
brown mussel
byssal attachment
Chinese mitten crab
chemical control
coatings, colonization
dams, disposal
dispersal mechanism
ecological interactions
economic development
educational program
electricity, Eurasian ruffe
European green crab
exotic species, filters
grass carp, impact
industry
inland lakes/rivers
invasive species
mollusk, monitoring
nonindigenous
physical control
pollution
population dynamics
predators, prevention
quagga mussel
recreation, round goby
shipworms
spiny waterflea
Suminoe oyster
tubenose goby
veliger, zebra mussel

Outreach

National Zebra Mussel Information Clearinghouse

Key Words
Eurasian ruffe
nonindigenous

September 1997 – August 1999

Enhancing, Expanding, and Operating the National Zebra Mussel and Aquatic Nuisance Species Information Clearinghouse

New York Sea Grant (Project A / EEP-10)
Dale R. Baker and Charles R. O'Neill

Minnesota Sea Grant (Project A / SE-12)
Douglas A. Jensen and Michael E. McDonald

Combined efforts by the National Clearinghouse (New York) and the Ruffe Research Database (Minnesota) are expanding the technical library to other ANS, including Eurasian ruffe, to better serve Clearinghouse audiences by providing and enhancing a searchable database via the World Wide Web. Research available on-line will also be available as reprints (as applicable to copyright laws), via interlibrary loan, or as annotated abstracts.
Audience: business / industry, elected officials, government agencies, maritime interests, researchers, resource managers, students (secondary, post-secondary), teachers / educators (secondary, post-secondary).

Products and Presentations

Library
Eurasian Ruffe Technical Library (developed in 1999).
Audience: anglers, elected officials, general public, government agencies, lake associations, media, recreational boaters, researchers, resource managers, students, teachers / educators.

Gary Cholwek

September 1994 – August 1999

USDA/Nationwide Zebra Mussel Training Initiative

New York Sea Grant - lead program (Project A / EEP-7)
Dale Baker and Charles O'Neill

Connecticut Sea Grant (Project A / E-6)
Nancy C. Balcom

Lousiana Sea Grant (Project A / ZM-3)
Michael Liffmann

Minnesota Sea Grant (Project A / SE-4)
Jeffrey L. Gunderson, Douglas A. Jensen, and Mike McLean

North Carolina Sea Grant (Project A / EA-10)
Barbara Doll

The purpose of this multi-year training initiative was to provide access to resources and informational materials, and provide training on zebra mussels, particularly to individuals in non-Sea Grant states. Led by New York Sea Grant, this multi-state initiative sponsored national teleconferences, a conference that spawned the Western Zebra Mussel Task Force (WZMTF), and the first West Coast and Heartland zebra mussel conferences. Conferences also held in the Upper Mississippi River Basin featured presentations on biology, ecology, prevention, control, management, risk assessment and impacts of zebra mussels. A training package was updated through this initiative and distributed to conference attendees.
Audience: aquaculture, business / industry, Cooperative Extension, elected officials, general public, government agencies, lake associations, maritime interests, media, property owners (shoreland), recreational boaters, researchers, resource managers, students (high school and college), teachers / educators (high school and college), utilities.

Products and Presentations

Note: The primary program contact is given for each product, if applicable.

Conferences and Workshops

Second Northeast Conference on Nonindigenous Aquatic Nuisance Species (April 18-19, 1997, CT).
Participants: 65; ***Audience:*** agencies, educators, industry, lake associations, researchers.

Developing Introduction and Spread Prevention Programs (May 1-3, 1995, CT).
Participants: 100; ***Audience:*** industry, lake associations, researchers, state and federal agencies.

Establishing a Western States Regional Task Force Panel (May 3, 1995, CT).
Participants: 50; ***Audience:*** government agencies, Extension, industry, representatives from Canadian provinces, researchers.

Lessons from the Great Lakes Satellite Conference (September 1997).
Participants: 1000 at sites in more than 40 states and provinces; ***Audience:*** drinking water treatment plants, Extension, lake associations, media, researchers, resource and regulatory agencies, surface water users.

Lower Mississippi River Basin Zebra Mussel Impact, Monitoring, and Control Workshop (January 1995).
Participants: 165; ***Audience:*** drinking water treatment plants, electric generation industry, petrochemical and petroleum industries, lake associations, media, researchers, resource and regulatory agencies.

Nationwide Zebra Mussel Training Initiative "Kickoff" Satellite Teleconference (December 1994).
Participants: 300+ people at 52 downlink sites in 22 states; ***Audience:*** drinking water treatment plants, Extension, lake associations, media, researchers, resource and regulatory agencies, surface water users.

Strategic Planning Session, Massachusetts Coalition of Lakes and Ponds (April 12, 1997, CT).
Participants: 45; ***Audience:*** general public, industry, lake managers, lakeshore residents, resource managers.

Zebra Mussel Menace Leadership Training for Educators and Natural Resource Professionals (September 1994, La Crosse, WI and Davenport, IA). ***Participants:*** 50 total; ***Audience:*** educators, natural resource managers, researchers.

Zebra Mussel Training Initiative

Key Words
aquaculture
ballast water
basic biology
bioaccumulation
biological control
bivalve
byssal attachment
chemical control
colonization
dispersal mechanism
ecological interactions
economic development
educational program
Eurasian ruffe
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
pollution
population dynamics
predators
prevention
quagga mussels
recreation
round goby
sea lamprey
spiny waterflea
veliger
zebra mussel

Outreach

Zebra Mussel Training Initiative

Conferences and Workshops *Continued*

*Zebra Mussels in Ireland Workshop (*Galway, Ireland, February 19-21, 1998).
Participants: 100; ***Audience:*** government, industry, researchers, resource managers, students from Republic of Ireland and Northern Ireland.

Zebra Mussels in Large River Systems Workshop (March 1996).
Participants: 60; ***Audience:*** drinking water treatment plants, environmental groups, natural resource managers, power plant operators.

Zebra Mussels in the Heartland Workshop (November 1997).
Participants: 60; ***Audience:*** local, state, federal, and tribal agencies.

Zebra Mussel Risk Assessment, Prevention, Impact, and Control Workshop (March 1997).
Participants: 60; ***Audience:*** local, state, and federal agencies.

Education Materials

Invasion of the Zebra Mussels: Just a Matter of Time Video (1995, CT). ***Distribution:*** 500; ***Audience:*** anglers, boaters, general public, lake managers, state and federal resource managers.

Mussel Menace! Zebra Mussels and You Leader Training Package (1993, revised 1996, 1998).
Distribution: 100 ; ***Audience:*** agencies, business / industry, educators, general public, lake associations, maritime interests, media, recreational boater organizations, utilities.

The Zebra Mussel: Impact and Control (bulletin, 1995).
Audience: business / industry, resource managers, utilities

Fact Sheets

Organizing a Zebra Mussel Task Force (1996, N.C.).
Distribution: 1,000 (includes distribution by other Sea Grant programs); ***Audience:*** extension agents and specialists, natural resource managers, state and local government agencies.

*Zebra Mussels and Aquaculture: What You Should Know (*1995, N.C.).
Distribution: 4,500 (includes distribution by other Sea Grant programs); ***Audience:*** aquaculturists.

Presentations

Aquatic Nuisance Species Education Products, Zebra Mussels: Lessons Learned in the Great Lakes National Teleconference (September 1997). ***Participants:*** 1,200; ***Audience:*** aquaculturists, Extension educators, industry, municipalities, natural resource managers, researchers, teachers, utilities.

Boater Attitudes and Awareness: A Comparison of Risks in Three Regions Using Surveys, Western Zebra Mussel Information and Monitoring Workshop and Western Zebra Mussel Task Force Meeting (Portland, OR, March 1997).
Participants: 20; ***Audience:*** educators, industry, natural resource managers, researchers.

Boater Attitudes and Awareness Regarding Spread of Exotic Species, Zebra Mussels Invade Dixie Teleconference (Gainesville, FL September 1995); and the Nationwide Zebra Mussel Training Initiative Teleconference (Ithaca, NY, December 1995). ***Participants:*** 3,700 total; ***Audience:*** aquaculture, business / industry, educators, natural resource managers, researchers.

Control of Zebra Mussels in Fish Producing Facilities, Heartland Zebra Mussel Information and Monitoring Workshop and 100th Meridian Initiative Meeting (Kansas City, MO, November 1997).
Participants: 20; ***Audience:*** aquaculture, educators, natural resource managers, public power and water project representatives, researchers.

Developing a Regional Strategy to Stop the Invasion of Aquatic Exotics, New England chapter conference of the North American Lake Management Society (June 21-22, 1996, CT).
Participants: 55; ***Audience:*** aquaculture, educators, natural resource managers, researchers.

Effective Exotic Species Boater Education: Where's the Best Bang for the Buck? Symposium on Nonindigenous Species in Western Aquatic Ecosystems, and Northwest Zebra Mussel Task Force Meeting (Portland, OR, March 1996). ***Participants:*** 170; ***Audience:*** aquaculture, business / industry, educators, natural resource managers, researchers.

Exotic Connection: Lake Superior to Inland Lakes, Minnesota Lakes Association Annual Conference (Duluth, MN, May 1996). ***Participants:*** 20; ***Audience:*** business, educators, lake associations, natural resource managers, researchers.

Minnesota's Approach to Prevent and Control the Spread of Aquatic Nuisance Species, Western Regional Aquatic Nuisance Species Forum on Nonindigenous Species (Portland, OR, July 1997). ***Participants:*** 47; ***Audience:*** aquaculture, business / industry, educators, natural resource managers, researchers.

Mussel Menace! Zebra Mussels and You, International Aquaculture '95 Conference (San Diego, CA, February 1995) and the Sixth Annual Minnesota Lakes Association Conference (St. Croix Falls, WI, October 1994). ***Participants:*** 3,070 total; ***Audience:*** aquaculture, educators, lake associations, natural resource managers, researchers.

Organizing a Zebra Mussel Task Force, Seventh International Zebra Mussel and Aquatic Nuisance Species Conference (New Orleans, LA, January 28-31, 1997).
Participants: 50; ***Audience:*** environmental consultants, industry, researchers, resource managers.

Overview and Update on Nonindigenous Invasive Species in Coastal Areas of the United States, American Association of Port Authorities Harbor, Navigation, and Environment Committee meeting (Duluth, MN, July 1998). ***Participants:*** 25; ***Audience:*** maritime interests.

Results of the Three-State Exotic Species Boater Survey, Sixth International Zebra Mussel and Aquatic Nuisance Species Conference (Toronto, Ontario, February 1995). ***Participants:*** 35; ***Audience:*** educators, natural resource managers, researchers.

Risk Assessment and Regulations Concerning Zebra Mussels and Aquaculture, Heartland Zebra Mussel Information and Monitoring Workshop and 100th Meridian Initiative Meeting (Kansas City, MO, November 1997). ***Participants:*** 20; ***Audience:*** aquaculture, educators, researchers, natural, public power and water project representatives, resource managers.

State Policy Incentives Aimed at Clean Boats: A Minnesota Case Study, Heartland Zebra Mussel Information and Monitoring Workshop and 100th Meridian Initiative Meeting (Kansas City, MO, November 1997). ***Participants:*** 20; ***Audience:*** aquaculturists, educators, natural resource managers, public power and water project representatives, researchers.

Statewide Educational Effort to Stop the Invasion of Exotic Species, University of Minnesota Extension Service Annual Conference, (St. Paul, MN, September 1994). ***Participants:*** 30; ***Audience:*** educators, natural resource managers, researchers.

Surveys Support ANS Boater Awareness Programming: How Can You Best Reach Them? Heartland Zebra Mussel Information and Monitoring Workshop and 100th Meridian Initiative Meeting (Kansas City, MO, November 1997). ***Participants:*** 20; ***Audience:*** aquaculturists, educators, natural resource managers, public power and water project representatives, researchers.

Transient Boater Awareness and Attitudes, Western Zebra Mussel Information and Task Force Meeting (Denver, CO, May 1995). ***Participants:*** 25; ***Audience:*** aquaculture, business / industry, educators, natural resource managers, researchers.

Zebra Mussel Control in Aquaculture Facilities, Western Zebra Mussel Information and Monitoring Workshop and Western Zebra Mussel Task Force Meeting (Portland, OR, March 1997).
Participants: 20; ***Audience:*** educators, industry, natural resource managers, researchers.

Zebra Mussels in Aquaculture: Concerns and Impacts, Great Lakes Panel's Symposium on Information and Education (Ann Arbor, MI, December 1996). ***Participants:*** 50; ***Audience:*** educators, fishing organization, natural resource managers, researchers.

The Zebra Mussel Invasion: Strategies to Curb Their Expansion, Protecting Endangered Freshwater Mussels in the St. Croix River Basin Workshop (St. Croix Falls, WI, September 1994).
Participants: 25; ***Audience:*** educators, natural resource managers, researchers.

The Zebra Mussel Menace: Leadership Training for Educators and Natural Resource Professionals, International Conference on Large Floodplain Rivers (La Crosse, WI, July 1994).
Participants: 400; ***Audience:*** business / industry, educators, natural resource managers, researchers.

Survey

Aquaculturist Survey (1994-1996, N.C.). ***Participants:*** 31 states; ***Audience:*** aquaculturists.

Outreach

Zebra Mussel Training Initiative
Related Project

Key Words
basic biology
bioaccumulation
biological control
chemical control
colonization
dispersal mechanism
ecological interactions
economic development
educational program
impact, industry
inland lakes/rivers
monitoring
nonindigenous
population dynamics
predators, prevention
quagga mussels
recreation, veliger
zebra mussel

September 1997 – August 1999

Mitigating A Zebra Mussel Infestation in California: A Management Training Initiative

California Sea Grant, Jodi L. Cassell

University of Southern California Sea Grant, Susan Yoder

Minnesota Sea Grant, Douglas A. Jensen and Marie E. Zhuikov

Modeled after the success of the Nationwide Zebra Mussel Training Initiative, this initiative was designed to provide proactive programming to people who need to prepare for the potential introduction of zebra mussels in California. Programming included workshops (one held concurrent with the *Eighth International Zebra Mussel and Aquatic Nuisance Species Conference*, March 1998) for small water projects in 1999, and development of a comprehensive training package produced in collaboration with the U.S. Fish and Wildlife Service and several other partners. ***Audience:*** business / industry, conservation and environmental groups, elected officials, government agencies, lake associations, property owners (shoreland), recreational boaters, researchers, resource managers, students (high school and college), teachers / educators (high school and college), utilities.

Products and Presentations

Presentation
Zebra Mussel Information Workshop, Eighth International Zebra Mussel and Aquatic Nuisance Species Conference (Sacramento, CA, March 1998). ***Participants:*** 80; ***Audience:*** business / industry, educators, resource managers, researchers.

Training Package
Special Western Edition, Mussel Menace! Zebra Mussels and You (1993, revised 1998).
Distribution: 100; ***Audience:*** business / industry, educators, resource managers, researchers.

Zebra Mussel Update

Key Words
basic biology
bioaccumulation
byssal attachment
chemical control
coatings
colonization
dispersal mechanism
ecological interactions
educational program
electricity
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
population dynamics
predators
prevention
quagga mussels
recreation
veliger
zebra mussel

June 1995 – March 1998

Zebra Mussel Update Newsletter

Wisconsin Sea Grant - lead program (Project A / AS-36)
Clifford Kraft

Illinois-Indiana Sea Grant, Brian Miller

Michigan Sea Grant, John Schwartz

New York Sea Grant, Chuck O'Neill

Ohio Sea Grant, Fred Snyder

The project focused on creating and distributing the *Zebra Mussel Update* newsletter. Beginning issues focused on Great Lakes concerns related to zebra mussels. In later issues, the content was expanded to include information from around the United States and circulation grew to more than 5000 subscribers. The *Updates* concluded with issue number 30 but are archived on the Wisconsin Sea Grant web site:
www.seagrant.wisc.edu/Communications/Publications/ZMU/index.html
Audience: anglers, business / industry, elected officials, general public, government agencies, lake associations, media, property owners, recreational boaters, researchers, resource managers, students (high school and college), teachers / educators (high school and college), utilities.

Products and Presentations

Newsletter
*Zebra Mussel Update Newsletter (*1995-1998). ***Audience:*** agencies, anglers, boaters, environmental centers, general public, lake associations, media, researchers, shoreland property owners, students, teacher / educators, utilities.

August 1992 – July 1997

Connecticut Zebra Mussel Outreach Program

Connecticut Sea Grant (Project A / E-5)
Nancy C. Balcom

This project provided continuing outreach and educational support for anyone interested in learning about zebra mussels and other aquatic nuisance species, including aquatic plants. Program responsibilities included coordinating state task force meetings and activities, regional newsletter production, presentations, and information dissemination. ***Audience:*** anglers, elected officials, general public, government agencies, lake associations, media, recreational boaters, researchers, resource managers, students (8-12 and college), teachers / educators (8-12 and college), utilities.

Products and Presentations

Display

Space Invaders: Non-Native Species in Northeast Waters (1997). ***Distribution:*** two sets on loan basis; ***Participants:*** three Audubon centers, two community fairs, one library; **Audience:** general public.

Newsletter

Aquatic Exotics News (published twice per year). ***Distribution:*** 1,200 per issue; ***Audience:*** agencies, industry, lake associations, researchers, task forces.

Presentations

Introduced Species (July 1997). ***Participants:*** 20; ***Audience:*** minority teachers (teachers of minorities participating in Sea Grant Pathfinder workshop).

One if by Land, Two if by Ballast Water (January 1997). ***Participants:*** 75; ***Audience:*** U.S. Power Squadron District 1 members & spouses.

Posters

Boaters/Anglers (1998). ***Distribution:*** 500; ***Audience:*** anglers, boaters, lake associations.
Watch out for Hitchhiking Weeds (1997). ***Distribution:*** 1,500; ***Audience:*** anglers, boaters, lake associations.

Proceeding

Proceedings of the Second Northeast Conference on Nonindigenous Aquatic Nuisance Species (July 1997). ***Distribution:*** 250; ***Audience:*** agencies, industry, lake associations, researchers, students.

Nancy Balcom

General
Zebra Mussel

Key Words
Asian clam
dispersal mechanism
educational program
Eurasian watermilfoil
fanwort
hydrilla
inland lakes/rivers
nonindigenous
prevention
recreation
zebra mussel

Outreach

General
Zebra Mussel

Key Words
basic biology
dispersal mechanism
educational program
prevention
zebra mussel

August 1992 – 1998

Zebra Mussel and Aquatic Nuisance Species Education

North Carolina Sea Grant, Barbara A. Doll

In an effort to educate boaters and anglers about how to prevent spreading zebra mussels, a poster was produced by North Carolina Sea Grant with coordination / review from Sea Grant programs in the mid-Atlantic region. Information about zebra mussels and other aquatic nuisance species was presented to a variety of audiences, including industry representatives, school teachers, natural resource managers and boating organizations. ***Audience:*** anglers, general public, government agencies, lake associations, recreational boaters, resource managers, water-dependent businesses and industry.

Products and Presentations

Brochure
Zebra Mussels: A Costly Threat to North Carolina (1992).
Distribution: 6,350; ***Audience:*** anglers, lake associations, recreational boaters, shoreline residents.

Identification Cards
Zebra Mussel WATCH Card (1994, produced by Wisconsin Sea Grant). ***Distribution:*** 83,000; ***Audience:*** anglers, lake managers, recreational boaters, shoreline residents.

Poster
Zebra Mussels (1995). ***Distribution:*** 3,800; ***Audience:*** fishing license dealers, lake managers, marina owners, state park managers, water-dependent industries.

Presentations
Zebra Mussels and other Aquatic Nuisance Species (1995 – 1998).
Participants: 100 (5 presentations between 1995 and 1998);
Audience: aquarium visitors, boating organizations, general public, teachers.

General
Zebra Mussel

Key Words
aquaculture
ballast water
basic biology
bioaccumulation
dispersal mechanism
ecological interactions
educational program
impact
inland lakes/rivers
monitoring
prevention
recreation
zebra mussel

1993 - 1998

Zebra Mussel Outreach and Education

Maine-New Hampshire Sea Grant
Brian Doyle and Julia Peterson, *University of New Hampshire*

While the spread of the zebra mussel in New England has slowed, it still represents a major threat to the region. Working with a number of collaborators, Maine-New Hampshire Sea Grant is involved in an ongoing zebra mussel education and outreach effort that emphasizes the need for continuing vigilance. ***Audience:*** anglers, elected officials, general public, government agencies, lake associations, media, power companies, property owners, recreational boaters, researchers, resource managers, students (K-12 and college), teachers / educators (K-12 and college), utilities.

Products and Presentations

Brochure
Northern New England Zebra Mussel Watch (1993). ***Distribution:*** 2,500; **Audience:** general public.

Presentation
*Zebra Mussel Presentation (*1993-1998). ***Distribution:*** 100; ***Participants:*** several thousand;
Audience: boaters, environmentalists, general public.

Poster
Stop the Zebra Mussel (1993). ***Distribution:*** 250; ***Audience:*** general public.

Sign
Stop the Zebra Mussel (1993). ***Distribution:*** 250; ***Audience:*** boaters.

1994 – 1997

Risk Assessment of Zebra Mussel Colonization of North Carolina Waters

North Carolina Sea Grant, Barbara A. Doll

General
Zebra Mussel

Key Words
colonization
risk assessment
zebra mussel

In 1997, a risk-assessment study of North Carolina's waters that used the zebra mussel's tolerances for temperature, dissolved oxygen, salinity, calcium and pH to calculate the likelihood of mussel infestation for 338 locations across the state was completed. The North Carolina Division of Water Quality and the U.S. Geological Survey provided the water quality data used in the assessment. The results are displayed on a folded map-size poster map that was produced using GIS. The map provides instructions on how to confront the zebra mussel issue proactively. Approximately 600 maps were distributed to registered water users, the North Carolina Lake Management Association, the U.S. Army Corps of Engineers and the North Carolina Zebra Mussel Task Force. Presentations were at several national and international workshops, reaching state and federal agencies, water quality regulators, resource managers and industry representatives. This study has been used as a model by other states, such as California and South Carolina. ***Audience:*** business / industry, government agencies, lake associations, researchers, resource managers, students (college), teachers / educators (college), water dependent utilities.

Products and Presentations

Map/Poster
Zebra Mussel Colonization: North Carolina's Risks (1997). ***Distribution:*** 600; ***Audience:*** registered water users (i.e. industry, water treatment plants).

Presentations
Risk Assessment of Zebra Mussel Colonization of North Carolina Waters presented at the following conferences: *Western States Zebra Mussel Conference*, Portland, OR (March 1997), *National Zebra Mussel Training Initiative Workshop*, Kansas City, MO (November 1997), *Zebra Mussel Information Workshop held in conjunction with the Eighth International Zebra Mussel and Aquatic Nuisance Species Conference*, Sacramento, CA (March 1998), *South Carolina Zebra Mussel Task Force Meeting*, Charleston, SC (September 1998). ***Participants:*** 165; ***Audience:*** agencies, industry representatives, lake managers, regulators, resource managers.

Jeffrey Reutter

Outreach

General
Zebra Mussel

Key Words
aquatic nisance species
basic biology
biological control
bivalve
colonization
dispersal mechanism
ecological interactions
educational programs
impact
inland lakes/rivers
monitoring
nonindigenous
predators
prevention
recreation
zebra mussel

1994 – 1998

New Jersey Zebra Mussel and Aquatic Nuisance Species Outreach Program

New Jersey Sea Grant, Eleanor A. Bochenek

The New Jersey Sea Grant program has developed a variety of materials about zebra mussels and other ANS and how to stop their spread. The program also organized a citizen's volunteer monitoring program for zebra mussels in the Delaware River watershed, Hudson-Raritan watershed and other waterbodies in NJ and PA, and assisted the New Jersey Department of Environmental Protection, Division of Fish, Game & Wildlife with designing and conducting a monitoring and identification program for zebra mussels in several key New Jersey lakes and reservoirs. ***Audience:*** agencies, anglers, general public, lake associations, media, property owners, recreational boaters, resource managers, students (5th grade-college), teachers, utilities.

Products and Presentations

Fact Sheet
The Zebra Mussel Menace (1993). ***Distribution:*** 25,000; ***Audience:*** anglers, boaters, general public, lake associations, natural resource managers, students, teachers.

Flier
Boaters: Don't Let Your Boat be a Zebra Mussel Carrier (1995). ***Distribution:*** 190,000; ***Audience:*** recreational boaters.

Identification Card
Zebra Mussel WATCH Card: (1993, produced by Wisconsin Sea Grant and customized for New Jersey). ***Distribution:*** 20,000; ***Audience:*** agencies, anglers, boaters, general public, lake associations, natural resource managers, students, teachers.

Monitoring Programs
Zebra Mussel Watch Volunteer Monitoring Program (1995-1998). ***Participants:*** 250; ***Audience:*** agencies, citizens, environmental groups, lake and watershed associations, schools.

Zebra Mussel Monitoring By State Agencies (1996-1998). ***Audience:*** Other state agencies (New Jersey Department of Environmental Protection, Division of Fish, Game & Wildlife).

Newsletter
*New Jersey "News"-Ance: Nuisance & Exotic Species Newsletter (*published every two years). ***Distribution:*** Over 300 per issue; ***Audience:*** anglers, boaters, general public, lake associations, natural resource managers, teachers.

Jim Lubner

1995 – 1998

South Carolina Zebra Mussel Outreach Program

South Carolina Sea Grant
M. Richard DeVoe, *South Carolina Sea Grant Consortium*
Steve de Kozlowski, *South Carolina Department of Natural Resources*

The program established a South Carolina task force to monitor, control, and prevent infestation of zebra mussels. An education program was developed to educate the public, particularly recreational boaters and anglers on how to detect zebra mussels, and ways to prevent spreading the mussels. ***Audience:*** anglers, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, utilities.

Products and Presentations

Identification Cards
Zebra Mussel WATCH Card. ***Distribution:*** 20,000; ***Audience:*** anglers, recreational boaters.

Sign
Zebra Mussel Warning Sign. ***Distribution:*** 250; ***Audience:*** anglers, recreational boaters.

General
Zebra Mussel

Key Words
bivalve
colonization
dams
dispersal mechanism
ecological interactions
economic development
educational programs
electricity
impact, industry
inland lakes/rivers
monitoring
nonindigenous
prevention,recreation
zebra mussel

June 1995 – February 1998

An Integrated, Regional Program of Research, Education and Outreach on Zebra Mussels in Southern Waters

Mississippi-Alabama Sea Grant (Project A / O-24-ZM1)
William Hosking and Richard K. Wallace

The project goals were to prevent the spread of zebra mussels by recreational boaters, inform the public about the threat zebra mussels pose, and cooperate and coordinate with other Gulf of Mexico Sea Grant programs to assist surface water users and the aquaculture industry. ***Audience:*** anglers, general public, lake associations, recreational boaters, resource managers.

Products and Presentations

Pamphlet
The Zebra Mussel Invasion in Alabama (1997). ***Distribution:*** 5,000; ***Audience:*** boaters.

Identification Card
Zebra Mussel WATCH Card (1995, produced by Wisconsin Sea Grant).
Distribution: 4,000; ***Audience:*** general public.

Newsletter
Zebra Mussel Network (produced twice per year). ***Distribution:*** 60; ***Audience:*** government agencies, industry.

Presentations
Beware of Zebra Mussels. ***Participants:*** 2,000; ***Audience:*** general public.

Poster
Zebra Mussels (1995, provided by North Carolina Sea Grant). ***Distribution:*** 150; ***Audience:*** boaters.

General
Zebra Mussel

Key Words
aquaculture
dispersal mechanism
ecological interactions
educational program
impact
inland lakes/rivers
zebra mussel

Outreach

General
Zebra Mussel

Key Words
aquatic plants
basic biology
bivalve
educational program
impact
industry
monitoring
nonindigenous
prevention
recreation
zebra mussel

August 1995 – February 1997

Vermont Zebra Mussel Education & Outreach Program

Connecticut Sea Grant (Project A / E-7)
Anne Bove and Michael Hauser,
Vermont Department of Environmental Conservation, Water Quality Division

The investigators developed outreach programs on zebra mussels and other aquatic nuisance species, with particular focus on the Lake Champlain Basin. Responsibilities included providing training and informational resources for the Lake Champlain Basin Zebra Mussel Task Force, the Zebra Mussel Citizen Action Program, and the Zebra Mussel Watchers Program. They helped coordinate and co-sponsor the Second Northeast Conference on Nonindigenous Species and contributed to the regional newsletter, *Aquatic Exotics News*. ***Audience:*** bait dealers, anglers, aquaculture, divers, elected officials, general public, government agencies, lake associations, media, property owners, recreational boaters, researchers, resource managers, students (grades 6-12), teachers / educators (grades 6-12), utilities.

Products and Presentations

Audiotape
Public service announcements. ***Distribution:*** 35; ***Audience:*** general public.

Fact Sheet
Zebra Mussel (1998). ***Distribution:*** over 3,000; ***Audience:*** general public, lake enthusiasts.

Information Card
Divers Take Note (1995). ***Distribution:*** over 500; ***Audience:*** recreational divers.

Map
Confirmed Zebra Mussel Range in Lake Champlain. ***Distribution:*** over 500; ***Audience:*** general public.

Presentations
Second Northeast Conference on Nonindigenous Aquatic Nuisance Species (April 18-19, 1997). ***Participants:*** 65; ***Audience:*** agencies, educators, industry, researchers, students.

Zebra Mussels in Vermont. ***Distribution:*** 70 presentations; ***Audience:*** civic, professional, and school groups in Vermont and New York.

Poster
Stop the Spread of Nuisance Aquatic Plants and Animals (1995). ***Distribution:*** 300; ***Audience:*** anglers, boaters, general public, lake managers.

Report
Assessment of Vulnerability of Vermont Lakes to Zebra Mussels (1995). ***Distribution:*** 100; ***Audience:*** lake associations and managers.

Training Materials
*Zebra Mussel Citizen Action Program (*1995, revised 1997). ***Participants:*** 40; ***Audience:*** volunteers.

Flora

Common Reed, *Phragmites australis*
Eurasian Watermilfoil, *Myriophyllum spicatum*
Giant Reed, *Arundo donax*
Nori, *Porphyra yezoensis*
Purple Loosestrife, *Lythrum salicaria*
Smooth Cordgrass, *Spartina alterniflora*

Sea Grant

ANS

Flora

For each research and outreach category, projects appear in chronological order by starting date; shared dates are alphabetized by project title. See pages 11 and 12 for a list of project categories.

Common reed *(Phragmites australis)*

Giant reed *(Arundo donax)*

Purple loosestrife *(Lythrum salicaria)*

Eurasian watermilfoil (*Myriophyllum spicatum*)

Nori (*Porphyra yezoensis*)

Smooth cordgrass (*Spartina alterniflora*)

Common Reed *(Phragmites australis)*

Theresa Talley

The invasive common reed (*Phragmites australis)* has invaded coastal areas throughout the U.S., from freshwater to marine salt marsh habitats. *Phragmites* is found on every continent except Antartica. Although this species appears indigenous to the U.S., evidence suggests that a more invasive genotype was introduced from Europe to this country in recent decades. The reed grows rapidly and is pollution and salinity tolerant, displacing native species such as cattails and other aquatic plants. *Phragmites* starts to grow so much earlier in the season than other plants that it effectively crowds out any later growth competition by native species, causing flora diversity to plummet.

Research

Effects on Ecosystems

Key Words
common reed
ecological interactions
inland lakes/rivers
nonindigenous Phragmites
population dynamics
wetlands

May 1998 – April 2000

Microbial Nitrogen Dynamics During Decomposition of *Phragmites australis* Compared to *Typha angustifolia*

New York Sea Grant (Project R / CMB-18)
Stuart Findlay, *Institute of Ecosystem Studies*

In Tivoli Bay North, one of four nationally designated estuarine reserves along the Hudson River, researchers compared the dynamics of decomposition for both invasive reeds (*Phragmites)* and the native cattails (*Typha*). Reeds stay standing long after they die compared to cattails which fall over. Thus the rates at which the plant matter decays differ as do the nutrient loads added to the water and the dynamics of populations of bacteria and fungi that decay the plants. This research determined the benefit of restoration efforts made in many coastal areas which focus on removing invasive reeds. Documenting important marsh functions related to specific plant communities will contribute to overall tidal wetland management.

Control and Mitigation

Key Words
coastal wetland
common reed
ecological interactions
impact
inland lakes/rivers
macrophyte
monitoring
nonindigenous Phragmites
reed
wetlands

March 1998 – February 2000

Strategies to Control Exotic Invasive Plant Species in Great Lakes Wetlands: A Field Evaluation

Ohio Sea Grant (Project R / ER-39)
David A. Francko, *Miami University*

The native aquatic and wetland flora of Great Lakes coastal wetlands are threatened by exotic invasive plant species. Work at the Old Woman Creek National Estuarine Research Reserve and other Lake Erie coastal wetlands has tracked the dynamics of the common reed *Phragmites australis* from the early colonization phase through range extension. Field work suggested that cutting emerging spring growth shoots of *Phragmites* followed by herbicide application prevented the recruitment of mature plants during the growing season. Cutting alone was much less effective. Preliminary work suggests that small-scale control of *Phragmites* may be possible without massive habitat disruption, and that at least some seedbark recruitment may occur if *Phragmites* is controlled.

Publications

Francko, D. and R. Whyte. 1999. A midsummer photosynthetic carbon budget for the Old Woman Creek wetland, Huron, OH: Contribution of aquatic macrophytes versus phytoplankton. *Ohio Journal of Science*, 99(2):6-9.

Common reed *(Phragmites australis)*

Eurasian Watermilfoil *(Myriophyllum spicatum)*

Anne Bove

Eurasian watermilfoil is an aquatic plant that was introduced to North America between the late 1800s and the early 1940s. Eurasian watermilfoil is found in more than 30 states and in parts of Canada. This plant is able to reproduce from fragments and spread rapidly to form dense mats on the water surface, which interferes with recreation, inhibits water flow, and impedes navigation. These fragments can also be lodged in various places on boats, boat trailers, anchors, and fishing gear, allowing Eurasian watermilfoil to spread to new waterbodies. Watermilfoil is hardy and can take root in a variety of lake bottoms, pH, salinity, and temperature conditions. This plant outcompetes native aquatic plants, drastically altering the ecological balance of an aquatic ecosystem.

Research

Control and Mitigation

Key Words
basic biology
biological control
chemical control
ecological interactions
Eurasian watermilfoil
inland lakes/rivers
nonindigenous
physical control
predators

February 1992 – January 1994

The Secondary Metabolites of Eurasian Watermilfoil and Their Relation to Potential Control Agents

Minnesota Sea Grant (Project R / NP-12)
Raymond M. Newman and Florence K. Gleason, *University of Minnesota*

This research project determined whether biologically active secondary metabolites of Eurasian watermilfoil affect native plant competitors and potential biocontrol agents by testing aquatic animals and plants. Subsequently, active metabolites may be isolated using a systematic extraction and bioassay process and be chemically characterized.

Publications

Newman, R.M. J.A. Perry, L.S. Mizner, and K. Holmberg. 1992. *The potential for biological control of Eurasian watermilfoil with native and naturalized invertebrates.* Minnesota Department of Natural Resources Project Report.

Solarz, S.L., and R.M. Newman. 1996. Oviposition specificity and behavior of the watermilfoil specialist *Euhychiopsis lecontei. Oecologia*, 106:337-344.

Eurasian watermilfoil (*Myriophyllum spicatum*)

Giant Reed *(Arundo donax)*

George W. Peck

The giant, bamboo-like giant reed (*Arundo donax*) is originally from the lower Himalayan / Mediterranean region and was brought to southern California by the Spanish missionaries in the 1700s for use in construction. It now covers thousands of acres of riverbanks, eliminating native plants such as cottonwood. In some habitats it has even shown the ability to displace the invasive common reed (*Phragmites australis).* It can grow up to 4 to 5 inches per day and reaches a maximum height of 30 feet. This species is generally confined to warm climates in the U.S. and is much less invasive in the northern part of its range.

Control and Mitigation

Key Words
biological control
giant reed grass

October 1996 – September 1998

Eradicating *Arundo donax* from California Ecosystems: Establishing the Most Effective Timing for Mechanical and Chemical Procedures

California Sea Grant (Project R / CZ-151)
Antonia Wijte, *California State University - Long Beach*

The project sought to optimize efforts to control the spread of *Arundo donax*, a perennial grass that has achieved dramatic expansion in southern California. A computer model was developed to quantify the carbohydrate sink strengths of different plant parts over the growing season in both a greenhouse and a field application experiment.

Giant reed (*Arundo donax*)

Nori *(Porphyra yezoensis)*

Katherine Watson

Nori, the Japanese name for *Porphyra*, is a large genus of red algae that grows on rocky shorelines around the world. Also known as laver (England), kim (Korea), sluckum (Native Americans of the Pacific Northwest), and karengo (New Zealand), the plant is a nutritious source of food for humans and the most valuable aquacultured seaweed in the world. The focus of a billion-dollar aquaculture industry, nori is used primarily as the wrapping around sushi rolls. Part of the aquaculture industry in Maine, the plant is being studied to assess the nori aquaculture industry on native flora and to evaluate other potential ecosystem impacts.

Effects on Ecosystems

Key Words
aquaculture
biological control
dispersal mechanism
ecological interactions
monitoring
nonindigenous
nori
population dynamics

February 1998 – January 2000

Effects of Nori Aquaculture on the Marine Flora of Cobscook Bay and Selected Sites within the Gulf of Maine

Maine-New Hampshire Sea Grant (Project R/FMD-152)
Anita Klein, Arthur Mathieson, and Donald Cheney, *University of New Hampshire*

Massachusetts Institute of Technology Sea Grant (Project R/RB-46)
Christopher Neefus, *Northeastern University*

Invasions by nonindigenous species are complex events. Due to the diversity of vectors, taxonomy, life history, and habitats among the invading species as well as the possible environmental, social, and economic impacts involved, the results of these invasions can range from negligible to catastrophic. To assess the impact of the fledgling nori aquaculture industry on the marine flora of Cobscook Bay and selected sites within the Gulf of Maine, the researchers examined the dispersal and persistence of *Porphyra yezoensis* at sites adjacent to current and new cultivation sites, developed genetic profiles, and established baseline information regarding the distribution and abundance of indigenous *Porphyra* species.

Publications

Cheney, D.P., Levine I., Rudolph, B., and Kapraun, D. 1998. Strain improvement of seaweeds for aquaculture through biotechnology: Current status and future prospects. *Journal of Phycology*, 34(3):12-13.

Cheney, D. B. Rudolph, L. Wang, B. Metz, K. Watson, K. Roberts and I. Levine. 1998. Genetic manipulation and strain improvement in commercially valuable red seaweeds. In *New Developments in Marine Biotechnology*, Y. Le Gal and H. Halvorson, (eds.), NY:Plenum Press, pp. 101-104.

Levine, I. and D. Cheney. 1998, North American *Porphyra* cultivation: From molecules to markets. In *New Developments in Marine Biotechnology*, Y. Le Gal and H. Halvorson, (eds.), NY:Plenum Press, pp. 141-144.

Patent

One Provisional U.S. Patent has been filed: U.S. Provisional Patent Application No. 60/069,563; D. Cheney, K. Watson and K. Roberts: *Strain manipulation and improvement in the edible seaweed* Porphyra.

Charles Yarish

Nori (*Porphyra yezoensis*)

Purple Loosestrife *(Lythrum salicaria)*

Nancy Balcom

A beautiful but aggressive invader, purple loosestrife arrived in eastern North America in the early 1800s. The plants were brought to North America by settlers for their flower gardens, and seeds were present in the ballast holds of European ships that used soil to weigh down the vessels for stability on the ocean. Since it was introduced, purple loosestrife has spread westward and can be found across much of Canada and the United States. This hardy perennial takes over wetlands, decreasing habitat for native birds, mammals, plants, fish, amphibians, and reptiles that depend on wetland habitats for their survival. Dense stands of loosestrife also impair recreational use of wetlands and rivers, impede water flow in drainage ditches, and invade right-of-ways, requiring costly management efforts.

Research

Effects on Ecosystems

Key Words
aquatic plants
biological control
dispersal mechanism
ecological interactions
nonindigenous
purple loosestrife
wetlands

July 1997 – June 1999

The Early Establishment Phase of the Invasive Hydrophyte Purple Loosestrife (*Lythrum salicaria*): Dispersal, Termination, and Seedling Establishment – Implications for its Biocontrol

Connecticut Sea Grant
Jane Molofsky, *University of Vermont*

This project determined the environmental conditions that favor the establishment of *L. salicaria* in uninfested wetlands and adjacent upland habitats. By examining dispersal distance of the seeds, optimal germination conditions, and survival and growth rate of the seedlings, the investigator determined the likelihood that purple loosestrife will spread from an infested habitat to an adjacent uninfested habitat, and which wetlands are most vulnerable to invasion.

Publications

Shadel W. & Molofsky, J. 1999. Germination and Establishment of the invasive hydrophyte, *Lythrum salicaria* (purple loosestrife). In *Proceedings of the Greater New England Symposium on the Ecology of Invasive Species* (February 27, 1999).

Outreach

General Outreach

Key Words
basic biology
biological control
colonization
ecological interactions
educational program
inland lakes/rivers
monitoring
nonindigenous
purple loosestrife
population dynamics
wetlands

January 1997 – September 1999

Purple Loosestrife Project

Michigan Sea Grant, Michael Klepinger and Doug Landis

The Purple Loosestrife Project integrates biological control of purple loosestrife with formal and non-formal educational opportunities for adults. A statewide volunteer network of biological control centers has been established, centered around nature centers and school sites. Twenty-five outdoor learning activities and classroom experiments, written by teachers with facilitation by Sea Grant, were published in a cooperators' handbook, a comprehensive guide to purple loosestrife biological control. ***Audience:*** elected officials, general public, government agencies, lake associations, media, nature centers and environmental groups, property owners, researchers, resource managers, students (K- 12 and college), teachers / educators, utilities.

Projects and Presentations

Curriculum Materials
Purple Loosestrife Project K-12 Learning Activities (1998). ***Distribution:*** 75;
Audience: formal and non-formal educators.

Fact Sheet
Purple Loosestrife Project at Michigan State University (1997). ***Distribution:*** 5,000;
Audience: general public.

Presentation
Getting Started: The Purple Loosestrife Project. ***Participants:*** 500;
Audience: educators, land managers, nature center staff, students.

Training Package
Purple Loosestrife Project Cooperator's Handbook (1998). ***Distribution:*** 75;
Audience: general public.

Video
Purple Loosestrife Project (1998). ***Distribution:*** 10; ***Audience:*** general public.

Web Site
Purple Pages Web Site: ***www.msue.msu.edu/seagrant/pp/***
Audience: general public, resource managers.

Purple loosestrife *(Lythrum salicaria)*

Smooth Cordgrass *(Spartina alterniflora)*

Lisa Levin

Smooth cordgrass is native to the eastern U. S. and was introduced into south San Francisco Bay in the mid 1970s. A coastal salt grass, it spread by purposeful introduction of rooted plants and dispersal of seeds on the tides. The spread of smooth cordgrass has the potential to alter the intertidal landscape of California through its ability to eradicate native cordgrass and encroach on open mudflats. This poses a threat to invertebrates, fish and waterfowl, and even commercial fish and crab populations. *Spartina alterniflora* has already played a role in flooding in Alameda and Contra Costa counties in California by blocking flood-control channels.

Control and Mitigation

Key Words
cordgrass
educational program
nonindigenous

March 1998 – February 1999

Initial Steps toward Eradication of Alien Cordgrass from California Waters

California Sea Grant (Project R/CZ-158)
Donald Strong, Lars Andersen, and Paul Olin, *Bodega Marine Laboratory*

Smooth cordgrass (*Spartina alterniflora*) is a serious threat to wildlife, flood control, navigation, and traditional uses of San Francisco Bay. The project developed a control technique, and increased public awareness about the smooth cordgrass invasion.

Publications

Anttila, C.K., C.C. Daehler, N.E. Rank, and D.R. Strong. 1998. Greater male fitness of a rare invader *Spartina alterniflora*, threatens a common native *Spartina foliosa* with hybridization. *American Journal of Botany*, 85(11):1597-1601.

Smooth cordgrass (*Spartina alterniflora*)

Other Projects

Ballast Water Initiatives
Multi-Species Projects

Sea Grant

ANS

Other Projects

For each research and outreach category, projects appear in chronological order by starting date; shared dates are alphabetized by project title. See pages 11 and 12 for a list of project categories.

Ballast Water Initiatives

Michigan Sea Grant

The ballast water of shipping vessels has been a primary method of aquatic nuisance species introduction throughout the world. Ballast water is essential to the safe and efficient operation of modern cargo ships and helps maintain ship's stability during transit along coasts and on the open ocean. Large ships often carry millions of gallons of ballast water. Ships exchange ballast water while in port as a normal procedure as cargo is loaded and/or unloaded, or while underway to improve stability and performance. Ballast water is taken from original coastal port areas and transported with the ship to the next port of call where the water may be discharged or exchanged. As a ship loads ballast it also loads many of the organisms living in that port. Not all transported species survive the trip or are able to live in a different location. However, every once in a while an invader successfully establishes itself. In North America, ballast water has been implicated in the introduction of the zebra mussel, spiny waterflea, round goby, Eurasian ruffe, and other aquatic nuisance species.

Research

Biology and Life History

Key Words
ballast water
nonindigenous

September 1997 – August 1999

Molecular Strategies to Characterize Microbial Diversity and Pathogens in Marine Ballast Water

North Carolina Sea Grant (Project R / NIS-3)
Jonathan B. Geller, *San Jose State University*

This research project involved the identification and characterization of microbial populations in the ballast water of ships travelling from foreign ports to U.S. ports (Wilmington, N.C. and Chesapeake Bay). The study used DNA isolation and molecular analysis to characterize the natural populations of bacteria from the ballast water samples. The study also tested for the presence of toxin genes from *Vibrio cholerae* and *Vibrio vulnificus*.

Preventing New Introductions

Key Words
ballast water
colonization
monitoring
nonindigenous

September 1997 – August 1999

The Relative Importance of Ballast Water from Domestic Ship Traffic in Translocation of Nonindigenous Species Among U.S. Ports

Massachusetts Institute of Technology Sea Grant (Project R / RC-63)
L. David Smith, *Northeastern University*

This study evaluated the role of ballast water in transporting species among domestic ports. Despite the fact that this appears to be one of the largest vectors for transfer of established species in this country, virtually little is know about translocation by domestic ship traffic. This study analyzed ballast water delivery patterns for vessels arriving from domestic versus foreign ports to the ports of Boston, the Chesapeake Bay, and Tampa / St. Petersburg. Ballast water was sampled, analyzed, and survivability measured from domestic voyages. These results were compared to ballast water contributions from foreign vessels.

Publications

LaVoie, D.M.; D.L. Smith; and G.M. Ruiz. 1999. Potential for intracoastal transfer of nonindigenous species ballast water of ships. *Estuarine Coastal and Shelf Science*, 48(5):551-564.

Outreach

General Outreach

Key Words
ballast water
educational program
impact
industry
prevention

Ballast water

March 1998 – August 2000

West Coast Ballast Water Initiative: An Outreach Program to Improve Ballast Management

California Sea Grant (Project A / EA-2)
Jodi Cassell, *California Sea Grant*
Jay Rasmussen, *Oregon Sea Grant*
Cynthia Slade, *San Francisco Estuary Project*

This education and outreach effort opened lines of communication and promoted cooperation between private maritime industry, regulators, researchers and members of the general public concerned with ballast water management. ***Audience:*** elected officials, general public, government agencies, maritime industry, researchers, resource managers.

Products and Presentations

Newsletter
Ballast Exchange. ***Audience:*** general public, maritime industries, natural resource professionals.

Presentations
Ballast Water Exchange Forums (six different forums throughout 1999).
Audience: general public, maritime industries, natural resource professionals.

Web Site
West Coast Ballast Outreach Project Web Site: ***ballast-outreach-ucsgep.ucdavis.edu***
Audience: general public, maritime industries, natural resource professionals.

Multi-Species Projects

Many ANS projects conducted by Sea Grant focus on more than one species. Research projects in this section examine the impact of multiple ANS on specific communities, habitats, and industries. Outreach projects encompass surveys, database and national ANS web site develop, curriculum projects, and information centers.

Research

Effects on Ecosystems

Key Words
ballast water
bivalve
colonization
dispersal mechanism
ecological interactions
monitoring
nonindigenous
population dynamics
wetlands

March 1997 – February 1999

Dry and Wet-Year Disturbance Dynamics and Trophic Guild Structure in Invaded Communities of San Francisco Bay

Oregon Sea Grant (Project R / NIS-01-PD)
John Chapman, James Carlton and Andrew Cohen, *Oregon State University*

Rapid assessment surveys in 1997-98 and 1998-99 allowed comparisons of ecosystem change during El Niño (increased precipitation and variable salinity) and La Niña weather periods. The project team measured and analyzed the distributions and relative abundance of introduced and native species to assess the impacts of river flows (and subsequent salinity disturbances) on their relative interannual population dynamics.

Publications

Chapman, J. W. 1999. Climate and nonindigenous species introductions in northern hemisphere estuaries. In E. Muckle-Jeffs, (ed.) *Proceedings of the International Zebra Mussel and Aquatic Nuisanc Species Conference*, Sacramento CA (March 1998).

Chapman, J. W. 1999. Climate and nonindigenous peracaridan crustaceans in northern hemisphere estuaries. In J. Pederson (ed.) *Proceedings of the National Conference on Marine Bioinvasions*, Massachusetts Institute of Technology, Cambridge, MA (January 1999).

Chapman, J. W. and T. M. Miller. 1999. The odd Northeast Pacific records of *Arctica islandica* (Linnaeus, 1767) are bait. *Festivus*, 31(5):55-57.

Cohen, A., C. Mills, H. Berry, M. Wonham, B. Bingham, B. Bookheim, J. Carlton, J. Chapman, J. Cordell, L. Harris, T. Klinger, A. Kohn, C. Lambert, G. Lambert, K. Li, D. Secord and J. Toft, 1998. *Puget Sound Expedition: A rapid assessment survey of non-indigenous species in the shallow waters of Puget Sound.* Washington State Department of Natural Resources, Olympia, Washington.

Effects on Ecosystems

Key Words
estuaries
live marine products
interdisciplinary studies
Puget Sound
nonindigenous
risk assessment methods
vectors

September 1997 – August 1999

Characterizing Pathways for the Introduction of Nonindigenous Species via Shipments of Live Seafood and Scientific Specimens

Washington Sea Grant (Project R / ES / -23)
Annette Olson and Warren Wooster, *University of Washington*

The project (1) assessed the risk of the unintentional introduction of nonindigenous species into Washington's marine waters via trade in live marine products, such as seafood or scientific specimens; and (2) developed and tested a method for risk assessment that incorporates both biological and social components of risk. By focusing on these little-studied or unregulated pathways, the research provided a scientific basis for designing best management practices and established working relationships for their dissemination. An additional benefit was the development of new risk assessment protocols.

September 1997 – August 2000

Degradation and Restoration of Lake Michigan, Past and Future of Nonindigenous Species

Illinois-Indiana Sea Grant (Project R / ANS-05-97)
David Lodge, *University of Notre Dame*

The overall goal was to provide quantitative descriptions of species characteristics that increase the probability of successful invasion. The information was shared with management agencies so that they can develop strategies to more effectively prevent future introductions. Three different invasion scenarios were studied: the invasion of Lake Michigan after glaciation; movement through one particular canal system, the Chicago Ship and Sanitary Canal (CSSC) system; and invasion of the Great Lakes from fish outside the Great Lakes drainage.

Publications

Lodge, D.M., R.A. Stein, K.M. Brown, A.P. Covich, C. Bronmark, J.E. Garvey, and S.P. Klosiewski. 1998. Predicting impact of freshwater exotic species on native biodiversity: Challenges in spatial scaling. *Australian Journal of Ecology*, 23:53-67.

Kolar, C. S. and D. M. Lodge. 1998. Developing predictions of invading species using data from the Laurentian Great Lakes. In *Proceedings of the Joint National Meeting of the American Society of Limnologists and Oceanographers and the Ecological Society of America*, St. Louis, MO (June 7-12, 1998).

Effects on Ecosystems

Key Words
ecological interactions
exotic species
nonindigenous invasion
life history characteristics
vectors

March 1998 – March 2000

Survey of Introduced Marine Invertebrates on Guam

Hawaii Sea Grant (Project R / MI-1)
Gustav Paulay and Barry D. Smith, *University of Guam*

The objectives of this study were to assess the regional impact of nonindigenous species on Guam, to evaluate the potential of species present on Guam to become nonindigenous nuisance species elsewhere, and to work with agencies in both Guam and elsewhere (especially Hawaii) to propose regulatory safeguards to prevent / lessen future impacts. In addition the work allowed a general evaluation of the impact of nonindigenous species in a coral reef ecosystem and thus provided a model for such impacts in other reef areas.

Effects on Ecosystems

Key Words
ballast water
bibalve
biodiversity survey
colonization
dispersal mechanism
impact
monitoring
nonindigenous
prevention

Outreach

ANS Information Centers

Key Words

aquaculture
ballast water
basic biology
bioaccumulation
biological control
bivalve
chemical control
colonization
disposal
dispersal mechanism
economic development
educational program
electricity
Eurasian ruffe
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
pollution
population dynamics
predators
prevention
recreation
round goby
sea lamprey
spiny waterflea
tourism
veliger
wetlands
zebra mussel

1989 – 2000

Ohio Aquatic Nuisance Species Information Center

Ohio Sea Grant, Fred Snyder and Karen Ricker

Since 1989, the Ohio Sea Grant College Program has developed fact sheets, posters, displays, newsletter articles, and other materials as part of its Aquatic Nuisance Species Information Center efforts. Over the past decade several hundred presentations on zebra mussels and other ANS have been made to local organizations and at state, national, and international conferences. The Center develops educational programs and materials on zebra mussels and other aquatic nuisance species, serves as a link between researchers and the private sector, and has provided the knowledge people need for preventing the further spread of various invasive species. ***Audience:*** anglers, business / industry, charter boat captains, elected officials, general public, government agencies, maritime interests, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators, utilities.

Products and Presentations

Displays

Aquatic Nuisance Species: Help Slow the Spread (1999). ***Participants:*** 10,000 (at Lake Erie Nature and Science Center); ***Audience:*** K-12 students, K-12 teachers, general public.

Aquatic Nuisance Species Information (1998-2000). ***Participants:*** 3,000 (at annual boat and sports shows); ***Audience:*** anglers, charter boat captains, general public, property owners, recreational boaters, resource managers.

Fact Sheets

Boaters: Take Action against Zebra Mussels (1996). ***Distribution:*** 100,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Round Gobies Invade North America (1995). ***Distribution:*** 82,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, students, teachers / educators.

Ruffe: A New Threat to our Fisheries (1996). ***Distribution:*** 30,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

The Spiny Waterflea, Bythotrephes cederstroemi*: Another Unwelcome Newcomer to the Great Lakes* (1992). ***Distribution:*** 11,200; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Zebra Mussels in North America: The Invasion and its Implications (1990, revised 1997). ***Distribution:*** 100,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Zebra Mussel Migration to Inland Lakes and Reservoirs: A Guide for Lake Managers (1994). ***Distribution:*** 30,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Posters

Aquatic Nuisance Species: Help Slow the Spread (1999, newsletter insert). ***Distribution:*** 6,000; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, media, recreational boaters, researchers, resource managers, students, teachers / educators.

Videos
Too Much Mussel (1991). ***Distribution:*** 141; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Zebra Mussels from Spawning to Settlement (1993). ***Distribution:*** 25; ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Web Site
Aquatic Nuisance Species Projects and Publications Web Site: ***www.sg.ohio-state.edu/publications/topics/fts-nuisance.html***. ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, media, recreational boaters, researchers, resource managers, students, teachers / educators.

1991 – 2000

Michigan Sea Grant Zebra Mussel and ANS Information Office

Michigan Sea Grant, John Schwartz and Michael Klepinger

The Michigan Sea Grant Zebra Mussel / ANS Information Office serves as a centralized source for information exchange among Michigan Sea Grant staff, state and federal agencies, researchers, water users, and others. The office was established as the Zebra Mussel Information Office in June 1991 and has broadened its scope in response to invasions by other nuisance species and to meet changing user needs. ***Audience:*** anglers, business / industry, elected officials, general public government agencies, lake associations, maritime interests, media, property owners, recreational boaters, researchers resource managers, students, teachers / educators, utilities.

Products and Presentations

Conference
Zebra Mussels in Michigan: Implications for Industries and Municipalities (annually since 1992). ***Participants:*** 1,000+; ***Audience:*** business / industry, elected officials, government agencies, researchers, resource managers, students, teachers / educators.

Fact Sheets
Potential Control of Zebra Mussels through Reproductive Intervention (1994). ***Distribution:*** 1,150; ***Audience:*** business / industry, elected officials, government agencies, researchers, resource managers, students, teachers / educators.

Map and Lake Monitoring Records
Monitored Lakes Database (updated quarterly). ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Zebra Mussel Sightings Map (updated annually). ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, recreational boaters, researchers, resource managers, students, teachers / educators.

Slide Program
The Spread of Zebra Mussels to Inland Lakes (1994). ***Distribution:*** 25 sets; ***Audience:*** business / industry, elected officials, government agencies, researchers, resource managers, students, teachers / educators.

Web Site
Exotic Species Web Site: ***www.msue.edu/seagrant/sgezmans.html***
Audience: business / industry, elected officials, government agencies, researchers, resource managers, students, teachers / educators.

ANS Information Centers

Key Words
aquaculture
ballast water
basic biology
bioaccumulation
biological control
bivalve
chemical control
colonization
disposal
dispersal mechanism
economic development
educational program
electricity
Eurasian ruffe
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
pollution
population dynamics
predators
prevention
recreation
round goby
sea lamprey
spiny waterflea
tourism
veliger
wetlands
zebra mussel

Outreach

ANS Information Centers

Key Words

aquaculture
ballast water
basic biology
bioaccumulation
biological control
bivalve
byssal attachment
chemical control
coatings
colonization
dams
disposal
dispersal mechanism
ecological interactions
economic development
educational program
electricity
Eurasian ruffe
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
policy
pollution
population dynamics
predators
prevention
quagga mussels
recreation
round goby
sea lamprey
spiny waterflea
veliger
wetlands
zebra mussel

1991 – 2000

Exotic Species Information Center

Minnesota Sea Grant, Jeffrey L. Gunderson, Douglas A. Jensen, and Marie E. Zhuikov

Established in 1991, the University of Minnesota Sea Grant Exotic Species Information Center educates water users on how to protect water resources from invasive ANS. The Center is composed of extension, communications, and education specialists who serve as primary sources of information on zebra mussels and aquatic nuisance species. Resources that the Center offers includes a comprehensive library of print materials, cards, videotapes, slides, graphics, specimens of ANS, training packages, sampling kits, and youth education resource kits. ***Audience:*** anglers, aquaculture, charter captains, conservation organizations, elected officials, environmental organizations general public, government agencies, lake associations, maritime interests, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators (K-12 and college), utilities.

Products and Presentations

Brochures

A Field Guide to Aquatic Exotic Plants and Animals (1992, revised 1995). ***Distribution:*** 25,000; ***Audience:*** anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

*Purple Loosestrife: What You Should Know, What You Can Do (*1996). ***Distribution:*** 1,000; ***Audience:*** anglers, boaters, educators, students, general public, government agencies, lake associations, marina operators, researchers.

Fact Sheets

Ruffe: A New Threat to Our Fisheries (1994, revised 1996). ***Distribution:*** 32,500; ***Audience:*** anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

Rusty Crayfish: A Nasty Invader (1994, revised 1995). ***Distribution:*** 3,700; ***Audience:*** anglers, boaters, educators, students, general public, government agencies, lake associations, marina operators, researchers.

Identification Cards

*Round Goby WATCH Card (*1996, revised 1997, 1998). ***Distribution:*** 310,000; ***Audience:*** anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

*Ruffe WATCH Card (*1994, revised 1995, 1997, 1998). ***Distribution:*** 445,000; ***Audience:*** anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

Poster

Don't Let These Invaders Hijack Your Boat (1992). ***Distribution:*** 900; ***Audience:*** anglers, boaters, educators, students, general public, government agencies, lake associations, marina operators, researchers.

Video

The Ruffe: A Small Fish – Big Problems (1993). ***Distribution:*** 20; ***Audience:*** anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

Web Site

Exotic Species Web Site: ***www.seagrant.umn.edu/exotics/index.html***
Audience: anglers, bait harvest and aquaculture industries, boaters, charter captain associations, commercial shipping, educators, general public, government agencies, lake associations, marina operators, media, researchers, students.

October 1998 – September 2000

Regional Research and Outreach Coordination Center for Nonindigenous Species in the Pacific Northwest

Oregon Sea Grant (Project A / NIS-06)
Robert E. Malouf

Washington Sea Grant Program (Project R / ES-32)
Andrea Copping, Terry Nosho, and Steve Harbell

The main project goal was to develop a Pacific Northwest Center - Marine Invasive Species Team in order to:

1. Foster regional coordination and collaboration on ANS in the Pacific Northwest;
2. Develop methods for sampling, identification, and handling of ANS in Pacific Northwest coastal waters;
3. Identify impacts of ANS in Pacific Northwest waters and develop research, education and management strategies to address them; and
4. Increase awareness of ANS and their potential impacts on the environment and the economy of the Pacific Northwest through education.

Audience: anglers, business / industry, elected officials, general public, government agencies, media, property owners, recreational boaters, researchers, resource managers, students (K-12 and college), teachers / educators (K-12 and college).

Products and Presentations

Booklet
Handling and Disposal of Non-Native Aquatic Species and their Packaging (2000).
Audience: general public, researchers, scientists.

Brochure
Aquatic Invasive Species: A Guide to Least-Wanted Aquatic Organisms of the Pacific Northwest (2000).
Audience: general public, researchers, scientists.

Fact Sheets
Chinese Mitten Crab (1999). ***Distribution:*** 1,000; ***Audience:*** general public, researchers, scientists.

PNW MIST – The Pacific Northwest Marine Invasive Species Team (2000).
Audience: general public, researchers, scientists.

Presentations
Alien Invaders. (1999). ***Participants:*** 200; ***Audience:*** students.

Alien Invaders: Educating Youth About Aquatic Non-Native Species (1999).
Participants: 25; ***Audience:*** teachers.

Impacts of Aquatic Exotics: What's at Risk (1999). ***Participants:*** 100;
Audience: industry, researchers.

Monitoring Estuarine Exotic Species (1999). ***Participants:*** 50;
Audience: volunteer monitoring groups.

Web Site
Pacific Northwest MIST Web Site: ***seagrant.orst.edu/mist***
Audience: anglers, business / industry, elected officials, general public, government agencies, media, property owners, recreational boaters, researchers, resource managers, students (K-12 and college), teachers / educators (K-12 and college).

ANS Information Centers

Key Words
aquaculture
ballast water
basic biology
biological control
bivalve
colonization
disposal
dispersal mechanism
ecological interactions
economic development
educational programs
European green crab
impact
industry
monitoring
nonindigenous
predators
prevention
recreation
recreational boaters
researchers

Outreach

Boater Surveys

Key Words
dispersal mechanism
educational programs
Eurasian ruffe
Eurasian watermilfoil
inland lakes/rivers
nonindigenous
prevention
purple loosestrife
recreation
sea lamprey
spiny waterflea
zebra mussel

1993 – 1994

Exotic Species and Freshwater Boater Survey

Minnesota Sea Grant, Jeffrey L. Gunderson and Douglas A. Jensen

This project surveyed 1,200 boaters in Minnesota, Ohio, and Wisconsin to determine the effectiveness of boater education programs, how to best reach boaters, the risks boaters pose for spreading aquatic nuisance species, and boaters' knowledge concerning aquatic nuisance species. ***Audience:*** anglers, elected officials, general public, government agencies, lake associations, media, property owners, recreational boaters, resource managers, students (high school and college), teachers / educators (high school and college).

Products and Presentations

Fact Sheet
Exotic Species and Freshwater Boater Survey: What Do Boaters Know and Do They Care? (1994, revised 1997). ***Distribution:*** 500; ***Audience:*** educators, elected officials, general public, government agencies, lake associations, recreational boaters.

Report
*Exotic Species and Freshwater Boater Survey: Results and Technical Report (*1994). ***Distribution:*** 50**;** ***Audience:*** educators, elected officials, general public, government agencies, lake associations, recreational boaters.

Exotic Species Day Camp

Key Words
basic biology
colonization
ecological interactions
economic development
educational program
Eurasian ruffe
impact
industry
inland lakes/rivers
nonindigenous
population dynamics
round goby
sea lamprey
spiny waterflea
zebra mussel

September 1997 – August 1999

Exotic Species Day Camp: A Regional Teacher Training Initiative Extending Sea Grant Education on Nonindigenous Species

Illinois-Indiana Sea Grant - lead program (Project A / SE (ANS)-06-97)
Robin G. Goettel

Michigan Sea Grant (A / NIS-2)
Michael Klepinger

Minnesota Sea Grant (A / SE-11)
Douglas A. Jensen and Bruce Munson

New York Sea Grant (Project A / SE (ANS)-06-97)
Helen Domske

Ohio Sea Grant (Project E / NIS-1)
Rosanne Fortner

The Exotic Species Day Camp project broadened distribution of aquatic exotic species education to teachers, students, environmental educators, and outdoor education center visitors in the Great Lakes region. Developed by the Great Lakes Sea Grant Network, this project was offered as a one-day intensive training session with the ultimate goal of educating youth so they can draw a community's attention to the exotics issue. The five Great Lakes programs shared eight interactive teaching resources on nonindigenous aquatic species that addressed the biology, geographic range, environmental and economic impacts, and human response to these "invaders." ***Audience:*** teachers / educators: K-12 classroom teachers and non-formal environmental educators.

Products and Presentations

Curriculum Materials
Compendium of Activities on Exotic Aquatic Species (in press). ***Audience:*** Formal / Non-formal educators.

Exotic Species Day Camp Teacher Resource Binder (1998). ***Distribution:*** 30; ***Audience:*** Formal / Non-formal educators.

Workshop
Exotic Species Day Camp (five workshops during 1998). ***Participants:*** 125 total for all programs; ***Audience:*** Formal / Non-formal educators.

1995 – 1999

Great Lakes Exotic Species Graphics Library and Public Education Project

Michigan Sea Grant, Peggy Britt

Developed in conjunction with the Great Lakes Network, the Graphics Library is a collection of 72 slides that are available for sale or loan for use in presentations, publications, news articles, or in educational programming. The slides can also be viewed on the Internet through the SGNIS site (www.sgnis.org). The slides are accompanied by educational resources that provide information about aquatic nuisance species in the Great Lakes. ***Audience:*** general public, government agencies, media, public interest groups researchers, resource managers, teachers / educators, utilties.

Products and Presentations

Display
Exotic Species in Michigan (1998). ***Audience:*** general public, students, teachers.

Fact Sheets
The Five Lampreys of Michigan's Great Lakes (1997). ***Distribution:*** 350;
Audience: general public, resource managers.

Purple Loosestrife in Michigan (1997). ***Distribution:*** 1,000;
Audience: general public, resource managers.

Slides
Graphics Library Slides and Illustrations (since 1995). ***Distribution:*** 7,900;
Audience: general public, government agencies, resource managers, students, teachers.

Web Site
Graphics Library Web Site: ***www.engin.umich.edu/seagrant/esgl.html***
Audience: general public, government agencies, resource managers, students, teachers.

Greg Lashbrook and Kathy Johnson

Graphics Library

Key Words
ballast water
biological control
dispersal mechanism
educational program
Eurasian ruffe
Eurasian watermilfoil
nonindigenous
purple loosestrife
round goby
sea lamprey
spiny waterflea
wetlands
zebra mussel

Outreach

HACCP Model and ANS

Key Words

aquaculture
aquatic nuisance species
bait fish
chemical control
colonization
dispersal mechanism
educational programs
Eurasian ruffe
HACCP
impact
industry
inland lakes/rivers
monitoring
nonindigenous
outreach
physical control
prevention
recreation
round goby
sea lamprey
spiny waterflea
veliger
zebra mussel

September 1997 – August 1999

Model HACCP-Like Plan to Restrict the Spread of Aquatic Nuisance Species via Sale of Baitfish and Fish for Stocking

Minnesota Sea Grant - lead program (Project A / SE-15)
Jeffrey L. Gunderson and Douglas A. Jensen

Illinois-Indiana Sea Grant (Project A / SE (ANS)-08-97)
Patrice M. Charlebois

Michigan Sea Grant (Project A / NIS-2)
John D. Schwartz and Michael Klepinger

Ohio Sea Grant (Project A / NIS-3)
Fred Snyder

The goal of project was to maintain viable baitfish and aquaculture industries in areas where ANS have invaded. Borrowing a successful approach used by the seafood industry to ensure a safe product, called Hazard Analysis and Critical Control Points (HACCP), Sea Grant is working with these industries to develop HACCP-like plans and training manuals. Sea Grant is also assessing the level of ANS and non-bait contamination at retail outlets in the Great Lakes region, and surveying angler attitudes toward ANS, ANS-free live bait, and risks for spread by anglers. ***Audience:*** anglers, aquaculture and wild bait harvest industries, government agencies, resource managers.

Products and Presentations

Manuals and Training Packages

HACCP-Like Training Manual and Hazards Guide for ANS-Free Bait and Fish (forthcoming).
Audience: aquaculture operators, resource managers, scientists, wild bait harvesters.

Presentations

Baitfish HACCP Plan (August 1999, IL-IN). ***Participants:*** 50;
Audience: business / industry, government agencies.

HACCP-like Program Training for Baitfish and Fish Stocking Industry (April 2000, MI).
Participants: 20; ***Audience:*** resource managers, scientists, students.

Preliminary Findings of Nontarget Fish Dispersal Via Live Bait Shipments in Ohio.
Ohio Academy of Sciences Annual Meeting (April 2000, OH). ***Participants:*** 35;
Audience: resource managers, scientists, students.

Surveys

Ohio ANS Bait Dealer Survey (1999, OH). ***Participants:*** 74; ***Audience:*** bait dealers.

Ohio ANS Bait Users Survey (1999, OH). ***Participants:*** 80; ***Audience:*** anglers.

September 1995 – February 2000

Making High Quality University Research and Education Products Readily Available to the User Public: A National Sea Grant Zebra Mussel and Nonindigenous Species Web Site

Wisconsin Sea Grant - lead program (Project A / AS-41)
Allen H. Miller and Terrell Hyde

Illinois-Indiana Sea Grant, Mark E. Einstein and Brian K. Miller

Michigan Sea Grant, Millie J. Flory and Martha Walter

Minnesota Sea Grant, Linda Aylsworth, Douglas Jensen, and Marie Zhuikov

The National Sea Grant Zebra Mussel and Nonindigenous Species World Wide Web site (*SGNIS*) makes Sea Grant research and outreach information readily available to industries, governments and the general public. *SGNIS* contains a comprehensive collection of research publications and education materials produced by Sea Grant programs across the country with the purpose of mitigating the spread and improving the control of these invading species. The site also contains Sea Grant information on three invasive fish, the Eurasian ruffe, as well as the round and tubenosed gobies, and the spiny waterflea. More than 150 research reports and 60 educational items are currently housed at the site including newsletters, proceedings of past international conferences and a slide library. For those new to ANS, the site provides a brief introductory written and pictorial description of the species. All entries, with the exception of conference proceedings and newsletters, have been peer-reviewed to ensure availability of the highest quality science.
Audience: anglers, business / industry, elected officials, general public, government agencies, lake associations, maritime interests, media, property owners, recreational boaters, researchers, resource managers, students, teachers / educators, utilities.

Products and Presentations

Presentation
SGNIS Presentation, Seventh International Zebra Mussel and Other Aquatic Nuisance Species Conference, New Orleans, LA (January 1997). ***Participants:*** 50; ***Audience:*** educators, researchers.

Web Site
SGNIS Web Site: ***www.sgnis.org/***
Audience: educators, natural resource managers, researchers.

Sea Grant Nonindigenous Species Site (SGNIS)

Key Words
aquaculture
ballast water
basic biology
bioaccumulation
biological control
bivalve
byssal attachment
chemical control
coatings
colonization
dams
disposal
dispersal mechanism
ecological interactions
economic development
educational program
electricity
Eurasian ruffe
Eurasian watermilfoil
filters
impact
industry
inland lakes/rivers
monitoring
nonindigenous
physical control
pollution
population dynamics
predators prevention
purple loosestrife
quagga mussel
recreation
round goby
sea lamprey
spiny waterflea
tourism
veliger
wetlands
zebra mussel

Outreach

Sea Grant Nonindigenous Species Site (SGNIS)

Key Words

aquaculture
ballast water
basic biology
bioaccumulation
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chemical control
coatings
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tourism
veliger
wetlands
zebra mussel

September 1997 – August 1999

Sea Grant Nonindigenous Species WWW Site and Compact Disk

Minnesota Sea Grant - lead program (Project A / SE-10)
Jeffrey L. Gunderson, Marie E. Zhuikov, Douglas A. Jensen, Mike McLean, Dale Baker, and Debbie L. Kaminov

Illinois-Indiana Sea Grant, Brian Miller

Michigan Sea Grant, Millie Flory and Peggy Britt

Wisconsin Sea Grant, Allen Miller

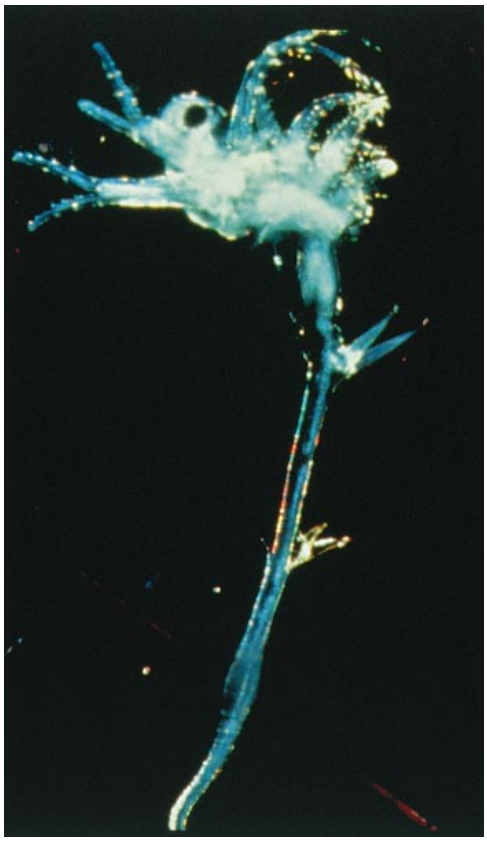
Since 1995, Minnesota Sea Grant has supported web site development by identifying and offering technical review of potential materials (fact sheets, graphics, journal articles, video clips) to be posted. In 1998, Minnesota Sea Grant led production of a *SGNIS* compact disk (CD) for those people without Internet capabilities, and produced an ordering brochure. Both the site and CD contain a comprehensive collection of peer-reviewed research and outreach publications and materials on ANS produced by Sea Grant and other programs and agencies. ***Audience:*** anglers, business / industry, elected officials, general public, government agencies, lake associations, libraries, maritime interests, media, property owners, recreational boaters, researchers, resource managers, students (K-College), teachers / educators (K-College), utilities.

Products and Presentations

Brochure
*SGNIS Exotic CD (*1998). ***Distribution:*** 10,300; ***Audience:*** see above.

Compact Disk
Sea Grant Nonindigenous Species Site Compact Disk (1998). ***Distribution:*** 30; ***Audience:*** see above.

Purple loosestrife *(Lythrum salicaria)*



Spiny waterflea *(Bythotrephes cederstroemi)*

March 1997 – February 1999

Funding for Biological Resources

Illinois-Indiana Sea Grant (Project A / CEH-02-97)
Patrice M. Charlebois

This project provided information to several types of audiences on biology, spread prevention, and possible impacts aquatic nuisance species including the zebra mussel, round goby, tubenose goby, and *Daphnia lumholtzi*. ***Audience:*** anglers, business / industry, general public, government agencies, lake associations, maritime interests, property owners, recreational boaters, researchers, resource managers, teachers / educators.

Products and Presentations

Can "Cozy"
Aquatic Hitchhikers.....Leave Them Stranded (March 1998).
Distribution: 3,000; ***Audience:*** anglers, general public, recreational boaters.

Fact Sheets
Daphnia lumholtzi: *The Next Great Lakes Invader?* (1998). ***Distribution:*** 500;
Audience: anglers, general public, maritime interests, recreational boaters, resource managers.

Help Prevent the Spread of Aquatic Exotic Plants and Animals (1998).
Distribution 2,000; ***Audience:*** anglers, general public, lake associations, recreational boaters.

Zebra Mussels: Answers for Lake Managers' Questions (1998).
Distribution 200; ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters, resource managers.

Poster
*Exotics Species Advisory (*June 1998). ***Distribution:*** 200; ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters.

Presentations
*Prevent the Spread of Exotics! (*January and February 1999).
Participants: 25,000; ***Audience:*** anglers, general public, lake associations, maritime interests, property owners, recreational boaters.

Round Goby Dispersal Barrier (June 1998).
Participants: 75; ***Audience:*** researchers.

Second International Round Goby Conference (May 1999).
Participants: 75; ***Audience:*** government agencies, researchers, resource managers.

*Zebra Mussel Mania (*March 1998).
Participants: 75; ***Audience:*** teachers / educators.

Zebra Mussels: Impacts and Education (May 1998).
Participants: 100; ***Audience:*** general public, government agencies, lake associations, maritime interests, property owners, recreational boaters, resource managers.

Proceeding
*Proceedings from the Second International Round Goby Conference (*August 1999).
Distribution: 100; ***Audience:*** government agencies, researchers, resource managers.

Reports
*Current Distribution of the Round Goby in Southern Lake Michigan (*January 1999).
Distribution: 25; ***Audience:*** government agencies, researchers, resource managers.

*Results of Angler Survey on Round Goby Outreach Tools (*February 1999).
Distribution: 15; ***Audience:*** government agencies, resource managers.

General ANS

Key Words
aquatic nuisance species
basic biology
Daphnia lumholtzi
dispersal mechanism
ecological interactions
impact
inland lakes/rivers
nonindigenous
physical control
prevention
recreation
round goby
tubenose goby
zebra mussel

Outreach

General ANS

Key Words
aquaculture
ballast water
basic biology
biological control
colonization
ecological interactions
educational program
impact
industry
monitoring
nonindigenous
population dynamics
prevention
zebra mussel

September 1997 – August 1999

Outreach and Education Proposal on Marine Bioinvasions

Massachusetts Institute of Technology Sea Grant (Project A / A-14)
Judith Pederson and Andrea Cohen

The MIT Sea Grant College Program outreach and education efforts are intended to disseminate scientific information to the public, scientists, managers, industry, and other stakeholders. The activities include taking the lead in convening a *National Conference on Marine Bioinvasions* in cooperation with several other Sea Grant programs, developing a web page, preparing fact sheets and information for the web, preparing a brochure to inform the public on marine bioinvasions, convening a steering committee to advise on scientific accuracy of materials, and distributing a zebra mussel kit to schools and other groups. ***Audience:*** business / industry, elected officials, general public, government agencies, maritime interests, media, recreational boaters, researchers, resource managers, students (upper division high school and college), teachers / educators.

Products and Presentations

Brochure
A Quick Guide to Marine Bioinvasions (1998).
Audience: agencies, general public, educators, resource managers, students.

Proceeding
First National Conference on Marine Bioinvasions: Abstracts from the Conference (January 24-27, 1999).
Distribution: 250; ***Participants:*** 275; ***Audience:*** government agencies, industry representatives, natural resource managers, scientists.

Lloyd Lemmerman

Zebra mussels (*Dreissena polymorpha*)

Program Highlights

Sea Grant

ANS

Program Highlights in Aquatic Nuisance Species Research and Outreach

The Highlights section briefly describes ANS issues and problems in coastal states and the research and outreach projects Sea Grant programs have undertaken to address problems caused by aquatic nuisance species. This section is organized by region, and within each region, program highlights are listed in alphabetical order. (**NOTE**: Only programs that are actively engaged in ANS projects are included in this report.) These descriptions were written by staff members from the participating programs and showcase the research and outreach activities of importance in each state. Some programs, especially those in the Great Lakes region, have faced zebra mussel problems for years and therefore have a longer "track record" of ANS projects. Other regions have not yet been inundated by as many nuisance species and have focused their efforts on projects to prevent ANS introductions — a very commendable strategy!

These highlights reflect the individuality of each program and therefore vary in length and in the type of information provided. However, each description includes:

- the main ANS issues in the state;
- the significance of the problem; and
- a summary of research and outreach activities related to ANS, as applicable.

Reprints of the highlights pages are available, on a limited basis, from the individual programs.

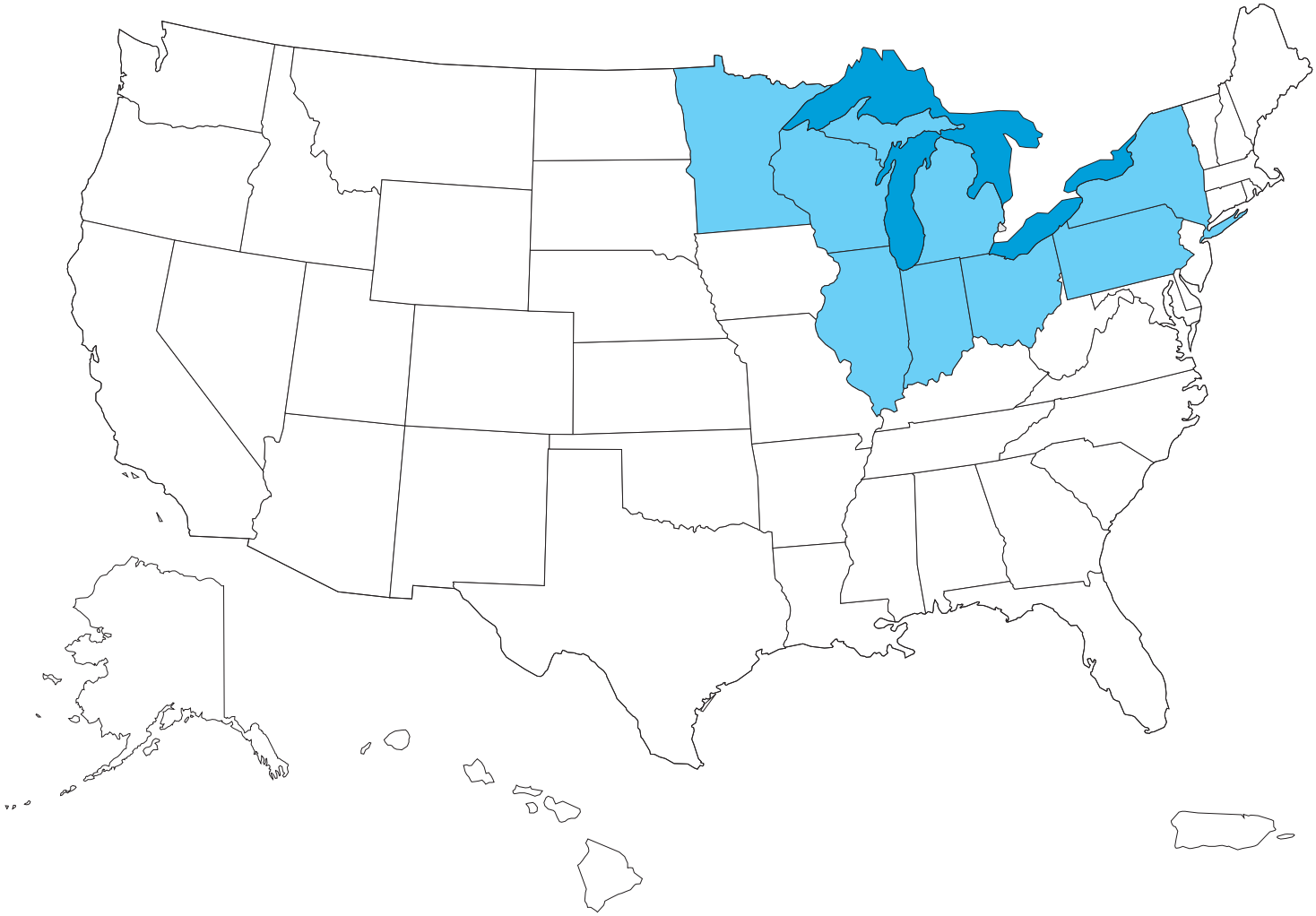
Great Lakes Region

Illinois-Indiana
Michigan
Minnesota
New York
Ohio
Wisconsin

Sea Grant

ANS

Great Lakes Region



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www.seagrant.sunysb.edu

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Fax: 614.292.4364
www.sg.ohio-state.edu

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Fax: 608.262.0591
www.seagrant.wisc.edu/

Sea Grant

Illinois-Indiana

Over the past 200 years, the deliberate and accidental introduction of nonindigenous plant and animal species in the Great Lakes has had various effects — some devastating such as the sea lamprey (*Petromyzon marinus*), and some benign. More recent invaders include the spiny waterflea (*Bythotrephes cederstroemi*), Eurasian ruffe (*Gymnocephalus cernuus*), round goby (*Neogobius melanostomus*), and zebra mussel (*Dreissena polymorpha*) — all transported from their native Europe to the Great Lakes in the ballast water of trans-Atlantic ships. The zebra mussel poses the greatest economic concern because of its ability to clog water intake pipes — the route by which about 655 billion gallons of Great Lakes water are drawn each day for use by more than 25 million people, thousands of crop and livestock farms, hundreds of lakeshore industries, and dozens of nuclear and fossil fuel power plants.

Their spread to inland rivers has resulted in adverse economic impacts not only in areas adjacent to Lake Michigan, but also in communities throughout Illinois and Indiana. New infestations have affected industrial and municipal water users, marina operators and people who depend upon inland rivers to harvest native mussels. Cleanup results in high costs to citizens and industry in repairing damage to boats and cleaning clogged intake pipes of treatment plants and water-dependent industries.

Round gobies are one of the most recent exotics to enter the Great Lakes. They are numerous in Illinois and Indiana waters of Lake Michigan, especially near Calumet Harbor and in the Calumet River. The round goby poses a potential threat to native fish. They compete directly with the mottled sculpin, a major prey of yellow perch. They may also reduce recruitment of important sportfish such as smallmouth bass and eat lake trout eggs. Round gobies are one of the few species which feed on zebra mussels. Because gobies in turn are prey for higher species such as smallmouth bass, walleye, and yellow perch, they create a pathway by which toxicants (heavy metals and polychlorinated biphenyls) accumulating in zebra mussels, can be harmful to fish species consumed by humans.

Sea Grant's scientists and outreach staff have combined efforts to tackle the numerous problems that have surfaced from the introduction of aquatic nuisance species in Lake Michigan and inland waters, particularly the zebra mussel and round goby.

David Riecks

Round goby sample (*Neogobius melanostomus*)

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Species of Concern
Eurasian ruffe
Round goby
Rusty crayfish
Spiny waterflea
Zebra mussel

Research

Research on invasion, impacts, and control provides resource managers and water users with methods to help prevent future ANS introductions.

Over the past four years, Illinois-Indiana Sea Grant has provided funding to determine the geographic spread, potential control measures, and ecosystem impacts of a number of aquatic nuisance species including invading Eurasian ruffe, round and tubenose gobies, zebra mussels, and rusty crayfish.

Potential Impacts of Invading Ruffe *(Gymnocephalus cernuus)* on Benthic and Pelagic Ecosystems of the Great Lakes

Funded by Illinois-Indiana Sea Grant since 1995, this project has resulted in producing significant information concerning the movement of food sources needed to sustain the invading Eurasian ruffe. University of Notre Dame and Loyola University biologists working on this project have been recognized for their Sea Grant-supported research in the recent report, *Great Advances in Scientific Discovery* issued to Congress by The Science Coalition. They predict that within the decade, the invading ruffe will move down into Lake Michigan, as well as into Lakes Erie and Ontario. Additionally, scientists are investigating how predators and competitive interactions will affect ruffe and the Lake Michigan native fish, yellow perch.

Degradation and Restoration of Lake Michigan, Past and Future of Nonindigenous Species

Project researchers are working on establishing quantitative descriptions of species characteristics that increase the probability of successful invasion. After establishing these descriptions, the research team plans to communicate its findings to management agencies responsible for developing effective strategies to prevent future introductions.

Round Goby and Mottled Sculpin Spawning Interactions

The goals of this project are to determine whether round gobies interfere with mottled sculpin spawning. By comparing and contrasting nest site selection in round gobies and mottled sculpins, researchers hope to find ways in which habitats can be modified to minimize round goby reproduction while protecting/enhancing mottled sculpin reproduction.

Invasion Susceptibility and Ecosystem Fragmentation of Great Lakes Coastal River and Lakes by the Newly-Introduced Round and Tubenose Gobies

The major goals of this project are to determine the susceptibility of adjacent connecting water bodies of the Great Lakes to colonization by gobies, to determine if velocity is potentially limiting to round gobies using a model stream system, and to determine what impacts round gobies may have on lentic fish using factorial experiments.

A Model of the Lake Michigan-Illinois River Zebra Mussel Metapopulation: Evaluating Possible Control Strategies

Researchers are investigating and modeling the metapopulation dynamics of zebra mussels in the connected waters of Lake Michigan and the Illinois River. In addition, the project hopes to quantify the flux of veligers from Lake Michigan into the Illinois River.

Population and Energetic Consequences of Zebra Mussel Fouling on Native Gastropod Fauna of Lake Michigan

The major findings of this project included developing a new technique for measuring the oxygen consumption of snails, and determining that the physical and chemical characteristics of shells are not responsible for differences in settlement rate on different snail species. Preliminary results showed a reduction in the consumption rate and a reduction in fecundity of fouled snails.

Dispersal of Exotic Species in the Great Lakes: Crayfish as a Model System for Benthic Species

The researchers hope to reconstruct the chronology of invasions by all crayfish species into the Great Lakes. Using genetic analyses of the crayfish in regions of Lake Michigan where the rusty crayfish (*Orconectes rusticus)* is displacing the northern crayfish *(O. propinquus)*, scientists will predict the future distribution of *O. rusticus* in the Great Lakes by comparing the environmental requirements of that species with the characteristics of Great Lakes littoral zones.

Outreach

Through training programs and information products, outreach staff empowers users and managers of Lake Michigan — and Illinois' and Indiana's inland waters — to reduce the introduction of new ANS. These efforts also help citizens cope with problems caused by existing species.

SGNIS Web Site: *www.sgnis.org*

The Sea Grant Nonindigenous Species (SGNIS) peer-reviewed site, developed in conjunction with Wisconsin Sea Grant, contains a comprehensive collection of research publications and education materials on nonindigenous aquatic species. The information on the site is intended to help others respond more rapidly by applying research findings to control strategies and by using quality education materials to teach practitioners in industry and resource management agencies. It meets diverse needs of audiences ranging from researchers to elementary teachers. Great care has been taken to ensure that all materials are of the highest quality and to make sure that all information is searchable and easily accessible to users. Web site visitors from over 86 countries use SGNIS to conduct literature searches, download entire documents, and download photos from the SGNIS photo library.

More than 70 percent of recreational boaters and anglers reportedly take steps to prevent the spread of aquatic nuisance species, due, in large part, to Illinois-Indiana Sea Grant outreach efforts.

Zebra Mussel Workshops

These workshops and support materials will provide inland lake associations with all of the information they need on zebra mussels including how to keep them out of an uninfected lake and steps to mediate their impacts if a lake is already infested. These workshops bring existing information and expertise developed on the Great Lakes to a new set of clients threatened by the zebra mussel invasion.

HACCP-Like Plan to Restrict the Spread of Exotics via the Baitfish/Aquaculture Vector

Baitfish have been identified by the Great Lakes Panel on Aquatic Nuisance Species as a possible vector for the spread of exotics. This project examines all aspects of the baitfish industry's processes. Identification of the problem areas, and a Hazard Analysis and Critical Control Points (HACCP)-like plan to circumvent the problems will allow the industry to take proactive steps to avoid spreading exotic species.

Zelda, the Zebra Mussel

A costumed character was developed by Illinois-Indiana Sea Grant in 1994 to draw attention to the issue of zebra mussels. Zelda is a larger than life-sized zebra mussel that has greeted over 10,000 visitors at public events and professional conferences throughout the U.S. She has appeared at Earth Day events, state fairs, University of Illinois and Purdue University Open House events, and has educated the public by generating feature articles in newspapers and zebra mussel news on television broadcasts.

Zebra Mussel Videoconference

Zebra Mussels: Lessons Learned in the Great Lakes used a videoconference format to transfer the latest scientific information to outreach personnel and water users around the nation who were new to the zebra mussel problem. State-of-the-art technologies allowed Sea Grant experts to discuss biology, spread and impact, along with updates on control methods. Case studies on rivers, large lakes, and inland lakes provided viewers with opportunities to discuss potential impacts from zebra mussel infestations in their localities. Four videotapes on zebra mussel control, biology, spread and impact, and outreach tools available were also developed and distributed nationwide.

Round Goby Conference

Sea Grant sponsored the first *International Round Goby Conference* in February 1996, which brought together 50 key researchers at U.S. and Canadian universities to discuss latest findings and brainstorm future directions for research and outreach. The conference resulted in a comprehensive round goby literature review that also provided new outreach strategies and information tools to educate the public about round goby concerns.

"I can assess potential impact and recommend future actions based on what I learned by attending this workshop. I was able to accomplish my objectives and returned to my lake association with a great package of information, and the knowledge of how to network in the future via the Sea Grant Program personnel."

George Rauh, Jr., Lakes and Dams Committee, Lake Sherwood Estates, Indiana

Zebra Mussel Conference for Inland Water Users

Over 170 municipalities, power and water utilities, and agency personnel have received valuable information on control problems and options through three zebra mussel conferences for inland water users (held in St. Louis, Cincinnati, and Tennessee). Many managers and utility operators in newly infested waters have begun proactive control programs or modified existing practices as a result of these workshops co-coordinated by the Illinois-Indiana and Ohio Sea Grant programs.

Zebra Mussel Teach-the-Teacher Workshops

In March 1995, two workshops provided information on zebra mussel monitoring, spread mechanisms, impacts, and control measures. The sessions were offered to water resource managers, Extension Service outreach professionals, and state management agency staff. Through his participation in the workshop, the president of an inland lake association in Missouri said, "I can assess potential impact and recommend future actions based on what I learned by attending this workshop. I was able to accomplish my objectives and returned to my lake association with a great package of information, and the knowledge of how to network in the future via the Sea Grant Program personnel."

Clarissa Gentzler

Zelda the Zebra Mussel gives preserved specimens to day camp participants.

K-12 Education

Zebra Mussel Mania Traveling Trunk

Zebra Mussel Mania is a 4-time award winning education kit developed by teachers for teachers that is now being used by hundreds of educators across the U.S. and Canada. The hands-on curriculum includes experiments, games, and stories. The trunk is filled with scientific apparatus, sample zebra mussel and native mussel shells, videos, posters, worksheets, and pre- and post-tests.

The Traveling Trunk is designed for educators of grades 3-12 who teach science, math, social studies, language arts, and cultural arts. Over 13,000 educators nationwide have been introduced to the Traveling Trunk, which is now available at 37 lending centers nationally. Teachers using Zebra Mussel Mania regard it as an excellent teaching tool because it facilitates public understanding of how the invasion of zebra mussels affects their daily lives.

Exotic Species Day Camp for Educators

This Great Lakes Sea Grant network project, coordinated by Illinois-Indiana Sea Grant, established a regional network of 130 classroom and non-formal educators who use Sea Grant resources to teach hundreds of educators in their local schools and environmental education centers. Five workshops were conducted around the Great Lakes. Participants received training on eight interactive teaching resources that have been developed by Sea Grant and the participants worked together to develop 34 classroom activities using these resources. A compendium of these activities, entitled *ESCAPE,* will be available to teachers nationwide.

Illinois-Indiana Sea Grant will continue its efforts to prevent the further spread of aquatic nuisance species through education and will provide control information and solutions resulting from research. Training efforts and information resources offered by Illinois-Indiana Sea Grant will contribute to reducing the ecological and adverse economic impacts of these species.

Michigan

Michigan's central location in the Great Lakes is both unique and challenging — unique because the state has an extensive shoreline (second only to Alaska), and challenging in the sense that when an aquatic nuisance species (ANS) enters the Great Lakes, it's not long before it impacts all of Michigan's waters. Two of America's most notorious ANS arrived here first: zebra mussels were discovered in Lake St. Clair in 1988, and round gobies were discovered in the St. Clair River in 1990.

In the Great Lakes, zebra mussels *(Dreissena polymorpha)* have permanently altered the ecosystem, and they cost millions to control each year throughout the region. In Michigan, zebra mussels have colonized nearly 100 inland lakes (25 lakes in 1998 alone). Meanwhile, the round goby (*Neogobius melanostomus*) has recently shown up in new locations around the Great Lakes, including northern Lake Michigan and the state's first inland lake, near Saginaw Bay. The aggressive goby is becoming increasingly abundant and competes with native fish for food and habitat. Complicating matters are the uncertain long-term impacts on native fish populations brought about by the Eurasian ruffe (*Gymnocephalus cernuus*) and spiny waterflea (*Bythotrephes cederstroemi*), both of which entered the Great Lakes in the mid 1980s.

In addition to battling new ANS, millions of U.S. and Canadian dollars are spent each year to control the parasitic sea lamprey (*Petromyzon marinus*), an invader that has been a problem in the Great Lakes for decades and particularly in northern Lake Huron. Inland, plants such as the Eurasian watermilfoil *(Myriophyllum spicatum)* continue to choke waterways in some Michigan locations, and the ubiquitous purple loosestrife *(Lythrum salicaria)* has now colonized every major watershed in the state.

Michigan Sea Grant

Michigan Sea Grant Extension works with wild bait harvesters in the Black River, MI.

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Species of Concern
Eurasian ruffe
Eurasian watermilfoil
Purple loosestrife
Round goby
Sea lamprey
Spiny waterflea
Zebra mussel

Research

Sea Grant researchers are working to understand the full impacts of round gobies and Eurasian ruffe in the Great Lakes. Research is also underway to control the introduction of ANS by the ballast water of cargo ships.

Current Michigan Sea Grant research projects will contribute to the understanding of long-term ecological and economic impacts of two potentially damaging invaders — the round goby and Eurasian ruffe.

Round gobies have been transferred throughout the Great Lakes in five years, have attained dramatically high numbers in some areas and continue to spread. At least two inland colonies have been discovered in the past year. Control measures and management actions depend on knowledge of what factors may limit the dispersal of gobies. Scientists know, for instance, that gobies compete with some native fish for food and habitat, but questions remain: what locations are most susceptible to colonization? Does water velocity affect the dispersal of gobies? A University of Michigan researcher, who first discovered gobies in the Great Lakes, is studying these types of questions with support from Michigan Sea Grant.

A second research project funded by Michigan Sea Grant will estimate the economic damages that will accrue to recreational anglers as a result of ruffe in the Great Lakes. The ruffe invasion of Lake Superior demonstrates the possibility of significant declines in walleye and perch populations in other Great Lakes waters. Perch and walleye are targeted by millions of recreational anglers throughout the Great Lakes region. The research will establish a theoretically sound baseline of assessment information for the perch and walleye fisheries. The results will not only inform ruffe control policy but will also apply more generally to Great Lakes fisheries policy.

Another project focuses on controlling the introduction of nonindigenous species in the Great Lakes. Led by the director of Michigan Sea Grant and supported by a private foundation, researchers are investigating the use of biocides to control the spread of aquatic exotics via ballast water. Research has been underway to investigate the feasibility of using a nonoxidizing biocide to treat ballast water. This project has addressed issues concerning the efficacy of a biocide as a control agent, the environmental acceptability of such an approach, the cost-effectiveness of biocide use, and the implications for ship safety and operation. To date, the main focus of the project has been the efficacy and environmental acceptability of glutaraldehyde use in treating both ballast-on-board and no-ballast-on-board vessels.

Jerry Bielicki

Ocean vessel docks in a Great Lakes port.

Michael Klepinger

A volunteer in the Lake Monitoring Program uses a plankton net to sample for zebra mussel veligers.

Outreach

In order to manage ANS effectively and prevent further ecosystem degradation, statewide cooperation is essential. Fortunately, with Michigan's 3,200 miles of Great Lakes shoreline, residents in the upper and lower peninsulas have a strong connection to the Great Lakes and a growing concern for their ecological health. Michigan Sea Grant has been capitalizing on this relationship through a strong outreach program. Through public presentations, conferences, teacher workshops, and educational materials, Sea Grant outreach educates citizens while giving them the tools they need to play an active role in preventing the further spread of nonindigenous species.

Through the Sea Grant Citizen Monitoring Program, volunteers have provided an estimated 2,000 hours of field monitoring and data that contribute to the understanding of the zebra mussel invasion.

Citizen Monitoring Program

In recent years, Michigan residents have become increasingly concerned as zebra mussels spread to inland lakes. Today, through the Sea Grant Citizen Monitoring Program, citizen volunteers collect data from inland lakes using equipment and instructional materials developed on the campus of Michigan State University. In addition to reporting new colonies of adult mussels, citizens using Sea Grant's zebra mussel veliger monitoring kit have provided an estimated 2,000 hours of field monitoring and data that contribute to understanding the zebra mussel invasion. Michigan teachers, nature centers, and the state's 350 lakefront property owner associations — important Sea Grant partners that helped develop the monitoring program — frequently use the equipment. Sea Grant coordinates the long-term equipment loan program, collects and verifies sampling data and publishes results, which receive widespread media attention. The straightforward, low-cost program demonstrates the capability of volunteer efforts in gathering scientifically useful water quality data, while tracking the spread of zebra mussels. Perhaps most importantly, the program engages property owners in lake resource management; this participation is critical in coping with exotic invaders. When a zebra mussel infestation is discovered, citizen leaders get the word out around the lake, post signs and hold workshops to help prevent the spread to other lakes. Today, the monitoring materials are being used as a model by Sea Grant programs from as far away as Washington and Florida.

Purple Loosestrife Project

Another high-profile nuisance species is purple loosestrife. The hardy wetland plant has become part of the Michigan landscape and has replaced native wetland plants in many locations along with the animals that depend on them. Long-standing control practices such as burning and herbicide application have failed. Michigan Sea Grant, in partnership with the Michigan State University (MSU) Department of Entomology, created the Purple Loosestrife Project at MSU, which is aimed at reducing the plant's numbers by integrating citizen stewardship education with biological control. The project began with a unique loosestrife locator postcard survey that engaged citizens in identifying nearly 500 of the largest wetland infestations in Michigan. Hundreds of teachers, students, naturalists, property owners, and citizen groups now participate in the project, helping to restore Michigan's biodiversity and natural wetland function while learning the key concepts of biological control. Since the Purple Loosestrife Project began in 1997, volunteers have raised and released *Galerucella* leaf-feeding beetles (one of the plant's natural enemies in Europe) across Michigan. The beetles are establishing populations in stands of purple loosestrife and are beginning to cause significant defoliation. In addition, Michigan Sea Grant assisted teachers in producing a *Cooperators Handbook*, which features 25 outdoor learning activities and classroom experiments, and serves as a comprehensive guide to purple loosestrife biological control.

Baitfish Industry and Concerns

Michigan Sea Grant is working closely with baitfish harvesters to assess and lower the risk of spreading aquatic nuisance species. In Michigan, wild baitfish is harvested and used in thousands of inland lakes as well as Lakes Superior, Huron, Michigan, St. Clair, and Erie. Michigan's baitfish industry ranks second in the Great Lakes (by volume) and is worth an estimated $25,000,000 annually. Concerns regarding the spread of ANS have threatened this economically viable business despite little information that baitfish transfers have led to the establishment of reproducing ANS populations. Sea Grant Extension Agents have participated in wild baitfish harvest operations across the state. A training manual was developed similar to the training manual developed by the National Seafood HACCP Alliance but tailored to the unique needs of the baitfish industry. The project provides a proactive compromise to what could become a contentious issue affecting nearly 100 wholesale and 750 retail baitfish operators in Michigan.

Doug Landis

A young boy lends a hand in the battle against purple loosestrife.

In the coming years, Michigan Sea Grant will continue to partner with state and regional ANS management agencies to reach common goals.

Education Programs

Michigan Sea Grant's ongoing educational activities target specific audiences as well as the general public. For example, Michigan Sea Grant has convened an annual conference for municipal/industrial water users nearly every year since 1991. The conference provides this specialized group with up-to-date information on how to cope with zebra mussels in the most cost-effective manner. Attendees have commented that this event is "an outstanding and very practical conference" that has led to more efficient practices and saved customers money.

In 1996, Michigan Sea Grant hosted the *Sixth International Zebra Mussel and Other Aquatic Nuisance Species Conference* which was attended by more than 500 people. Michigan Sea Grant has also played a key role on the international conference planning committee nearly every year since the conference began.

Throughout the year, Michigan Sea Grant actively distributes literature on exotic species, including research-based fact sheets, identification cards, and brochures that give practical information on how boaters and anglers can help prevent the spread of aquatic nuisance species. Through public lectures, Michigan Sea Grant's director and extension agents have informed citizens throughout the region about the impacts of invading aquatic organisms. In addition, the aquatic nuisance species information office responds to hundreds of calls each year from property owners, journalists, researchers, and policy-makers.

One of the most prominent resources available to this varied audience is the Great Lakes Exotic Species Graphics Library, maintained by Michigan Sea Grant. Since its beginning in 1991, a variety of clients have purchased or borrowed thousands of slides from the extensive collection to illustrate media articles, presentations, and scientific reports. In collaboration with the Great Lakes Sea Grant Network, Michigan Sea Grant is currently working to expand the library's scope to include nuisance species from across North America.

In the coming years, Michigan Sea Grant staff will continue to partner with state and regional ANS management agencies. Sea Grant staff serve on the Great Lakes Panel on Aquatic Nuisance Species created by Congress in the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (PL 101-646) and on the ruffe control committee formed by that group. Staff members played a key role in the Panel's development of the Information/Education Strategy for Aquatic Nuisance Prevention and Control. In recent years, staff members have also provided Congressional and state testimony at hearings. Michigan Sea Grant's director gave Congressional testimony in 1996 on the value of continued funding to support research and outreach on nonindigenous species. Recently, Michigan Sea Grant's ANS program coordinator testified before the State of Washington Zebra Mussel and Green Crab Task Force. With Michigan's assistance, Washington State is developing an outreach program modeled in part after Michigan Sea Grant's successful public education campaigns and education programs for municipal and industrial water users.

These educational activities and collaborations — combined with Michigan Sea Grant's focus on practical research and a strong outreach program — help Michigan citizens and others better understand, prevent, and cope with aquatic nuisance species.

Michigan Sea Grant

Michigan Sea Grant's ANS educational display and publications

Minnesota

Minnesota Sea Grant

A student from Marshall School in Duluth, Minnesota takes a closer look at zooplankton from the Exotic Aquatics Traveling Trunk.

With more shoreline than the continental Pacific Coast, Minnesota's rich water resources are at great risk for environmental and economic impacts due to the spread of invasive aquatic nuisance species (ANS). With over 160 ANS in the Great Lakes, Lake Superior serves both as a vital water resource, but also as a potential source for spread and impacts. Loss of biodiversity, extirpation of endangered or threatened species, effects on natural food webs, fish, water quality, and nutrient and contaminant cycling are examples of ecosystem impacts in the Great Lakes. Economic losses each year due to ANS are in the millions of dollars.

Devastating impacts caused by invaders such as the sea lamprey (*Petromyzon marinus*), zebra mussels *(Dreissena polymorpha)*, Eurasian ruffe (*Gymnocephalus cernuus*), threespine stickleback *(Gasterosteus aculeatus)*, round goby (*Neogobius melanostomus*) and others threaten the economic vitality of the Great Lakes region, and these species are well poised to spread inland. However, despite growing infestations in the Duluth-Superior harbor and in the Mississippi River, zebra mussels have been found in only one Minnesota inland lake. Eurasian ruffe and round goby infestations in the harbor have grown, but also have not spread inland. Meanwhile, Eurasian watermilfoil *(Myriophyllum spicatum)* infestations have slowed to about five lake infestations annually since 1992. Infestations are currently found in 120 lakes and rivers statewide. Purple loosestrife *(Lythrum salicaria)* continues to choke out native plants, birds, mammals, frogs, and fish in nearly 2,000 wetlands. Spiny waterfleas (*Bythotrephes cederstroemi*) remain in Lake Superior and in three inland lakes. By integrating research, outreach, and education, the University of Minnesota Sea Grant Program continues to sponsor programs about these invaders. Program goals are to prevent the spread of Lake Superior invaders to other waters, to develop techniques to control or manage ANS, and to understand the environmental and economic impacts of ANS.

Sea Grant
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Species of Concern
Eurasian ruffe
Eurasian watermilfoil
Purple loosestrife
Round goby
Sea lamprey
Spiny waterflea
Threespine stickleback
Zebra mussel

UNIVERSITY OF MINNESOTA

Research

"The Sea Grant program has provided practical and invaluable technical assistance to the Western Zebra Mussel Task Force (WZMTF) in the WZMTF's efforts to prevent the spread of zebra mussels into the western United States. The Sea Grant Program has a common sense approach to exotic education and an understanding of the public that is extremely useful to agencies initiating exotic species prevention programs."

Linda Drees, WZMTF Co-Chair & U.S. Fish and Wildlife Service (Region 6) Nonindigenous Species Coordinator

Currently, Minnesota Sea Grant sponsors research to evaluate innovative, environmentally-safe solutions for control and management of ANS such as sea lamprey, Eurasian ruffe, and Eurasian watermilfoil. At an investment of $15 million annually, sea lamprey control efforts rely primarily on lampricides to protect a Great Lakes fishery valued at about $4.5 billion annually. University of Minnesota scientists are examining whether sea lamprey smell attractants can create new possibilities for control. Minnesota Sea Grant-sponsored researchers are leading a team from six universities to examine impacts, genetics, and control of Eurasian ruffe. A third research project has identified a native aquatic beetle that feeds on Eurasian watermilfoil. Under certain conditions, the beetle can help unclog waterways, which may improve recreational opportunities and reduce management costs. A fourth study is examining the potential for spiny waterfleas to push polychlorinated biphenyls up the food web into Great Lakes salmon.

Minnesota Sea Grant

Eurasian ruffe (*Gymnocephalus cernuus*)

Outreach

The Exotic Species Information Center

Prevention through public outreach and education is the key to stop or slow the spread of ANS. Established in 1991, the Exotic Species Information Center is recognized as a leader in effective public education campaigns and programming. For example, the Center produces the *Ruffe WATCH* and *Round Goby WATCH ID* cards, which recently won an award because of their high-quality, consistent message, and cost savings to partners Great Lakes-wide. Staff also recently won an award for contributions to the Sea Grant Nonindigenous Species (SGNIS) web site. Each year, the Center responds to hundreds of requests for materials and technical assistance on ANS issues from various public audiences well beyond Minnesota. In fact, nearly 70 percent of all requests are from the other 49 states, Canadian provinces, and other countries. Center technical information collections have expanded to over 50 ANS based on public interest.

Collaboration among state and federal agencies is important to effectively manage, control and prevent the spread of ANS. Since 1994, Minnesota Sea Grant took a lead role regionally and nationally to sponsor and promote ANS programming. Often, Center staff have been invited to provide expert testimony at teleconferences, workshops, and task force meetings, most notably the Western Zebra Mussel Task Force, the Western Regional Panel on ANS, and the Great Lakes Panel on ANS. Currently, staff provide leadership on several task forces such as the Recreational Activities Committee of the ANS Task Force, Great Lakes Sea Grant Network Nonindigenous Species Outreach Committee, Great Lakes Panel on ANS, Information & Education Committee, Western Regional Panel on ANS, and the Western Zebra Mussel Task Force.

Sea Grant-sponsored programming educates people about ANS through public presentations, conferences, youth education, and teacher workshops. To date, the Center has distributed over 600,000 publications, videotapes, slides, graphics, ANS specimens, monitoring kits, and youth education resources. Over the past five years, news articles promoting public awareness on Sea Grant exotic species research and outreach reached an estimated 275 million people.

Promoting Zebra Mussel Outreach Programming Nationwide

Minnesota Sea Grant

Goby-catching kids, cousins Cody and Tom Krause, and friend, display their catch and rig. The youths caught the largest number of round gobies ever found in the Duluth-Superior harbor and were able to identify the fish due to Sea Grant public education efforts through the media.

The Sea Grant/USDA Nationwide Zebra Mussel Training Initiative has been a very significant effort to prepare the country for the arrival of zebra mussels. As in the Great Lakes, proactive programming, early monitoring and control can save millions of dollars each year for water-using industries and municipalities. The initiative is led by New York Sea Grant, in collaboration with the Connecticut, North Carolina, Louisiana, and Illinois-Indiana Sea Grant programs. Minnesota provided expertise on boater education and programming for aquaculture and state fish stocking projects. Sea Grant-sponsored national teleconferences, a conference that spawned the Western Zebra Mussel Task Force (WZMTF), and the first West Coast and Heartland zebra mussel conferences all reached nearly 9,000 people. As an outgrowth of the WZMTF, the Western Regional Panel on ANS was formed. Presentations to state officials resulted in the formation of the Utah Zebra Mussel Work Group and a briefing for Utah congressional aides. Staff also provided testimony for development of the 100th Meridian Initiative, a multi-agency effort to prevent the westward spread of zebra mussels through public education and watercraft inspections.

Beginning in 1994, Minnesota Sea Grant sponsored the first Upper Mississippi River workshops, which used the leader training package, *Mussel Menace! Zebra Mussels and You*. Currently, over 30 states are reaching boaters with prevention messages through the use of water access signs — many as a result of outreach efforts to extend the results of the *Three State Exotic Species Boater Survey*. Sea Grant was also instrumental in helping aquaculture industries prevent zebra mussel spread, mitigate impacts, and reduce complexity and cost of regulations.

A new 2-year initiative teams Minnesota, New York and North Carolina expertise with the two California Sea Grant programs to bring workshops for water-related agencies to California. Many delegates attending the first workshop, held in conjunction with the *Eighth International Zebra Mussel and ANS Conference*, received the *Special Western Edition, Mussel Menace!* produced by Minnesota Sea Grant. Minnesota Sea Grant also hosted the *Ninth International Zebra Mussel and Aquatic Nuisance Species Conference* in April 1999, in Duluth, Minnesota. Over 400 delegates attended this 4-day conference, which featured over 190 presentations on ANS from 12 countries.

"The Minnesota Sea Grant exotic species ID cards are some of the best examples of regional cooperative efforts to produce education materials to help public awareness of aquatic nuisance species. These types of cooperation have the advantage of providing consistent messages, while keeping cost low, and avoiding duplication of effort."

Jay Rendall, past Vice-Chair of Great Lakes Panel on ANS, and Exotic Species Program Coordinator, Minnesota Department of Natural Resources, St. Paul

Regional Eurasian Ruffe Initiative

The Minnesota and Michigan Sea Grant programs joined forces to further the understanding of the invasive fish, Eurasian ruffe, and its impacts on sport and commercial fishing in North America. The first *International Symposium on Biology and Management of Ruffe*, held in March 1997, impacted the future of Great Lakes fishery management. Over 100 scientists, managers, and educators learned from the world's 50 foremost experts about topics such as applied ruffe management, and predicting environmental and economic costs. Five European researchers published the results of Sea Grant-sponsored research by invitation in a special section in the *Journal of Great Lakes Research* (1998, vol. 24, no. 2). Public outreach from the symposium raised awareness Great Lakes-wide through mass media and radio public service announcements (produced by Wisconsin Sea Grant) that reached over one million people. Today, a symposium abstract booklet, ruffe fact sheets, and the *Ruffe WATCH ID* cards continue to promote awareness.

ANS Control and Risks to Baitfish and Aquaculture Industries

Aquaculture and baitfish industries are often implicated as a vector of spread for ANS. A Great Lakes Sea Grant Network effort offers a solution by working with baitfish, and public and private fish stocking programs to reduce risks for spread and impacts on operations. Led by Minnesota Sea Grant in collaboration with the Illinois-Indiana, Michigan, and Ohio Sea Grant programs, the goal of this initiative is to maintain viable baitfish and aquaculture industries in areas where ANS have invaded. Borrowing a successful approach used by the seafood industry to ensure a safe product, called Hazard Analysis and Critical Control Points (HACCP), Sea Grant is working with the bait and aquaculture industry to identify control points where risks for spread could be greatly reduced. In consultation with these industries, HACCP-like plans and training manuals were developed. Currently, Sea Grant is assessing the level of ANS and non-bait contamination at retail outlets in the Great Lakes region. Surveys are also evaluating angler attitudes toward ANS and ANS-free live bait, and assessing overall risks for spread by anglers.

"The Sea Grant program in Minnesota is on the verge of tackling some of our most important environmental issues — exotic species. Recently, the Minnesota Sea Grant program was the leader across the entire Great Lakes system in developing an effective research program for dealing with the exotic fish species, the Eurasian ruffe. The program has been extremely valuable for dealing with other exotic species such as zebra mussels. Research on these species will help to clarify the extent of the problem in the United States, identify the possible economic impacts, and most importantly suggest solutions."

Gerald J. Niemi, Director, Center for Water and the Environment, Natural Resources Research Institute, University of Minnesota

Minnesota Sea Grant

Minnesota Sea Grant Exotic Species Information Center Coordinator Doug Jensen shows Duluth-area students a Eurasian ruffe specimen from the Exotic Aquatics Traveling Trunk at Minnesota Sea Grant's learning station during the St. Louis River Quest.

K-12 Education

Minnesota Sea Grant is providing teaching tools that broaden programs to educate our future environmental stewards about ANS so that they can help prevent the spread. Youth education traveling trunks, called *Exotic Aquatics*, contain nine lesson plans with posters, maps, books, museum-quality preserved exotic species, and an award-winning videotape produced by the Minnesota Department of Natural Resources. Lesson plans emphasize an interdisciplinary approach to learning, useful to help meet graduation standards. As a measure of their popularity, today 23 trunks are available by reservation from 14 regional lending centers. More than 100 formal and non-formal teachers have used the trunks to teach an estimated seven thousand students (mostly grades 4-7).

In 1998, Minnesota Sea Grant hosted a special training session for teachers from Minnesota and northern Wisconsin, called the *Exotic Species Day Camp*. Co-hosted by the Great Lakes Aquarium at Lake Superior Center and the University of Minnesota Duluth Department of Education, the one-day workshop featured teaching resources for students (including the traveling trunks, and the SGNIS web site). Lesson plans from this workshop and five others by Great Lakes Sea Grant programs are included in a Great Lakes ANS youth education compendium.

Other Outreach Collaboratives

Minnesota continues to support several multi-program Sea Grant outreach initiatives. One coordinated by Wisconsin Sea Grant is an on-line interactive national web site called the Sea Grant Nonindigenous Species Site (or SGNIS): ***www.sgnis.org***. Since 1995, Minnesota Sea Grant has supported web site development. In 1998, Minnesota Sea Grant coordinated production of a SGNIS compact disk (CD) for people without Internet capabilities. The site and CD contain a comprehensive collection of peer-reviewed research and outreach publications and materials on ANS produced by Sea Grant and other programs and agencies.

Based on concerns over the spread of zebra mussels to inland lakes, the Minnesota Volunteer Zebra Mussel Detection Program, coordinated by Minnesota Sea Grant and the Department of Natural Resources, helps protect inland waters through early detection monitoring. Kits developed by Michigan Sea Grant are loaned to shoreland property owners, lake associations, and other organizations to monitor for zebra mussels in inland lakes and rivers. The program currently has over 200 volunteers enrolled. Based on a new 2-year initiative, Minnesota will create educational computer presentations that will be distributed to collaborating programs and be used in several lake association workshops.

Minnesota Sea Grant will continue to provide leadership and partner with agencies and programs concerning ANS issues through conferences, workshops, presentations, publications, and other media.

New York

Ian Stupakoff

NYSG Scholar Hudson Roditi places zebra mussels in a "depuration chamber," a microcosm that mimics the basic characteristics of the natural environment.

Unique among the 29 Sea Grant programs nationwide because of its marine and Great Lakes shorelines, New York Sea Grant (NYSG) engages in research, education, and technology transfer to promote the understanding, sustainable development, utilization, and conservation of its diverse coastal resources. Currently, NYSG funds approximately 60 scientific research and outreach projects at numerous campuses and field stations throughout the Great Lakes and marine districts.

Although New York Sea Grant addresses a variety of aquatic nuisance species (ANS) issues, of greatest concern are the effects of the zebra mussel on the state's public and private infrastructure. Over the last decade, combating these exotics has cost the state at least $28 million, affecting electric power generation, drinking water facilities and residential water supplies, food processing, automotive parts manufacturing, photographic products manufacturing as well as other industries which rely heavily on raw surface water for cooling, flushing, or processing of water.

The zebra mussel — a genus including zebra mussels *(Dreissena polymorpha)* and quagga mussels (*Dreissena bugensis)* — contributes to the fouling of raw water intakes which results in the loss of pumping ability, clogged pipes, obstructed valves, obnoxious smells from decayed mussel flesh, increased corrosion of cast iron pipes, and safety hazards if sprinkler systems fail to deliver fire fighting water. As documented in research papers published in New York Sea Grant's National Aquatic Nuisance Species Clearinghouse's publication *Dreissena!*, since mid-1997, these organisms have also been shown to have an impact on the habitat, food webs, and biodiversity within the Lake Erie and Lake Ontario systems. For example, because zebra mussels feed on phytoplankton and detritus, it is likely that they have helped clear the lakes of phytoplankton.

New York is also experiencing ecological impacts on native species caused by the recent invasions of several other aquatic nuisance species into its waters: the blueback herring *(Alosa aestivalis)* in the Erie Canal and Lake Ontario, the round goby (*Neogobius melanostomus*) in the eastern basin of Lake Erie, the New Zealand mud snail *(Potamopyrgus antipodarum)* in Lake Ontario, and the "fishhook waterflea" (*Cercopagis pengoi)* in Lake Ontario and the Finger Lakes. The recent invasion in Cayuga Lake and the Erie Canal by the Asian clam *(Corbicula fluminea)* may also cause infrastructure and ecological impacts. Other problems facing New York include the long-term ecological impacts of such well-established nonindigenous fishes as the alewife *(Alosa pseudoharengus)*. From the Great Lakes region to the Hudson Valley and the marine district there is concern for the potential habitat and biodiversity issues related to such non-indigenous plants as purple loosestrife *(Lythrum salicaria)*, common reed (*Phragmites australis)*, water chestnut *(Trapa natans)*, and Eurasian watermilfoil *(Myriophyllum spicatum)*. Also, the introduction of the Japanese (Western Pacific) shore crab *(Hemigrapsus sanguineus)* in western Long Island Sound may be the cause of an increase in the consumption of juvenile clams.

Sea Grant
New York

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Species of Concern

Alewife
Asian clam
Blueback herring
Common reed
Eurasian watermilfoil
Fishhook waterflea
Japanese shore crab
New Zealand mud snail
Purple loosestrife
Quagga mussel
Round goby
Water chestnut
Zebra mussel

Research

Over the last decade combating New York's aquatic nuisance species has cost the state at least $28 million.

New York Sea Grant maintains a strong research program with a focus on zebra mussel studies and the ecological effects of other nonindigenous species on fisheries. While zebra mussels are ubiquitous and abundant in many major freshwater ecosystems in New York and elsewhere, very little is known about their influence on the biogeochemical cycling of metals. By evaluating the daily processes and functions of zebra mussels, NYSG researchers assessed the role of zebra mussels in influencing metal cycling in freshwater ecosystems, with a focus on the upper Hudson River region. The intent of this study was also to evaluate the prospect that these organisms might hold great promise as bioindicators for the presence of toxic metals in freshwater systems.

Overall, researchers reported assimilation efficiencies of chromium (2%), silver (4%), selenium (approximately 70%) and cadmium (72%) measured from numerous algal and particle types. They observed that assimilation efficiency varies greatly between elements and varies significantly within elements depending on food type acting as the source of the trace element. Additional experiments included a measure of zebra mussel absorption efficiencies of metals from the dissolved phase as well as analyses to determine both short-term efflux rates of metals out of zebra mussel tissues as well as long-term efflux of metals which have entered slowly-exchanging pools within the organisms.

Researchers at Rennselaer Polytechnic Institute's Darrin Fresh Water Institute on Lake George are currently developing a genetic probing method whereby water samples can be quickly and simply screened for zebra mussel veligers without the requirement of being taken to the laboratory for identification. An important objective and extension of the project is to cooperate with industrial user groups that are concerned with the colonization of their facilities by zebra mussels. This NYSG-funded work also explores the possibility of developing a commercial product based on the probe technology that may be of interest to other agencies for use with numerous molluscan species.

Confirmed reports of *Cercopagis pengoi* in Lake Ontario in August 1998 brought about NYSG funded research on the invader known as the fishhook waterflea. A scientist is researching this microscopic alien's feeding and reproductive behavior, the corridor by which it invaded the lake, and its impacts on the Lake Ontario food web. This information is needed to develop an informed management policy on the lake's fisheries.

In another part of the state, a scientist at the Institute of Ecosystem Studies, is working closely with the Habitat Restoration Project and in particular with the Hudson River National Estuarine Research Reserve. Located in Tivoli Bay North, one of four nationally-designated estuarine reserves along the Hudson, this NYSG-funded project focuses on comparing the dynamics of decomposition for both invasive reeds (*Phragmites australis*) and the native cattails (*Typha latifolia*). According to the researcher, reeds stay standing long after they die compared to cattails which soon fall over. Thus the rates at which the plant matter decays differ as do the nutrient loads added to the water and the dynamics of populations of bacteria and fungi that decay the plants. Documentation will be important in determining the benefit of restoration efforts made in many coastal areas that focus on removing invasive reeds. Reed invasion and potential reed removal are central issues on the Hudson and the documentation of important marsh functions related to specific plant communities will contribute to overall tidal wetland management.

James Cook

In many wetlands, invasive common reeds (right) flourish at the expense of native cattails.

On Lake Ontario, a NYSG-funded study entitled *The Role of Embayments and Inshore Areas as Nursery Grounds for Young-of-Year Alewife and Other Species* examined how nonindigenous species such as alewife and rainbow smelt have had a significant impact on its ecosystem as well as those of other Great Lakes areas. This research will help management agencies designate appropriate locations for monitoring zooplankton in Lake Ontario and will provide basic information for the continuing efforts to model the dynamics of the alewife populations in the lake.

In an effort to determine how changes in nutrient levels and exotic mussels are affecting the Lake Erie food web and the future of the fish community, a multi-agency study *Sustaining Fisheries in a Changing Environment: The Effects of Oligotrophication and Invasion of Dreissenids in Eastern Lake Erie* was initiated in February 1998. This 2-year NYSG study involved a collaborative effort by researchers to specifically study the interactions between the number of smelt produced by the lake; growth rates of predatory fish such as smallmouth bass, walleye, and lake trout; and changes in the lake's ability to support fish. This approach will help explain how lowered nutrient levels from phosphorous reductions and zebra mussel activities will aid in the prediction of future fish production to take necessary management actions. As such findings continue to unfold, a greater emphasis will be placed on plans to expand studies on Lake Erie in order to better manage its fisheries resources.

New York Sea Grant continues to disseminate information on exotic species to researchers and the media while also "teaching the teachers."

Outreach

National Aquatic Nuisance Species Clearinghouse

Sea Grant's National Aquatic Nuisance Species Clearinghouse (NANSC) was established in August 1990 as the New York Sea Grant Zebra Mussel Information Clearinghouse. Created with the realistic goal to help industry groups and agencies respond efficiently and effectively to threats posed by aquatic nuisance species and invasive species, NANSC collects and disseminates information about ANS biology, spread, impact, and control. As a collaborative effort of the National Sea Grant College Program and various industry partners, the Clearinghouse continues to be funded by New York Sea Grant, the Great Lakes Sea Grant Network, National Sea Grant, and through subscriptions to its informative publication, *Dreissena!* Widely distributed to researchers and the media, *Dreissena!* includes bi-monthly updates on the North American range of the zebra mussel as well as up-to-date aquatic nuisance species publication listings and annotations.

In 1997, using funds from the National Sea Grant College Program, the Clearinghouse expanded its mission to include important aquatic nuisance species beyond zebra mussels. The species added to the technical collection at this time include the Eurasian ruffe (*Gymnocephalus cernuus*), the round goby, the tubenose goby (*Proterorhinus marmoratus*), the rudd (*Scardinius erythrophthalmus*), the spiny waterflea (*Bythotrephes cederstroemi*), the blueback herring, the Asian clam and other freshwater aquatic nuisance species.

While the library's technical collection is now heavily weighted toward freshwater invasive species, the Clearinghouse is in the process of including a number of very important marine organisms as well. Presently, with over 3,000 publications assembled, the technical collection is believed to be the most extensive one of its kind in the world.

The Clearinghouse is currently adding publications on the European green crab *(Carcinus maenas)* and the Chinese mitten crab *(Eriocheir sinensis),* both of which are having major impacts on the shoreline and fisheries of the Pacific Coast; the Amur River corbula *(Potamocorbula amurensis),* an exotic in the San Francisco Bay that, on a daily basis, consumes much of the phytoplankton in some areas; the grass carp *(Ctenopharyngodon idella)*; and the Suminoe oyster *(Crassostrea ariakensis),* a recent introduction to Chesapeake Bay. Other recent additions to the Clearinghouse's technical collection include: shipworms *(Teredo navalis),* which perhaps in response to changes in water quality, are causing major damage to wooden piers in New York Harbor; the brown mussel *(Perna perna),* a new Gulf of Mexico resident; the predatory fishhook waterflea; the veined rapa whelk (*Rapana venosa*) in the Chesapeake Bay; wood buring gribbles (*Limnoria* spp.); and a new biofouling mollusk recently found in Tampa Bay, the green lipped mussel (*Perna vividis*).

Since its inception, the Clearinghouse has been a nexus for identifying zebra mussel and aquatic nuisance species research throughout North America and elsewhere, and for linking researchers with similar interests. NYSG helped to bolster the causes of the Clearinghouse by taking part in the coordination of a Nationwide Zebra Mussel Training Initiative — a series of outreach workshops held in Louisiana, Oregon, Colorado, Missouri, and Utah that collectively were attended by hundreds of individuals from industry, government, environmental associations, academia, and the media.

"About one out of every ten established aquatic nuisance species has had serious impacts on Great Lakes ecosystems."

Edward L. Mills, Director, Cornell Biological Field Station

Other Outreach Efforts

To educate and inform a wide-ranging audience, New York Sea Grant addresses a variety of prevalent water issues concerning New York State residents. For example, in coordination with municipal water authorities, NYSG has co-sponsored workshops on zebra mussel impacts on taste and odor control in public drinking water facilities. Thousands of Great Lakes homeowners attended a separate series, also co-sponsored by New York Sea Grant, to learn how to control zebra mussels in residential water systems.

On the international front, the Program presented three papers on zebra mussel control at the *Zebra Mussels in Ireland: An International Workshop* held in Galway, Ireland in February 1998. Sponsored in part by the New York and Connecticut Sea Grant programs, the event attracted more than 120 individuals from government, academia, and private sectors to learn of the zebra mussel, its impacts and control at the conference.

While the NANSC has disseminated aquatic nuisance species information to researchers and the media, New York Sea Grant's coastal educators have been "teaching the teachers" by increasing the scope of educational activities. Formal and non-formal educators attended the first-ever *Exotic Species Day Camp* on Earth Day 1998 to investigate educational resources related to biological invaders of the Great Lakes. Participants went on a journey through cyberspace to explore exotic species web sites as well as to the Aquarium of Niagara Falls, where they spent a large portion of the day learning about exotic species resources and educational products that have been developed by Sea Grant programs around the Great Lakes basin. Subsequently, NYSG coastal educators have played a leadership role in the direction of Great Lakes outreach.

Looking to the future

Overall, more than 145 established exotic species have successfully invaded the Great Lakes, including 15 fish species that have found their way into Lake Ontario so far. It has been documented that about one out of every ten established exotics has had serious impacts on Great Lakes ecosystems. Recent reports confirm that many exotic species have been found to potentially cause genetic alterations in native populations as well as compete for and succeed in obtaining food and nesting sites. Exotic species introductions are unpredictable and more likely to cause permanent changes. Some consider invasive species to represent the single greatest threat to the Great Lakes ecosystem. Invasive nuisance species will continue to be an issue in the Great Lakes into the 21st century, an area where the significance of the problem will present a challenge to managers and stakeholders alike, emphasizing the need for prevention and control action. Providing aquatic nuisance species research and outreach to legislators, resource agencies, scientists, the media, and the general public will continue to be an important mission of New York Sea Grant.

Cornell University Photography

Dr. Edward L. Mills holds zebra mussels found in Oneida Lake at the Cornell Biological Field Station.

Ohio

Lake Erie is Ohio's most valuable natural resource. Its unique qualities include being the southernmost, shallowest, warmest, and the most biologically productive Great Lake. In most years, Lake Erie produces more fish for human consumption than the other four Great Lakes combined. Its walleye and smallmouth bass sport fisheries are nationally renowned. The economic benefits from its recreational and commercial uses total hundreds of millions of dollars per year.

However, Lake Erie's productivity and high level of use also make the lake vulnerable to ecosystem disruptions — especially those caused by the invasion of aquatic nuisance species (ANS). Sometimes referred to as "exotic" species, ANS are non-native plants and animals that are invading the Great Lakes and other waters in North America. In their own native waters they may be harmless, but when transplanted to Ohio, they compete with native animals and plants for food and habitat. Species such as zebra mussels (*Dreissena polymorpha*), first discovered in Lake Erie in 1988, have drastically altered the lake's ecosystem. Unintentionally brought over from Europe in the ballast water of shipping vessels, zebra and the closely related quagga mussels (*Dreissena bugensis*) have reduced phytoplankton populations, decimated native clam populations, and have drastically altered habitat by covering both hard substrates and the softer mud and sand bottoms in Lake Erie. Although water clarity greatly increased due to zebra mussel filtering, this has led to weed-choked harbors and a restructured ecosystem that has changed sport fish populations. Industries are also negatively impacted by zebra mussels. Ohio's power and drinking water utilities now spend millions of dollars per year keeping water intake pipes clear of these invaders.

Other ANS are also causing problems in Lake Erie. The round goby (*Neogobius melanostomus*), a small, aggressive bottom-feeding fish, eats the eggs and young of native fish and competes with native species for food and habitat. Another invader, the spiny waterflea (*Bythotrephes cederstroemi*), is a tiny crustacean that eats the same microscopic food as minnows and other young native fish. In Lake Erie, round gobies have reached population densities of dozens per square meter and spiny waterfleas have also flourished. Purple loosestrife (*Lythrum salicaria*), a nuisance plant, has infiltrated thousands of acres of wetlands thereby decreasing habitat for native plants and animals. Efforts are underway to prevent the spread of these ANS to Ohio's inland waters.

Ohio Sea Grant continues to play a proactive role in the control of ANS and in helping resource users address the effects of an altered ecosystem. Through a combination of research, outreach, and education programs, Ohio Sea Grant focuses on preventing and controlling the spread of ANS, while educating citizens about the problems they cause.

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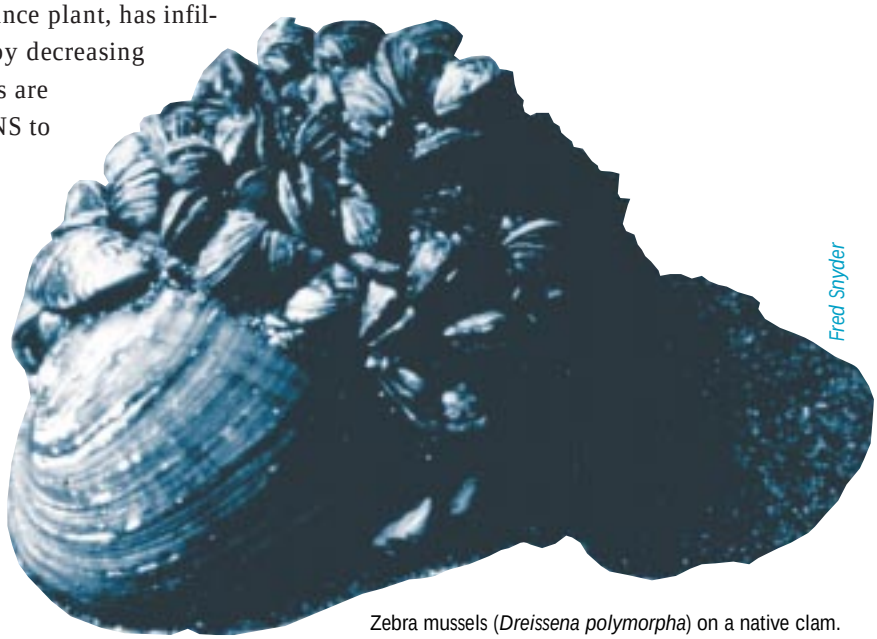
Species of Concern
Common reed
Purple loosestrife
Round goby
Sea lamprey
Spiny waterflea
Zebra mussel



Fred Snyder

Zebra mussels (*Dreissena polymorpha*) on a native clam.

Research

Lloyd Lemmerman

Zebra mussel specimens are prepared for testing.

Ohio Sea Grant has funded research on aquatic nuisance species since the late 1980s. The program has developed a strong reputation as a leader in zebra mussel research and for finding solutions to this particular ANS.

Zebra Mussel Biology and Control

Beginning in November 1988 — just one month after the first zebra mussel was found at Stone Laboratory in Lake Erie — Ohio Sea Grant initiated the first project on this animal in the Great Lakes. Project researchers studied the basic biology of the mussel and documented the explosion of its population in Lake Erie's western basin. By the following year, zebra mussel densities in the basin reached 30,000 per square meter. In some warm, nutrient-rich areas zebra mussels were reaching maturity in 11 months and producing up to one million eggs per year. Compared to zebra mussels in Europe, the proliferation of this mollusk in Lake Erie and the Great Lakes has been much more rapid than originally expected.

In 1989, Ohio Sea Grant created the Zebra Mussel Testing Center. This laboratory, with support from Sea Grant, the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and many private companies has evaluated numerous chemicals and processes to determine their effectiveness in controlling zebra mussels. One of the most important results has shown that potassium is very effective at killing zebra mussels.

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Ecosystem Impacts

Zebra mussels are filter feeders, and consume large quantities of small plantonic organisms (e.g. algae) from the water. Research has shown that while zebra mussel filtration has increased water clarity, they dramatically altered aquatic food webs by reducing phytoplankton levels, the source of food for microscopic animals such as zooplankton. These tiny animals serve as a food source for larval and juvenile fish as well as forage fish species that support sport and commercial fisheries. This is part of the reason that the economic value of the Lake Erie sport fishery has fallen from over $650 million annually before the zebra mussel invasion, to approximately $250 million today.

Ohio Sea Grant researchers, in collaboration with investigators at NOAA's Great Lakes Environmental Research Laboratory and with support from the Lake Erie Protection Fund, have documented an unexpected result of zebra mussel filtration. It appears that when zebra mussels inhale a piece of *Microcystis*, a harmful blue-green alga capable of producing a toxin called "microcystin," they stop filtering and spit it out. As time progresses, the mussels remove competing beneficial alga, allowing *Microcystis* to bloom, creating a potential public health problem.

Recently, Ohio researchers documented the spread of zebra mussels onto soft substrates within Lake Erie. The implications of this finding could be very important for Lake Erie. Will this new colonization seal contaminants into the sediment beneath the zebra mussel assemblages or will zebra mussel filtration mobilize contaminants? Research on contaminant uptake and transfer indicates that zebra mussels accumulate contaminants such as polychlorinated biphenyls (PCB) at 10 times the level of native clams. These contaminants are passed up the food chain when the zebra mussel is eaten. Research results show that PCB concentrations of 0.1 parts per million (ppm) in zebra mussels, increase ("biomagnify") to 0.2-0.8 ppm in the round gobies that eat them, and then increase to 1.1-1.8 ppm in smallmouth bass that eat the round gobies.

Other ANS-Related Research

Ohio Sea Grant scientists have also been prominent in documenting the economic impact of zebra mussels. Between 1989 and 1994 Great Lakes power plants spent over $120 million controlling zebra mussels at water intakes. Today the average large power plant in the Great Lakes region spends approximately $350,000 annually controlling zebra mussels. Ohio Sea Grant investigators are also very active in research on a number of other aquatic nuisance species including the common reed (*Phragmites australis*), a plant that rapidly dominates Lake Erie wetlands; the round goby and its impact on native fish species including smallmouth bass; the spiny waterflea, a very predacious zooplankton; and the development of environmentally friendly ways to control the sea lamprey (*Petromyzon marinus*).

Outreach

Ohio Sea Grant has combined its innovative research program with a diverse outreach component, bringing research information and education programs to Ohio's citizens and industries. Through public programs, conferences, teacher workshops, newsletter articles, fact sheets, and other materials, Sea Grant has informed Ohio's citizens about ANS issues and, even more importantly, has provided the knowledge people need for preventing the further spread of invasive species.

Restricting ANS Spread via Baitfish and Aquaculture Shipments

The harvesting of bait and food fishes from wild populations and their live shipment — often in lake or river water — poses a threat of spreading ANS among lakes and drainage basins. Should aquaculture facilities become infested with ANS, they too may play a role in unintended distribution. Ohio Sea Grant is collaborating with the Minnesota, Michigan, and Illinois-Indiana Sea Grant programs to identify potential pathways that may spread ANS and to inform the industries involved about the need and means to screen fish shipments for unwanted species. Bait shipments are being surveyed statewide for the presence of ANS, and anglers are being surveyed to determine their habits in using and disposing of live bait.

Boat Bottom Paint Applicator Certification Program

Ohio Sea Grant and the Ohio Department of Agriculture developed and implemented the state's first boat bottom paint applicator certification program. Previous research in 1990 had shown that commercial anti-fouling paints were highly effective in preventing the fouling of boats and motors by zebra mussels — a new use for this application in Lake Erie. Since certain anti-fouling paints are labeled as restricted-use pesticides, certification of applicators was needed to allow the marine industry to remedy zebra mussel fouling problems.

Exotic Species Day Camp Workshop

To assist K-12 teachers in developing appropriate ANS curriculum activities for their students, Ohio Sea Grant offered a day-long workshop to Ohio teachers. Part of a Great Lakes Sea Grant Network project, the *Exotic Species Day Camp* offered educators a hands-on learning experience about zebra mussels, round gobies, purple loosestrife and other ANS, and their impact on Great Lakes ecosystems. Participants also used computers to explore various web sites that focus on ANS. An outcome to this workshop will be a collection of field-tested ANS classroom activities that will be available and relevant to teachers nationwide. Lessons will be compiled into a compendium of activities and made available to schools throughout the country.

Conferences

Ohio Sea Grant planned and organized the *First International Zebra Mussel Research Conference* in Columbus in December 1990 with over 200 attendees from 20 states and Canada. Since its inception, this conference has served as a model that has been repeated annually in both the U.S. and Canada, most recently in Sacramento, New Orleans, and Toronto. Renamed the *International Zebra Mussel and other Aquatic Nuisance Species Conference* in 1995 to recognize the impact of other invasive species, the conference has played a significant role in fostering the dissemination of Sea Grant information among various agencies, states, regions, and countries.

As zebra mussels continued their invasion from the Great Lakes to inland rivers and lakes, electric power and drinking water plant operators began finding their plant intake structures fouled by the mussels. Recognizing that plant operators in the Great Lakes region had developed zebra mussel control expertise that could benefit their inland counterparts, Ohio Sea Grant developed an information program to transfer this technology.

The first *Inland Zebra Mussel Conference* was held in Cincinnati in 1995, attracting over 100 attendees. Later conferences in St. Louis and Chattanooga were developed jointly with Illinois-Indiana Sea Grant. From these outreach efforts nearly 200 facility operators gained technical knowledge they used to keep intakes and pump houses open and minimize control costs.

Karen Ricker

A participant at the Exotic Species Day Camp workshop examines a specimen.

"The Exotic Species Day Camp was a great hands-on way to learn about aquatic nuisance species. I have used the activities to help my students learn about the environment — the good and the bad — and what they can do to improve it. A major benefit to me as a teacher is that I have been able to take the information from the workshop and use it across the curriculum. The connection between the arts and sciences has been great."

Beth Patrilla, sixth grade teacher, Sacred Heart School, Toledo, Ohio

"Ohio Sea Grant has been instrumental in developing fact sheets and other educational materials about aquatic nuisance species. In addition, their participation and collaboration has been invaluable in the development and implementation of the Ohio State Management Plan for ANS and other cooperative outreach projects."

Randy Sanders,
Ohio Aquatic Nuisance Species Coordinator,
Ohio Department of Natural Resources,
Division of Wildlife

Publications, Displays, and Web Site Materials

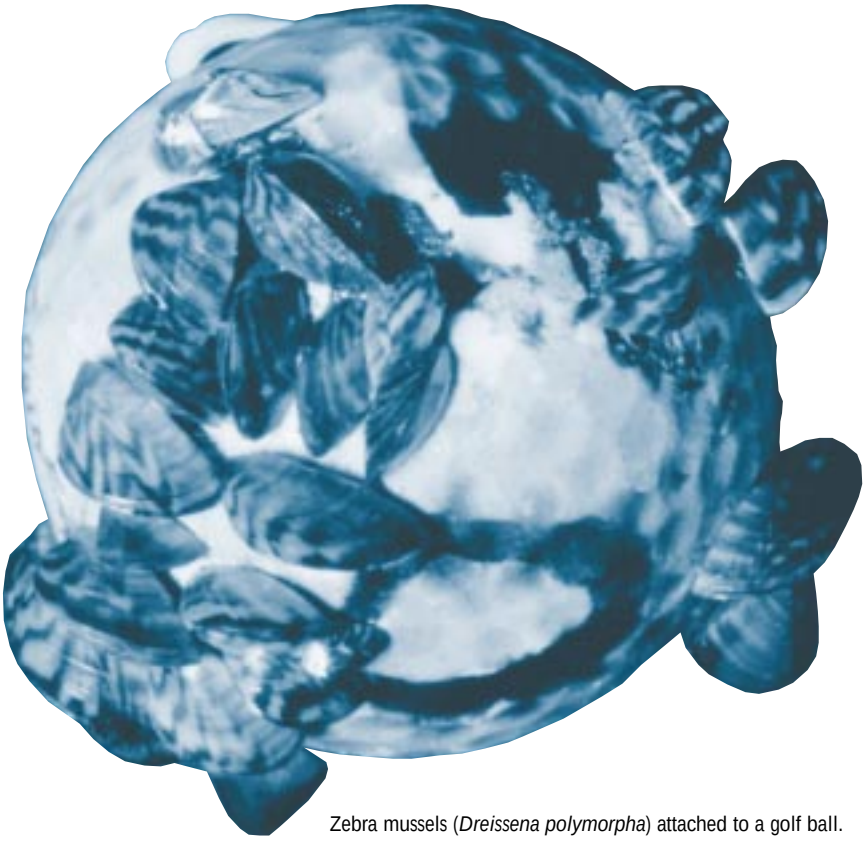
Ohio Sea Grant has been active in developing ANS materials such as fact sheets and newsletter articles for Ohio's citizens and residents throughout the Great Lakes basin. With a generous donation from Brunswick Marine in the mid-1990s, Ohio Sea Grant was able to print and distribute hundreds of thousands of fact sheets on zebra mussels and other ANS for the Great Lakes Sea Grant Network. Ohioans and other subscribers also receive ANS information through the program's newsletter *Twine Line* that includes articles on nonindigenous species on a regular basis. With advances such as computer technology and web site development, Ohio Sea Grant has been able to place its ANS publications on-line for quick access at the following direct link: ***www.sg.ohio-state.edu/publications/topics/fts-nuisance.html***. This page on the program web site includes over 40 links to fact sheets, technical bulletins, newsletter articles, research projects, and researchers involved in ANS work. The web site is updated on a regular basis.

Besides making information available through printed and electronic communications, Ohio Sea Grant has developed displays that present information about ANS affecting Ohio's waters. Displays have been featured at the annual boat and sports shows in the Cleveland metropolitan area, and at the Lake Erie Nature and Science Center in Bay Village, Ohio. Hundreds of thousands of school children, non-formal and K-12 teachers, and other adults have learned about ANS problems and solutions through these outreach efforts.

In the upcoming years, Ohio Sea Grant will continue to focus its research, outreach, and education programs on ANS prevention and control. Collaborative efforts with the Great Lakes Sea Grant Network, the Great Lakes Environmental Research Laboratory, and the Ohio Department of Natural Resources will continue in an effort to stop the spread of aquatic nuisance species.

Wisconsin

With more than 800 miles of Great Lakes coastline, several major ports and more than 14,000 inland lakes, Wisconsin is keenly aware of the threat posed by invasions of aquatic nonindigenous species. Since 1990, the University of Wisconsin Sea Grant Institute has played a leading role in helping state agencies, power and water utilities, local government, and the public minimize the spread and impact of zebra mussels *(Dreissena polymorpha)* and other invasive aquatic species through a combination of research, outreach, and public information programs. These efforts deserve much credit for the fact that today, eight years after they colonized the state's coastal waters, zebra mussels have spread to only seven inland lakes and two Wisconsin rivers so far.



Clifford Kraft

Zebra mussels (*Dreissena polymorpha*) attached to a golf ball.

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Species of Concern
Eurasian ruffe
Round goby
Spiny waterflea
Tubenose goby
Zebra mussel

Research

Wisconsin Sea Grant's research has focused on ecosystem effects.

Much of Wisconsin Sea Grant's research on invasive species in recent years has focused on the effect of zebra mussels on the ecosystems which they invade. Key findings to date indicate that zebra mussels can negatively affect the growth and survival of larval fish, that connected waterways are much quicker to become colonized than lakes, and that zebra mussels tend to accumulate the more toxic types of polychlorinated biphenyls (PCBs).

Three outdoor mesocosm experiments with larval fathead minnows showed that zebra mussels negatively affect the growth rate and survival of larval fish. The addition of nutrients (nitrogen and phosphorus) increased the growth and survival of larval fish and offset the negative effects of zebra mussels on fish growth by 24 percent. Water column mixing by aeration increased the growth of zebra mussels but reduced larval fish survival by 55 percent relative to controls. The researchers report that zebra mussels caused larval fish to shift more rapidly from eating zooplankton to feeding on benthic, or bottom-dwelling, prey.

In the first systematic evaluation of the rate of zebra mussel spread to inland lakes, another Wisconsin Sea Grant study showed that zebra mussels have not spread to isolated inland lakes as rapidly as through connected waterways. The investigators also found that zebra mussels have not colonized various lake regions at similar rates, suggesting lake colonization varies according to regional conditions. Evidence was also found showing that inland lakes can become inoculated with zebra mussels without colonization taking place.

Besides altering the nutrient cycle in infested waters, zebra mussels affect the cycling of contaminants. In a unique look at the bioaccumulation of PCBs by zebra mussels, a research team led by University of Wisconsin (UW) at Madison sought to clarify the influence of zebra mussels on the distribution and fate of dioxin-like coplanar PCB congeners in Green Bay, Lake Michigan. The findings indicate that these oily mussels preferentially accumulate more coplanar congeners than other PCB congeners, though only slightly. A scientific paper based on this study was recently accepted for publication.

Sea Grant support also enabled two scientists from the Belarus region of the former Soviet Union, where zebra mussels are native, to exchange information with U.S. scientists during a nine-month visit at the University of Wisconsin-Madison. The Belarussian researchers shared their extensive knowledge of zebra mussel biology and ecology gained from 20 years of studying the mussel. This international collaboration resulted in several science journal articles, presentations, and tests of models of invasive species population dynamics, spread, and ecological impacts.

A continuing study led by Wisconsin Sea Grant researchers is evaluating how lake characteristics affect the success of zebra mussel colonization. The study is also examining how zebra mussel infestations may affect the transfer of energy from primary producers to higher trophic levels. So far, this research has found no detectable effects on lake water characteristics beyond normal year-to-year variations in the first four years after colonization. However, near-shore areas have shown deteriorating recreational quality due to large zebra mussel concentrations. The researchers suspect some of the mussels' typical effects may have been masked by the strong 1997-1998 El Niño conditions, which substantially affected the seasonal hydrologic cycle of small lakes in the region.

Charlse Ramcharan

Zebra mussel (*Dreissena polymorpha*)

Outreach

Charles Ramcharan

Zebra mussels attached to seaweed.

UW Sea Grant's award-winning outreach efforts continue to focus on collecting and disseminating a wide range of information about zebra mussels and other invasive species at the state, regional, national, and international levels.

Since 1990, the UW Sea Grant Communications Office has printed more than 1.5 million wallet-sized *Zebra Mussel WATCH* cards on behalf of Sea Grant programs, government agencies, environmental groups, and affected utilities and industries in 26 states and the Province of Ontario. The card serves as a fundamental, low-cost tool for heightening public awareness of the mussel and the problems it poses, and the demand for reprints as well as new, customized versions of the card remains strong, averaging nearly 250,000 a year.

From May 1990 through May 1997, Wisconsin Sea Grant published *Zebra Mussel Update*, a 4-8 page quarterly national newsletter that chronicled the mussel's invasion of the Great Lakes and other North American waters. By 1996, nearly 10,000 copies of each issue of the *ZMU* were being distributed free of charge to subscribers throughout the Great Lakes region and beyond in a collaborative project involving the Wisconsin and Ohio Sea Grant programs and Brunswick Marine. The institute maintains an online archive of all 30 issues of the *ZMU* at ***www.seagrant.wisc.edu/ Communications/Publications/ZMU/***.

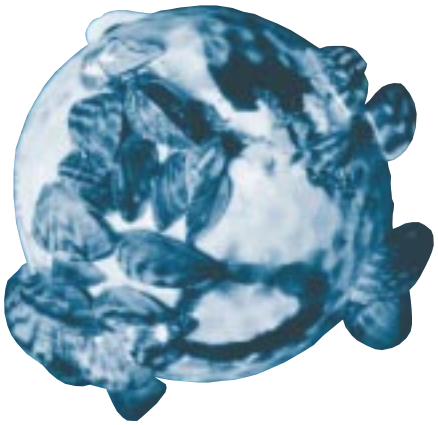
A major part of Wisconsin Sea Grant's outreach and public information efforts in recent years has been coordinating development of the Sea Grant Nonindigenous Species (SGNIS) web site (*www.sgnis.org*). A collaborative project with the Illinois-Indiana, Minnesota and Michigan Sea Grant programs, this online database was created to ensure that all Sea Grant zebra mussel research and outreach information was readily available to utilities, industries, government agencies, and the interested public. This award-winning web site contains more than 150 peer-reviewed research reports and 60 educational items, as well as a plethora of newsletters, conference proceedings, and a graphics library. Recent work has focused on adding papers and publications about zebra mussels from other organizations and adding material on other nuisance species like the round and tubenose goby, ruffe, and spiny water flea. This has added 11 articles from NOAA's Great Lakes Environmental Research Laboratory, 76 papers from the U.S. Army Corps of Engineers Waterways Experiment Station, and more than 240 articles from other sources of nonindigenous species literature. UW Sea Grant's portion of the project consists of identifying appropriate articles, obtaining permission from authors and publishers, preparing the digital citation, and maintaining quality control.

Wisconsin's award-winning outreach includes an online ANS database and printing 1.5 million *Zebra Mussel WATCH* cards for distribution throughout the Great Lakes region and beyond.

In another recent Great Lakes Sea Grant Network outreach project, UW Sea Grant worked with citizen volunteers to monitor lakes for early signs of zebra mussel infestation. The project provided training and sampling kits in 1996 and 1997 for volunteers who monitored 15 different lakes in Wisconsin. The quality and quantity of samples collected by the citizen volunteers was consistent with that done by professional personnel and demonstrated the utility of having samples collected by volunteers.

In partnership with Minnesota Sea Grant, UW Sea Grant also capitalized on its expertise in radio programming to produce two collections of public service announcements about the ruffe, a Eurasian invader that devastated native perch and walleye populations in Minnesota's St. Louis River at Duluth-Superior and has spread to other tributaries along Lake Superior's southern shore. Designed to raise public awareness of the ruffe and publicize ways to slow its spread to other waters, the programs were provided free of charge to radio stations throughout the Lake Superior area.

Because they are a vital part of the state economy, Wisconsin places a high value on preserving and protecting its aquatic resources. The continuing threat posed to these resources by invasive species thus makes ANS research and outreach an ongoing priority for the University of Wisconsin Sea Grant Institute.



Northeast Region

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Massachusetts Institute of Technology
Woods Hole Oceanographic Institution

Sea Grant

ANS

Northeast Region

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Sea Grant

Connecticut

Nancy Balcom

Purple loosestrife
(*Lythrum salicaria*)

Certain types of aquatic nuisance species (ANS) have been in Connecticut for many years, such as Eurasian watermilfoil (*Myriophyllum spicatum*), purple loosestrife (*Lythrum salicaria*), and fanwort (*Cabomba caroliniana*). Several marine fouling organisms have been present in Long Island Sound since the 1970s. More recently, introductions of particularly troubling species have been documented. For example, in 1993, the Asian clam (*Corbicula fluminea)* was discovered in the lower Connecticut River, and in 1995 the Japanese shore crab (*Hemigrapsus sanguineus*) was discovered in Long Island Sound. In 1996 and 1997, hydrilla (*Hydrilla verticillata*) was discovered in two southeastern Connecticut ponds. In 1998, zebra mussels (*Dreissena polymorpha*) were discovered in a northwestern Connecticut lake, and a small population of the water chestnut (*Trapa natans*) was found in lower Connecticut River waters, most likely originating from plants growing in the Connecticut River in Holyoke, Massachusetts.

These ANS are significant both ecologically and economically. Displacement of native flora and fauna and even a shift of the ecosystem may result from their presence. The Connecticut River is of particular concern, because of its large extent and its ecological diversity. Recently listed by The Nature Conservancy as one of the "Last Great Places" in the Western Hemisphere, it was designated as one of two Wetlands of International Importance in the U.S. by the United Nations, and named as an American Heritage River by the U.S. Environmental Protection Agency. The entire Connecticut River comprises the Silvio O. Conte National Fish and Wildlife Refuge. Endangered freshwater mussels such as the dwarf wedge mussel inhabit the main stem of the river. Power-generating facilities on the Connecticut River have already incurred expenses for Asian clam control.

While the Connecticut is the mightiest river in the state, the discovery of zebra mussels in the northwestern part of the state focuses immediate concerns on the Housatonic River system. A federally-listed bog turtle and two freshwater mussels may be affected. The Housatonic River supports state trout management areas and its water is utilized by industries and hydroelectric power-generating facilities. The economic impacts could be most significant in this part of the state. In lakes where the growth of non-native weeds like Eurasian watermilfoil is rampant, recreational activities such as swimming and boating are adversely affected. Treatment options currently used in Connecticut include herbicides, mechanical harvesting, handpulling, drawdowns, and biocontrol methods using triploid grass carp and weevils.

Another consequence of ANS introductions is that their presence may cause some communities to restrict water access. For example, lakeside residents seeking to prevent the introduction of mussels or weeds into their lakes are considering whether to limit or restrict boating and fishing activities. These restrictions range from permitting access to residents only; to restricting access times to specific daylight hours; or requiring mandatory boat inspections and/or washing stations. These efforts result in continuing controversy among town residents, lake managers, state agency personnel, and anglers, especially when local policies are drafted without the input of all affected groups.

Sea Grant
Connecticut

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Species of Concern
Asian clam
Eurasian watermilfoil
Fanwort
Hydrilla
Japanese shore crab
Purple loosestrife
Water chestnut
Zebra mussel

Research

"As many as 15,000 species are transported globally each week in the ballast water of oceangoing ships."

James T. Carlton, Williams College - Mystic Seaport

Dispersal of zebra mussels and other aquatic organisms via ballast water operations has been a topic of intense scrutiny in the 1990s. The Maritime Studies Program of Williams College (based at Mystic Seaport in Connecticut) has received funds from the U.S. Coast Guard and other federal agencies to study the sources and composition of ballast water entering U.S. harbors, facilitated by Connecticut Sea Grant. The "shipping study" as it is commonly known, documented a ballast water discharge rate of about 2.4 million gallons per hour in the U.S., and the numerous freshwater and marine species contained in those discharges.

With the possible exception of the Connecticut River, overland dispersal of zebra mussels was determined the most likely mechanism by which zebra mussels could enter Connecticut. Connecticut Sea Grant and the Michigan Department of Natural Resources / Michigan Sea Grant College Program sponsored research to assess the overland dispersal of zebra mussels into inland North American lakes. The study, conducted by Williams College - Mystic Seaport, and Wisconsin Sea Grant, examined the potential for overland dispersal by waterfowl and recreational watercraft. Results showed that waterfowl are unlikely to disperse zebra mussels. For boats, however, transportation on entangled macrophytes and in livewells appeared to be the most common means of transporting adult and larval zebra mussels, respectively. This research enables managers and educators to focus efforts on the primary ways zebra mussels will be introduced to inland lake systems isolated from infested waters.

In another landmark study in the San Francisco Bay area, co-funded by the U.S. Fish and Wildlife Service and Connecticut Sea Grant, researchers found that in some areas of San Francisco Bay, 100 percent of the native species had been displaced, creating "introduced communities." They found that a new species was introduced about every 24 weeks, destabliliz-ing California's economy.

In 1997, Connecticut Sea Grant initiated a small grants program for Vermont researchers, and is currently supporting two efforts. The first project assessed the active dispersion of adult zebra mussels upstream. The results will have implications for resource managers trying to establish refugia for native clams. A second project, examined the environmental conditions that favor the establishment of purple loosestrife in uninfested wetlands and adjacent upland habitats.

Ladd Johnson

Research results show that zebra mussels *(Dreissena polymorpha)* can be transported by entangled waterplants on recreational boats and trailers.

Outreach

Between 1995 and 1998, the scope of the zebra mussel outreach program in Connecticut was expanded to include other ANS. Outreach specific to zebra mussels took a lower profile until their discovery in 1998. Monitoring programs for zebra mussels by individual power and water companies continued. A traveling ANS display was set up at Audubon Centers, community fairs, and nature centers. More than 350 copies of the 10-minute spread prevention training video, *Invasion of the Zebra Mussels: Just a Matter of Time?*, have been distributed and hundreds of signs posted at boat ramps statewide.

Collaborations with the Northeast Sea Grant programs and the Vermont Department of Environmental Conservation (VT DEC) continued, particularly through the regional newsletter, *Aquatic Exotics News*. VT DEC received Sea Grant ANS funding through Connecticut Sea Grant to continue zebra mussel outreach in the Lake Champlain basin. The Zebra Mussel Citizen Action Program, a spread prevention program, and the Zebra Mussel Watchers Program, a statewide monitoring program, continued their efforts in Vermont. Extensive monitoring has documented the progression of zebra mussels in Lake Champlain and two inland lakes.

Nancy Balcom

Sign posted at the Twin Lake boat launch, where zebra mussels were first found in Connecticut.

Regional training efforts to broaden understanding of the current ANS situation in the Northeast were enhanced when Connecticut Sea Grant collaborated with VT DEC to convene the *Second Northeast Conference on Nonindigenous Aquatic Nuisance Species*, in Burlington, VT. The 1997 conference served as a forum for researchers, resource managers, educators, and industry members from the northeastern United States and Canada to compare notes and discuss concerns and research findings on zebra mussels, fish, crustaceans, and aquatic plants. Experts from Florida, Minnesota, California, and New York were invited to share their experiences, findings, and policies with regard to the management and control of nonindigenous species. A volume of extended abstracts was produced and distributed. The response to the conference was very positive.

"The conference was one of the better ANS meetings that I have attended. The speakers did a good job of representing the diverse range of issues related to nonindigenous species concerns."

Timothy Sinnott, New York Department of Environmental Conservation

National and International Efforts

Nationally, Connecticut Sea Grant facilitated the meeting on the 100th Meridian Initiative during the *Heartland Zebra Mussel Workshop* in Kansas City, MO in late 1997. Representatives of federal and state agencies and the province of Manitoba, Canada, and members of the Western Regional Panel were among those individuals setting goals and developing the means to try to prevent the spread of zebra mussels west of the 100th meridian line, as charged by the Nonindigenous Species Act of 1996.

In 1998, zebra mussel training went international to Galway, Ireland. A longstanding collaborative agreement between the Northeast Sea Grant programs, the National University of Ireland, Galway, and the Queens University of Belfast led to a request for assistance when zebra mussels invaded the Shannon River in Ireland in 1997. The Connecticut and New York Sea Grant programs supported the travel of five U.S. zebra mussel experts to Galway to participate in a 3-day workshop attended by researchers, policy makers, and industry members from the Republic of Ireland and Northern Ireland. Experts from Europe also shared their expertise and perspective on the zebra mussel which was quite different from the North American viewpoint. Connecticut Sea Grant coordinated the participation of the speakers from the United States, and assisted with the workshop planning. The spread of zebra mussels throughout Ireland and the resulting impacts on infrastructure will, in many ways, parallel the progression in North America. Since returning, the U.S. workshop participants have answered requests for additional assistance and resources from Irish workshop participants, including providing journal articles, technical reports, slides, and examples of outreach and educational materials.

Curtailing the tendency of the human species to assist bioinvasion, — intentionally or unintentionally — should go a long ways towards addressing the global bioinvasion problem.

The discovery of the Japanese shore crab in Long Island Sound provided an ideal opportunity for a doctoral student to study the ecology of the marine crab and its competitive interaction with other crabs. Connecticut Sea Grant helped support this on-going project, including providing funds to enable a 3-month study of the crab in its native habitat. The crab has become the dominant species in the Sound's upper intertidal zone, and its omnivorous habits may have an impact on juvenile shellfish such as blue mussels.

Connecticut Sea Grant will continue to expand its efforts to stem bioinvasions by coordinating a multi-program effort to increase public awareness of the problems associated with invasive aquatic and wetland plants. Products will include identification guides for resource managers and educational material for homeowners, who may inadvertently buy invasive species at garden and home centers, and use them in water gardens and aquaria. This project, which also involves Sea Grant programs in Florida, North Carolina, Minnesota, and Illinois-Indiana, aims to reduce the cultivation, distribution, and planting of undesirable species and lessen chances for serious environmental damage and loss of biodiversity resulting from their escape into inland waters and wetlands. Curtailing the tendency of the human species to assist with bioinvasions — intentionally or unintentionally — should go a long ways towards addressing the global bioinvasion problem.

Anne Bove

Eurasian watermilfoil (*Myriophyllum spicatum*)

Maine-New Hampshire

Over the past few years, Maine-New Hampshire Sea Grant has supported projects that addressed several aquatic nuisance threats. These endeavors have involved two potential regional problems — zebra mussel infestation and nonindigenous / native seaweed interactions — and one West Coast environmental issue — the impact of the recently introduced European green crab on native species.

Maine-New Hampshire Sea Grant

As part of its zebra mussel education and outreach effort, ME-NH Sea Grant developed a volunteer monitoring network. Here, Sea Grant Extension Specialist Julia Peterson and St. Anselm College Biology Professor Barry Wicklow prepare to deploy a zebra mussel settlement sampler in New Hampshire's Piscataquog River.

Sea Grant
Maine-New Hampshire

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Species of Concern
European green crab
Zebra mussel

THE UNIVERSITY OF MAINE

THE UNIVERSITY OF NEW HAMPSHIRE 1923

Research and Outreach

In order to develop regulations that would be both effective against introducing zebra mussels and non-prohibitive to the baitfish industry, the Fish and Game Department relied heavily on Sea Grant supported research and information, and maintained an open dialogue with baitfish industry representatives.

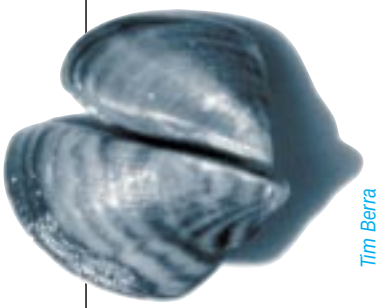
Zebra Mussels

As the zebra mussel (*Dreissena polymorpha*) problem spread out in all directions from the Great Lakes in the late 1980s and early 1990s, Maine-New Hampshire Sea Grant initiated an outreach and education project designed to provide information about zebra mussels to concerned citizens and professionals. One major focus of these educational efforts was to reach recreational boaters and anglers with information about zebra mussels, and how to prevent their spread into the region. Much of this information was disseminated via Sea Grant brochures, fact sheets, boat ramp signs, presentations, a traveling exhibit, and articles in a range of periodicals.

Another important audience targeted for the outreach effort included professionals such as water resource managers, fisheries specialists, municipal water suppliers, hydropower operators, researchers, teachers, and marine dealers. Approximately 80 professionals from these areas attended a regional conference held in New Hampshire during November 1994. The Maine-New Hampshire Sea Grant Extension Program with assistance from Connecticut Sea Grant and the Vermont Department of Environmental Conservation sponsored the conference. For many of the attendees, this conference was the most comprehensive and up-to-date source of technical information to which they had had access.

Along with Sea Grant's efforts, the New Hampshire Fish and Game Department issued new regulations governing the importation of baitfish into the state. These new regulations were developed to address the risk of inadvertently introducing zebra mussels with baitfish importation. In order to develop regulations that would be both effective against introducing zebra mussels and non-prohibitive to an important industry in the state, Fish and Game relied heavily on Sea Grant supported research and information, and maintained an open dialogue with baitfish industry representatives. The regulations essentially prohibited the importation of baitfish from states known to have bodies of water infested with zebra mussels unless certain criteria were met. In addition, Fish and Game included a section on zebra mussels in their statewide guide to water body access points and listed Sea Grant as the contact point for more information.

Due to the slowing of the zebra mussel's spread and the accompanying shortage of support for projects related to this menace, Maine-New Hampshire Sea Grant has moved its zebra mussel-related efforts to a lower level of priority. Working through the University of New Hampshire (UNH) Cooperative Extension Lakes Lay Monitoring Program, Sea Grant supports a range of outreach efforts, including educational presentations, monitoring efforts, species identification assistance, and the distribution of guidelines for boaters. Maine-New Hampshire Sea Grant also refers people who are interested in more in-depth information to zebra mussel experts and information centers associated with other Sea Grant programs.



Tim Berra

Zebra mussel (*Dreissena polymorpha*)

Maryland Sea Grant

Nonindigenous/Native Seaweed Interactions

Nori, the Japanese name for *Porphyra,* is a large genus of red algae that grows on rocky shorelines around the world. Also known as laver (England), kim (Korea), sluckum (Native Americans of the Pacific Northwest), and karengo (New Zealand), the plant is a major source of food for humans and the most valuable aquacultured seaweed in the world. The focus of a billion-dollar aquaculture industry around the world, nori is used primarily as the wrapping around sushi rolls.

The establishment of a *Porphyra* aquaculture effort in the Gulf of Maine was delayed for several years by regulatory concerns over the potential ecological impact of introducing a non-native seaweed to the area. There was simply no scientific basis for predicting environmental impacts. Ultimately, the permit applications were approved after Coastal Plantations was able to provide data indicating that the combination of environmental conditions at its site in Cobscook Bay, Maine, would prevent the natural reproduction of the strain it wanted to cultivate, *Porphyra yezoensis.*

Porphyra has now been under cultivation in Cobscook Bay for several years. Coastal Plantations is working to expand its operations and other companies are looking to set up *Porphyra* aquaculture operations in the Gulf. To address the renewed concerns about environmental impacts, Sea Grant is supporting a research effort to assess the impacts of the nori aquaculture industry on the native flora of the Bay, and to evaluate other potential impacts within the Gulf. While the imported species currently represents a great economic advancement for the region, it has the potential to become a nuisance species as well. The researchers are examining the distribution of *Porphyra yezoensis* at current cultivation sites, developing genetic profiles for several commercially valuable strains of the seaweed, and establishing baseline information regarding the distribution and abundance of native *Porphyra* species within potential cultivation sites. Their work will provide regulatory agencies and the aquaculture industry with a basis for making decisions about expanding the industry and introducing new species to the area. It will also provide valuable information on the potential impacts of nonindigenous seaweeds.

To address the concerns about environmental impacts, Sea Grant is supporting a research effort to assess the impacts of the nori aquaculture industry on the native flora of the Bay, and to evaluate other potential impacts within the Gulf.

Green Crab Impacts on the West Coast

The recent introduction of the European green crab (*Carcinus maenas*) to the West Coast is a source of great concern for the welfare of native ecosystems, aquaculture, and fisheries. A relatively small crab native to western Europe, the green crab has spread to Africa, Australia, and the United States. It is well suited to its role as an exotic colonizer. The green crab feeds on a wide array of prey, with over 150 genera of animals and plants having been recorded in its diet. It can live in water with a salinity as low as five percent and over-winter in water temperatures below freezing. It can use a range of habitats, including open sand, mudflats, shell, cobble, algae, and rock. Finally, females can carry broods of up to 200,000 eggs and the larvae can remain in the plankton for up to 80 days, factors that greatly increase the species' potential for dispersal and the colonization of new areas.

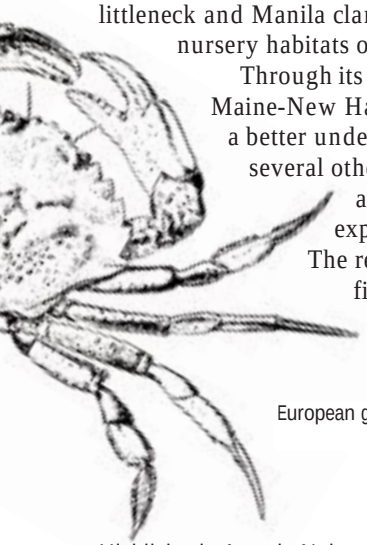
The green crab has been in residence on the East Coast for decades, and its range stretches from Virginia to Nova Scotia. On the West Coast, it was first detected in San Francisco Bay 10 years ago. Since then, it has moved north and south to occupy a range of 450 km.

The green crab has a long record of impacting and displacing native species, and there are several commercial species of particular concern on the West Coast. The populations of native littleneck and Manila clams, the Pacific oyster, and the Dungeness crab are all at risk as are the nursery habitats of salmon and several flatfish.

Through its support of a UNH zoologist with particular expertise in the green crab, Maine-New Hampshire Sea Grant expects to make a contribution toward developing a better understanding of the crab's potential impact. Working with colleagues from several other institutions, the UNH researcher is seeking to assess the current abundance and distribution of the green crab on the West Coast, to monitor its range expansion, and to estimate its impact on several native invertebrate populations. The results of this research will help resource managers, aquaculturists, commercial fishers, and other stakeholders anticipate the severity and nature of the crab's colonization and to identify actions that might be taken to lessen its impact.

Charles Yarish

Nori (*Porphyra yezoensis)*

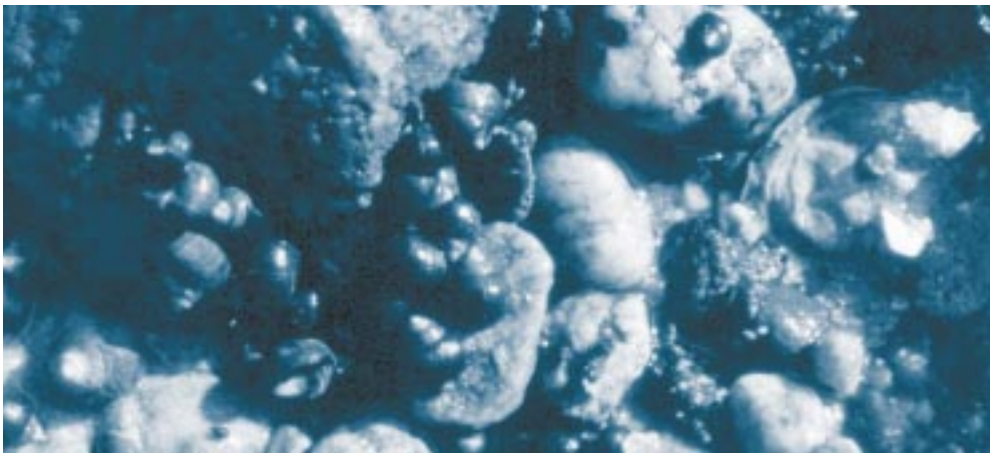


European green crab (*Carcinus maenas)*

MIT
Massachusetts Institute of Technology

The problem of aquatic nuisance species invasions is pervasive. In Massachusetts, the spread of aquatic weeds, deliberate introductions of fresh water fish, and introduced plant species are of concern. In 1993, the Massachusetts Institute of Technology Sea Grant College Program (MIT Sea Grant) began collaboration with the northeast Sea Grant programs on several projects and publications related to the introduction of the zebra mussel (*Dreissena polymorpha)*. MIT Sea Grant offered a summer camp program, *Exotic Species in Ecosystems*, to children from low-income, urban communities; distributed boater information cards and posters; and continues to distribute the zebra mussel kit to teachers of grades 4-6. Until recently, zebra mussels had not appeared in Massachusetts, although another fresh water clam, *Corbicula fluminea*, has invaded rivers near western Massachusetts.

Only recently have research efforts been focused on the extent and impact of marine introduced species. Marine invaders reach Massachusetts shores by several transport vectors: ballast water, fouling organisms from vessels, aquaculture, recreational activities, the seafood industry, canals, and research related activities. Ballast water and shipping are considered the major transport vector, but other vectors introduce species that have ecosystem, economic, and health related impacts. Because vessels primarily bring goods into Massachusetts, they discharge minimal amounts of ballast water. Nonetheless, there are many recorded marine bioinvaders — the common periwinkle snail (*Littorina littorea*), the European green crab (*Carcinus maenas*), the star tunicate (*Botryllus schlosseri*), and more recently, the Japanese shore crab (*Hemigrapsus sanguineus*). In addition to the unintentional introductions mentioned, several species have been introduced with aquaculture ventures. One of these, the edible oyster (*Ostrea edulis*) is mysteriously appearing throughout coastal Massachusetts. Some of the diseases affecting shellfish may have arrived with the introduction of species from outside the region. Documentation on the economic and ecological costs of these invaders in New England is minimal, but this is changing. New initiatives to understand the human health, economic, and ecological impacts of marine invasive species are underway.



Judith Pederson

Periwinkle snails (Littorina littorea)

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Species of Concern
European green crab
Japanese shore crab
Periwinkle snail
Zebra mussel

Research

Training the next generation of scientists, educating stakeholders, and reaching out to the public will lead to support for legislation, for ANS prevention programs, and for early ANS detection.

The MIT Sea Grant College Program funds a variety of research projects on aquatic nuisance species (ANS). One current project evaluates the role of ballast water in transporting species among domestic ports, an area where little is known about this mechanism as a source of species introductions. The purpose is to compare the relative contributions of ballast water and biota from ships of foreign versus domestic origin to U.S. ports. This includes identifying and analyzing ship patterns for the ports of Boston, Chesapeake, and Tampa/St. Petersburg; sampling and analyzing organisms; and measuring the survival of organisms during transfer and upon release of ballast water from domestic voyages. This information will assist managers in developing strategies to prevent or reduce the spread of nonindigenous introductions from this vector.

Another on-going project examines the effects of a fledgling nori aquaculture industry, *Porphyra yezoensis*, on the native marine flora at farming sites in Cobscook Bay, Maine. Several transects in intertidal areas near the farm site and artificial transects were established and followed throughout the year to determine if nori recruits and survives the winter temperatures. The findings to date suggest that *P. yezoensis* does not have the ability to complete sexual reproduction, but it may recruit ephemerally during the summer months. To date, no *P. yezoensis* plants were found on artificial substrates or survived the winter suggesting that nori can be cultivated, where permitted, and not escape and compete with native plants. A provisional patent on strain manipulation and improvement in the edible seaweed *P. yezoensis* has been obtained.

Previous ANS research focused on the biological control of zebra mussels. Researchers used indigenous bacteria and their products to test whether they controlled zebra mussels. The results showed bacterial isolates are effective antagonists against zebra mussels and that products from bacteria caused mortality. Products from selective bacteria may have potential applications in developing antifouling coatings and bioactive molluscides.

Katherine Watson

Nori (*Porphyra yezonis)* nursery site at Huckins Ledge. Inset: Closeup of nori transect in the field pulled out of the water.

Outreach

The goals of the MIT Sea Grant College Program's outreach and education efforts are to disseminate scientific information to the public and stakeholders, and provide opportunities for exchange of reliable, research-based information. Early efforts were focused on zebra mussels and more recently on marine introductions. In 1996, a regional workshop, *Exotic Species: Issues Relating to Aquaculture and Biodiversity*, brought together scientists, managers, and industry representatives as presenters and participants to discuss the issues. Information from the workshop was used by Massachusetts agencies. After the workshop, the agencies prepared a draft policy on sources of molluscan shellfish for aquaculture, committed to drafting comprehensive finfish regulations, and raised awareness of ballast water management issues. Since 1997, outreach efforts have included: convening and organizing the *National Conference on Marine Bioinvasions*, preparing written materials such as fact sheets and brochures, creating a web site, and distributing a zebra mussel kit.

The first *National Conference on Marine Bioinvasions* was held on January 24-27, 1999 at MIT. The U.S. Secretary of the Interior, Bruce Babbitt, was the keynote speaker and expressed alarm over the accelerating rate of exotic species transfers. He announced the administration's commitment to preventing and controlling invaders through the release of an Executive Order calling for interagency cooperation and new funding, and challenged scientists to assist him in his efforts by identifying problems and solutions. Several Sea Grant Programs were key supporters of the conference including Oregon, Connecticut, California, Mississippi-Alabama, Woods Hole Oceanographic Institution, and the Maine-New Hampshire programs.

Several themes emerged from the formal presentations and informal discussions at the conference. There was consensus that prevention is less costly than control of invaders once they are established. Only a few exceptions were identified where early detection and rapid response may result in eradication or minimal damage by an invading species. Current knowledge of the relative risk of other transport vectors in addition to ballast water was highlighted as poorly documented, but necessary information for developing policies. Other topics focused on patterns of invasions, ecological and evolutionary consequences of invasions, and concern about the introduction of the smallest invaders, such as cholera, which introduce new diseases to humans and organisms. The meeting ended with a lively panel discussion and a commitment to continue to bring attention to the less-well studied problems associated with marine invasions.

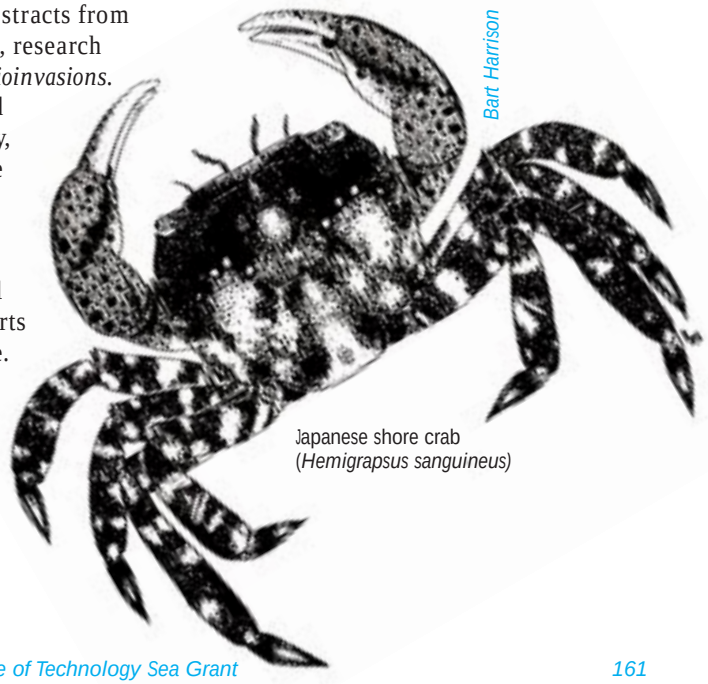
Other MIT Sea Grant outreach activities include distribution of print materials and electronic dissemination of information about marine invaders through the following web site: ***massbay.mit.edu/exoticspecies/index.html***. The site provides general information on marine introductions, and sources such as aquaculture and ballast water, describes technologies for managing ballast water introductions, and serves as a resource for the public and teachers. A featured invading species is the Japanese shore crab, the focus of researchers at the University of Massachusetts, Dartmouth. Visitors to the web pages are shown a drawing of the crab and its distinguishing characteristics, a description of its habitat, and a map showing its current distribution. A questionnaire allows the public to identify potential sitings of *H. sanguineus* at new locations. New material is added to the web site on a regular basis.

Publications available from the outreach efforts include fact sheets, abstracts from conferences, a general information brochure, *Guide to Marine Bioinvasions*, research publications, and the *Proceedings from the National Conference on Marine Bioinvasions*.

MIT Sea Grant's combined research and outreach efforts have increased awareness and knowledge of invasive species in the public sector, industry, government, and within the scientific community. Collaboration with state agencies, especially the Massachusetts Coastal Zone Management Office, Massachusetts Port Authority, and the Massachusetts Division of Marine Fisheries enhance the ability to develop policies and identify issues. Collaboration with other Sea Grant programs fosters regional and national coordination on ANS efforts. Future activities will continue to expand efforts to distribute ANS research findings and information to a broader audience.

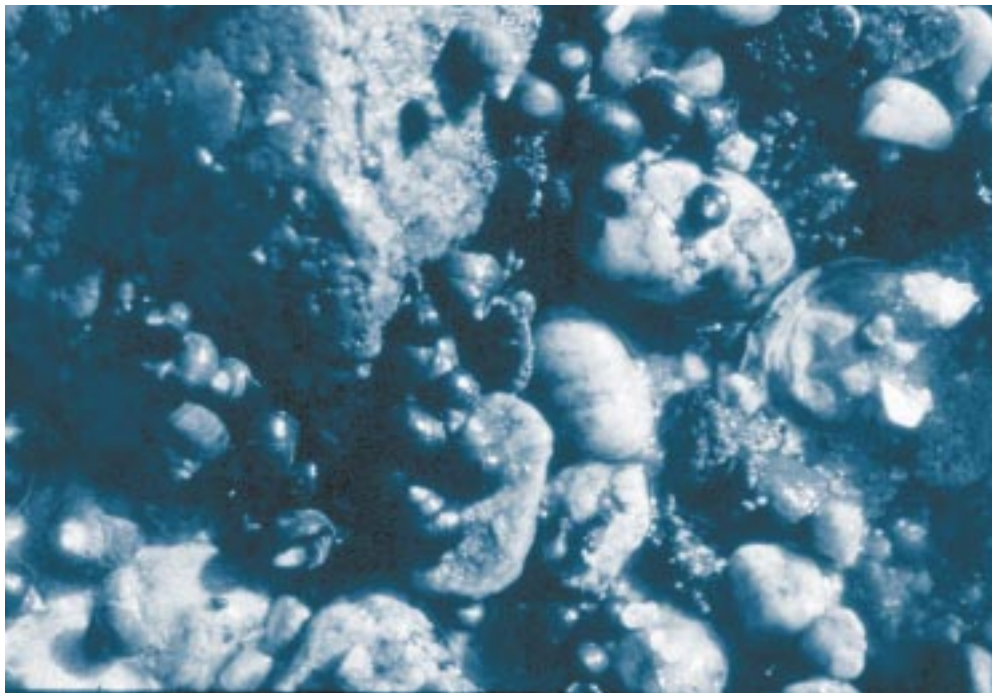
"Marine bioinvasions have large consequences for our food supply, our economy, our fishing industry, and human health. These invasions also threaten to degrade and homogenize coastal waters in every corner of the seven seas."

Bruce Babbit, U.S. Secretary of the Interior, National Conference on Marine Bioinvasions *keynote address*



Bart Harrison

Japanese shore crab (*Hemigrapsus sanguineus*)



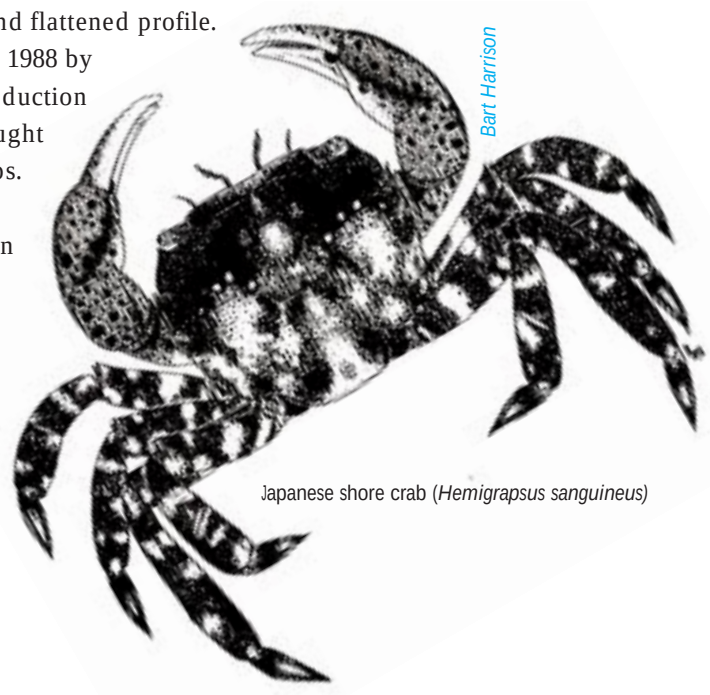
WHOI
Woods Hole Oceanographic Institution

Over the years, numerous aquatic nuisance species — non-native, marine and freshwater species of plants and animals — have been introduced in Massachusetts' waters. A recent workshop, convened by the MIT Sea Grant College Program, brought together researchers and coastal managers to share recent research results in the field of marine bioinvasions and to discuss future directions and management options. Proceedings of the workshop, supported in part by WHOI Sea Grant, are available.

While some of the best-known Sea Grant research and outreach efforts in the field of aquatic nuisance species (ANS) are focused on zebra mussels (*Dreissena polymorpha*), the fresh waters of Massachusetts have remained zebra mussel-free. The extent of ANS research supported by WHOI Sea Grant in the early 1990s focused on the role of strontium and calcium in the shell development of the zebra mussel. The research required investigators to travel to the Great Lakes region and to obtain numerous state and federal permits to bring the freshwater mollusk into Massachusetts, where they could study it in the Woods Hole laboratories. However, in 1994, a small marine crustacean native to Japan made its way into some of the Commonwealth's southern estuaries, offering researchers an opportunity to investigate a marine bioinvader in waters closer to home.

The 1994 discovery of the Japanese shore crab (*Hemigrapsus sanguineus*) was made along the southeastern Massachusetts coast. The discovery led to an all-out search for *Hemigrapsus sanguineus* along the entire Massachusetts coastline. It didn't take long before researchers confirmed several sightings of the crab in rocky intertidal areas in Buzzards Bay, Cape Cod, and along the shores of Cape Cod Bay.

Hemigrapsus sanguineus belongs to the Grapsidae family, uncommon in the Northeast, and is characterized by a squarish carapace and flattened profile. *H. sanguineus* was first discovered in the United States in 1988 by university students on New Jersey's Cape May. The introduction of this crab, like that of many other exotic species, is thought to occur via transport of larvae in ballast water from ships. It is now established as far south as North Carolina and as far north as New Hampshire, although there have been unconfirmed sightings of the crab in Maine.



Japanese shore crab (*Hemigrapsus sanguineus*)

Sea Grant
Woods Hole

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Species of Concern
Japanese shore crab

Research

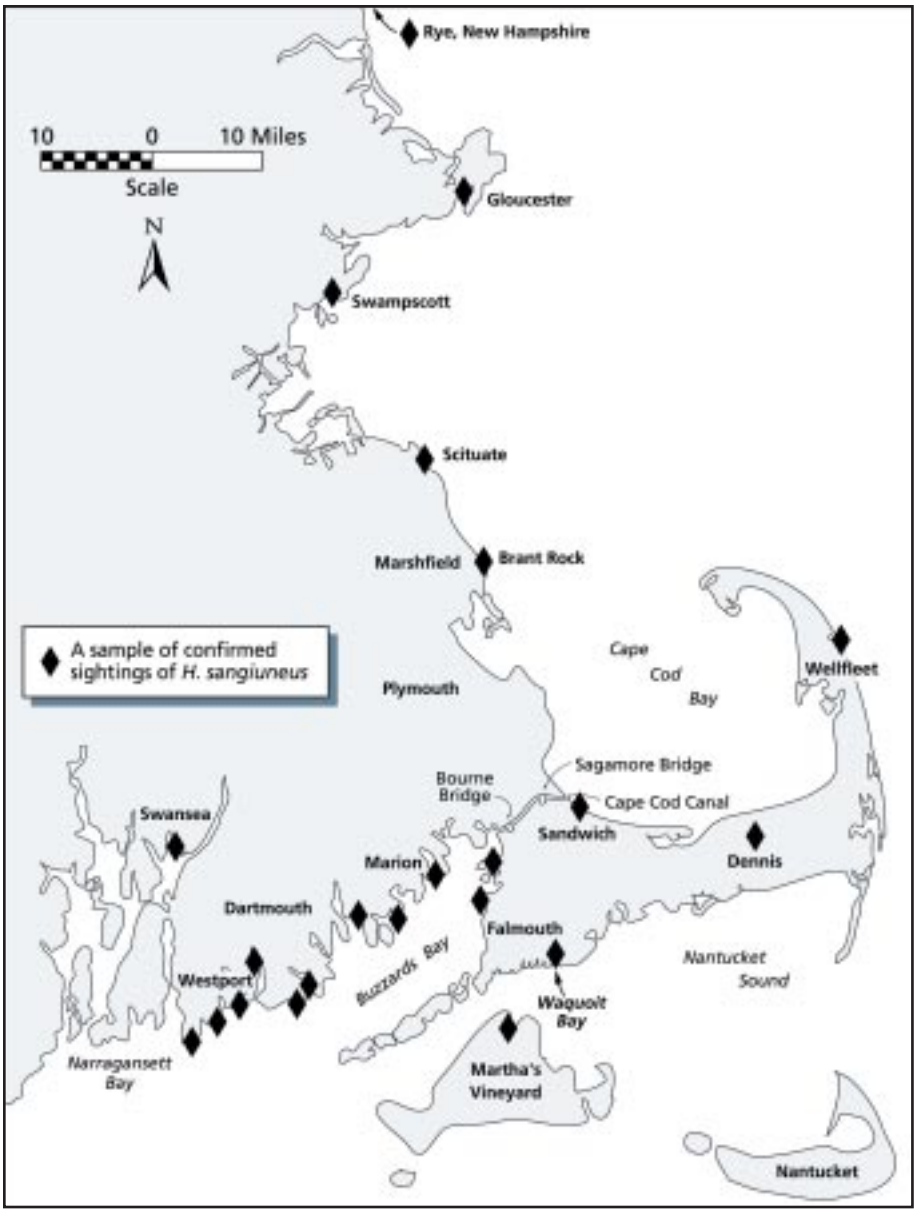
"Ideally, the status of [an] ecosystem before, during, and after a successful [biological] invasion should be compared to infer changes that occurred as a result of the invasion."

Nancy O'Connor.
WHOI Sea Grant researcher, University of Massachusetts, Dartmouth

WHOI Sea Grant researchers have conducted field and laboratory sampling of the Japanese shore crab to determine its distribution and abundance and to study its preferred diet. The initial studies set out to gain an understanding of the basic biology and ecology of *Hemigrapsus*, in order to determine the potential influence the crab might have on southeastern New England coastal ecosystems.

Field surveys conducted in 1996 indicate that *H. sanguineus* resides only in rocky intertidal areas or intertidal areas where comparable substrates exist. The crabs also prefer polyhaline areas within estuaries. Gut analyses of the crabs revealed that *H. sanguineus* is not limited to a plant diet, as indicated in the literature, but is instead omnivorous. Analysis of gut contents revealed crustacean parts, unidentifiable clams and other mollusk shells, algae, and insects.

In a follow-up research project that began in 2000, investigators — including several graduate students — are examining the effects of newly established *H. sanguineus* populations on resident crabs, including the green crab (*Carcinus maenus*), rock crabs (primarily *Cancer irroratus*), and mud crabs in the family Xanthidae. To do so, researchers are sampling sites along the Massachusetts coastline and parts of Narragansett Bay, looking at both temporal changes in crab populations as *Hemigrapsus* invades and increases in abundance, and comparing spatially separated populations to determine whether changes observed are consistent in direction and magnitude among sampling sites. Possible consequences of newly established *Hemigrapsus* populations will be of interest not only to researchers, but to resource managers and educators as well. In the future, WHOI Sea Grant will continue to examine the impact that nonindigineous species have on coastal ecosystems.



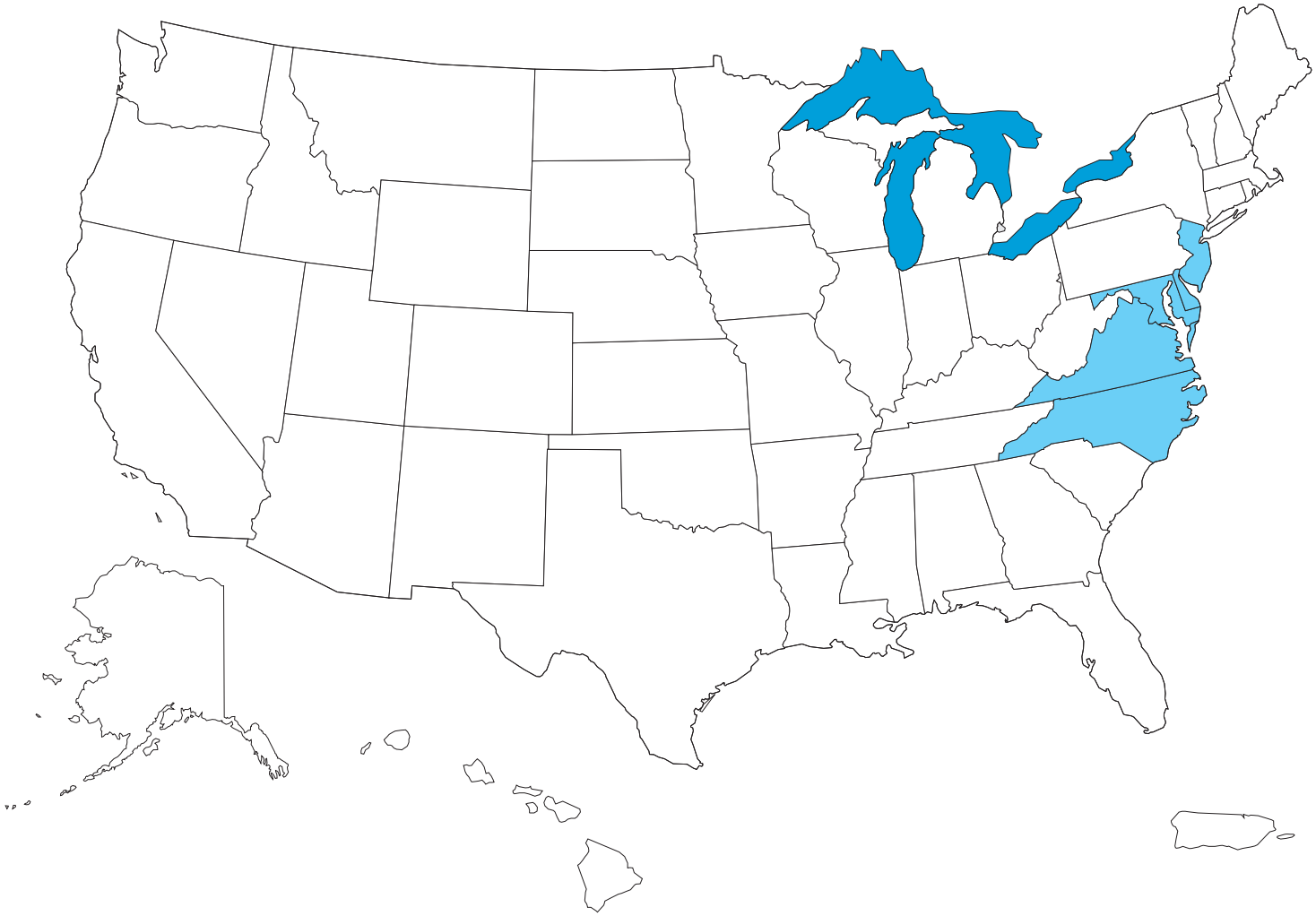
Mid-Atlantic Region

Delaware
New Jersey
North Carolina
Virginia

Sea Grant

ANS

Mid-Atlantic Region



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virginia-sea-grant/

Sea Grant

Delaware

According to the U.S. Office of Technology Assessment, an estimated 350 species of non-native plants and animals have been introduced to U.S. coastal waters. These aquatic nuisance species (ANS) can threaten native plants and animals and cause major economic problems for water users, from industries to homeowners.

A healthy marine environment is critical to Delaware. The state's coastal treasures include more than 260 miles of saltwater shoreline, 90,000 acres of tidal wetlands, two National Estuaries including the Delaware Bay and the Inland Bays, and the busiest canal in the nation — the Chesapeake and Delaware Canal.

The University of Delaware Sea Grant College Program conducts research that addresses coastal challenges, develops new products from the sea, and provides objective information that will contribute to the wise use, conservation, and management of marine resources. Marine Advisory Service and Marine Communications staff help relay our findings to the public through media ranging from workshops to web sites.

Delaware Bay is one of the busiest shipping corridors in the United States, handling over 70 million tons of cargo each year. Ships from all over the world bring crude oil and commodities to the tri-state port complex that spans the shore from Wilmington, Delaware; to Camden, New Jersey; to Philadelphia. These ships often take on ballast water in their home ports to provide stability for the transoceanic voyage to Delaware Bay. This ballast water may contain huge numbers of eggs and larvae of marine organisms that are native to the various home ports, but foreign to U.S. waters. These larvae may be pumped into Delaware Bay when arriving ships release ballast water to decrease their draft for the trip upstream.

Sea Grant
University of Delaware

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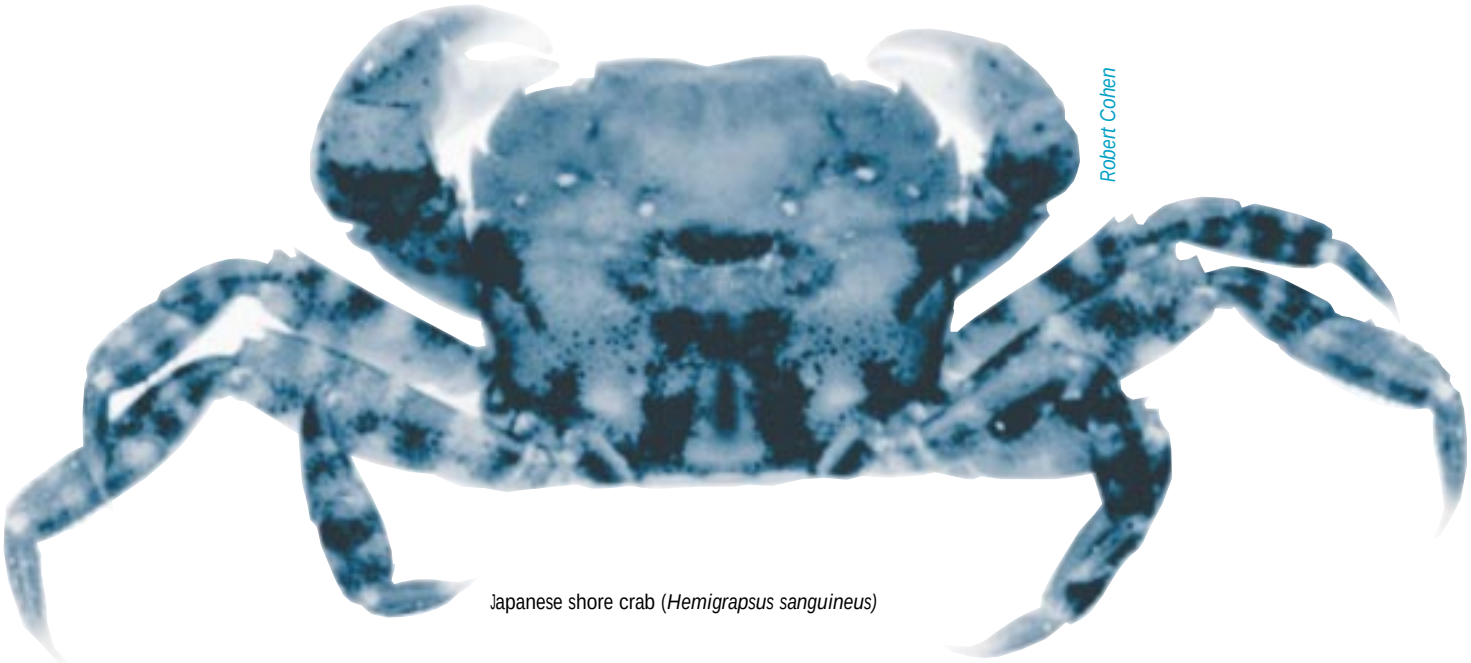
Species of Concern
Asian clam
Grass carp
Hydrilla
Japanese shore crab
Purple loosestrife
Zebra mussel

UNIVERSITY OF DELAWARE



Robert Cohen

Japanese shore crab (*Hemigrapsus sanguineus*)

Robert Cohen

Zebra mussels (*Dreissena polymorpha*)

Research

Japanese Shore Crab

Some larvae from ballast water have established thriving populations in Delaware Bay. One such species is the Japanese shore crab (*Hemigrapsus sanguineus)*. The Japanese shore crab was discovered in Delaware Bay in 1989. While this 3-inch crustacean normally inhabits the western Pacific Ocean, it now ranks as one of the Delaware Bay's most abundant crab species.

How did the Japanese shore crab become established so quickly? Recently, with Sea Grant funding, University of Delaware marine biologists discovered that the Japanese shore crab is well equipped to outcompete native crabs, such as the mud crab and rock crab. Recent lab work indicates that the Japanese crab's growth rate may be greater than that of Delaware's native crabs.

The Japanese shore crab's reproductive season also is longer than that of native crabs. While most native crabs reproduce in June and July, the Japanese crab's reproductive season extends from May to October. The Japanese shore crab's speed also gives it an edge. Native crabs are relatively sluggish, making them easy prey for fish like tautog and black sea bass and for sea birds, while the Japanese shore crab is a very active species and a fast runner, making it harder for predators to catch. Through further work, researchers hope to determine what impact the fast-moving crab may have on the local ecosystem. The Japanese shore crab has now spread as far north as New Hampshire and as far south as North Carolina.

The Zebra Mussel: A Threat on the Move

In July 1988, the zebra mussel (*Dreissena polymorpha*), a creature new to North American waters, was found in Lake St. Clair, near Detroit. The small black-and-white striped mussel apparently hitched a ride to the United States in the ballast water of Eurasian tankers bound for the Great Lakes.

Like the Mediterranean fruit fly, the sea lamprey, and many other nonindigenous species before it, the zebra mussel soon proved it could cause damage by attaching itself to nearly anything in fresh water, from intake pipes at power companies to boat engines. The animal's tremendous filter-feeding capacity also has impacted the food supply available to native fish in some waterways. The zebra mussel has now invaded freshwater areas in more than 20 U.S. states. Fortunately, it has not yet appeared in Delaware waters.

Research at the University of Delaware Sea Grant College Program has resulted in the first reported protein sequence from the zebra mussel. Biochemists have genetically fingerprinted one of the proteins that is a key component of the zebra mussel's byssus, the bundle of threads rooted at the base of the animal's foot. At the end of each thread is an adhesive plaque that contains the glue that enables the zebra mussel to anchor itself to solid surfaces.

By determining the chemical nature of this glue, researchers believe they may be able to not only unlock the door to a better zebra mussel control, but they may also be able to identify a unique waterproof adhesive with potential applications in dentistry, ophthalmology, and other medical fields.

By determining the chemical nature of the zebra mussel's "glue," researchers believe they may be able to not only unlock the door to a better zebra mussel control, but they may also be able to identify a unique waterproof adhesive with potential applications in dentistry, ophthalmology, and other medical fields.

There are at least three different proteins in the zebra mussel's byssus, but scientists are trying to determine what role each of these proteins plays. For example, one protein may serve as a protective varnish for the byssal threads, while another may be responsible for stickiness. Delaware Sea Grant researchers are working to determine exactly where these proteins are found in the byssal threads and how they work.

A major challenge in this research has been acquiring a steady supply of zebra mussel protein for laboratory analysis. Recently, the research team overcame this hurdle through the development of a bacterial expression system. Using the tools of molecular biology, the scientists introduce the gene for the zebra mussel protein they identified into cultures of a common bacterium, *E. coli.* The bacteria then begin manufacturing the protein. Once purified, the protein can be used for a variety of analyses, including antibody research that may someday yield the recipe for a biochemical control for this mollusk.

The protein generation system represents a major step forward in the conduct of this research. Formerly, the researchers needed to shuck hundreds of half-inch zebra mussels, shipped to the lab from the Niagara River, in order to acquire enough of the protein for research.

Outreach

Robert Cohen

Asian clams (*Corbicula fluminea*)

Getting Ready for Zebra Mussels

To prepare for a possible zebra mussel invasion, the University of Delaware Sea Grant College Program has worked with colleagues at Sea Grant programs in New Jersey, Maryland, Virginia, and North Carolina to develop a variety of educational materials about this nuisance species. Delaware scientists also have conducted research targeted at developing an effective zebra mussel control.

In addition to producing newsletters, radio public service announcements, and other materials, Delaware Sea Grant outreach specialists coordinated the development of the Mid-Atlantic Sea Grant network's zebra mussel reports issued in 1994 and 1995. The reports were distributed to more than 10,000 industries, government agencies, and private citizens. Additionally, the outreach staff helped coordinate regional meetings to inform industry representatives and resource managers about zebra mussel monitoring and control strategies.

Partnering with the state Department of Natural Resources and Environmental Control, the Delaware Sea Grant outreach team developed a decal alerting boaters and anglers about the zebra mussel and steps to prevent its introduction to Delaware waters; the decal has been distributed to Delaware boaters through the state Boating Education Office. Outreach staff also continue to introduce teachers and their students to aquatic nuisance species through workshops and in-service programs.

What Other Invaders Threaten Delaware Waters?

Nearly every part of the nation faces at least one highly damaging non-native species. In addition to the Japanese shore crab, which now inhabits Delaware Bay, and the zebra mussel, which has not yet been identified in state waters, here are some other aquatic exotics of concern to Delaware.

Asian Clam (*Corbicula fluminea*). In 1980, the Arkansas Nuclear One Power Plant was forced to shut down because hundreds of these tiny clams had clogged its waterlines, prompting the Nuclear Regulatory Commission to issue a directive requiring every nuclear facility in the nation to determine whether fouling by the clam posed a hazard. At that time, the clam's impact in the United States was estimated at $1 billion. In the Mid-Atlantic region, it has caused fouling problems at nuclear power companies in the Delaware River watershed.

Grass Carp (*Ctenopharyngodon idella*). This Asian fish has been used to control aquatic weeds such as hydrilla. However, the grass carp can cause environmental harm if reproductive populations become established in the wild because it indiscriminately consumes aquatic vegetation, destroying food and habitat for fish and waterfowl. While most states in the Mid-Atlantic region permit the use of triploid (believed to be sterile) grass carp for weed control in designated areas, Maryland has outlawed the fish in fear that it will be released into Chesapeake Bay to eat the vegetation the region has worked to restore.

According to the U.S. Office of Technology Assessment, no environment on earth has escaped introductions of nonindigenous species, with the possible exception of Antarctica. At least 40 nonindigenous species now inhabit Delaware's ponds, rivers, and bay waters.

U.S. Fish and Wildlife Service

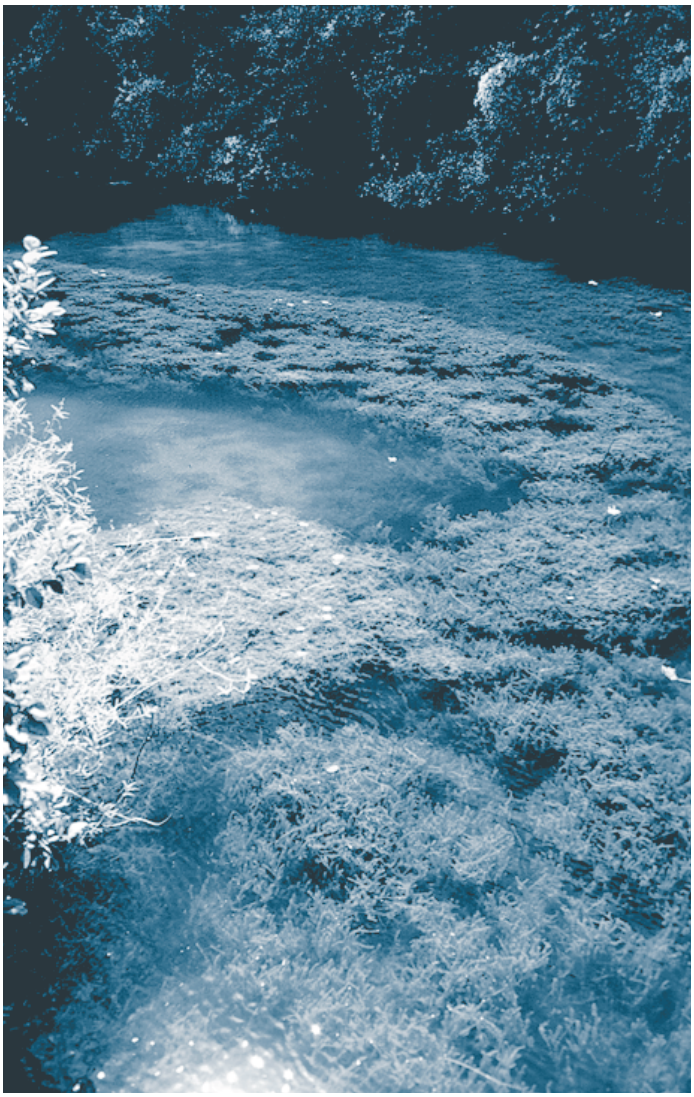
Grass carp (*Ctenopharyngodon idella*)

Delaware has been invaded by numerous nonindigenous species, some of which have caused significant ecological and economic harm to the state.

Forbes Darby, in Pathways and Management of Aquatic Non-Indigenous Species in Delaware *University of Delaware Sea Grant College Program, 1999*

Hydrilla (*Hydrilla verticillata*). This plant is currently viewed as Delaware's number one aquatic pest. Hydrilla forms impenetrable mats of vegetation that choke off water flow, increase sedimentation, and reduce an ecosystem's overall productivity, in addition to disrupting boating and other recreational activities. Imported from Sri Lanka, it was introduced into the Potomac River in Washington, DC, most likely by a hobbyist dumping out the contents of an aquarium. From there, the plant was probably transported accidentally to Delaware, entangled on a boat propeller or trailer. Since the 1970s, hydrilla has spread to 11 water bodies in the state. While control costs for the plant continue to mount in Delaware and many other states, hydrilla appears to offer habitat for fish in the Potomac River and may help filter the river's muddy water. Chesapeake region authorities continue to monitor the plant to determine if it will continue to benefit the estuary, or if it will, as demonstrated elsewhere, threaten native grasses.

Purple loosestrife (*Lythrum salicaria*). Aided by absence of predators, this European plant has spread across North America, where it is now found in wetlands in many U. S. states and Canadian provinces. Purple loosestrife can grow from 3-to-6 feet tall; it is easily identified from June to September, when it boasts bright pinkish-purple flowers along its spike. The plant invades wetlands, ultimately choking out native vegetation, creating a dense purple landscape almost totally devoid of wildlife. So far in Delaware, purple loosestrife has been identified in freshwater wetlands in New Castle and Kent counties, from cloverleafs along the I-95 corridor, and in wetlands in the Woodland Beach Wildlife area. Currently, state agricultural agents and resource managers are testing the use of the black-margined loosestrife beetle (*Galerucella calmariensis*), which appears to prey solely on purple loosestrife, as a natural means of controlling the plant.



Ken Taylor

Hydrilla (*Hydrilla verticillata*)

Fred Snyder

Purple loosestrife (*Lythrum salicaria*)

New Jersey

Aquatic nuisance species have entered waterways throughout North America as a result of intentional and accidental introductions. Some of these organisms have had a beneficial effect, such as many recreational fishes and aquaculture species, while others have had a detrimental effect, such as the Asian clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*), and caused significant economic and environmental damage. Many more potentially harmful species will be intentionally or accidentally released into North American waterways. Nuisance species are also impacting freshwater and coastal waters throughout the United States. Nonindigenous species such as purple loosestrife (*Lythrum salicaria*) and the common reed (*Phragmites australis*) have invaded wetlands, competing with native wetland plants.

Scientists believe that nearly every waterway in North America could be infested by zebra mussels and quagga mussels (*Dreissena bugensis*) within the next 20 years. Zebra mussels are rapidly approaching New Jersey's borders with a population located in the Hudson River (just north of the Tappan Zee Bridge), and are posing a real threat to New Jersey's estuarine and fresh waters.

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Species of Concern
Common reed
Purple loosestrife
Quagga mussel
Zebra mussel

NEW JERSEY
MARINE SCIENCES
CONSORTIUM

J. Ellen Marsden

Zebra mussels (*Dreissena polymorpha*) encrust a rock.

Because salinity levels are high in most of the bays along New Jersey's coast, these regions have a lower probability of zebra mussel infestation. However, in other parts of the state, zebra mussels have the potential to inhabit inland lakes, ponds, and the Delaware River.

Potential Zebra Mussel Impacts

New Jersey, the most densely populated state and a key industrial center, is situated between the Hudson River estuary (eastern border) and the Delaware River estuary (western border); both have been designated as "National Estuaries" by the U.S. Environmental Protection Agency. These National Estuaries are important marine transportation and industrial centers, and provide habitat to valuable wildlife species, recreational opportunities to millions of boaters and anglers, and a source of water for drinking and industrial purposes.

The Hackensack and Passaic Rivers (Hudson River estuary) parallel the Hudson River as they flow southward into Newark Bay. Depending on water flow, zebra mussels could potentially inhabit the Hackensack River to its mouth, but infestation is more likely up river. The Passaic River is freshwater from the headwaters to as far south as the Dundee Dam and then becomes tidal and brackish to its mouth. Zebra mussels could probably infest the Passaic River to Newark Bay. Since salinity levels are higher in Newark Bay, there is a low probability of zebra mussel infestation in the bay itself. The Arthur Kill flows between Newark and Raritan Bays. Salinity levels are high throughout the Arthur Kill and even higher in Raritan Bay. Therefore, the probability of zebra mussel infestation in these waterways is low.

In the Delaware River estuary area, the Delaware River is tidally influenced from Trenton, NJ to its mouth. The salinity in the river is determined primarily by the rate of freshwater discharge. At times of low freshwater discharge, saltwater will intrude as far north as Philadelphia but only in trace amounts. During normal flow rates, the Delaware River is considered freshwater as far south as Chester, PA. At the mouth of Delaware Bay, salinity levels approach those of ocean water. Zebra mussels are primarily a freshwater mollusk but can tolerate salinity levels from zero to about 10 parts per thousand. Therefore, zebra mussels could potentially inhabit the entire Delaware River proper and northern stretches of Delaware Bay and, depending on river flow rates, could extend into more southern regions of Delaware Bay.

New Jersey has approximately 1,200 lakes and ponds comprising approximately 51,000 acres. Three hundred and eighty-one of these lakes and ponds (24,000 acres) are public waterbodies. In addition, there are approximately 6,450 miles of streams and rivers throughout the state. Various waterbodies, including several reservoirs in the northern and central regions of the state, have the proper conditions to sustain zebra mussel populations. However, as one reaches the pinelands section of south Jersey, many of the waterways have low calcium and pH levels. Hence, many of these waters are at low risk of an invasion by zebra mussels. Salinity levels are high in most of the bays along the Jersey coast. Therefore, these regions have a low probability of zebra mussel infestation.

Fred Snyder

A zebra mussel cluster.

Impacts on Industry

The following New Jersey industries could potentially be impacted by an invasion of zebra mussels: power generating facilities, municipal water authorities, petrochemical and pharmaceutical firms, and others. In addition, many agribusinesses, golf courses, marinas, boaters, and even homeowners could also be impacted.

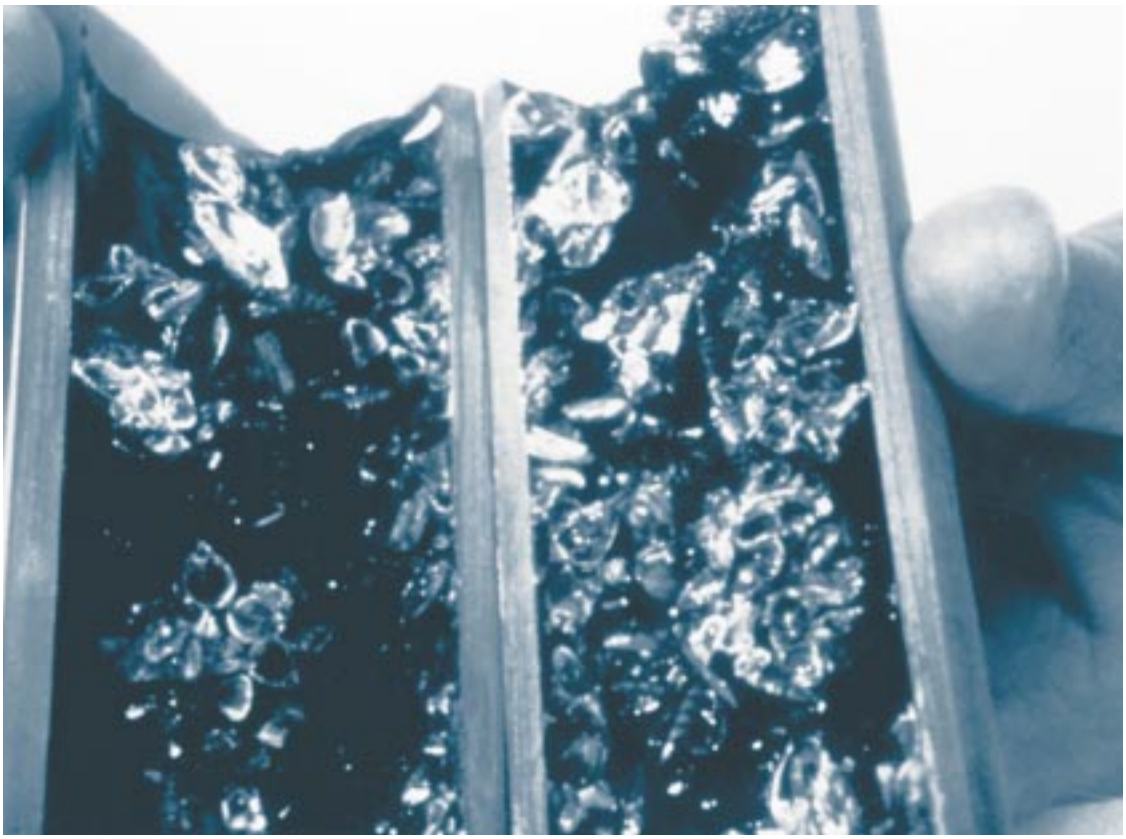
Researchers have shown that some of the primary vectors for spreading zebra mussels are natural dispersion, barge traffic, and recreational anglers/boaters. Many New Jersey boaters travel to the Great Lakes, Hudson River, Finger Lakes and other infested waterways to the north for pleasure boating and fishing, and could potentially introduce the zebra mussel to a New Jersey waterway. Even anglers fishing from banks and wading in zebra mussel infested streams, rivers, and lakes could potentially introduce the zebra mussel to New Jersey. Larvae can be carried in bait bucket water and in the bilge water and engines of boats. Many bass tournaments are held throughout the state and participants could spread the zebra mussel. Bait dealers located throughout New Jersey purchase bait such as minnows from other states. The bait could be shipped in water containing zebra mussel larvae that is then unintentionally dumped into a local waterway.

Commercial ships, especially barges, can be a major vector for spreading zebra mussels. However, the majority of New Jersey's waterways are not used for shipping. In the Delaware River, there is some commercial ship traffic, but vessels only travel as far north as the Philadelphia/Camden area. It is possible that zebra mussels could be introduced into the river from Philadelphia. Ships also travel in Raritan Bay, the Arthur Kill, and Newark Bay, but the salinity is probably too high for zebra mussels to establish a population.

Once the zebra mussel invades New Jersey, it will travel from one waterbody to another via the old canal systems (i.e. Raritan Canal) which link different waterbodies. This natural dispersion mechanism could spread the mussel throughout much of the state.

Other aquatic nuisance species that have been or may be introduced will pose a threat to New Jersey's estuarine and fresh waters. For example, the veined rapa whelk (*Rapana venosa*) was recently discovered in Chesapeake Bay and could make its way to Delaware Bay and seriously impact the Delaware Bay oyster industry.

Industries such as power generating facilities, municipal water authorities and pharmaceutical firms could potentially be impacted by an invasion of zebra mussels.



Great Lakes Sea Grant Network Graphics Library

Cross-section of a pipe clogged with zebra mussels.

Outreach

"The curriculum material allowed the class to investigate the problem on a large and local scale. The curriculum allows the student to use problem solving skills in order to come up with some possible solutions on how to keep the mussel and other exotic animals and plants out of New Jersey and other critical habitats. Teaching and making the problems around us real to the student is a difficult task — this assignment was both informative and fun."

Frederick J. Szeles, Jr., Bridgewater Raritan High School teacher


NEW JERSEY SEA GRANT MARINE ADVISORY SERVICE

ZEBRA MUSSEL MENACE

sea notes series no. 11


New Jersey "News"-Ance

Nuisance & Exotic Species Newsletter

Message from the Editors

Zebra Mussels Invade Inland Lakes

Zebra Mussel Watch

New Jersey Sea Grant is currently focusing ANS outreach programs on zebra mussel education and prevention. Using and adapting curriculum produced by Virginia Sea Grant, the New Jersey program developed a zebra mussel curriculum that targeted students in grades 8 through 12. Included in the curriculum packet is a bibliography of available Sea Grant publications and various fact sheets and reports produced by Sea Grant programs in the Mid-Atlantic, Great Lakes, and New England regions. In 1995, New Jersey Sea Grant gave presentations and disseminated the curriculum to the following audiences: New Jersey Marine Education Association *Teach at the Beach Workshop*, Hackensack Meadowlands *Critical Issues Seminar*, New Jersey Marine Sciences Consortium *Statewide Systemic Initiative Summer Institute*, New Jersey Science Convention annual meeting, 4-H agents and program leaders, and the Association of New Jersey Environmental Educators. To date, over 100 curricula have been distributed in New Jersey and Pennsylvania.

More than 20,000 *Zebra Mussel WATCH* cards, developed by Wisconsin Sea Grant and modified for the Mid-Atlantic Zebra Mussel Network, have been distributed to recreational water users especially boaters and anglers, industries, schools, the general public, government agencies, and natural resource managers and biologists in both New Jersey and Pennsylvania. A Sea Note Series fact sheet, *The Zebra Mussel Menace*, targeting recreational boaters in the region was prepared. The fact sheet is designed to educate recreational boaters and anglers about the zebra mussel and ways to prevent its spread. Over 25,000 fact sheets have been distributed to boaters, anglers, industries, schools, the general public, bait/tackle shops, fishing license vendors, and natural resource managers and biologists in both New Jersey and Pennsylvania.

A citizen's volunteer monitoring program for zebra mussels was organized in the Delaware River watershed, Hudson-Raritan watershed and other waterbodies in New Jersey and Pennsylvania. Participants are drawn from local watershed and lake associations, environmental groups, government agencies, schools, and concerned citizens in both states. Over 250 volunteers from New Jersey and Pennsylvania are monitoring for zebra mussels.

A flier was produced for insertion into the New Jersey Department of Motor Vehicles Boater Registration Packets. One hundred and ninety thousand fliers were placed in boater registration packets that inform boaters about the zebra mussel and how to slow its spread.

New Jersey Sea Grant has also designed educational materials and conducted public presentations about zebra mussels for water resource user groups and public interest groups in New Jersey and Pennsylvania. In addition, articles have been written for local and state newspapers and magazines.

In 1996, a zebra mussel and other aquatic nuisance species newsletter was written and disseminated to over 300 water users and teachers in New Jersey and Pennsylvania. The second issue was produced in fall 1998. The newsletter became a biannual publication in 1999 and concentrates on both zebra mussels and other aquatic nuisance species.

North Carolina

North Carolina's risk of aquatic nuisance species (ANS) introduction is high. Both natural river systems and created canals, such as the Intracoastal Waterway, link North Carolina to neighboring states. Recreational boats are commonly transported from Michigan, Illinois, Ohio, Pennsylvania, Tennessee and other states to our larger lakes. And water is moved daily from the Mississippi River network to Atlantic-bound drainages through the sale of fish for bait and for stocking fish farms.

North Carolina and the surrounding region contain several large river systems that originate east of the Appalachian Mountains and flow in a southeast direction, towards the Atlantic coast, often crossing state lines along the way. Once these freshwater inland rivers meet the coastal plain, they mix with ocean water to form brackish water estuaries and tidal river mouths. This unique variation in environments allows for a wide variety of freshwater and marine aquatic nuisance species to colonize the region. When an exotic species reaches a waterbody within the region, it usually spreads throughout the area. Past examples include the Asian clam (*Corbicula fluminea*), hydrilla (*Hydrilla verticillata*), and Eurasian watermilfoil (*Myriophyllum spicatum*).

Besides the threat of zebra mussels (*Dreissena polymorpha*), North Carolina has been fighting ANS introductions for decades. Approximately $1.6 million were spent in 1995 on chemical control of hydrilla just in Lake Gaston. The Asian clam reached North Carolina in the 1970s and wreaked havoc on many power companies in the state. They currently exist in every major river system in North Carolina and in most of the smaller tributaries that feed these systems. Populations are at manageable levels in most locations.

Zebra mussels have not yet reached North Carolina. The state's priority is to prevent an introduction through education and to promote a network of monitors that will provide an early warning in the case of an introduction. North Carolina has substantial and important habitats vulnerable to the introduction of zebra mussels, including 2.5 million surface acres of fresh water and approximately one-third of our 2.3 million acres of estuaries, which have salinities of less than 10 parts per thousand, the tolerance range for zebra mussels.

Zebra mussels pose enormous economic and ecological impacts. More than 140 industries and public facilities, including water treatment plants, pulp and paper mills, power generation facilities, and processing plants, withdraw more than one million gallons of water per day from our rivers, streams, and reservoirs. This does not include the numerous agricultural and golf course users. There are 1.7 million recreational anglers in the state who spend an estimated $900 million annually. North Carolina provides habitat for 60 species of freshwater mussels, over half of which are already listed as threatened, endangered, or species of special concern. If zebra mussels colonize North Carolina's larger rivers, it is estimated that 13 species could be extirpated from our state. Among those, four species could be extinct.

Uninformed boaters, anglers, lake managers, and aquaculturists pose the threat of carelessly introducing an exotic nuisance species to our state. Aggressive education, regulation, and prevention programs implemented by one state can also be nullified by the complacence of neighboring states that share a common water resource boundary. Therefore, North Carolina Sea Grant has pursued multi-state and regional partnerships and cooperation for addressing the issue of ANS introduction and dispersal.

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Species of Concern
Asian clam
Eurasian watermilfoil
Hydrilla
Zebra mussel

Fred Snyder

Zebra mussel (*Dreissena polymorpha*)

Research

Most large, at-risk facilities have already outlined plans for preventing and managing the costly mollusks. Determining the risk is the first step toward a plan of action.

Risk Assessment

North Carolina may not avoid a zebra mussel infestation of its waters, but it has the advantage of time to prepare. Other parts of the country, particularly the Great Lakes region, have not had this luxury. But their experiences and research have yielded information that can help control facilities damage when zebra mussels do reach North Carolina shores.

Most large, at-risk facilities have already outlined plans for preventing and managing the costly mollusks. But many smaller facilities — including municipal water treatment plants, industrial processing facilities and lake associations — have not taken precautions. Determining the risk of zebra mussel colonization for a particular waterway or region is the first step toward developing a plan of action. It can also help resource managers better target education, monitoring, and enforcement programs.

North Carolina Sea Grant has worked to help North Carolina and other states prepare for the zebra mussel threat. In 1997, the Program completed a risk-assessment study of North Carolina's waters that used the zebra mussel's tolerances for temperature, dissolved oxygen, salinity, calcium, and pH to calculate the likelihood of mussel infestation for 338 locations across the state. Data for the assessment came from the North Carolina Division of Water Quality and the U.S. Geological Survey.

The results of the study were displayed on a folded map-size poster that was produced using Geographic Information System technology. The map provides instructions on how to confront the zebra mussel issue proactively. Six hundred copies of the map have been distributed to registered water users, the North Carolina Lake Management Association, the U.S. Army Corps of Engineers, and the North Carolina Zebra Mussel Task Force. Results of the risk assessment study and methods for calculating zebra mussel risk were presented at several national and international workshops, reaching state and federal agencies, water quality regulators, resource managers, and industry representatives. The study has been used as a model by other states such as California. South Carolina Sea Grant is about to complete a similar study following the presentation to their zebra mussel task force.

Zebra Mussels and Aquaculture

Research conducted by Cooperative Extension fisheries specialists with the Zoology Department at North Carolina State University included a 31-state phone survey of aquaculturists to determine if they were aware of the problems zebra mussels can cause. The survey revealed that most aquaculturists were uniformed, even in areas where the mussels were present. With Sea Grant funding, researchers developed a fact sheet that describes potential impacts of zebra mussels to the aquaculture industry, such as clogging cages or net pens, reducing food availability for fish, and interfering with seining. The fact sheet also details the mussel's environmental requirements, lists tips for prevention, and outlines methods of control and monitoring. Forty-five hundred copies of the fact sheet were distributed throughout the country as part of the National Zebra Mussel Training Initiative.

Duke Power

Duke Power Company

Ballast Water Analysis

In 1997, Sea Grant awarded funding to a researcher at the University of North Carolina at Wilmington, to identify and characterize microbial populations in the ballast water of ships traveling from foreign ports to U.S. ports (Wilmington, N.C. and Chesapeake Bay). The study used DNA isolation and molecular analysis to characterize the natural populations of bacteria from the ballast water samples. The study also tested for the presence of toxin genes from *Vibrio cholerae* and *Vibrio vulnificus*.

Outreach

Ontario Ministry of Natural Resources

Zebra mussels siphoning plankton from the water column.

Through the training initiative, North Carolina Sea Grant has educated extension specialists, resource managers, government agencies, and industry representatives on the need for state and regional task forces and how they can be used effectively to guide a zebra mussel outreach program.

North Carolina Zebra Mussel Task Force

During 1992, North Carolina Sea Grant organized one of the first statewide zebra mussel task forces in a state that did not have zebra mussels. The North Carolina Zebra Mussel Task Force is currently chaired by North Carolina Sea Grant's water quality specialist and includes members from key federal and state agencies, municipalities, utility companies, and extension programs. The purpose of the task force is to provide guidance and coordination for statewide zebra mussel monitoring, education, and public awareness activities. As chair, North Carolina Sea Grant serves as the central location for distributing zebra mussel information and coordinates statewide monitoring activities. Task force activities include meetings, mailings, maintaining an inventory of monitoring sites, and conducting workshops and conferences. The task force will serve as an emergency response unit in the event of zebra mussel arrival.

Key stakeholders have kept ahead of zebra mussels through serving as members of the task force. The North Carolina Division of Water Resources credits Sea Grant with "keeping them up-to-date on new developments on the zebra mussel front." As the manager of all major water withdrawals in the state, the Division of Water Resources appreciates the usefulness of the educational materials Sea Grant has developed in cooperation with the task force. They have passed zebra mussel information on to many municipalities, private water systems, and industries that withdraw from surface waters and have also set up prominent displays in the public areas of their offices using the zebra mussel posters and cards supplied by Sea Grant.

Other states have begun to develop similar task forces. For example, North Carolina Sea Grant has assisted South Carolina Sea Grant in organizing a zebra mussel task force in their state. In addition, through participating in the National Zebra Mussel Training Initiative, organized by New York Sea Grant, North Carolina Sea Grant helped other states and regions around the country develop similar task forces under the leadership of the Cooperative Extension Service and other state and federal agencies. The training initiative provided assistance to government agencies and extension programs in land-locked states through satellite teleconferences and regional training workshops. The initiative also developed educational fact sheets and materials to provide additional guidance.

Through participating in the training initiative, North Carolina Sea Grant has educated extension specialists, resource managers, government agencies, and industry representatives on the need for state and regional task forces and how they can be used effectively to guide a zebra mussel outreach program. North Carolina Sea Grant also prepared a fact sheet on forming task forces, which includes guidelines on how to recruit, organize, and operate such a program. A thousand copies of the fact sheet were distributed through the initiative.

North Carolina Sea Grant leads a multi-state effort to halt zebra mussel dispersal.

Ken Taylor

Outreach efforts focus on protecting native mussel species.

Reaching the Public

Since 1992, North Carolina Sea Grant has produced six informational publications on zebra mussels, hoping to help North Carolinians identify the mollusk and prevent its spread through state waters. Educational brochures and posters target water quality regulators, boaters, and industry operators who depend on good water quality or who could take steps to stop the mussel's progress.

Since 1995, the Program has educated a variety of audiences about zebra mussels and other aquatic nuisance species, including industry representatives, teachers, natural resource managers, and boating organizations. Public presentations addressing biology, dispersal mechanisms, economic and ecological impacts, and efforts to prevent further spread of nuisance species were a primary mechanism for this education. Presentations on strategies for organizing zebra mussel task forces, and risk assessment of zebra mussel colonization were also conducted at national and international conferences around the country. These presentations reached more than 280 people. Many more listeners learned about zebra mussels through a 20-minute live radio talk show out of Morehead City, N.C.

In 1992, North Carolina Sea Grant banded with Sea Grant programs in the mid-Atlantic to educate target audiences throughout the region about the threat of zebra mussels. The mid-Atlantic Sea Grant group organized three workshops and developed educational materials targeted at water dependent industries, educators, regulators, natural resource managers, and researchers. North Carolina Sea Grant helped plan and organize conferences in Baltimore, MD, and Atlantic City, NJ, and together with Virginia Sea Grant hosted a regional conference that reached approximately 35 large water-users and resource managers.

Each conference hosted speakers from the Great Lakes who presented information about monitoring and controlling zebra mussels. Exhibits included vendors who design or manufacture control and monitoring equipment, or provide consultation services specific to individual monitoring and control needs. Through this regional effort, North Carolina Sea Grant developed a fact sheet that examines the possibility of a zebra mussel colonization of the mid-Atlantic region, which includes North Carolina, Virginia, New Jersey, Maryland and Delaware. The fact sheet discusses the possible routes of entry the mollusk may take and examines the characteristics of the mid-Atlantic environment that would make it a hospitable host for the prolific mussel. Approximately 5,400 copies of the fact sheet have been distributed and continue to serve as an information resource today.

Virginia

The Chesapeake Bay, fed by 48 major rivers and 100 tributaries that drain 64,000 square miles of land, is particularly vulnerable to invasion by aquatic nuisance species (ANS). Its extensive coastal and freshwater areas support valuable commercial and recreational fisheries, industry, shipping, recreational boating, and marine enterprises. These water-dependent activities, with their associated traffic from all over the world, create many opportunities for nonindigenous species to enter the Chesapeake Bay area.

There are numerous examples of ANS that have resulted in negative impacts to the Chesapeake Bay region. One of the most serious is the oyster parasite MSX (*Haplosporidium nelsoni*), which many scientists believe was introduced in the Chesapeake through an infected shipment of non-native oysters. Hydrilla (*Hydrilla verticillata)*, a rapidly spreading aquatic plant brought from Florida via the aquarium trade, clogs canals and waterways, impacting public water supplies and impeding navigation. Another invader was discovered in the lower Chesapeake Bay in 1998, the veined rapa whelk (*Rapana venosa)*. This large predatory gastropod feeds on bivalve mollusks. Native to the Sea of Japan, *Rapana* was probably transported via ballast water to the Black Sea in the 1940s where it rapidly became established. Although little is yet known about *Rapana's* impact in the Chesapeake, its heavy predation on mussel and oyster populations in the Black Sea has created much concern about the fate of the Chesapeake Bay's bivalve population.

What does the future hold for other non-native species in the Chesapeake Bay? The National Biological Invasion Shipping Study (NABISS), based at the Smithsonian Environmental Research Center (SERC), sampled foreign ballast water from more than 70 vessels arriving at Chesapeake Bay ports and found live organisms in over 90 percent of the ships. These organisms included diatoms, dinoflagellates, barnacles, clams and mussels, copepods, flatworms, polychaete worms, and juvenile fish. Although it remains to be seen which of these organisms have or will establish populations in the Bay, it is obvious that the potential exists. While some of these species may appear to be benign, many of these organisms could have delayed effects, and there are potentially many more nonindigenous species in the Bay that have not yet been identified. Other ANS proven to be harmful, such as the zebra mussel (*Dreissena polymorpha*), are not yet found in the Bay region, but the potential for their invasion in the near future is well documented. All of these factors create the need for the kind of proactive outreach and education efforts that the Virginia Sea Grant program provides.

The goal of Virginia Sea Grant outreach and education activities is to increase citizens' awareness and understanding of the issues involved in the accidental and intentional introductions of aquatic nonindigenous species in the Chesapeake Bay region and to recommend actions that can be taken to slow and prevent the introduction and establishment of these organisms. In addition to providing information for the general public and user groups such as lake managers and utilities, Virginia Sea Grant has targeted science educators and students as an audience for information and programs on aquatic nuisance species.

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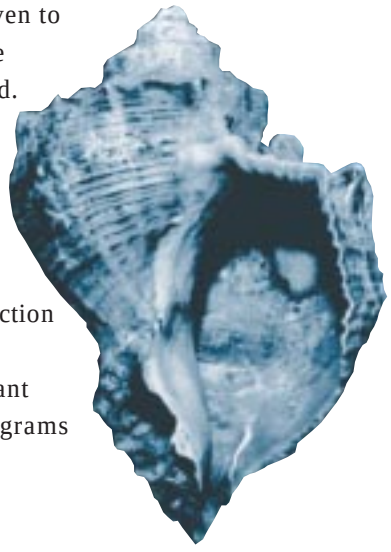
Species of Concern
Hydrilla
Rapa whelk
Zebra mussel

William & Mary VIMS Virginia Institute of Marine Science School of Marine Science



Virginia Sea Grant

Veined rapa whelk (*Rapana venosa*) shell

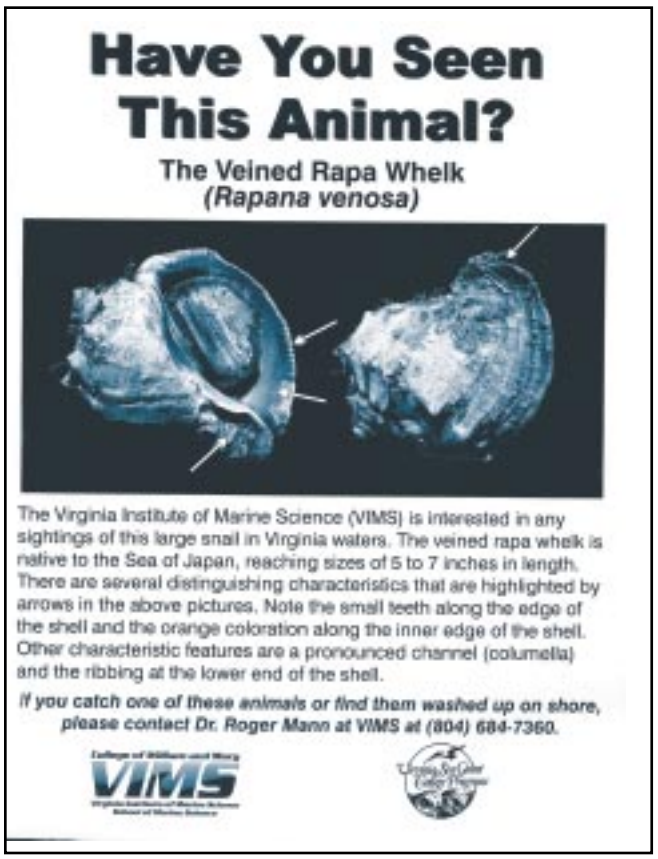
Outreach

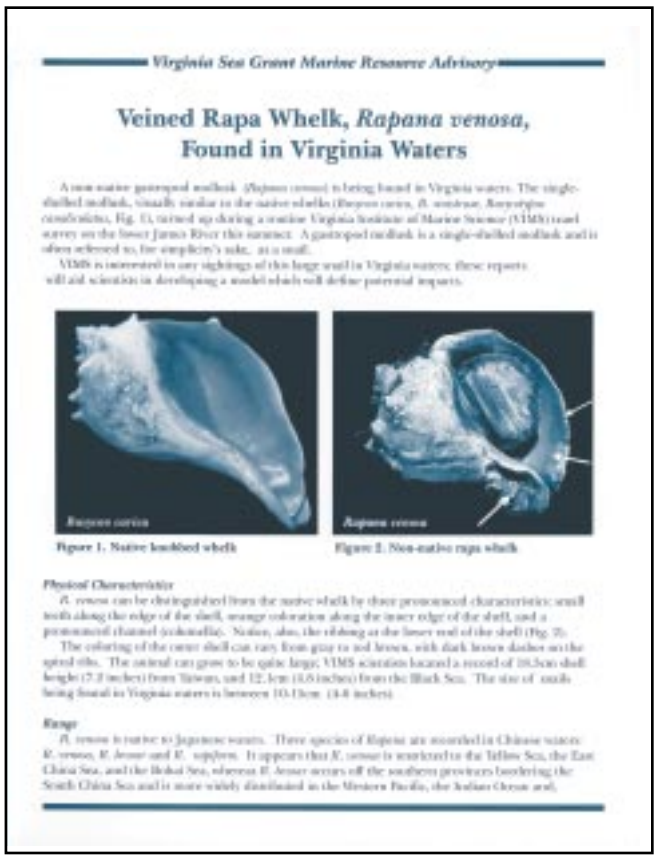
There is strong evidence that posters are increasing public awareness. The posters for the Veined Rapa Whelk helped alert the public to the need for live research specimens.

Responding to Rapana

In September 1998 soon after the initial discovery in the lower Chesapeake Bay of the veined rapa whelk, *Rapana venosa*, outreach activities were implemented in response to this invader. *Rapana* is native to the Sea of Japan and has been introduced to the Black Sea, where it is a voracious predator on mussels, oysters, and other bivalve mollusks. Its presence in the Chesapeake raised immediate concern for the Bay's already beleaguered oyster population as well as for the hard clam fishery. Because very little is known about this organism's biology and behavior in the Chesapeake, researchers at the Virginia Institute of Marine Science (VIMS) needed to quickly obtain specimens of *Rapana* for research. The most obvious source was watermen who fish the area regularly with crab pots and other gear, and who were likely to capture whelks. A fact sheet and "wanted" poster were developed by the VIMS Sea Grant Marine Advisory Program in collaboration with VIMS Molluscan Ecologists.

Thousands of fact sheets and posters were quickly distributed to docks, piers, marinas, watermen's associations, seafood dealers and processors, and the media. Response to the publications was swift, resulting in four live specimens of *Rapana* within the first week. So much interest was generated by the posters that a "*Rapana* hot line" has been established to take the calls and record information 24 hours a day. Currently, VIMS molluscan ecologists are continuing research on *Rapana* distribution, behavior, larval development and habitat use.





Science Education and Aquatic Nonindigenous Species

Nonindigenous species are mentioned very briefly, if at all, in most science textbooks. However, the topic of exotic introductions can enrich secondary-level life science and ecology programs through the study of adaptation, species competition, and biodiversity.

In 1994, educators from the Virginia Institute of Marine Science's Virginia Sea Grant Marine Advisory Program developed a teaching unit on ANS, targeting educators and students of secondary science. This program, *Invasion of an Exotic Species: Stop the Zebra Mussel*, incorporates data from a 1993 Sea Grant research project that assessed the risk for the introduction and establishment of the zebra mussel in Virginia's major bodies of water. The information is used in student-centered activities that emphasize data analysis, logical reasoning, and group collaboration.

This program continues to be in demand, and in 1998 was updated with current information on ballast water research in the Chesapeake and the recent discovery of the veined rapa whelk. Since 1995, over 1,000 middle and high school students have participated in a zebra mussel classroom lesson conducted by an educator from VIMS. In addition, 520 educators have received the teaching unit by attending workshops, after-school seminars, and conference presentations conducted by the Virginia Sea Grant educators. The teaching unit has been disseminated to an additional 380 teachers in workshops conducted by Sea Grant educators in New Jersey, Delaware, Maryland, and Alabama. In 1995, New Jersey Sea Grant educators used the Virginia activities as a model, replacing the Virginia data on water quality and shipping and boating patterns with analogous data from local New Jersey watersheds. In 1996, Virginia Sea Grant educators created an interactive web site based on the print version of the teaching unit (see ***www.vims.edu/adv/ed/zm/index.html***) that was incorporated into part of Virginia Sea Grant's Virtual Marine Education Center (***www.vims.edu/adv/ed/***).

Bill Jenkins

Juliana Harding, a scientist at the Virginia Institute of Marine Science, rinses a rapa whelk specimen collected from Chesapeake Bay in November 1998.

Since 1995, over 1,000 middle and high school students have participated in a zebra mussel classroom lesson conducted by an educator from VIMS.

Public Awareness Posters

State-wide distribution of a Sea Grant-funded zebra mussel poster, produced by the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University, has been ongoing since 1995. This large poster, which includes a color illustration of a zebra mussel and information on how to decrease the risk of its introduction in Virginia, has been distributed to hundreds of people, including marina operators, Coast Guard Auxiliary units, educators, and the public. There is strong evidence that the posters are an effective tool for increasing public awareness. For example, in March 1997, a boatyard manager at Cobb's Marina in Little Creek, near Norfolk, Virginia was washing down a large boat that had just been transported overland from Indiana. He noticed several large clumps of mussels, some still alive, in the debris that he had removed from the boat. Recognizing the mussels from the Virginia Sea Grant poster which was displayed on the marina's bait box, the manager told his wife, who reported the incident to the Sea Grant Marine Advisory Office. “It was really a miracle that he took a second to glance down and look at the mussels before he washed them into the creek,” Mrs. Cobb said. “He knew from the poster that these had to be zebra mussels.” The information was relayed to the Virginia Department of Game and Inland Fisheries office near Little Creek, and a fisheries biologist positively identified and disposed of the zebra mussels the same day.

Other calls about possible local zebra mussel sightings have been fielded by the Sea Grant Marine Advisory office, but fortunately the majority of reports are false alarms. The mussels usually turn out to be very small ribbed mussels, *Geukensia demissa*, which are common in the Chesapeake Bay area. But nearly all these calls result from the presence of a Sea Grant poster at a pier, marina, or waterfront restaurant, so the posters are doing their job.

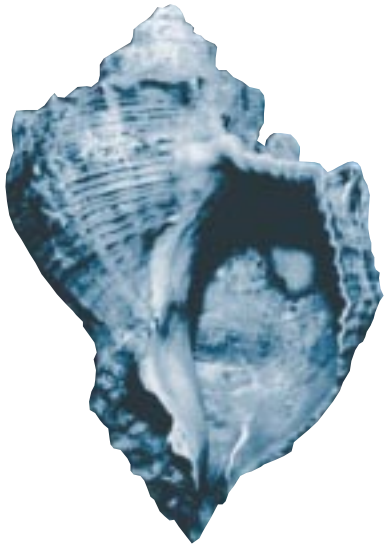
In August 1999, a Virginia Sea Grant educator and the Conservation Committee of the National Marine Educators Association (NMEA) coordinated a Symposium on Aquatic Bioinvasions for Educators: *Spreading the Word about the Spread of Exotics*. Held at the NMEA conference at the College of Charleston, over 200 educators attended presentations and viewed exhibits on aquatic invaders presented by representatives from Sea Grant, the National Estuarine Research Reserves, the North Carolina Aquariums and the Louisiana Universities Marine Consortium.

Collaborators

Virginia Sea Grant currently collaborates with three agencies in addressing aquatic nonindigenous species issues in the Chesapeake Bay area:

- The Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University partnered with the Virginia Sea Grant Marine Advisory Program from 1993 to 1995 in Sea Grant-funded outreach, education, and research on zebra mussels. Formal funding for this partnership ended in 1995, but the two programs maintain an informal network.
- The Virginia Division of Game and Inland Fisheries (VDGIF), Fisheries Division, provides support in investigating reports of zebra mussel sightings, and has disseminated thousands of the zebra mussel ID cards that were produced jointly by VDGIF and Virginia Sea Grant.
- The EPA Chesapeake Bay Program's Exotic Species Workgroup, Living Resources Subcommittee, coordinates regional information on exotic species and has developed strategies for dealing with the introduction of ANS into the Chesapeake Bay basin.

Through state-level efforts, as well as coordinated regional efforts begun in 1993 by the Mid-Atlantic Sea Grant Network (New Jersey, Delaware, Maryland, Virginia, and North Carolina), Virginia Sea Grant has helped increase the awareness of citizens in the region concerning the ANS issue. Thousands of educators, students, lake managers, boat owners, marina operators, utility operators, and others have learned how to help prevent zebra mussel invasions thanks to Sea Grant posters, publications, programs, exhibits, and classroom lessons. While the zebra mussel has not yet become established in the Chesapeake Bay region, the groundwork Sea Grant has done to prepare for it has set the stage for the effective prevention and control of other aquatic nuisance species that may pose a more immediate threat.



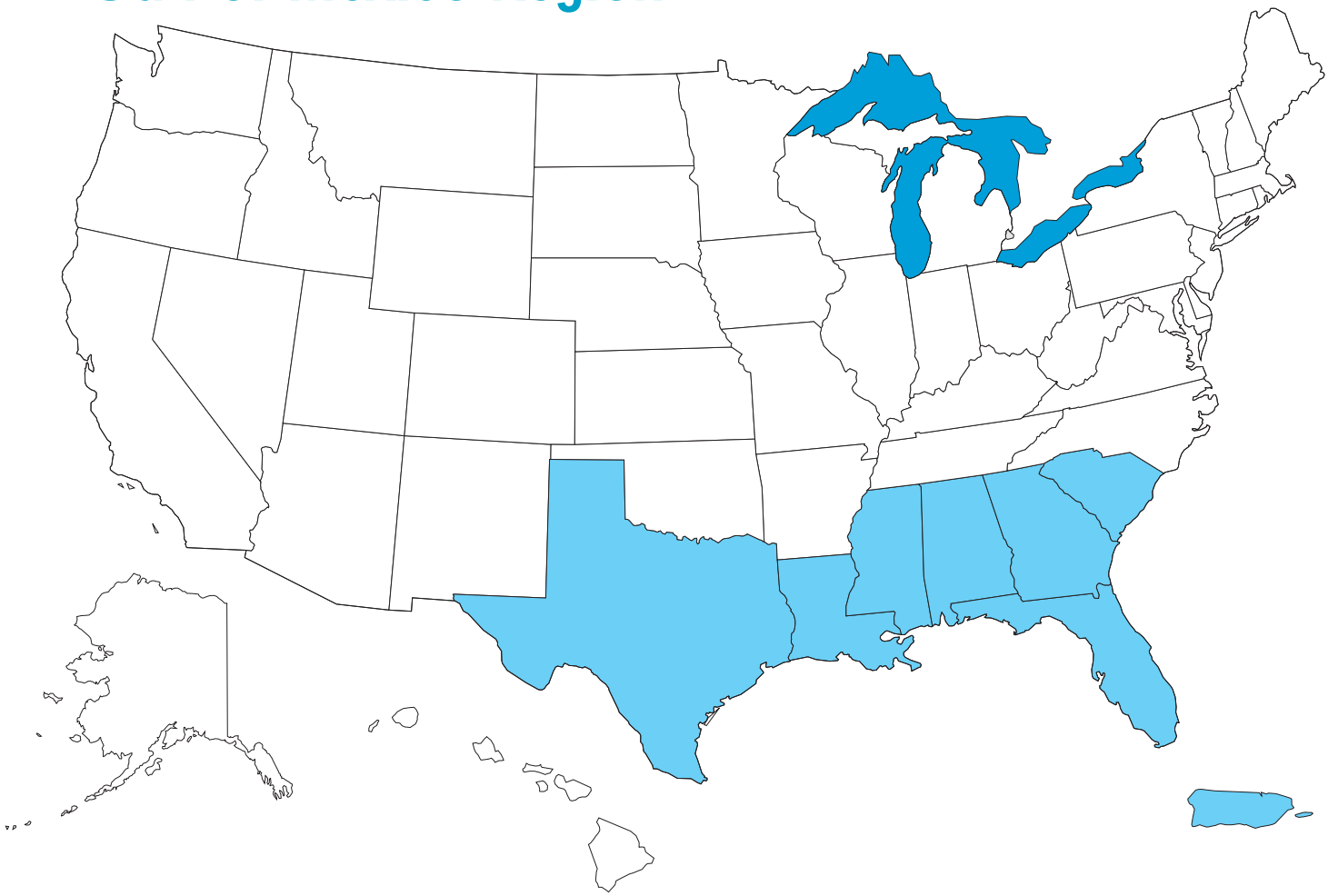
Southeastern Atlantic & Gulf of Mexico Region

Florida
Louisiana
Mississippi-Alabama
South Carolina
Texas

Sea Grant

ANS

Southeastern Atlantic & Gulf of Mexico Region



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Sea Grant

Florida

Florida is the destination of choice for 40 million tourists each year providing the state with much needed tax revenue. The state's tropical and subtropical climates lure people from the United States and around the world. It is this same warm climate that makes Florida's environment a safe haven for many aquatic nuisance species. To date, 61 non-native aquatic species have established permanent populations in Florida. These non-native species have been transported into Florida via air, sea, and land routes.

Florida's geographical location makes it a gateway into the United States for many importers. Businesses such as the tropical fish and aquarium plant industries contribute to the over $5 billion dollars of imported commodities that come into the state each year. These groups have been either directly or indirectly responsible for the introduction of several aquatic nuisance species.

Additionally, over 400,000 recreational boaters trailer their boats into Florida each year, adding millions of taxable dollars to the economy. However, there is always the potential for transporting an aquatic nuisance species (ANS) into Florida. One must remember that importing a non-native species is not the same thing as introducing a non-native species into the environment. Each year, hundreds of non-native plants, animals and fish species are imported into Florida without any negative repercussions. Introducing a non-native species, whether intentionally or unintentionally, can have long-term negative effects on the state's native habitats. When ANS become established outside their natural habitat, they are almost impossible to control or eradicate. The ANS compete with the native species for habitat and food, transmit parasites or diseases, and they have been known to adapt by hybridizing with native species. Once established, ANS plants and animals can decrease native habitat diversity and degrade water quality.

Melaleuca trees *(Melaleuca quinquenervia)* were intentionally introduced into the southern part of Florida specifically to help dry up the swampy Everglades. The introduction was so successful that the melaleucas have virtually eliminated all other vegetation in areas where they have become established. Melaleuca grows in terrestrial as well as in completely aquatic situations. The Everglades, the mostly treeless "river of grass," has become in some places the "river of trees" — a completely alien habitat to the plants and animals that have evolved to live in the glades. During the 60 years since its introduction into the state, melaleuca has taken over hundreds of thousands of acres of Everglades, threatening the very existence of this internationally known eco-treasure.

The walking catfish *(Clarias batrachus)* was unintentionally introduced into Florida's environment during the 1960s either as an escapee from a brood fish farm or during transportation of the stock. The species is capable of overland migrations that normally take place at night or during periods of rain. Walking catfish are opportunistic feeders and compete with native fishes if the food supply is limited.

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Species of Concern
Zebra mussel

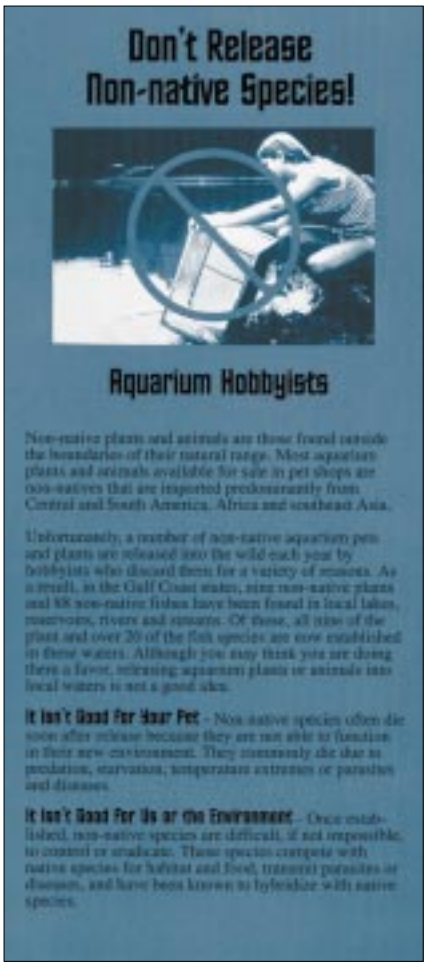
Research

Some water bodies in Florida have characteristics that are suitable for zebra mussel inhabitation.

Since its introduction into North America via ballast waters of oceangoing vessels, the zebra mussel (*Dreissena polymorpha*) has traveled from the Great Lake states all the way down the Mississippi to New Orleans. The total prevention and control costs for these mussels has exceeded the $5 billion mark in the Great Lakes region alone.

A 1997 Florida Sea Grant funded research project identified Florida waterways that could be susceptible to zebra mussel infestation. Habitat suitability indices (HSI) were defined for each parameter: temperature, pH, calcium content, dissolved oxygen, salinity, transparency, and substratum. The overall suitability of Florida waters for zebra mussel success was shown to be relatively low. However, the study made no assumption regarding the capacity of zebra mussels to acclimate or adapt to Florida's environmental conditions. It was believed at one time that the zebra mussel could not exist outside of the cooler waters of the Great Lakes.

The research indicated that some water bodies in Florida contained suitable water quality to provide an acceptable environment for the zebra mussel. The Big Bend region, the St. Johns River system, and water bodies north of Lake Okeechobee all have characteristics that are suitable for zebra mussel inhabitation and are popular destinations for boating and fishing.



Outreach

Aquarium Hobbyists

Regardless of whether the introduction is intentional or unintentional, if an ANS becomes established, it will in all probability have a negative effect on its new environment. Due to the prolific amount of non-native species that pass through the state each year, it is important to educate residents and tourists on appropriate ways to handle them. A potential source of introduction comes from aquarium hobbyists. Aquariums are typically filled with exotic fish, reptiles and plants. The contents of these tanks are frequently dumped into nearby water bodies and even ditches. The owners believe they are doing their pets a favor, but they are not. As part of a Gulf of Mexico Sea Grant outreach project, the Florida Sea Grant Extension Program designed a colorful brochure to inform and educate the hobbyists about the possible consequences of dumping the contents of their aquariums into local waters. The take away message is that there are alternative methods for disposing of these non-natives. For instance:

- return the animal to the store where it was purchased — stores may give in-store credit;
- donate them to another hobbyist, an office, or school;
- advertise to give them away for free;
- euthanize the animal (fish, reptile or amphibian) by simply placing it in a bowl of water and then putting it into the freezer (cold temperatures are a natural anesthetic and this is considered a humane method of euthanasia); and
- leave plants in the sun to dry and then use in yard as mulch or compost.

This brochure has been distributed to the Gulf of Mexico Sea Grant Programs, U.S. Fish and Wildlife Services, Federation of American Aquarium Societies, 67 Cooperative Extension Service offices in Florida, and to various aquarium hobbyist newsletter editors. The information is also available on the Florida Sea Grant web site at: ***www.flseagrant.org/exotics.htm***.

Zebra Mussel Prevention

The Florida Sea Grant Extension Program has also designed a proactive program to address the issue of zebra mussels being transported into Florida. The most likely method of introduction seems to be via boats being trailered into Florida. If these boats have been in zebra mussel infested waters within four days of being launched in one of Florida's water bodies, there is a very real chance that these mussels could spread and become the next notorious aquatic nuisance species for Florida.

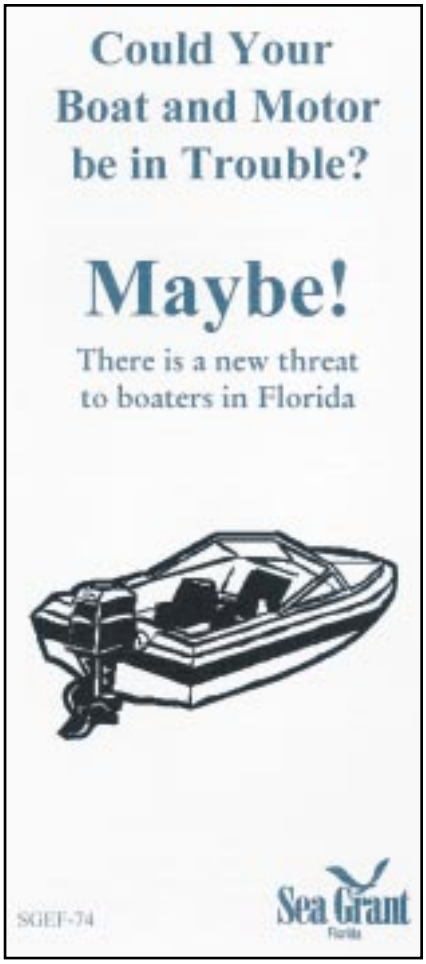
While it is difficult to promote awareness of a non-event, Florida Sea Grant has designed an outreach campaign to inform and educate tourists and residents about the potential impact to Florida's environment if the zebra mussel is introduced into Florida's waters. To date, two low-power radios have been installed just inside Florida's border on I-95 (1610 am) and I-75 (1300 am). Both radios broadcast a brief segment targeting both tourists and residents returning to Florida who are trailering their boats and who may have recently had their boats in zebra mussel invested waters. The drivers are advised to stop at the Welcome Stations to pick up a brochure with more information.

Both Welcome Stations stock a supply of the Florida Sea Grant produced brochure *Could Your Boat and Motor be in Trouble? Maybe!* This 4-page brochure briefly explains the damage that can be done to boats and the potential damage that could be done to the environment if this ANS is introduced into Florida's waterways. The brochure also contains simple how-to steps to protect both recreational boats and the environment. Florida Sea Grant also produced a zebra mussel identification card. The card contains information on how to identify them, what you should do if you find one, whom to contact, preventative steps, and the possible effects to Florida's water bodies should these mussels become established.

Florida Sea Grant Extension also produced a zebra mussel fact sheet (*Zebra Mussels – A Florida Perspective*) in conjunction with the U. S. Geological Survey Nonindigenous Aquatic Species Program where the national database for nonindigenous aquatic species is located. It is this working relationship that led to the information that zebra mussels had been intentionally brought to Florida in a container. These mussels were immediately confiscated and destroyed with no ill exposure to Florida's environment.

Florida Sea Grant's research and outreach efforts are designed to inform Florida's residents and tourists about the consequences of introducing non-native species into the state's waterways and environment. These efforts advocate a proactive approach to eliminating further introductions of aquatic nuisance species into the state's water bodies.

Regardless of whether the introduction is intentional or unintentional, if an ANS becomes established, it will in all probability have a negative effect on its new environment.



Florida Sea Grant outreach programs advocate a proactive approach to eliminating further introductions of aquatic nuisance species.

Louisiana

Historically, a variety of plant and animal nonindigenous aquatic nuisance species (ANS) have negatively impacted Louisiana, and Louisiana Sea Grant has sponsored research and outreach to reduce such impacts. For example, in the 1980s when the numbers of voracious nutria (*Myocastor coypu*) in Louisiana reached levels that seriously threatened coastal estuarine and marsh habitats (areas vital for the nurturing and growth of commercial and recreational species of fish), Louisiana Sea Grant sponsored research projects to study the animal's life cycle and the planting of selected grasses and other methods to reduce their numbers and impacts.

Louisiana's ecology and economy are especially vulnerable to the introduction of ANS because the state is dominated by water — the Mississippi River, coastal marshes, and many fresh and brackish bayous. In fact, about 40 percent of the nation‘s coastal wetlands are in Louisiana and a large proportion of its people work and play in the aquatic environment.

In the 1990s, when Louisiana Sea Grant realized that some state industries or freshwater lakes might be affected by a zebra mussel invasion advancing down the Mississippi River from the Great Lakes, it partially funded some basic physiological research on the zebra mussel (*Dreissena polymorpha*), while initiating outreach efforts to introduce the species to groups that may have to cope with an invasion. Initially, this ANS was a threat to industry rather than the environment and the initial proactive effort, conducted in conjunction with the National Sea Grant Zebra Mussel Initiative led by New York Sea Grant, was successful in preventing any zebra mussel-caused shutdowns or other industrial catastrophes. In subsequent years, as the zebra mussel spread to Louisiana and settled in the major river systems, Louisiana Sea Grant has taken steps to reduce a broad range of impacts.

By 1999, the state of Louisiana began to actively control ANS plants such as hydrilla (*Hydrilla verticillata*) and water hyacinth (*Eichhornia crassipes*) in popular recreational waters, and introduced some monitoring for nonindigenous species on a number of lakes and bayous. Local associations and businesses also became interested and as a result, an early infestation of giant salvinia (*Salvinia molesta*) was isolated at Toledo Bend Reservoir on the state’s western border. Because this plant is believed to be popular among water gardeners, the Louisiana Department of Wildlife and Fisheries immediately began asking water garden plant suppliers to stop marketing the plant.

In 1998, a new ANS was discovered in the drainage canals in New Orleans — the Rio Grande cichlid (*Cichlasoma cyanoguttatum*). It was outcompeting native fishes and depleting grass beds along the south shore of Lake Pontchartrain. The Rio Grande cichlid is believed to be the result of dumping by an aquarium hobbyist. This ANS is currently controlled by local recreational fishers who claim that it is “good eating.”

In response to these new ANS invasions, Louisiana Sea Grant began to use its teacher-education program to heighten ANS awareness among the general population and to encourage habits that control these species. Fliers on this topic for aquatic hobbyists, produced in cooperation with the Sea Grant programs in the Gulf of Mexico region, have been widely distributed. Presentations have also been made at water garden societies to further encourage public involvement in ANS control. At the turn of the century, giant salvinia appears to be infesting only Toledo Bend Reservoir in Louisiana and the Rio Grande cichlid appears to be confined to the New Orleans area.

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Species of Concern
Giant salvinia
Hydrilla
Nutria
Rio Grande cichlid
Water hyacinth
Zebra mussel

Research and Outreach

Louisiana's ecology and economy are especially vulnerable to the introduction of ANS because the state is dominated by water — the Mississippi River, coastal marshes and many fresh and brackish bayous.

From 1993 to 1997, Louisiana Sea Grant sponsored and participated in numerous workshops, conferences, and other outreach projects designed to stimulate monitoring and awareness among the users of surface water such as municipal utilities, the aquaculture industry, and navigation interests. The program provided seed money that led to research conducted in Louisiana State University's Department of Biological Sciences on zebra mussel physiology, feeding habits, and reproduction in rivers as well as other aquatic environments. In 1995, the program combined outreach and research to gather data while teaching monitoring protocol and control processes to personnel in 10 power plants owned by Entergy Inc. in Louisiana, Mississippi, and Arkansas. The research goal was to understand the zebra mussel's viability in the southern riverine environment. This project resulted in developing a simplified monitoring protocol, *Sampling for Zebra Mussels in Industrial Facilities*, that has been distributed throughout the country.

Louisiana Sea Grant, Louisiana State University's Coastal Fisheries Institute, and the U.S. Army Corps of Engineers supported ecological research on zebra mussels, comparing their growth and living conditions in the upper and lower Mississippi River. Besides increasing the understanding of the zebra mussel in the riverine environment, this research provided data to help the towing industry address problems caused by zebra mussel fouling in towboats' raw water intakes.

The zebra mussel taught Louisiana Sea Grant that an aquatic nuisance species can be dispersed by the same people that it impacts. Recreational boaters and aquaculturists were the targets of the program's nonindigenous efforts between 1995 to 1997 when Louisiana Sea Grant joined with the Alabama and Mississippi Sea Grant Extension programs to publish audience-specific brochures such as *Keep Our Waters Free of Zebra Mussels* for recreational boaters, and a series of aquaculture species-specific critical control point brochures for aquaculturists. In 1999 Louisiana Sea Grant produced a waterproof poster to remind recreational boaters and anglers about ANS. *Protect Your Boat and Louisiana's Waters* is posted at all public and many private boat landings throughout the state. These materials have also been shared with Sea Grant Programs across the country.

Beginning in 1998, Louisiana Sea Grant placed increased emphasis on potential dispersal of ANS through inland navigation and contact with transoceanic vessels in the state's ports. Louisiana State University's Coastal Fisheries Institute studied the effects of zebra mussels on towboats and barges using the inland waterways. As part of the project, the researchers taught operators, maintenance foremen, and ship repair personnel that they can affect the environment by the type of control or treatment used on ANS infesting their raw water intake systems. A supporting fact sheet was developed and distributed for use throughout the eastern inland river system entitled *Zebra Mussels in Commercial Vessels on Inland Waterways*.

In conjunction with direction from the National ANS Task Force and the President's Nonindigenous Council, Louisiana Sea Grant has begun a cooperative effort to consolidate all databases and lists of Louisiana species to be used as a management baseline. This will be turned over to the state agency charged with ANS management in the future.

The leaders of Louisiana Sea Grant realize that the types of aquatic nuisance species that will impact the state in future years may change, but the issues related to why aquatic nuisance species are a problem do not change. People need to clearly understand that any ANS has unique potential to wreak havoc because of its adaptability and prolific reproduction capability. In addition, people have unique potential to control this havoc if they are conscious of deliberate and accidental ANS introductions.

Louisiana Sea Grant College Program

Zebra mussels have become a foulant for inland navigation by settling in towboat sea chests and keel coolers.

Gulf-Wide Projects

Since 1997, Louisiana Sea Grant has led Gulf-wide outreach projects to foster a general understanding of ANS concepts in partnership with the Alabama Sea Grant Extension, Mississippi Sea Grant Extension, the Florida Sea Grant College Program, and the Texas Sea Grant College Program. Although this group initiative focuses on selected target audiences — surface water using industries and utilities, aquaculture, recreational boaters, inland and transoceanic navigation, and those state government agencies that may have some responsibility associated with aquatic nuisance species — each of the partnering Sea Grant programs has taken the lead with one or more of these groups. Besides coordinating the effort of all of the regional partners, Louisiana Sea Grant is responsible for the surface water using industry / utility audience and the navigation audience.

With the surface water using industries and utilities, Louisiana Sea Grant has used workshop presentations and news releases to remind people of the on-going nature of the problems associated with aquatic nuisance species, and the industrial practices necessary to keep impacts at a minimum: know your company's aquatic environment and ecosystems, identify all unknown species in your system, try to confine deliberate introductions to native species, and control ANS in an ecologically-safe manner. In partnership with the Tennessee Valley Authority and the U.S. Fish and Wildlife Service, Louisiana Sea Grant publishes a national *Zebra Mussel Newsletter* concentrating on these topics and the program has contributed ideas to a series of ANS public service announcements being developed by Mississippi Sea Grant Extension as well.

Transoceanic navigation has been identified by the U.S. Coast Guard and the International Maritime Organization (IMO) as a possible dispenser of ANS during ballast exchange. After researchers determined that an open-ocean ballast water exchange by transoceanic shipping will kill freshwater ANS that may be living in the vessel's ballast, both the U.S. Coast Guard and the IMO have recommended the exchange for all transoceanic shipping before entering ports or coastal waters. In cooperation with some members of the Gulf of Mexico region shipping community, Louisiana Sea Grant published a paper for ports and shippers called *Assessing the Potential for Introduction of Nonindigenous Species through U.S. Gulf of Mexico Ports.* It encourages compliance with Coast Guard mandates and guidelines for open ocean ballast exchange and provides the shipping community with a method for assessing their vulnerability to new ANS introductions through ballast water. To better understand and approach the question of ANS dispersal in ballast water, the Gulf of Mexico Sea Grant programs have participated in three EPA Gulf of Mexico Program workshops for the shipping community on this topic during 1999-2000.

ANS outreach should consistently promote interest in native species, knowledge and appreciation of local ecosystems, and practices that result in the sustainability of all resources.

Louisiana Sea Grant College Program

Aquatic nuisance species research and outreach endeavors are affected by the intersection of the Mississippi River System with the Gulf of Mexico.

People need to clearly understand that any ANS has the potential to wreak havoc because of its adaptability and prolific capability, but people have the potential to control this by awareness of ANS introductions.

Lloyd Lemmerman

Zebra mussels *(Dreissena polymorpha)* on a native clam.

Other Collaborative Efforts

In support of the Gulf of Mexico Sea Grant partners' efforts, Louisiana Sea Grant has distributed brochures about accidental dispersal of ANS to aquarium and water garden hobbyists and retailers, recreational boaters and anglers, and coordinated a workshop in 1999 for state government officials on developing an ANS regional management plan. Program personnel have also appeared on a local radio program for anglers in order to discourage deliberate introductions and accidental transfer of ANS larvae or plants in bait buckets or on recreational boats and trailers.

Finally, Louisiana Sea Grant has participated in planning and implementing many workshops and conferences on ANS regionally and nationally. The most recent conference was *Aquatic Nuisance Species: A Focus on the Southeast* held in Charleston, S.C. in 1999. It was designed to give all southeast coast target audiences a broad understanding of the ANS situation in their states. Sea Grant staff from the Gulf programs have presented papers on outreach techniques at the 1996 and 1998 *International Zebra Mussel and other Aquatic Nuisance Species* conferences in Michigan and California respectively, sharing outreach experiences and ideas with other groups with similar goals. Louisiana Sea Grant served as a Gulf representative on the National ANS Task Force's Ballast Water Program Effectiveness and Adequacy Criteria Committee during 1998-99.

While Sea Grant research and outreach in the Gulf of Mexico Region must continue to focus on aquatic nuisance species, especially as the world becomes smaller and species transfers become more frequent, Louisiana Sea Grant has added a positive outreach approach. To reduce the impacts of ANS, Louisiana Sea Grant tries to consistently promote interest in native species, knowledge and appreciation of local ecosystems, and practices that result in the sustainability of all resources.

Mississippi-Alabama

The Mississippi-Alabama Sea Grant Consortium began coordinating research and Extension activities addressing issues related to zebra mussels, and other aquatic nuisance species, in the early 1990s. The two states are home to significant commercial navigational routes, numerous industrial surface water users, the largest aquaculture industry in the United States, millions of acres of fishable waters, and one of the richest native freshwater areas in North America — all of which might be impacted by nonindigenous species. The Great Lakes region's experience with zebra mussels and the sudden spread of mussels down the Mississippi River made it clear that basic education and research programs were needed to inform the public and policy makers about the problems posed by zebra mussels and other non-native species. Initial education programs evolved into a partnership with Louisiana Sea Grant to use common resources to address problems specific to the three states. This partnership then expanded to include all five Gulf of Mexico Sea Grant programs, with each state producing products that focus on particular issues and sharing these products within the region.

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Species of Concern
Zebra mussel

Research and Outreach

Cooperative support for these projects have been provided by the following groups:

- U.S. Army Corps of Engineers
- Tennessee Valley Authority
- Alabama Power Company
- United States Coast Guard
- Mississippi Cooperative Extension Service
- Alabama Cooperative Extension System
- Texas, Louisiana and Florida Sea Grant Programs
- Weiss Lake Improvement Association
- Auburn University, Department of Fisheries and Allied Aquacultures
- Mobile County Public Schools
- Baldwin County Public Schools
- Alabama 4-H Center
- Alabama Department of Conservation and Natural Resources
- Cahaba River Basin Initiative

Richard Wallace

A boater properly cleans the propeller to prevent the spread of ANS.

Research was undertaken to assess the potential impact of zebra mussels (*Dreissena polymorpha*) on the aquaculture industry and the potential for aquaculture to spread zebra mussels to public and private waters. The spread of zebra mussels into or out of culture facilities can be prevented to some extent by employing practices already in place to prevent the spread of disease. Culture facilities would be impacted similarly to other surface water users, but many of the chemicals used to control zebra mussels would not be suitable. Some treatments commonly used in aquaculture may be effective. Other research addressed the potential spread of zebra mussels to uninfested waters. Factors that may limit the spread of the zebra mussels in southern waters are uncertain. The study focused on establishing water quality parameters relative to the survival of zebra mussels and assessed the risk of spread to water bodies not directly connected by commercial navigation. Of particular interest was the identification of a popular fishing lake as being particularly vulnerable to zebra mussel establishment.

Outreach activities in the two-state consortium are conducted by the Sea Grant Extension Programs in each state with close cooperation in areas of mutual interests. Projects include:

- a multi-faceted effort to inform the aquaculture industry of the specific perils posed by zebra mussels based on research findings;
- a newsletter aimed at agencies and industries to keep them informed on the spread of zebra mussels in the south and on other nonindigenous species issues;
- a project to educate boaters on their potential role in spreading nonindigenous species;
- an education effort aimed at children through the public schools and 4-H;
- an initiative to involve marina owners and property owners at a lake identified by researchers as having a high probability of zebra mussel introduction and survival;
- production and dissemination of materials aimed at informing water gardeners on how to properly dispose of plants and animals which are being used throughout the Gulf region;
- creation of a Gulf of Mexico Aquatic Nuisance Species Media Directory, a series of public service announcements for use Gulf-wide and an aquatic nuisance species web site (***www.msstate.edu/dept/crec/ans.html***); and
- production and distribution of an aquatic nuisance species educational curriculum for Extension 4-H Youth Agents throughout the Gulf region.

Research efforts have identified the potential impacts of zebra mussels on the aquaculture industry, preventative measures, and solutions to aquaculture activities becoming a vector of zebra mussels. Researchers have also characterized state waters relative to their ability to support zebra mussel populations and began developing risk assessment for specific water bodies. In one case, researchers were able to do a more in-depth assessment for the Mobile Water and Sewer Board which resulted in a science-based management plan.

Just a few years ago, citizens, managers and policy makers in Mississippi and Alabama knew little about the threats posed by zebra mussels and other nonindigenous species. Outreach programs using a variety of materials and methods have raised the public's general awareness of the problem and provided useful information on preventing further spread of exotic species. More specifically, over 4,000 school children were provided information on zebra mussels; zebra mussel posters and identification cards were distributed to 23 state-managed lakes as well as to selected marinas, locks and public boat launches; ten articles on zebra mussels were published in aquaculture trade magazines; information on several aspects of nonindigenous species were provided to over 100 county agents resulting in state-wide coverage in both states; and over 2,000 property owners and visitors were reached through directed mailings in cooperation with a lake association and marina.

South Carolina

The natural features of South Carolina are diverse and striking — and provide a potential "welcome mat" for the permanent residence of the zebra mussel (*Dreissena polymorpha).* Five main estuaries drain major watersheds originating from as far away as western North Carolina. There are approximately 750,000 acres of estuaries, which comprise almost 10 percent of the southeast U.S. coast's estuarine system. When these freshwater inland rivers meet the coastal plain, they mix with ocean water to form brackish water estuaries and tidal mouths. The environmental variations invite a wide assortment of both fresh water and marine aquatic nuisance species to make their homes here. Significant portions of these estuarine waters have salinities of less than 10 parts per thousand, the presumed tolerance range for the zebra mussel.

In addition to estuarine waters, South Carolina has about 750,000 surface areas of freshwater, some 1,617 lakes (greater than 10 acres), over 50,000 farm ponds, and over 11,000 miles of rivers and creeks. Zebra mussels and other aquatic nuisance species pose huge economic and ecological threats. More than 450 industries, public water suppliers, power generator facilities, agricultural operations, and golf courses withdraw more than 5 billion gallons of water per day from the state's rivers, lakes, and reservoirs.

South Carolina's water resources also support an abundance of flora and fauna. Nearly one-quarter of the state is classified as wetlands, which provide critical habitat for a number of threatened and endangered species of fish, shellfish, birds, and mammals. The great diversity of wildlife inhabiting the state's coastal region includes notable populations of striped bass, sturgeon, bald eagles, ospreys, alligators, and wood storks.

The Port of Charleston is ranked as the second largest container port of the East and Gulf coasts, the largest on the Gulf and Southeast coasts, fourth in the nation, and thirteenth in the world. There have been numerous opportunities for aquatic aliens to enter estuaries through ship ballast water.

Surface waters support an active sportfishery in South Carolina. More than one million anglers participate with a total economic impact of over $398 million annually. Many of the lakes in South Carolina are home to a host of fishing tournaments which attract anglers from throughout the country; hooking a prize striped bass from the Santee-Cooper Lakes system is on the mind many of them. Anglers trailer their boats into the state; those from states that have already established zebra mussel populations represent a likely source of a zebra mussel invasion into South Carolina. In 1997, $14.4 billion was expended for recreation and tourism statewide, attesting to the fact that there is a great influx of visitors to the state.

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South Carolina

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Species of Concern
Giant salvinia
Zebra mussel

South Carolina Sea Grant

A South Carolina estuary.

Outreach

South Carolina has been more fortunate than other states when it comes to invasive species. But the potential exists to have more problems as interaction between regions and nations increases.

Because of the many potential avenues for invasion by the zebra mussel, and its continued spread throughout many other states, the South Carolina Sea Grant Consortium began a South Carolina Zebra Outreach Program in 1993. In May of that year, the South Carolina Sea Grant Consortium and the then South Carolina Water Resources Commission, established the South Carolina Zebra Mussel Task Force. The task force was charged with the primary duties of implementing an integrated and collaborative monitoring, public awareness, and education program to prepare government, academia, and industry for a zebra mussel invasion.

The South Carolina Zebra Mussel Task Force is composed of representatives from key federal and state agencies, municipalities, and utility companies. Through meetings, workshops, and other forms of communication, the task force has worked to develop a statewide management strategy for a zebra mussel infestation. It reviews and disseminates up-to-date information generated nationwide on zebra mussel distribution, ecology, impacts, and control strategies.

Other task force activities have included the identification of vulnerable freshwater resources based on key parameters such as salinity, calcium, pH, and water temperature, and the development of a zebra mussel/water monitoring program. More than 20,000 zebra mussel identification cards have been distributed. Throughout the state, 250 zebra mussel warning signs were posted at boat landings. The Spring 1997 issue of the South Carolina Sea Grant Consortium's *Coastal Heritage* was dedicated to exotic species, in particular, the zebra mussel.

Rhandy Helton

Giant salvinia (*Salvinia molesta*)

South Carolina has been more fortunate than other states, so far, in not having a problem with zebra mussels. The task force has drawn upon the experience, research, and information of specialists from other states that have been invaded by the zebra mussel. New York Sea Grant Extension program experts visited South Carolina, providing lectures and seminars on zebra mussel identification, monitoring strategies, and control methods for state resource managers, public and private utility operators, and university scientists.

Near-term plans include development of a public education package for distribution through the 46 county Cooperative Extension Service offices, marina owners and operators, and state welcome centers. A risk assessment project may be commissioned in the future.

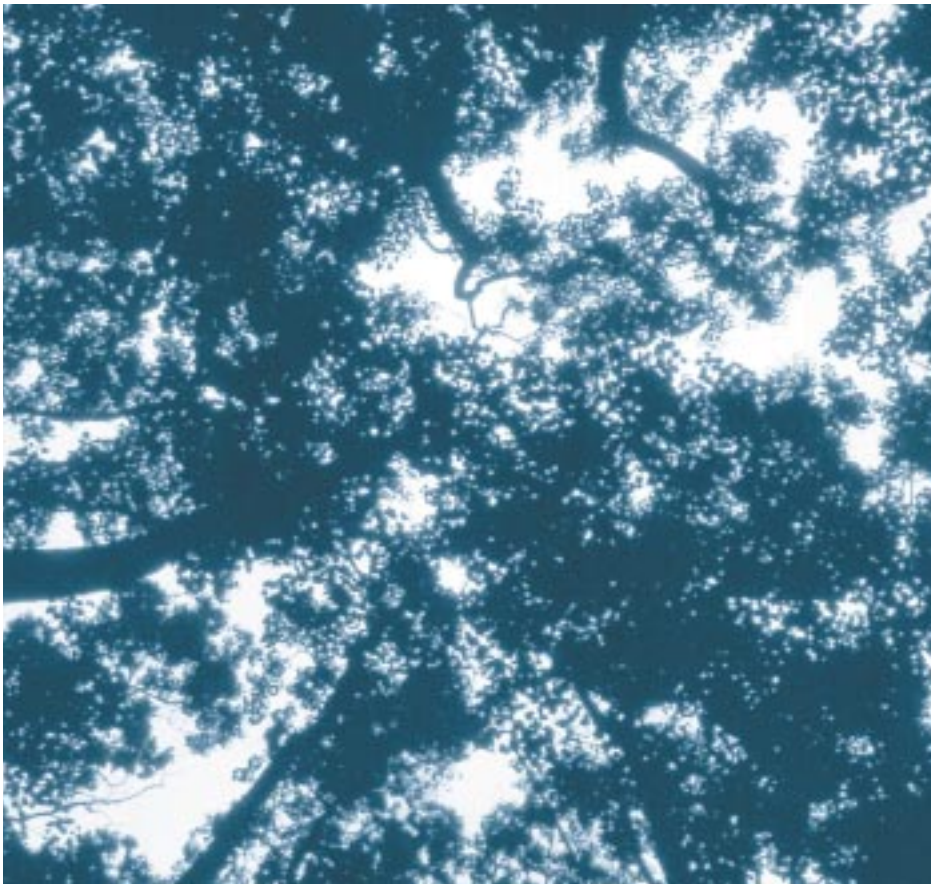
In the early years of the South Carolina Zebra Mussel Task Force, meetings were held several times a year. Since then, however, the task force meets annually. The September 1998 meeting featured guest speakers from North Carolina Sea Grant Extension and Louisiana State University. Their presentations on risk assessment suggested that South Carolina waters generally are of low risk potential, primarily due to the low natural concentrations of one of the zebra mussel's limiting factors — calcium. Nevertheless, the South Carolina Zebra Mussel Task Force will continue to remain intact to ensure that the state is prepared for a zebra mussel outbreak.

South Carolina Sea Grant, along with the Louisiana and North Carolina Sea Grant programs and other key agencies, sponsored the *Aquatic Nuisance Species: A Focus on the Southeast Conference*. This conference, held in Charleston in October 1999, was the first of its kind in the Southeast Atlantic Region. It was designed to help scientists, policy makers, and industrial leaders develop a balanced understanding of aquatic nuisance species, their potential impacts, and methods for their control.

In the meantime, the problem of alien weeds continues to grow in South Carolina as landowners plant exotic plants for aquatic landscaping, affecting fish habitat, flow of irrigation water, and boating access. The state recently fought off an outbreak of giant salvinia (*Salvinia molesta*), an aquatic weed native to Brazil that has spread rapidly in Louisiana and Texas, creating dense floating mats and crowding out native plants. There have been problems with other noxious weeds, as well. According to South Carolina Sea Grant aquatic specialists, the state is seeing more problems with aquatic nuisance species because there are greater interactions among regions and nations, with people and goods moving throughout the world.

Texas

The Texas Sea Grant College Program is an active participant in the Gulf regional outreach project, *Gulf of Mexico Region Project Relative to Invasions of Zebra Mussels and Other Nonindigenous Nuisance Species.* Introductions of aquatic nuisance species (ANS) are increasing in frequency as well as in the extent of damage they cause to both the environment and the economy. Zoogeographics suggest that the five Gulf of Mexico Sea Grant programs are part of the most naturally hospitable portion of the continent for introduced species. This area is especially vulnerable to ANS because of the natural dispersal factors, mild climates, significant aquaculture operations, recreational cross-state boating, shipping activities, and the Gulf Intracoastal Waterway. All five programs share a number of aquatic nuisance species such as nutria (*Myocastor coypu*), grass carp (*Ctenopharyngodon idella*), water hyacinth (*Eichhornia crassipes*), and hydrilla (*Hydrilla verticillata*).



Jim Hiney

The canopy formed by fast growing Chinese tallow *(Sapium sebiferum*) competes with native species.

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Species of Concern
Chinese tallow
Giant salvinia
Grass carp
Hydrilla
Nutria
Water hyacinth

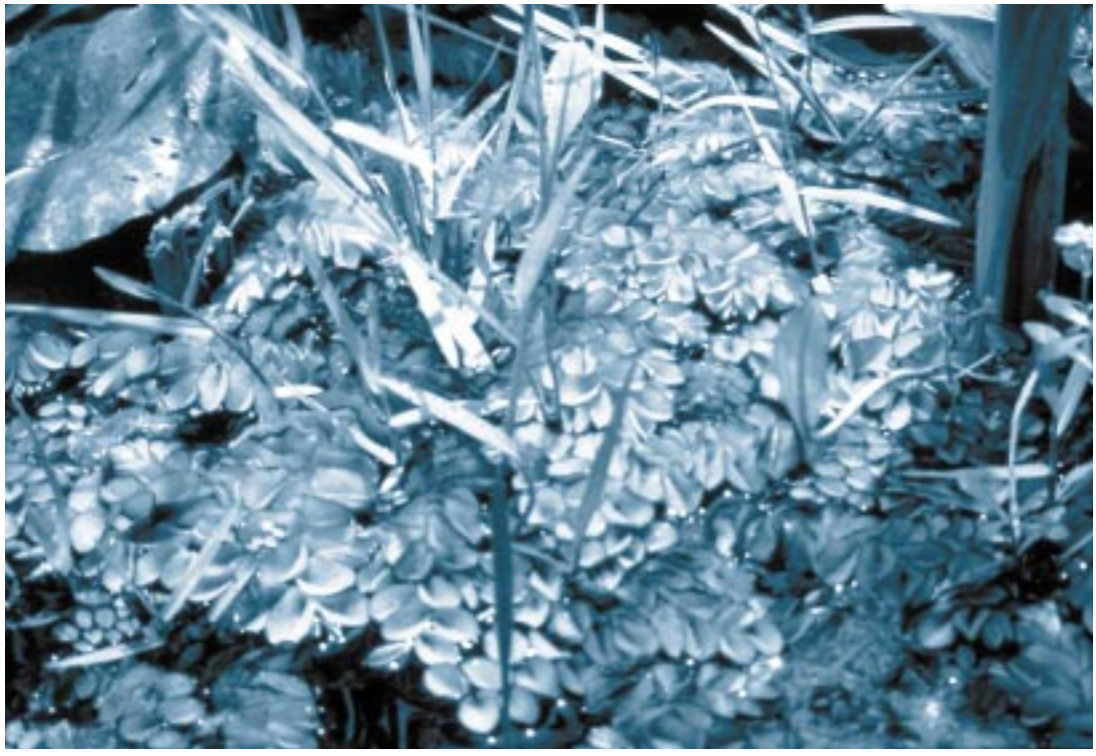
Outreach

Texas directs warnings about aquatic plants to a national audience.

The Texas Marine Advisory Service and the Marine Information Service, the outreach component of the Texas Sea Grant College Program, concentrate their efforts on increasing the public's general awareness of the overall ANS problem as well as on introductions of shrimp viruses frequently associated with aquaculture. Outreach began with an *Aquatic Nonindigenous Species Workshop* for Gulf-wide participants. More than 500 copies of a subsequent conference report have distributed throughout the Gulf region. Also, a recent issue of Sea Grant's quarterly magazine *Texas Shores* entitled *Corporate Raiders of Nature* focused on those nonindigenous species commonly found in the state, including aquatic nuisance species such as Chinese tallow (*Sapium sebiferum*) and hydrilla. Approximately 6,000 copies of *Texas Shores* are circulated in the state and region.

The Texas program has distributed more than 2,000 fliers *Don't Release Non-Native Species* targeting aquarium hobbyists and water gardeners, and will reprint 10,000 fliers on giant salvinia (*Salvinia molesta*) — a prohibited nuisance aquatic fern — in partnership with the U.S. Geological Survey, Texas Parks and Wildlife Department, and the U.S. Fish and Wildlife Service. The flier is now being revised to broaden its usefulness and will be distributed nationwide.

In Texas, state and federal agencies have a continuing concern about the use of non-native shrimp in coastal aquaculture operations and the frequent occurrence of exotic shrimp. Texas Sea Grant personnel have co-chaired the shrimp virus sessions at three nonindigenous workshops co-sponsored by the Environmental Protection Agency and the Gulf of Mexico Program. The shrimp virus components of these workshops were the culmination of a 2-year effort of the Joint Subcommittee on Aquaculture (JSA) of the President's Council on Science and Policy. The JSA was created in 1996 to identify existing authorities among federal agencies, identify research needs, conduct a risk assessment, and identify management actions for the shrimp virus issue. In addition to serving as a co-chair for the sessions, Texas Sea Grant also produced the results of each session. Final recommendations on the shrimp virus issues have been made to EPA's Gulf of Mexico Management and Policy Committees as well as to the JSA, and subsequently to the President's Council on Science and Policy.



Ron Jones

Giant salvinia (*Salvinia molesta*)

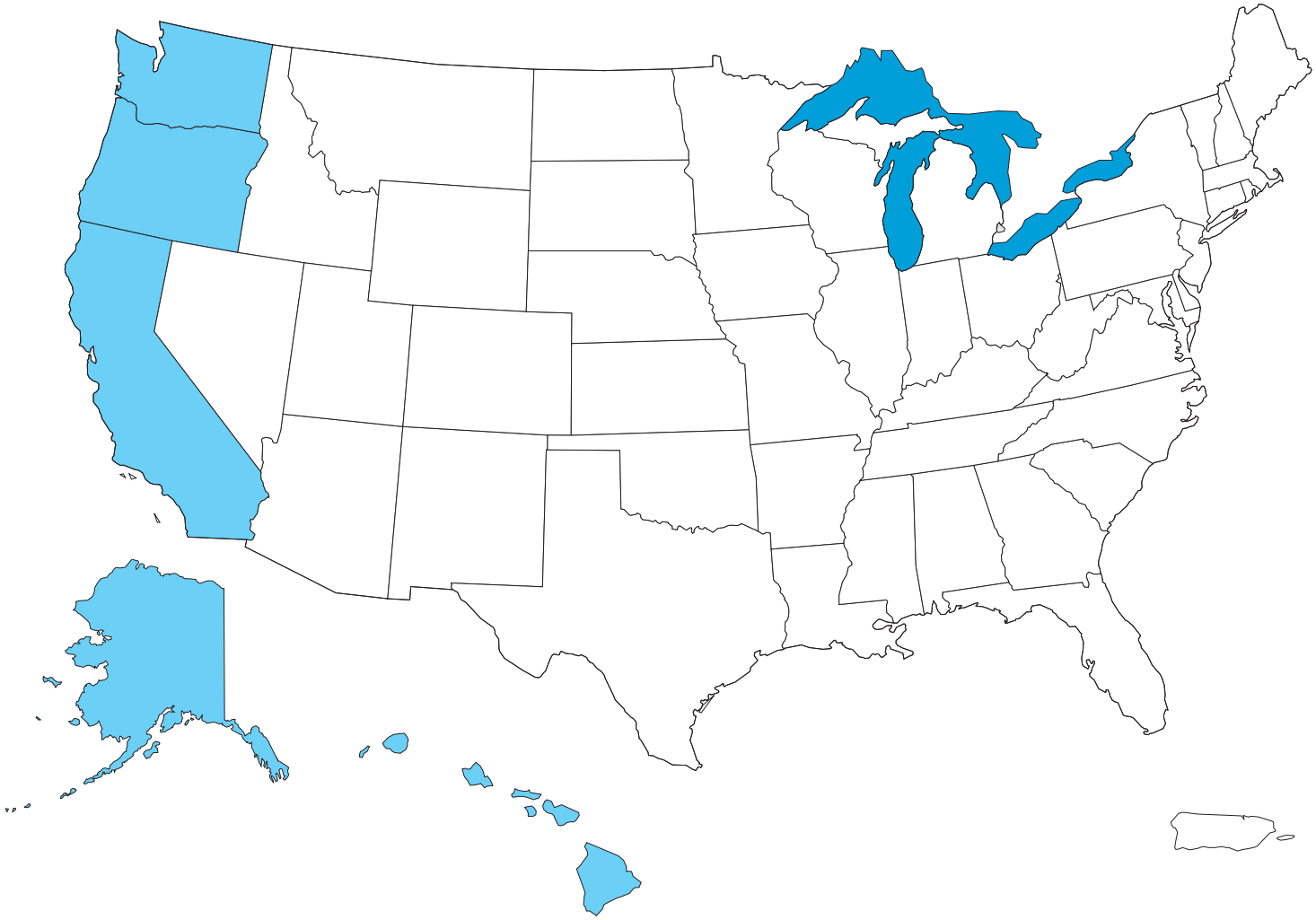
Pacific Region

California
Southern California
Hawaii
Oregon
Washington

Sea Grant

ANS

Pacific Region



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Sea Grant

California

Aquatic Nuisance Species (ANS) may constitute the largest single threat to the biological diversity of the world's coastal waters. California, with its 1,100 mile coastline, has encountered numerous problems with these uninvited "guests" that can be costly in both economic and environmental terms. Problem species range from a tiny sabellid worm that attacked the abalone aquaculture industry to an alien cordgrass that threatens to eliminate essential mudflat habitat for birds and fish. The San Francisco estuary alone is now host to more than 200 aquatic nuisance species.

The European green crab (*Carcinus maenas*,) an ANS, has a reported range from Monterey Bay to southern Washington. A European native, it was discovered along the Atlantic coast during the last century. Ballast water is suspected as being a likely vector, along with shipments of live seafood or bait. Green crab predation has resulted in significant reductions in native bivalves and crustaceans in Bodega Bay. It is also suspected of preying upon juvenile Dungeness crabs, cultured clams and oysters.

The spread of the Atlantic saltmarsh smooth cordgrass (*Spartina alterniflora*) has the potential to alter the landscape through its ability to replace native cordgrass. California Sea Grant research shows that dense smooth cordgrass stands formed by *S. alterniflora* over open mudflat habitats pose a threat to invertebrates, fish, and waterfowl, and even commercial fish and crab populations. *Spartina alterniflora* has already played a role in flooding in Alameda and Contra Costa counties by blocking flood-control channels.

The following initiatives were undertaken by California Sea Grant researchers and outreach personnel on behalf of the state and region to effectively deal with these problem species. Damage estimates to industry and the environment already range in the millions of dollars. With the results of this work, future economic and environmental losses can be significantly reduced.

Debra Ayres

Spartina control: Researcher Katy Zarimba stands in front of hybrid smooth cordgrass (*Spartina foliosa* X *alterniflora)* that was treated with an herbicide while the left half of the test plot was untreated.

Sea Grant California

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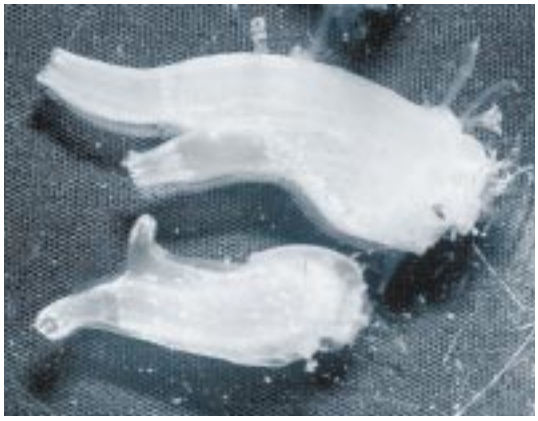
Species of Concern
Asian mussel
European green crab
Sabellid worm
Sea squirt
Smooth cordgrass
Zebra mussel

Research

Recent research projects sponsored by California Sea Grant focus on such species as ascidians ("sea squirts"), sabellid worms, European green crabs, isopods, Asian mussels, and smooth cordgrass.

The Introduction of Nonindigenous Ascidian Species into Southern California Harbors and Marinas



Charles C. Lambert

Ascidians *(Ciona savignyi)*

The presence of marine animals called ascidians, or sea squirts, are important indicators of ANS invasions because they do not naturally disperse very well. Project leaders have identified nonindigenous ascidian species (*Ciona savignyi* and *Styela clava*) in 13 harbors from San Diego to Santa Barbara, determined their relative abundance, tested their salinity and temperature tolerances, and collected samples of abundant species to determine whether they produce pharmacologically important compounds. Nonindigenous ascidians are now the dominant fouling organisms in the more sheltered parts of the harbors and marinas in southern California. A survey of 45 harbors in Washington and British Columbia was completed in September 1998. Researchers found that five of the introduced species present in southern California are also present in these waters.

Carolynn Culver

Adult sabellid polychaete worm *(Terebrasabella heterouncinata)*

Containment of Sabellid Pests of California Abalone: Assessment of Habitats and Hosts at Risk of Infestation

In recent years, the California abalone aquaculture industry has suffered high losses from a sabellid polychaete worm (*Terebrasabella heterouncinata*) that deforms the abalone shell and impairs its growth. The economic impacts of this pest have been reduced as abalone mariculture facilities have learned methods to control the spread of the worm. However, the threat to the environment continues as larvae enter the habitat through discharge from both onshore and offshore facilities. California resource managers are using the research data to prevent further spread of this species.

Safety and Efficacy of Green Crab Biological Control

The European green crab has the potential to cause direct losses to the oyster, mussel, and clam mariculture industries, as well as to the Dungeness crab fishery. It may also cause erosion and destabilization of marsh channel banks, levees, and dikes. The parasitic barnacle (*Sacculina carcini)* was tested for its safety as a possible control agent. Mathematical models were developed to assess how parasites like *Sacculina*, which block the reproductive capability of the host, might be used as biological controls.

Settlement, Survival, Growth, and Reproduction of the Nonindigenous Mussel (*Musculista senhousia*): Effects of Eelgrass

Jeff Crooks

Asian mussel *(Musculista senhousia)*

The nonindigenous Asian mussel (*Musculista senhousia*) impedes the establishment and growth of native eelgrass where the mussel is abundant and eelgrass is sparse — e.g., in transplanted or fragmented beds. In dense eelgrass beds, however, the mussel is suppressed. This project characterized *Musculista* populations in shallow subtidal areas suitable for eelgrass. Scientists tested the hypothesis that eelgrass controls the mussel by indirectly limiting its food supply. Regulatory and advisory agencies and private environmental practitioners will use the results to determine effective eelgrass planting strategies and to set permit requirements.

Contrasting Effects of Ecosystem Alteration by Two Exotic Wetland Invertebrates

ANS species can alter ecosystems by changing the physical architecture of the environment. This research examined modification of the physical environment in California bays by two exotic "ecosystem engineers" and quantified their effects on the physical properties of invaded environments. The isopod (*Sphaeroma quoyanum*) destroys sensitive salt marsh habitat through its extensive burrowing activities in banks. The Asian mussel creates habitat by the deposition of biological products and by the construction of dense byssal mats that stabilize and trap sediments.

Outreach

Conferences

In March 1998, California Sea Grant hosted the *Eighth International Zebra Mussel and Aquatic Nuisance Species Conference* in Sacramento. This was the first time the conference was held in the western states, and it attracted more than 300 participants who gathered to learn and share knowledge about ANS.

A major focus of the conference was preventing the spread of the zebra mussel (*Dreissena polymorpha*) in the western U.S. An eastern European native, the zebra mussel was transported to this country in the ballast water of ships originating in freshwater European ports. Since its introduction into the Great Lakes region in the 1980s, this aggressive species has spread to more than 20 states and two Canadian provinces. California Sea Grant has initiated projects to educate the public to prevent its spread into western states.

At the conference, a ballast water workshop examined the role of ballast in the introduction of ANS and explored different regulatory and management options to limit dispersal of organisms. A special session on West Coast non-native introductions was devoted to aquatic species such as the European green crab, the sabellid worm, the Chinese mitten crab (*Eriocheir sinensis*), and the Asian clam (*Potamocorbula amurensis*).

Education at all levels — from school children to policymakers — was a recurring theme of the conference. The adverse effects of ANS can include economic impacts such as damage to municipal water systems, loss of recreational opportunities, and potential disruptions of entire ecosystems. Continued work needs to be done to alert the general public about ANS and to generate the necessary scientific data so that informed management decisions can be made about prevention and control of ANS.

The adverse effects of ANS can include economic impacts such as damage to municipal water systems, loss of recreational opportunities, and potential disruptions of entire ecosystems.

In October 1996, California Sea Grant also sponsored the workshop *Marine and Aquatic Nonindigenous Species in California: An Assessment of Current Status and Research Needs.* Researchers, resource managers, and representatives of state agencies and industry attended this program development workshop held in San Francisco. Presentations focused on the European green and Chinese mitten crabs, Asian clam, zebra mussel, ballast water management and policy, sabellid worm, and the spread of nonindigenous aquatic plants, all of which have the potential to adversely affect coastal and freshwater aquatic ecosystems in California. These and other nonindigenous species and directions for current and new research were discussed and outlined in a summary proceedings. Measures to monitor the establishment and dispersal of ANS and the need for targeted control methods were identified as key elements for future research.

West Coast Ballast Water Initiative: An Outreach Program to Improve Ballast Management

This outreach program educated the shipping industry, government agencies, and the general public about ANS and ballast water management issues relevant to the West Coast and Pacific region. Its objectives included facilitating industry interest and participation in seeking an alternative to open-ocean ballast water exchange.

Recreational Boater Education

Transport of recreational boats is considered an important vector for the introduction of zebra mussels. Funding from California Sea Grant and the U.S. Fish and Wildlife Service was used to develop a regional program to teach recreational boaters about zebra mussel risk and preventative measures. A random mail survey was also conducted to evaluate the base knowledge and awareness among boaters. This was the first major effort to initiate proactive zebra mussel educational programming in the western part of the country.

Southern California

The European zebra mussel (*Dreissena polymorpha*) is a recently introduced aquatic nuisance species that is causing major economic and biological impacts in the eastern United States. In infested areas of the eastern U.S., zebra mussels have clogged water intakes at power plants and municipal water facilities, causing facility shutdowns and significant financial investment for their removal and control. Zebra mussels have also created problems in recreational sport fisheries by altering aquatic food webs and fouling boats, docks, and beaches.

Although California state agencies are actively screening for zebra mussels at agriculture check stations, it is likely that the mussel will eventually be transported to the state through a direct vector or via a water body adjoining another state. This highly prolific species has an affinity for attaching to hard surfaces, and has spread rapidly from its original site of introduction in the Great Lakes in 1988 to its present distribution in more than 20 states east of the Continental Divide. Transport of recreational boats overland is the most likely vector for introducing the zebra mussel to the West Coast.

California depends upon an extensive system of aqueducts and reservoirs to supply drinking water, irrigation, and industrial water supplies to its major metropolitan centers. The introduction of the zebra mussel would pose a major threat to the operations of water delivery systems, hydroelectric power systems, and recreational boating and fishing industries throughout the state. The potential also exists for rapid transport of the mussel via aqueducts, inland river systems, and recreational boaters. Prior to the workshops developed by Sea Grant, there was no attempt to provide training on risk assessment, monitoring, and control strategies to the water industry, municipalities, and agency staff in California. Such training and linkages to the Great Lakes information base are definitely needed to develop sufficient prevention measures, and to provide for rapid response and localized control when and if the zebra mussel is introduced to the state. The University of Southern California (USC) Sea Grant program strives to stimulate proactive planning by public and private agencies in dealing with this potential threat.

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Species of Concern
Zebra mussel

USC
UNIVERSITY
OF SOUTHERN
CALIFORNIA

J. Ellen Marsden

Zebra mussel *(Dreissena polymorpha)* cluster

Outreach

In California, the introduction of the zebra mussel would pose a major threat to the operations of water delivery systems, hydroelectric power systems, and recreational boating and fishing industries throughout the state.

The main outreach activity conducted by USC Sea Grant focused on proactive planning in response to a potential zebra mussel invasion. The first year of the project consisted of hosting a 1-day workshop which transferred the results of Sea Grant sponsored projects on zebra mussels to California state, regional, and municipal authorities. The purpose was to foster preparedness and prevention planning measures toward the possible invasion of zebra mussels in the state. This workshop was held in March 1998 as part of the *Eighth International Zebra Mussel and Aquatic Nuisance Species Conference* in Sacramento. Some of the topics covered included information on zebra mussel biology, how to perform public outreach and educational programming, possible vectors of transport into the state, training for water and power resource managers, and how to monitor for the zebra mussel. Workshop attendees received a *Zebra Mussel Training Package*. In the second year of the project, USC Sea Grant focused on providing contacts and coordinating with existing Sea Grant resources on the web and in print, and making plans to sponsor several small training workshops in various parts of the state.

After the March workshop, a survey was mailed to all conference attendees. Seventy surveys were returned and were very positive about the quality of the subject matter presented and its usefulness. The attendees represented many areas of interest, including public education, scientific research, business, and resource management.

Collaborators and Other Sponsors

Collaborators on this project include personnel from Minnesota Sea Grant who developed the training packages; California Sea Grant, who conducted small workshops throughout the state in the second year of the grant; and members from the New York and North Carolina Sea Grant programs.

The University of Southern California Sea Grant Program will continue to take a proactive approach in preventing the spread of zebra mussels and other aquatic nuisance species along the California coast.

Maran Hilgendorf

Zebra mussels *(Dreissena polymorpha)*

Hawaii

Because Hawaii relies on shipping to receive about 98 percent of all consumer goods and industrial cargo, it will remain vulnerable to the introduction of aquatic nuisance species (ANS) that arrive in Hawaii as passengers in ballast waters or attached to the hulls of wet and dry cargo vessels. The high level of imports will not diminish in the foreseeable future because Hawaii produces mainly specialized tropical crops, such as pineapple, coffee, and sugar, in exportable quantities. For example, less than 40 percent of fresh fruits and vegetables consumed by residents are grown locally. The balance, which includes temperate-zone fruits and vegetables, must continue to be imported. In addition, all industrial equipment and materiel are imported because Hawaii has never had any heavy industry. Historically, Hawaii has been an agriculture-based economy.

The high level of ship traffic, therefore, will continue to be the transport corridor for ANS. The magnitude of this transport system is reflected in the number of cargo ships and tankers that stop at the eight major harbors in the state. In 1998, a total of 8,442 vessels visited Hawaii's commercial ports. The number of naval vessels that call at Pearl Harbor, a major U.S. naval base, is unknown.

Shipping is a viable pathway for the introduction of ANS to Hawaii, but it is only one corridor of access. What is becoming an increasing common entry point is through aquarium species that are imported, and then disposed of improperly into streams and rivers. Many freshwater endemic species have been displaced or are in danger of being replaced by the introduced species. Another entry point for ANS is the deliberate importation of species for cultivation.

The impact of the small investments made to obtain preliminary data, catalog taxonomy, or alleviate economic devastation to a small rural Hawaiian coastal community has been nothing short of astonishing. Hawaii Sea Grant now has the beginnings of baseline data on the proliferation of introduced species in the major harbors of Hawaii and Guam. This information is critical in future assessments of alien species that may be introduced through various pathways. In addition, the corrections made to existing collections will provide researchers with accurate nomenclature and habitat sites for each organism. A proposed monograph on sponges in Hawaii will be a watershed publication and a major reference source for researchers and resource managers.

Finally, the unique effort that saved a vital native product, taro, and turned destructive channeled apple snails (*Pomacea canaliculata*) into an economic golden goose for a native Hawaiian community, is one for the record. This activity involved an undergraduate student, funded to do a summer research project under the Hawaii Sea Grant College Program's Undergraduate Summer Research Program, who determined the qualitative and quantitative feed requirements for cultivating snails collected from the wild. In collaboration with the residents of Keanau-Wailuanui, Hawaii Sea Grant Extension has developed a culturing system that takes the snails removed from the taro patches to market size. This has been a source of revenue for the Keanae-Wailuanui community, which has a 35 percent unemployment rate. The cash flow has enabled the community association to promote their cultural, educational, and economic goals.

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Species of Concern
Channeled apple snail

Clyde Tamaru

Channeled apple snail
(Pomacea canaliculata)

Hawaii Sea Grant

A taro patch damaged by channeled apple snails *(Pomacea canaliculata).*

Research and Outreach

Baseline Biodiversity Assessment of Natural Harbors in Guam and Hawaii

This study conducted during 1995-96 found seven species of bivalves in Pearl Harbor, Oahu and three in Apra Harbor, Guam. A literature review of the biota revealed that there were 335 recorded species of marine organisms in Guam and 700 species in Hawaii. As a part of this study, researchers were able to identify 230 species of bivalves in Hawaii and 200 species in Guam. They concluded that there were several indigenous bivalves that were either in danger of extinction, or have become extinct and that the intense development surrounding the two harbors makes the biota highly vulnerable to change. This study has established the state of knowledge of the two harbors prior to 1995. Funding was provided by the Insular Pacific Marine Research Program which is managed by the University of Hawaii Sea Grant College Program.

Survey of Introduced Marine Invertebrates on Guam

A detailed survey of Apra Harbor, Guam is currently being conducted. In the 13 zones into which the harbor has been divided, researchers have identified over 600 species of macroinvertebrates as well as over 20 nonindigenous species. Another 20 organisms are suspected of being alien species, but have not yet been verified. Three habitats have been identified, based on the abundance of numbers of ANS: buoys, harbor walls, and reefs. The good news is that while buoys and harbor walls are dominated by ANS, the reefs are maintaining their autonomy. Only a small number of nonindigenous species were found on reefs.

The far reaching results of Hawaii Sea Grant's apple snail research is remarkable especially because it was done by an undergraduate student.

Native and Nonindigenous Marine Sponges of the Hawaiian Islands: Taxonomic and Biogeographical Statue

Detailed sampling was conducted and shallow-water sponges were collected from all major harbors in the Hawaiian Islands. In addition, collecting was done at selected sites and the already existing collection of sponges at the Bishop Museum were examined. This major effort to develop an orderly record of taxonomy discovered that 38 percent of the sponges in Pearl Harbor were nonindigenous or cyptogenic. More than 40 specimens have not yet been described. Of the specimens in the Bishop Museum collection, identification was incomplete and of those that had been previously labeled, 30-40 percent were misidentified. The final products of this effort will be a monograph of Hawaiian *Porifera* and additional specimens added to the sponge collection at the Bishop Museum. Funding for this project was provided by the Insular Pacific Marine Research Program.

Feedlot for the Hawaiian Escargot

The far-reaching results of this research is especially remarkable because it was done by an undergraduate student over a 3-month period. The student identified an appropriate feed and feeding rate that improved the channeled apple snail meat quality, resulting in a texture and taste desired by high-end restaurant chefs. These snails were destroying taro corms and drastically reducing the productivity of the infested taro patches. The student-developed system, along with other methods used by the farmers, has been able to eliminate about 95 percent of the snails. The taro industry currently generates about $12 million in annual revenues.

Control of the Channeled Apple Snail, *Pomacea canaliculata*

A simultaneous extension effort (see previous project) developed the destructive snail into an economic "golden egg." With the support of Sea Grant Extension program, the channeled apple snail became the source of cash for Keanau-Wailuanui, a rural coastal community, with 35 percent unemployment. The farmers sell the snails they gather from their taro patches to their community association for $1.00 per pound, which then markets the snails to either local food vendors or high-end restaurants as escargot for $4.00 per pound.

Oregon

The approach of aquatic nuisance species (ANS) has been identified as one of the most severe environmental threats facing the marine waters of the Pacific Northwest. Several established and emerging nonindigenous invaders threaten critical habitat and important commercial species in the Pacific Northwest and could cause drastic changes in the ecology of marine, estuarine, and freshwater systems. The Oregon and Washington Sea Grant programs have developed a coordinated, joint approach to the shared regional threat.

Coastal estuaries in Washington and Oregon provide critical habitat for many commercially important species, such as Dungeness crab, and many marine fish species, including salmonids. These estuaries are particularly susceptible to ANS introductions. The growing diversity and continuing arrival of new ANS in West Coast estuaries is an indication that these ecosystems are highly vulnerable to invasion. Oregon Sea Grant researchers have demonstrated that ANS which possess an ability to cope with large changes in salinity and other environmental variables have an advantage over native marine forms and can become established in these areas, causing significant ecological and economic impacts.

Shellfish production and commercial fisheries are major components of the Pacific Northwest coastal economy. Total molluscan shellfish production exceeded 17 million pounds in Oregon and Washington in 1996 and had a wholesale value of nearly $80 million; moreover, the domestic market is expanding. The commercial harvest of Dungeness crab in the two-state area was over 36 million pounds in 1997 and had an ex-vessel value of $50 million. Although salmon stocks have been on the decline for many years, nearly 20 million pounds were harvested in 1997 and had an ex-vessel value of $27 million.

Nonindigenous species have long been established in the Pacific Northwest, including a number that have been intentionally introduced and that form an integral part of the regional aquaculture industry like the Pacific oyster (*Crassostrea gigas)* and the Atlantic salmon (*Salmo salar*). Other invaders, such as the oyster drill (*Ocenebra triangulata*), represent a long-established and recognized economic burden on oyster growers. It is the more recently established and newly arriving ANS that are of greatest concern as these species have not yet been assimilated into the ecosystem and their impact is unknown.

Sylvia Yamada

European green crab *(Carcinus maenas)*

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Species of Concern
Brazilian elodea
Chinese mitten crab
Eurasian watermilfoil
European green crab
New Zealand mud snail
Smooth cordgrass
Water hyacinth

Chinese mitten crab *(Eriocheir sinensis)*

Lee Mecum

Oregon Sea Grant is very concerned about three recently introduced ANS: the European green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), and the New Zealand mud snail (*Potamopyrgus antipodarum*). The European green crab has invaded many parts of the world, where its appetite for commercially valuable clams and crabs has threatened important fisheries. First seen in San Francisco Bay in 1989, it has been moving northward up the coast to Humboldt Bay, CA. Researchers have recently seen the crab in Coos Bay, OR. An able colonizer and efficient predator, this small shore crab has the potential to significantly alter any ecosystem it invades. Studies have demonstrated its use of a wide range of food items. On the Pacific coast there is concern that green crab could cause major losses for oyster and clam farmers by preying on young oysters and both young and adult clams.

The growing diversity and continuing arrival of new ANS in West Coast estuaries is an indication that these ecosystems are highly vulnerable to invasion.

The Chinese mitten crab, a native to coastal rivers and estuaries in China and Korea, was first reported in south San Francisco Bay in 1992. Once there the crab spread rapidly throughout the San Francisco Bay estuary and the Sacramento-San Joaquin delta. A single adult was found in the lower Columbia River in 1997. An expanding mitten crab population poses several ecological and economic threats.

The New Zealand mud snail is a native of New Zealand but has long been established in Australia and Europe. It was found in North America initially in 1987 in the Snake River, ID, and has more recently been found in Montana and the lower Columbia River. It occupies a wide range of habitats, most commonly in moderate currents on solid substrates. Population levels may exceed 100,000 per square meter, which is nearly a solid layer of snails.

The economic and ecological impacts of nuisance aquatic plants have also increased dramatically over the last 25 years in the western states. Problem aquatic species include submerged, emergent, and floating-leaf species. Examples include the Eurasian watermilfoil (*Myriophyllum spicatum*), Brazilian elodea (*Egeria densa*), water hyacinth (*Eichhormia crassipes*), and smooth cordgrass (*Spartina alterniflora*). Many of these species significantly alter fresh-water habitats, resulting in lower dissolved oxygen levels and physical obstruction for migrating fish species, including salmonids.

Donald Strong

West Coast native *Spartina foliosa* (short plants in foreground) is threatened by alien *Spartina alterniflora* (tall plants in background).

Research

Oregon Sea Grant's role with respect to ANS is clear: the program wishes to create new information through research and disseminate information through outreach. It is not Oregon Sea Grant's role to set policy or enforce regulations.

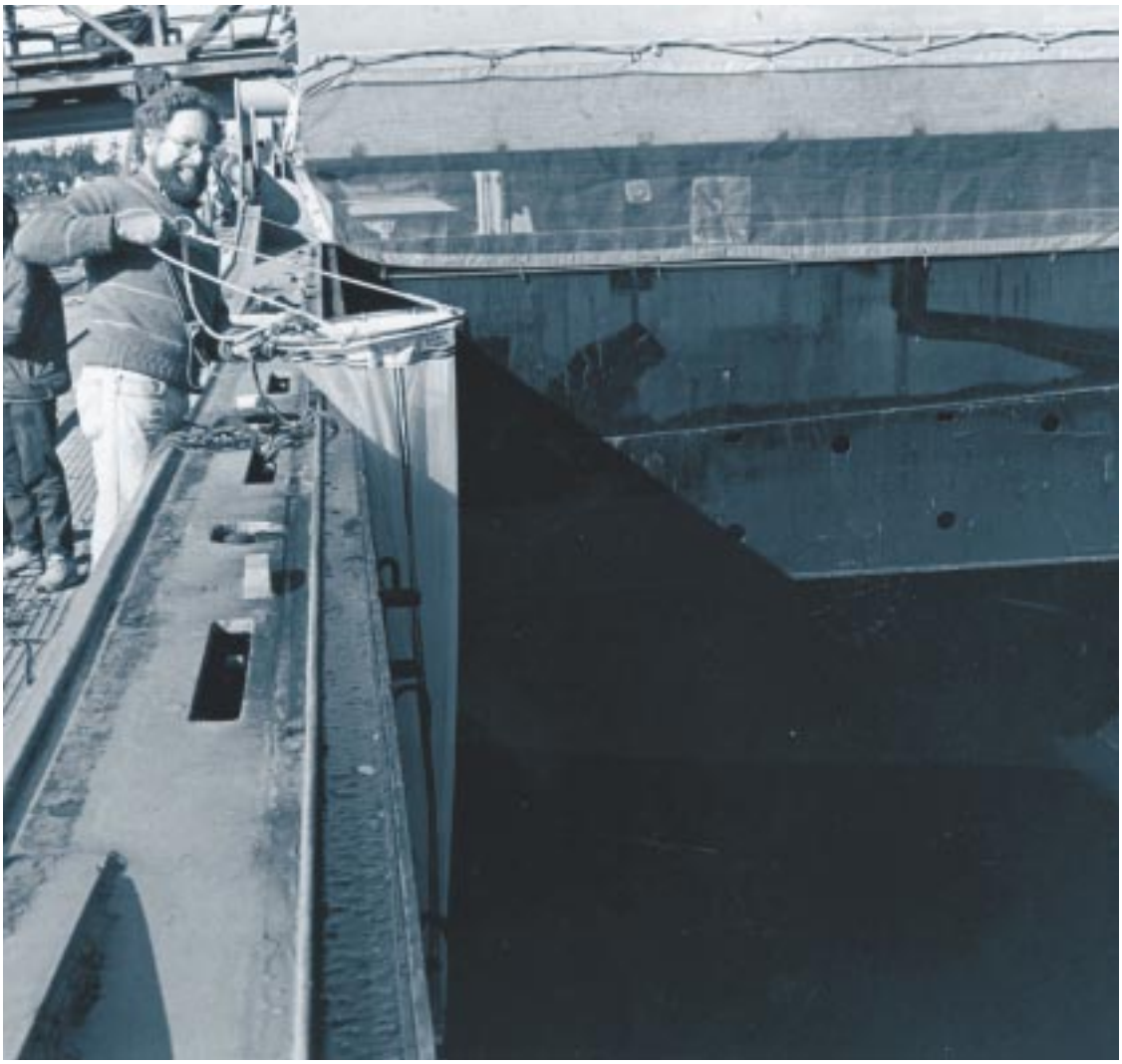
Oregon Sea Grant's first pioneering research on ANS was conducted in the 1980s by the University of Oregon. In studies at Coos Bay, OR, researchers established the critical importance of ballast water discharge in introducing ANS into that estuary.

Today the Pacific Northwest faces threats from several ANS. In their joint effort, the Oregon and Washington Sea Grant programs have initially focused on the European green crab because it is a highly visible, potentially damaging, and newly introduced species about which practically nothing is known in Pacific Northwest waters. The species is also a major concern to Pacific Northwest shellfish growers and others. Finally, the process of green crab introduction and expansion is still underway, offering a unique opportunity for study.

Research initiated in 1997 by Oregon Sea Grant is developing standardized methods for tracking the introduction and spread of the green crab. Researchers at Oregon State University have conducted preliminary surveys of green crabs in the Pacific Northwest, working closely with agency staff and with Sea Grant outreach personnel in both Oregon and Washington.

Oregon Sea Grant also supports a project studying the distribution and abundance of both nonindigenous and native aquatic species in San Francisco Bay and Pacific Northwest estuaries. The San Francisco Bay is one of the most heavily invaded aquatic ecosystems in the world and an important beachhead for introduced nondigenous species that are spreading through northeast Pacific estuaries, including those in Oregon. Results to date indicate that ballast water from ships is the major vector for these invasions.

The San Francisco Bay is one of the most heavily invaded aquatic ecosystems in the world and an important beachhead for introduced nondigenous species that are spreading through northeast Pacific estuaries, including those in Oregon.



Joseph Cone

James Carlton established Oregon Sea Grant 's research interest in ballast water transport of ANS during the late 1980s.

Outreach

Formal endorsements of MIST have come from virtually every partner governmental agency, including the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and numerous state agencies. Many interested parties probably concur with the Aquatic Nuisance Species Coordinator for the Service in California, who described MIST as "an innovative and cooperative approach" to a serious regional problem.

In conjunction with Washington Sea Grant, in 1998 Oregon began developing the Pacific Northwest Marine Invasive Species Team — MIST (***www. seagrant.orst.edu/mist/index.html***). MIST's role is to:

- coordinate information sharing among all levels of university, government, and private industry researchers and outreach professionals throughout the Northwest;
- ensure continuity of the timely dissemination of ANS-related research findings;
- facilitate technology transfer between researchers and end users; and
- focus research and outreach in the areas of greatest need.

One of the early forces for the MIST's formation was the *European Green Crab Conference* that was held in Vancouver, WA in February 1998, and was sponsored by the two neighbor Sea Grant programs. The conference attracted over 120 researchers, shellfish growers, crabbers, agency staff, and volunteers and staff of nongovernmental organizations. This conference alerted a substantial number of concerned parties in the region to the threat presented by this predatory invader and provided support for the MIST center concept.

Early outreach attention has emphasized the European green crab. Training sessions for growers, biologists, students, and volunteers are being developed by MIST's regional coordinators, using materials developed by invertebrate researchers and taxonomists. The regional coordinators are located on the Oregon coast (Newport), the Washington coast (South Bend), Puget Sound (Seattle), and the Columbia River (Portland).

The training sessions began in 1999. They have been held in conjunction with industry meetings and volunteer gatherings, but independent sessions were also scheduled as needed. The training sessions covered ANS identification and life history, potential ecological and economic impacts, mitigation techniques for reducing ecological and economic impacts, and prevention of further spread of ANS. Oregon Sea Grant is also producing a training video for these research-based training sessions.

In addition to the MIST's work, the Oregon Sea Grant Extension specialist in Portland focuses on aquatic health, and part of his efforts address the ecological and economic impacts of ANS. Oregon Sea Grant's marine educator has conducted workshops and made presentations to a variety of groups on identifying and understanding the European green crab. He also has developed an interactive game for 4th-6th grade students. Furthermore, in 1998 the Visitor Center of Oregon State University's Hatfield Marine Science Center established an aquatic display tank and provided exhibit information regarding ANS. The Visitor Center is administered by Oregon Sea Grant and is visited by approximately 200,000 individuals each year plus hundreds of school groups. MIST is now working on a more developed, long-term ANS display at the Visitor Center.

Another Oregon Sea Grant outreach project is the production of a major publication focusing on the European green crab, written by researchers from Oregon Sea Grant and the Smithsonian Environmental Research Center. The book will capture the state of the knowledge of this species. Future Oregon Sea Grant outreach activities will continue to examine the impact of aquatic nuisance species on the Pacific Northwest coast.

CA Dept. of Fish and Wildlife

European green crabs *(Carcinus maenas)*

Washington

Ecological and economic impacts caused by aquatic nuisance species (ANS) have been well documented throughout the world. The approach of ANS has been identified as one of the most severe environmental threats facing the marine waters of the Pacific Northwest. Several established and emerging nonindigenous invaders threaten critical habitat and important commercial species in the Pacific Northwest, and could lead to drastic changes in the ecology of marine, estuarine, and freshwater systems.

Coastal estuaries in Washington and Oregon provide critical habitat for many commercially important species such as Dungeness crab and many marine fish species including salmonids. These estuaries are particularly susceptible to ANS introductions. The growing diversity and continuing arrival of new ANS in estuaries is an indication that these ecosystems are highly vulnerable to invasion. Northeastern Pacific estuaries exhibit low species diversity, are geologically young, and are often impacted by human activity. Nonindigenous species with an ability to cope with large changes in salinity and other environmental variables, have an advantage over native marine forms and can become established in these areas, causing significant ecological and economic impacts.

Shellfish production and commercial fisheries are major components of the Pacific Northwest coastal economy. Total molluscan shellfish production exceeded 17 million pounds in Oregon and Washington in 1996 and had a wholesale value of nearly $80 million; moreover, the domestic market is expanding. The commercial harvest of Dungeness crab in the two state area was over 36 million pounds in 1997 and had an ex-vessel value of $50 million. Although salmon stocks have been on the decline for many years, nearly 20 million pounds were harvested in 1997 and had an ex-vessel value of $27 million.

Severe declines in salmonid populations in the Pacific Northwest have been the result of habitat degradation, overharvest, and natural cyclic changes in the ocean environment. The Columbia River is the largest river on the West Coast, draining nearly 260,000 square miles from southern British Columbia to the Pacific Ocean. Traveling more than 1,200 miles, its flow of 123 million gallons per minute is ten times that of the Colorado River, and second only to the Mississippi River in average annual runoff. The river provides major habitat for salmon and steelhead, and is also used for power generation, transportation, and irrigation. Nearly 200 dams, 38 major hydroelectric projects, and eight navigation locks utilize this freshwater resource. Emerging ANS threaten both salmonid habitat and built structures throughout the system, with the potential for major ecological and economic impacts. Exotic species may exacerbate freshwater and estuarine habitat problems, with further impacts to these stocks through both direct and indirect means. Thirteen salmonid stocks may be listed as threatened under the Endangered Species Act with severe implications for both land and marine based activities.

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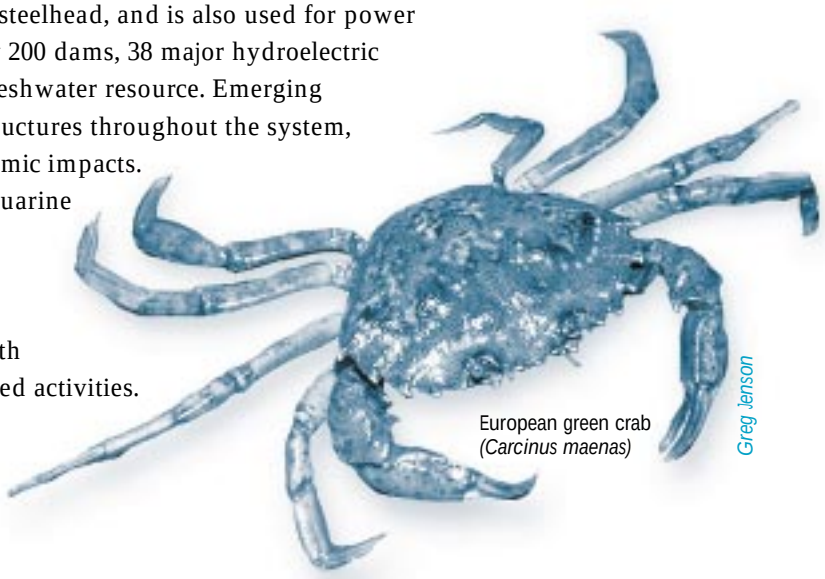
Species of Concern
Asian copepod
Chinese mitten crab
European green crab
Smooth cordgrass



European green crab
(Carcinus maenas)

Greg Jenson

Research

Washington Sea Grant is involved in a number of ANS-related research projects in the Pacific Northwest.

Jeff Cordell

Asian copepod *(Pseudodiaptomus inopinus)*

Results of one research project outlined ways to prevent ANS introductions in the booklet *Handling and Disposal of Non-Native Aquatic Species and their Packaging*.

Characterizing Pathways for the Introduction of Nonindigenous Species via Shipments of Live Seafood and Scientific Specimens

The objective of this research project was to assess the risk of the unintentional introduction of ANS into Washington State marine waters via trade in live marine products, such as seafood or scientific specimens. In addition, the project team developed and tested a method for risk assessment that incorporates both biological and social components of risk. The focus of this assessment was on products that are known historically to have served as vectors for unintentional ANS introductions, but have been infrequently studied or which are not presently regulated. The long-term objective is to assist government and the private sector in developing and disseminating information on best management practices (BMPs) that minimize risks of unintentional ANS introductions. There were three stages to the project: scoping (1998), risk assessment (1998-99), and dissemination of results (1999).

Effects of the Invasive Asian Copepod *Pseudodiaptomus* on Pacific Northwest Estuaries

The Asian copepod *(Pseudodiaptomus inopinus)* is one of several species of ballast water-introduced copepods (small water-column dwelling crustaceans) that have recently become established in North American West Coast estuaries. Biological surveys conducted in 1979-80, 1991-92 and 1996 have found that this copepod has become established and abundant in the Columbia River and many smaller coastal estuaries between southern Washington and southern Oregon. It has not yet invaded northern California, southern British Columbia, or more inland estuaries in Puget Sound. Unlike the Sacramento-San Joaquin estuary, where a succession of exotic copepods has resulted in a temporally changing plankton assemblage, *P. inopinus* appears to be a stable and dominant component of the zooplankton where it occurs in the Pacific Northwest. It is abundant in tidal brackish areas of estuaries that are utilized as rearing ground for fish such as juvenile salmon and smelt — species that often feed heavily on copepods. In light of declining stocks of Pacific salmon and other estuarine fishes in this region, it is of particular interest to fisheries scientists and managers to determine if the introduction and establishment of this copepod has affected commercially important fish and their endemic planktonic prey.

This project evaluated the extent and ecological effects of the invasion of the Asian calanoid copepod *Pseudodiaptomus inopinus* in Pacific Northwest estuaries. Because little is known about the biology and ecology of *P. inopinus* and because this species occurs in regions of estuaries utilized by juvenile salmon, this study will provide valuable new information about (1) the geographical spread of the invasion, (2) seasonal changes in the relative abundance of *P. inopinus* and other assemblage members, and (3) the role of *P. inopinus* in estuarine food webs, including potential effects on juvenile salmon and other commercially important fish and invertebrates.

Potential Impacts of a Nonindigenous Crab on Selected West Coast Commercial Invertebrates

The recent introduction of the European green crab (*Carcinus maenas)* to the western U.S. coast portends substantive ecological impact in estuarine and marine systems. This project studied *Carcinus'* response to two categories of invertebrate prey: mobile Dungeness crab (*Cancer magister*) and sessile bivalves. The project gauged the potential ability of this exotic crab to significantly perturb populations of these valued commercial species by direct predation and displacement from habitat.

Outreach

The Washington Sea Grant Program is involved in a major outreach project to coordinate information and educational activities in the Pacific Northwest.

The Pacific Northwest Marine Invasive Species Team — MIST (*www.seagrant.orst.edu/mist/index.html*)

The Washington and Oregon Sea Grant Programs have joined forces to form the Pacific Northwest Marine Invasive Species Team (PNW MIST). PNW MIST members coordinate regional research and outreach on coastal ANS such as the European green crab and Chinese mitten crab (*Eriocheir sinensis*). MIST uses the strengths of each Sea Grant program and its communication network to forge strong links between researchers, user groups, agencies, and non-governmental organizations.

Invasions by ANS are among the most severe threats facing marine ecosystems of the Pacific Northwest. Several established and emerging ANS threaten critical habitat and important commercial species (such as Dungeness crab) and many marine fish species, including salmonids. ANS could lead to drastic changes in the ecology of marine, estuarine, and freshwater systems. While there are introductions that do not have such devastating impacts, only time and research can reveal whether an introduction will be harmful or benign.

A single boat carrying zebra mussels (*Dreissena polymorpha*) or a single restaurant improperly disposing of live seafood products can bring an infestation to a watershed. As such, an informed and educated public is essential to help control the spread of ANS. It is therefore essential that information/education efforts convey up-to-date and accurate facts. PNW MIST will ensure that accurate and timely information is available through its close linkages with scientists engaged in research on ANS at the nation's universities and federal laboratories. Regional coordination and dissemination of ANS information will help guide decisions that strongly affect the region's environmental quality.

Washington Sea Grant, Oregon Sea Grant, and PNW MIST have developed a series of ANS educational products in collaboration with the State of Washington, the National Estuary Program, the Georgia Basin/Puget Sound International Task Force, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game.

An informed and educated public is essential to help control the spread of ANS.

PNW MIST can provide:

- support for regional ANS management and research efforts, including access to a national Sea Grant network of ANS expertise and materials;
- presentations and training programs on ANS for youth and adult audiences;
- a variety of publications, including fact sheets on specific species and introduction pathways, identification materials, and a 20-page booklet, *Bio-Invasions: Breaching Natural Barriers;*
- attractively designed posters and T-shirts introducing concepts about ANS;
- a web page with updates on regional ANS and links to other Internet sites about these species; and
- a brochure to help lab researchers who use marine organisms or media to minimize risks of introductions.

Some new projects PNW MIST plans to undertake during the next few years include:

- producing a regional training video on ANS identification and handling;
- planning a conference on ANS for Pacific Northwest municipal/industrial water users;
- developing teacher training materials and workshops; and
- developing ANS exhibits for aquariums and science centers in Oregon and Washington.

Fiscal Years 1999 and 2000 Sea Grant Aquatic Nuisance Species Projects

Contact the sponsoring Sea Grant program for project information.

Principal Investigator	Sea Grant Program	Project Title	Focus Area	First Year of Funding
Andrea Cohen	CA	Testing Ballast Water Treatment at a Municipal Wastewater Treatment Plant: Assessing Effectiveness, Limiting Factors and Cost	Ballast	1999
Jennifer Dugan	CA	Evaluating the Health Risk Posed by the Invasive Chinese Mitten Crab	Ecology	1999
Jonathan Geller	CA	Post Invasion Genetic Structure of European Green Crab Populations and its Implications for their Control	Control	1999
Armond Kuris	CA	Biological Control of Invasive Green Crabs: A New Rapid and Reliable Safety Test of a Proposed Control Agent	Control	1999
Antonia Wijte	CA	Combating *Arundo donax*, and Other Rhizomatous, Aquatic and Estuarine Nuisance Grasses, by Exploiting their Ecophysiological Characteristics	Control	1999
Heather Crawford	CT	A National Invasive Aquatic Plant Outreach / Research Initiative — CT Component	Outreach	1999
Robert Whitlatch	CT	Species and Community Attributes Affecting Invasion Success by Exotic Species	Prevention	1999
Victor Ramey	FL	A National Invasive Aquatic Plant Outreach / Research Initiative — FL Component	Outreach	1999
Michael Hadfield	HI	Assessment of Invasibility of Native Biotas and the Impacts of Invasive Invertebrate Animals on Native Species in Bays and Estuaries	Ecology	1999
Christopher Puttock	HI	Assessment of Invasive Introduced Macroalgae of Hawaii	Ecology	1999
Craig Smith	HI	The Impact of Invading Mangroves on Hawaiian Soft-Sediment Communities	Ecology	1999
Patrice Charlebois	IL-IN	Sustaining Wild Harvest and Aquaculture of Bait Fish in ANS Infested Waters and Reducing Risk of ANS Spread — IL-IN Component	Outreach	1999
Patrice Charlebois	IL-IN	A National Invasive Aquatic Plant Outreach / Research Initiative — IL-IN Component	Outreach	1999
Patrice Charlebois	IL-IN	Biological Control of Purple Loosestrife by 4-H Field Volunteers — IL-IN Component	Outreach	1999
Robin Goettel	IL-IN	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — IL-IN Component	Outreach	1999

Principal Investigator	Sea Grant Program	Project Title	Focus Area	First Year of Funding
Brian Miller	IL-IN	Transferring Sea Grant Zebra Mussel Research and Outreach Results to the Nation Using a World Wide Server — IL-IN Component	Outreach	1999
Daniel Schneider	IL-IN	The Role of Larval Mortality in Metapopulation Dynamics and Control of the Zebra Mussel in Freshwater and Estuarine Systems — IL-IN Component	Control	1999
Pamela Blanchard	LA	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — LA Component	Outreach	1999
Gregory Ruiz	MD	Understanding Patterns and Effects of Nonindigenous Species Invasions on Multiple Spatial Scales: A Quantitative and Comparative Approach	Prevention	1999
Anastassios Perakis	MI	Economic Impact of Measures to Limit the Introduction of Nonindigenous Species through the St. Lawrence Seaway Shipping	Ballast	1999
Orland Sarnelle	MI	Understanding the Influence of Zebra Mussels on Toxic Cyanobacterial Blooms	Ecology	1999
John Schwartz	MI	Sustaining Wild Harvest and Aquaculture of Bait Fish in ANS Infested Waters and Reducing Risk of ANS Spread — MI Component	Outreach	1999
John Schwartz	MI	Biological Control of Purple Loosestrife by 4-H Field Volunteers — MI Component	Outreach	1999
Chryss Chryssostomidis	MIT	Second Conference on Marine Bioinvasions	Outreach	1999
David Smith	MIT	Identification and Ranking of Transport Vectors of Marine Bioinvaders to and from New England	Prevention	1999
Doug Jensen	MN	A National Invasive Aquatic Plant Outreach / Research Initiative — MN Component	Outreach	1999
Doug Jensen	MN	Biological Control of Purple Loosestrife by 4-H Field Volunteers — MN Component	Outreach	1999
Doug Jensen	MN	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — MN Component	Outreach	1999
Doug Jensen Jeff Gunderson	MN	Sustaining Wild Harvest and Aquaculture of Bait Fish in ANS Infested Waters and Reducing Risk of ANS Spread — MN Component	Outreach	1999
Doug Jensen Jeff Gunderson	MN	Multi-State Survey to Evaluate Effectiveness of ANS Boater Education Programming	Outreach	1999
Barbara Doll	NC	A National Invasive Aquatic Plant Outreach / Research Initiative — NC Component	Outreach	1999
Dale Baker	NY	Lake Champlain Sea Grant Outreach Program	Outreach	1999

Principal Investigator	Sea Grant Program	Project Title	Focus Area	First Year of Funding
Dale Baker Helen Domske	NY	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — NY Component	Outreach	1999
Charles O'Neill Dale Baker	NY	Maintain and Operate the National Aquatic Nuisance Species Clearinghouse Technical Library and Searchable Bibliographic Database	Outreach	1999
Joseph Makarewicz	NY	*Cercopagis*—A New Exotic Cladoceran to the Great Lakes	Ecology	1999
Daniel Molloy	NY	Use of Bacteria for the Biological Control of Zebra Mussels	Control	1999
Dianna Padilla	NY	The Role of Larval Mortality in Metapopulation Dynamics and Control of the Zebra Mussel in Freshwater and Estuarine Systems — NY Component	Control	1999
Rosanne Fortner	OH	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — OH Component	Outreach	1999
Fred Snyder	OH	Sustaining Wild Harvest And Aquaculture of Bait Fish in ANS Infested Waters and Reducing Risk of ANS Spread — OH Component	Outreach	1999
Robert Bourke	Oceanit Labs.	Development of a Shipboard Ultrasonic Ballast Water Organism Control System	Ballast	1999
Thomas Rogers	Lynntech Inc.	Electrochemically Generated Ozone for On-Board Control of Nonindigenous Invasive Species in Ballast Water	Ballast	1999
Eric Obert	PA	Sustaining Wild Harvest and Aquaculture of Bait Fish in ANS Infested Waters and Reducing Risk of ANS Spread — PA Component	Outreach	1999
Michael Jahncke	VA	Application of Hazard Analysis Critical Control Point (HACCP) Principles as a Risk Management Approach for Exotic Pathogen Control and Exotic Species Control in Aquaculture	Control	1999
Roger Mann	VA	Current Distribution, Potential Range Expansion, and Ecological and Commercial Impact, and Control of the Nonindigenous Marine Gastropod *Rapana venosa*	Control	1999
David Armstrong	WA	Habitat Utilization By A Nonindigenous Crab	Ecology	1999
Andrea Copping	WA	Exotic Aquatics on the Move: Building a Web of Awareness for Geography Educators and Students — WA Component	Outreach	1999
Sally Hacker	WA	Invasion and Eradication of the Alien Plant, *Spartina anglica*, in Puget Sound, Washington, Salt Marshes and Mud Flats	Control	1999
Allen Miller	WI	Transferring Sea Grant Zebra Mussel Research and Outreach Resultsto the Nation Using a World Wide Server — WI Component	Outreach	1999

Principal Investigator	Sea Grant Program	Project Title	Focus Area	First Year of Funding
John Gallagher	DE	Sustained Restoration of *Phragmites*-Infested Wetlands: A Vegetation Alternative to Cyclic Spray and Burn	Restoration	2000
Martin Berg	IL-IN	Consequences of Round Goby Invasion for Littoral Zone Communities: Effects on Sculpins and Benthic Invertebrates	Ecology	2000
Gary Lamberti	IL-IN	Zebra Mussels, Round Gobies, and Eurasian Ruffe: Predicting Ecological Impacts of the "Exotic Triad" to Improve Control	Control	2000
Chris Rehmann	IL-IN	Predicting Zebra Mussel Transport in Rivers and Estuaries	Control	2000
John Sansalone	LA	A Screening Assessment of Dissolved Air Flotation for Control of Nonindigenous Invasive Species in Ballast Water	Ballast	2000
Gregory Zimmerman	MI	Habitat Restoration During Biocontrol of Purple Loosestrife	Restoration	2000
Chryss Chryssostomidis	MIT	Marine Bioinvasions in Massachusetts: A Proposal to Conduct a Massachusetts Rapid Assessment Survey	Ecology	2000
Karin Limburg	NY	Ecological Constraints on Establishment of a Freshwater-Resident Population of Blueback Herring in the Mohawk/Hudson Drainage	Ecology	2000
Isaac Wirgin	NY	Genetic Characteristics of Great Lakes and Atlantic Coast Sea Lamprey Populations	Control	2000
Maria Gonzalez	OH	Effects of Round Goby on Yellow Perch-Amphipod Interactions within Zebra Mussel Colonies and Macrophyte Beds	Ecology	2000
Roy Stein	OH	Modeling Smallmouth Bass Consumption of Round Goby in Lake Erie: Implications for Predator Growth and Contaminant Transfer	Ecology	2000
Robert Malouf	OR	Marine Invasive Species Team (MIST): Regional Outreach on Nonindigenous Species — OR Component	Outreach	2000
Andrea Copping	WA	Marine Invasive Species Team (MIST): Regional Outreach on Nonindigenous Species — WA Component	Outreach	2000
Nancy O'Connor	WHOI	Effects of the Asian Shore Crab *Hemigrapsus sanguineus*	Ecology	2000

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Purple Loosestrife

Rapa Whelk

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Other Information Sources

In addition to the resources above, the following web sites offer additional ANS information:

Aquatic Nuisance Species Task Force
www.anstaskforce.gov/

Exotic Aquatics on the Move
ag.ansc.purdue.edu/EXOTICSP/

Great Lakes Panel on Aquatic Nuisance Species
www.glc.org/ans/ans-res/httoc.html

National Aquatic Nuisance Species Clearinghouse
www.entryway.com/seagrant/

Sea Grant Nonindigenous Species Site (SGNIS)
www.sgnis.org/

U.S. Fish and Wildlife Service Invasive Species Site
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Sea Grant

The Prevention Message

Through Sea Grant research and outreach projects, guidelines have been established to prevent the spread of ANS for any recreational activity associated with water. The following are general preventative guidelines that apply to most recreational activities occurring in marine and inland waters.

- Always thoroughly inspect equipment (boats, trailers, SCUBA gear, anchors, lures) for attached ANS or aquatic vegetation before transporting.
- Always drain water from boat, livewells, and bilges before leaving any water access area.
- Always clean equipment that has been in infested waters before using it in other waters.
- Never use aquatic nuisance species for bait.
- Never transport aquatic nuisance species from one area to another.
- Never release animals or plants (aquarium species, bait, water garden plants) into the wild.
- Never dump live bait or fish into any water area
- Never dip a bait bucket into a water body if it contains water from another lake, stream, river, or other water source.

Prevention methods for the commercial shipping industry are being developed through ballast water projects, as described on page 106.