

Acknowledgments

SEA GRANT DRAWS ON UNIVERSITY EXPERTISE IN RESEARCH, EDUCATION AND technology transfer to promote wise use and management of marine and Great Lakes resources for the public benefit. Sea Grant reaches its audiences through direct interaction, mass media and other modes of communication such as fact sheets, journals, videos and newsletters.

The Ohio Sea Grant College Program is one of 29 programs in the National Oceanic and Atmospheric Administration's (NOAA) National Sea Grant College Program in the Department of Commerce. There is a Sea Grant program in every coastal state, except for Pennsylvania, and in Puerto Rico. For more information, contact the Sea Grant program nearest you or the National Sea Grant office.

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Summary

For a summary of this report, read the introductory stories on pages 2-9.

An overview of the research projects is provided on pages 10-12.

An overview of the outreach projects is provided on pages 41 and 42.

Preface

SINCE THE MID-1980S, WHEN THE ZEBRA MUSSEL WAS FIRST DISCOVERED IN THE Great Lakes basin, the National Sea Grant College Program has played a leading role in the federal response to the problem. Sea Grant outreach personnel were among the first to recognize the enormous potential for adverse ecological and economic impacts and helped generate a quick response. This took the form of interagency research planning and development of control legislation for nonindigenous aquatic nuisance species.

Through its long-standing partnership with academia and a competitive peer-reviewed research process, Sea Grant researchers have been able to address more basic areas of research, which the more mission-driven agencies are unable to do. Sea Grant's nonindigenous species research covers wide-ranging topics, from manipulating zebra mussels' reproductive physiology as a possible means of control, to modeling ballast exchange at sea for control of aquatic animals while maintaining ship stability and safety. This work complements the research of other agencies and the interagency research plan for nonindigenous aquatic nuisance species.

At the same time, Sea Grant outreach efforts are the basic avenues by which water users learn about ways to predict the arrival of zebra mussels and combat them once they're established. This is increasingly important as zebra mussels continue to spread throughout the United States.

It is our intent that this report provide the reader with accomplishments to date and a synopsis of the program up through the funding of new research projects in the 1993 fiscal year.

Bernard Griswold, Ph.D.
Division Director
National Sea Grant College Program

Nomindigenous Species Control Act

AQUATIC NUISANCE PREVENTION AND CONTROL, PUBLIC LAW 101-646—NOV. 29, 1990

To prevent and control infestations of the coastal inland waters of the United States by the zebra mussel and other nonindigenous aquatic nuisance species.

Foreword

FOR THE DIRECTORS OF THE SIX SEA Grant programs in the Great Lakes Sea Grant Network, one of the 29 programs in the National Sea Grant College Program of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, I am very pleased to present this summary of our research and outreach efforts to address the problems and issues associated with the invasion of the Great Lakes region and eastern United States by the zebra mussel, *Dreissena polymorpha*, and the quagga mussel, *Dreissena bugensis*.

Zebra mussels were first officially reported in the Great Lakes in June 1988. However, given the mussels' size, it is estimated that zebra mussels were introduced into the Great Lakes in 1985 or 1986, when one or more transoceanic ships discharged ballast water into Lake St. Clair.

Sea Grant researcher David Garton discovered the first zebra mussel on the U.S. side of Lake Erie in October 1988 at The Ohio State University's F.T. Stone Laboratory at Put-in-Bay, Ohio. Recognizing the significance of this introduction, the Great Lakes Sea Grant Network immediately went to work. Our programs attacked the problem of combatting zebra mussels from all sides, combining research, education, technology transfer and outreach efforts.

As regional leaders in education, environmental communications and technology transfer, we recognized our duty to devote all available resources to this critical problem. We also recognized our responsibility to focus the vast university-based research expertise at the region's academic institutions on the zebra mussel issue and to cooperate and collaborate with federal programs to develop a comprehensive, coordinated nonindigenous species research agenda.

The U.S. Great Lakes Nonindigenous Species Coordinating Committee was formed to foster cooperation and collaboration and to develop the coordinated research agenda. In addition to the six Great Lakes Sea Grant programs, the committee included the Great Lakes Environmental Research Laboratory (GLERL) of NOAA, the National Fisheries Research Center-

Great Lakes of the U.S. Fish and Wildlife Service, 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. Later, this committee expanded to become the Great Lakes Panel on Exotic Species of the Aquatic Nuisance Species Task Force.

This report briefly summarizes the zebra mussel research and outreach efforts of the National Sea Grant College Program. It includes brief descriptions of all research projects funded by National Sea Grant with the special zebra mussel appropriations and all research projects funded by the local Sea Grant programs in the Great Lakes. This information should be useful to elected officials, decision makers, scientists, businesses and industries, students and the general public.

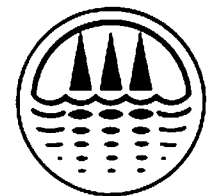
Jeffrey M. Reutter, Ph.D.
Director
Ohio Sea Grant College Program

"The U.S. Great Lakes Nonindigenous Species Coordinating Committee was formed to foster cooperation and collaboration and to develop the coordinated research agenda."

The Great Lakes Sea Grant Network



Wisconsin Sea Grant Institute



Minnesota Sea Grant College Program



Illinois-Indiana Sea Grant Program



New York Sea Grant Institute



Michigan Sea Grant College Program



*Range of color patterns seen in zebra mussels
in North America.
(photo by J. Ellen Marsden)*



Zebra mussels "feed" by filtering plankton from the water. In this shot the mussels have their bronchial siphons extended and open. The mussel on the right shows the front view. Zebra mussels filter 16.5 times more water than the mussels native to Lake Erie. (photo by Fred Snyder)

Exotics & the Great Lakes

IN 1869, IT WAS PURPLE LOOSESTRIPE. In 1873, alewife and chinook salmon. In 1879, common carp.

Exotics are nothing new in the Great Lakes. Scientists believe the sea lamprey led the way back in the 1830s. Since then, however, a host of others have followed, everything from plants to fish to mollusks. Today, scientists estimate that 136 foreign travelers make their home in the Great Lakes.

About half of these travelers are from Europe, according to scientists Joseph Leach, William Mills and James Carlton, who've completed a survey of Great Lakes exotics. These species made the trip to America by stowing away in the ballast water of ocean-going vessels. When the vessels dumped their ballast into the Great Lakes, the travelers had a new home. Evidence indicates that the Great Lakes' most famous recent invader, the zebra mussel, got its start that way.

Zebra mussels look like small clams and are about the size of a thumbnail. A small tuft of fibers — called byssal threads — protrudes from the hinge on their bodies. These fibers allow the mussels to attach to any hard surface — including other mussels. Female mussels can reach maturity in less than a year. Once mature, they can produce more than one million eggs per year. The eggs hatch into free-swimming larvae — called veligers. Veligers can remain in the water column for more than a month before settling and attaching. During this time, they can be transported great distances by currents. Once they

settle, they begin to filter the water — up to a liter per day — using plankton for food.

But perhaps the definitive zebra mussel characteristic is a seeming urge to roam. History tells us that zebra mussels have always been on the move. They're native to the Ponto-Caspian region of western Russia. But with the construction of canals across Europe in the 1700s and 1800s, they rapidly expanded their range. By the 1830s, zebra mussels covered much of the continent and had invaded Great Britain.

Today, zebra mussels have made their mark on the Great Lakes. Since their discovery in Lake St. Clair in 1988, the tiny striped mollusks have spread rapidly. Because of its shallow, warm, nutrient-enriched environment, Lake Erie is, was, and probably always will be the most significantly affected of the Great Lakes; however, to date, zebra mussels have spread to all of the Great Lakes and waterways in 18 states and the provinces of Ontario and Quebec. They've cost municipal and industrial water facilities millions of dollars in clean-up and control costs. They've disrupted Great Lakes recreation, causing thousands of dollars in damage to boats, docks, buoys and beaches. Over the next decade, scientists estimate that the cost of the zebra mussel invasion for Great Lakes water users could go as high as \$5 billion.

Zebra mussels have also affected the environment in other significant ways. So far, Sea Grant scientists have learned that zebra mussels are prodigious filter feeders — they re-

move tiny organisms from the water column at the rate of about a liter per day. Since the invasion, water clarity in Lake Erie has increased almost six-fold, allowing rooted aquatic plants to flourish and even clog harbors. Diatoms and rotifers — microscopic plants and animals at the base of the aquatic food chain — have been reduced by as much as 80 percent in some areas.

Also, scientists have learned that the zebra mussel, though small, is damaging to other organisms. In parts of Lake Erie and Lake St. Clair, where zebra mussels and native clams were both present, the native clams are now almost gone.

In addition, data suggest that zebra mussels' fatty tissues allow them to accumulate toxic chemicals at levels 10 times higher than native mussels. When eaten, zebra mussels pass this contaminant burden on to fish and on to small shrimp-like organisms called gammarids, which eat both zebra mussel waste products and dead mussel tissue.

To further complicate things, a second zebra mussel species, *Dreissena bugensis*, or "quagga" mussel, has been found in Lake Erie, Lake Ontario and the St. Lawrence River. This mussel can colonize much deeper habitats than *Dreissena polymorpha* — it's the only zebra mussel found below 110 meters. Also, it is lighter in color than the more famous black and brown striped zebra mussel. Another difference is substrate preference. Unlike "standard" zebra mussels, quaggas have been found on soft surfaces such as sand and mud.



THE GREAT LAKES BASIN IS HOME TO 22 MILLION Americans, 9 percent of the total U.S. population. The eight Great Lakes states are home to 30 million Americans.

▼ The Great Lakes basin covers 94,000 square miles and is larger than the states of New York, New Jersey, Connecticut, Massachusetts, Vermont and New Hampshire combined.

▼ The Great Lakes shoreline covers more than 11,000 miles — a distance equal to almost 45 percent of the Earth's circumference.

▼ The Great Lakes contain 6 quadrillion gallons of fresh water. That's about 20 percent of the world's fresh surface water and 95 percent of the U.S. supply.

▼ Each day, 655 billion gallons of Great Lakes water are used for various purposes — 94 percent of this water produces 20 billion kilowatt-hours of electricity by passing through hydroelectric plants and returning to the Great Lakes ecosystem.

▼ About 25 million people get their drinking water from the Great Lakes and the St. Lawrence River.

▼ The 145 U.S. and Canadian ports and terminals on the Great Lakes and St. Lawrence Seaway move more than 200 million tons of commodities each year.

▼ In 1986, about 17 percent of U.S. manufacturing industries were located in the Great Lakes basin.

▼ In 1988, there were more than 3.5 million registered recreational boats in Great Lakes states — a third of all registered watercraft in the country.

SOURCES:

Great Lakes Basin, published by Michigan Sea Grant, publication number MICHU-SG-89-503.

The Great Lakes Economy: Looking North and South, prepared by the Federal Reserve Bank of Chicago and the Great Lakes Commission.

Still unclear in all of this are the implications — for fisheries, biodiversity and pollution. Do zebra mussels hurt the walleye fishery by stealing food from the smaller fishes that walleye feed on? Will zebra mussels cut a simplifying swath through the complex ecosystem, doing to lakes what purple loosestrife has done to marshes? Will zebra mussels pass super-concentrated pellets of pollutants back up the food chain? Scientists seek answers to these and other questions.

Much progress has been made, however. In the laboratory, researchers have been able to artificially induce zebra mussel spawning. If large mussel populations in the wild could be “tricked” into spawning at inappropriate times, this could be a promising control technique.

Also, research has shown that potassium, bromine, ozone and ultraviolet light are potential control strategies — and possible alternatives to chlorine. Currently, more than 30 compounds are also being studied to determine their environmental impact and effectiveness against zebra mussels. Chlorine is currently the most popular control strategy, but increased chlorination clearly contradicts the efforts of the Great Lakes community to reduce the amount of chlorine entering the ecosystem.

Zebra mussels pose a complex set of challenges, both now and for the future. The spread is continuing, and mussel densities at Lake Erie water intakes are approaching 1 million per square meter. To meet these challenges, research must continue. Control methods must be developed, tested and made affordable. Industries, marinas — all those directly affected by zebra mussels — must have a direct line to the latest information. The general public must get involved — even simple precautions will help slow the spread.

In short, there must a coordinated campaign against zebra mussels through research, education, communication and information transfer. Clearly, zebra mussels are a national problem and no longer just a Great Lakes issue. This problem demands an effective solution.

That's where Sea Grant comes in. ▲

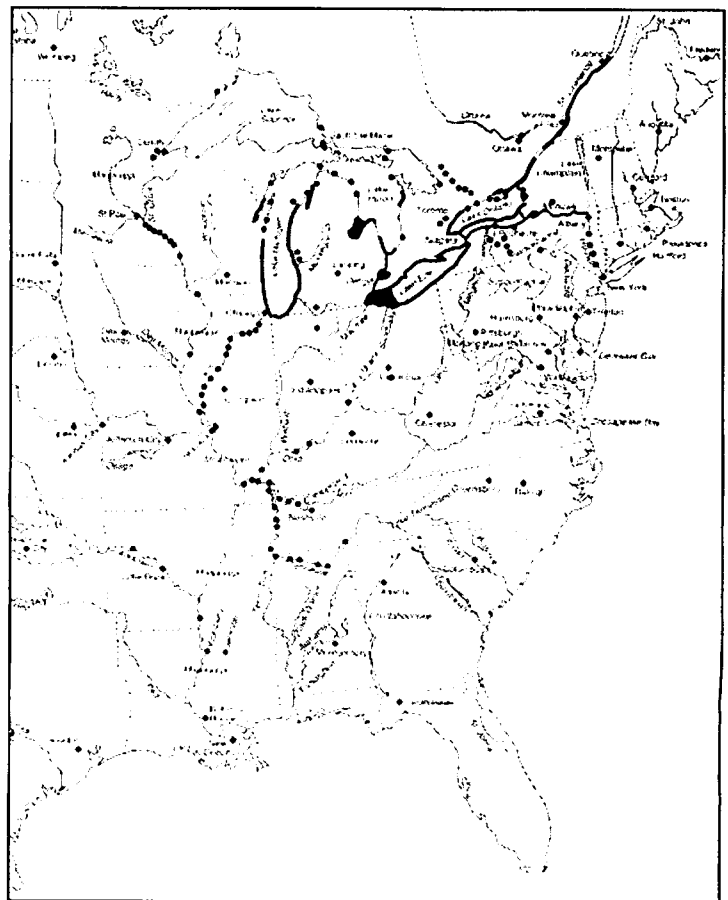
Zebra mussel distribution

compiled by New York Sea Grant with information from industries, agencies and Sea Grant programs throughout North America.

North American Range of the Zebra Mussel (°)
as of 18 January 1991



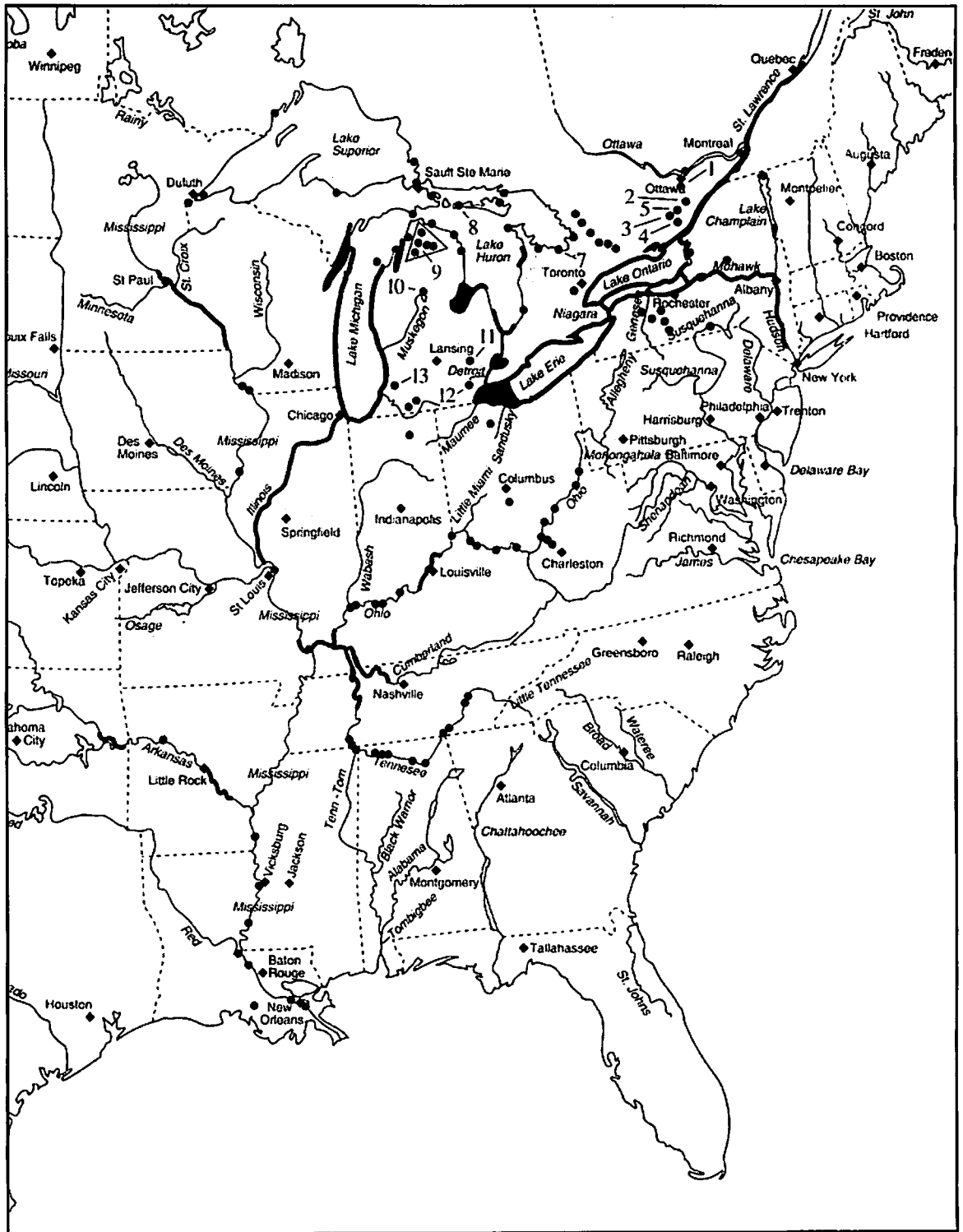
North American Range of the Zebra Mussel (°)
as of 15 October 1992



Zebra mussel distribution

North American Range of the Zebra Mussel ()
as of 15 December 1993*

1. Hog's Back Lock, Rideau River, Ottawa, ONT
2. Burritt's Rapid Locks, Rideau River, Ont
3. Lower Rideau Lake, ONT
4. Opinicon Lake, ONT
5. Big Rideau Lake, ONT
6. Owen Sound Harbour, ONT
7. Collingwood Harbour, ONT
8. Mississagi Strait, ONT
9. Burt Lake, Crooked Lake, Paradise Lake, Pickerel Lake, Walloon Lake, Michigan
10. Houghton Lake, Michigan
11. Cass Lake, Walled Lake, Michigan
12. Belleville Lake, Michigan
13. Lake Paw Paw, Michigan



What is Sea Grant?

SOME HAVE CALLED IT A COMMITMENT. Others call it a bridge, a bond, a partnership.

Congress called it Sea Grant. A national program created in 1966, Sea Grant is all of these things. It's a commitment to solve coastal problems and develop marine resources. It's a bridge between government and academia, scientist and private citizen. It's a bond uniting 29 state programs, 300 colleges and universities and millions of people. It's a partnership with a purpose — to help Americans understand and more wisely use our precious Great Lakes and ocean waters.

Sea Grant today is what Congress intended — an agent for scientific discovery, technology transfer, economic growth and social understanding.

It's happening all over. Every day, Sea Grant scientists make progress on the important marine issues of our time. Extension agents quickly take this information out of the laboratory and into the field, working to help save a coastal business, a fishery, sometimes even a life. A dedicated corps of writers and communications specialists spreads the word to the public. And Sea Grant educators bring the discoveries into the nation's schools, using them

to pioneer new and better ways of teaching, helping to create a new generation of scientifically literate Americans.

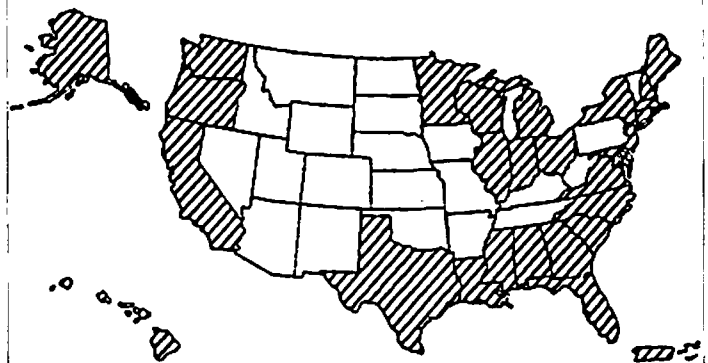
Together, separate elements create a cohesive whole, ensuring that Sea Grant meets the challenges of its mandate. National Sea Grant Director David Duane describes it this way: "Being a

marine program, the boundaries between such traditional elements of Sea Grant as research, education and extension are indistinct. Moreover, each element has a key role in the holistic continuum which makes up this unique program."

The returns are great — far exceeding the investment. In 1987, Sea Grant had an \$842 million impact on the national economy — a return triple that of 1981 and more than 20 times the federal investment of \$39 million. Not included in this figure are the impacts

"The boundaries between such traditional elements of Sea Grant as research, education and extension are indistinct. Moreover, each element has a key role in the holistic continuum which makes up this unique marine program."

Network of Sea Grant Programs



Sea Grant has programs in most coastal and Great Lakes states as well as in Puerto Rico

of better scientific knowledge and better education — important but almost immeasurable.

Clearly, Sea Grant's strength is its ability to meet problems head-on and efficiently solve them.

Today, one of those challenges is the zebra mussel. Sea Grant is meeting this challenge. Proceeding as it always has, Sea Grant is drawing on a wealth of scientific expertise to develop feasible solutions. But it's also keeping the public informed in all the effective and innovative ways that the collective creativity within Sea Grant can generate.

This publication is testimony to part of that effort, expertise and creativity — an overview of the Great Lakes Sea Grant Network's progress in combatting zebra mussels to date. ▲

Sea Grant research

10

OHIO SEA GRANT RESEARCHER David Garton initiated the first of several zebra mussel research projects in late 1988, and outreach programs were underway in all six Great Lakes Sea Grant programs by late 1989. However, the magnitude of the problem demanded a more significant federal response.

The Northeast-Midwest Institute and the Great Lakes Task Force in Congress, led by Senator John Glenn of Ohio, immediately went into action and passed the Nonindigenous Species Control Act in late 1990. A concerned Congress, led by Congressman Carr of Michigan, Congressman Regula of Ohio and Senator

Glenn, then appropriated \$1.8 million to support Sea Grant's zebra mussel research and outreach programs. Fortunately, funds have been reappropriated every year since. These funds have been distributed competitively among the 29 Sea Grant programs through a national call for research proposals and an extensive peer review process. These federal funds have effectively leveraged significant amounts of state, local and private sector support.

Of the \$1.8 million Congress appropriated for zebra mussel activities in the 1991 fiscal year, the National Sea Grant College Program designated nearly \$1.3 million for research

projects. Following a regional call for research proposals in early 1991, the National Sea Grant College Program received 58 proposals. The proposals were reviewed and ranked by a panel of experts, and 18 were funded.

During the 1992 fiscal year, a \$2.9 million special congressional appropriation for zebra mussel projects was divided, with more than \$1.8 million designated for research and almost \$1 million designated for outreach. Following a national call for research proposals, the National Sea Grant College Program received 77 proposals and funded 13.

Of the \$2.8 million appropriated during the 1993 fiscal year, more than \$1.7 million was directed for research, allowing the National Sea Grant College Program to fund 12 projects from a total of 55 submitted.

In 1990, the U.S. Great Lakes Nonindigenous Species Coordinating Committee developed a framework for nonindigenous species research with six major areas:

- 1 Biology/Life History of Nonindigenous Species
- 2 Ecosystem Effects of Nonindigenous Species
- 3 Socio-Economic Analysis: Costs and Benefits of Nonindigenous Species
- 4 Control and Mitigation of Nonindigenous Species
- 5 Prevention of Introduction of Nonindigenous Species
- 6 Reducing the Spread of Established Nonindigenous Species



Researcher David Garton dives for zebra mussel samples.
(photo by Lloyd Lemmerman)

Both the U.S. and Canadian research communities use these major research areas to focus their efforts. The National Sea Grant College Program has endeavored to address all aspects of the zebra mussel problem and supports projects in all six areas.

Biology/Life History of Nonindigenous Species

Sea Grant has supported nine projects in this area from six state Sea Grant programs. Literature surveys of European research were conducted to avoid duplication; however, it quickly became apparent that the zebra mussel in the Great Lakes behaves differently than it does in Europe.

Sea Grant researchers found that genetic variability in the zebra mussel is much greater than expected, which has allowed it to adapt quickly to local temperature regimes. Unfortunately, this will facilitate the mussel's spread, and thermal tolerance studies conducted in northern latitudes may not be directly transferable to southern states.

It was equally disturbing to learn that the veligers could remain suspended for more than 30 days, which is two to three times longer than reported in a number of European studies. This fact, coupled with observations of up to 1 million eggs in mature females, or more than 10 times the number often reported in European literature, and females that can reach maturity in less than 12 months, has made the spread of the mussel more rapid than anticipated.

The metabolic rate and oxygen needs of zebra mussels increase greatly above 30°C, resulting in

smaller individuals and slower reproduction. This may be very useful information in our efforts to control and eliminate the mussel.

Genetic research has also demonstrated that the quagga is indeed a second species of zebra mussel.

Ecosystem Effects of Nonindigenous Species

In keeping with current resource management efforts to handle aquatic systems and address problems on an ecosystem basis rather than species by species, Sea Grant has invested significantly in efforts to understand the complete impact of the zebra mussel on aquatic ecosystems by supporting 29 projects at four state programs. Results have been astonishing.

Densities of zebra mussels in the western basin of Lake Erie frequently exceed 70,000/m². At water intakes, these densities approach 1,000,000/m². Veliger densities exceed 100,000/m³. Their filtering rate depends on their size and the amount of food available. They remove phytoplankton of the size preferred by *Daphnia*, and *Daphnia* have responded with reduced reproduction and survival. Planktonic diatom densities in western Lake Erie from the 1980s to the 1990s have been reduced 85 percent; copepods have also seen major decreases; and some rotifers have all but disappeared. Few algae survive gut passage, and only benthic (bottom dwelling) algae have any likelihood of surviving and escaping from pseudofeces (filtered particles rejected by the mussels as food). This has resulted in up to a four-fold increase in water clarity.

Bacteria are smaller, and bacterial production is reduced 60 to 70 percent in the presence of zebra mussels; but their numbers were not affected.

Zebra mussels use native clams as substrate for colonies, much to the detriment of the native clams that have nearly all been eliminated from western Lake Erie and Lake St. Clair. However, zebra mussel aggregations at the bottom provide great habitat for many benthic macroinvertebrates, with up to 53 taxa reported. These aggregations are dominated by amphipods, turbellaria, gastropods and oligochaetes. Benthic algae and rooted aquatic plants also increase in the presence of zebra mussels.

A significant number of large freshwater drum and yellow perch eat zebra mussels, but they have had no noticeable impact on zebra mussel densities. Because zebra mussels have a body fat content about ten times higher than native clams, they are able to accumulate contaminants at much higher levels. The change in the pattern of contaminant cycling through aquatic systems, caused by zebra mussels, is of great concern, particularly if sport fish are going to use zebra mussels as a significant portion of their food. This has the potential to lead to significant human health risks.

Hard-water, mesotrophic (moderately to highly productive) lakes with rocky substrates are likely to be ideal habitats for the zebra mussel as it spreads. In these situations, the dramatic environmental changes discussed in this section can be anticipated.



Socioeconomic Analyses: Costs and Benefits of Nonindigenous Species
Sea Grant has funded five projects in this area at two state Sea Grant programs. Utilities in both the United States and Canada are spending millions of dollars to clean zebra mussels out of machinery and to prevent further introductions. Private boaters and charter fishing businesses are also experiencing problems with zebra mussels fouling and clogging cooling system. Fortunately, only two percent of recreational users indicate that they have reduced their use of the lakes because of the zebra mussel invasion.

Control and Mitigation of Nonindigenous Species

Sea Grant has addressed this important issue by supporting 13 research projects at six state Sea Grant programs. A number of chemicals designed to kill and/or prevent the attachment of zebra mussels have been evaluated and found to be safe and effective under a variety of environmental conditions. However, most remain quite expensive and/or require additional regulatory approvals before they can be used. As a result, chlorine remains the most commonly used chemical to kill zebra mussels.

Potassium has been found to be very effective in inhibiting the heart and respiratory activity of the mussels. Sea Grant researchers actually performed EKGs and MRI testing on zebra mussels to obtain this information. Potassium chloride has been found to be the most economical and environmentally compatible form.

Physical removal techniques are being investigated at several pro-

grams. A robot has been designed to physically clean the inside of pipes. Ultraviolet light is quite effective on young larvae but loses effectiveness as the mussels grow. Quagga mussels have been found to be more resistant to the ultraviolet light.

Biological controls are also being investigated. A strain of bacteria has been identified that can kill zebra mussels in less than five days.

Sometimes the best way to learn how to kill an organism is to learn how to grow it. As a result, several Sea Grant researchers have been developing techniques to raise zebra mussels in their laboratories. They have found chemicals that artificially induce zebra mussels to spawn. Through these, there may be potential to control zebra mussels by inducing them to spawn at inopportune times. Once the researchers were able to induce the mussels to spawn, they immediately began evaluating chemicals that would inhibit or interfere with spawning.

Researchers are also evaluating narcotizing agents such as carbon dioxide. It is hoped that by first relaxing the mussel with a narcotizing agent, it could be killed with a smaller dose of chlorine or some other chemical. This could reduce the cost and the adverse environmental impacts associated with chlorine.

Prevention of Introduction of Nonindigenous Species

While everyone wishes zebra mussels had never been introduced, the significance of their impact clearly demonstrates the importance of working to prevent further introductions. Conse-

quently, Sea Grant has supported a project to evaluate the safety of ballast water exchanges at sea. This technique deposits freshwater organisms into a salt water environment where they cannot survive, and vice versa. Results indicate that such exchanges are entirely safe for the vessel if wave heights are 10 feet or less. Ballast exchanges when waves are 20-foot high should be avoided.

Reducing the Spread of Established Nonindigenous Species

Reducing the spread of zebra mussels is very important. Sea Grant has attempted to enlist the help of private boaters and anglers by demonstrating how their activities can facilitate the spread. Research demonstrated that veligers were frequently found in all types of water contained in boats, including engine cooling systems, bilges, live wells and bait buckets. Adult mussels were only observed on vegetation entangled on boat trailers; on some days, 30 percent of the boat trailers transported mussels this way.



The following pages briefly summarize 59 Sea Grant zebra mussel research projects in the six areas initiated between 1988 and 1992. This group includes several projects supported with funds from the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service and state Sea Grant program development funds. A list of 12 new research projects — initiated in September 1993 with a special congressional appropriation — begins on page 37. Some of the best university researchers are working with National Sea Grant on zebra mussel concerns. Addresses for the researchers begin on page 65.

Research projects

initiated in 1988-1992 by the National Sea Grant College Program and the Great Lakes Sea Grant Network Programs. Results provided are as of May 1993.

Biology/Life History of Nonindigenous Species

Physiology of Zebra Mussels

David W. Garton, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-20-PD

Date: 4/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To determine seasonal patterns of metabolism associated with critical life history events, e.g., spawning during the summer.

Results

- In 1990, zebra mussels' metabolic rate peaked in early July—two weeks before veligers reached peak densities—indicating a link between spawning and metabolic rate.
- Zebra mussels' oxygen demands increase dramatically above 30°C.

Biom mineralization and the Requirement for Strontium During Larval Development of the Zebra Mussel (*Dreissena polymorpha*)

Scott M. Gallager, Judith E. McDowell and Alan Kuzirian, Woods Hole Oceanographic Institution, and Joseph P. Bidwell, University of Massachusetts

Program: Woods Hole Oceanographic Institution Sea Grant Program

Project Number: R/M-25

Date: 8/1/91 to 7/31/92

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine how much strontium and calcium zebra mussel larvae need to mineralize their first shells.
- To pinpoint the period in the life cycle when larvae need these minerals.
- To use electron microscopy to further describe how zebra mussels develop as embryos and larvae.
- To identify a "weak link" in the zebra mussel life cycle.

Genetics of Zebra Mussels: Critical Data for Ecological Studies and Development of Effective Long-Term Control Strategies

J. Ellen Marsden, Illinois Natural History Survey

Program: Illinois-Indiana Sea Grant Program

Project Number: ZM/1

Date: 8/1/91 to 7/31/93

Primary Source of Funds: Pass-through from EPA

Objectives

- To determine whether zebra mussels within the Great Lakes are a genetically uniform population or represent many different subpopulations.
- To examine whether different zebra mussel subpopulations are the result of separate introductions from Europe.
- To determine whether subpopulations respond differently to control techniques and environmental conditions.

Biology/Life History of Nonindigenous Species

In order to accurately predict an ecosystem's response to an invading species, scientists need to understand the life history and population dynamics of the species. Basic biological research in the areas of life history, population dynamics, physiology and behavior, genetics, parasites and diseases—coupled with review of the existing research literature—may lead to the discovery of ecologically safe, effective and inexpensive control measures and may reveal the invader's vulnerability to particular alternatives. Further, research on the ecological and environmental tolerances of nonindigenous species answers important questions about the geographic limits of infestation and which native species and habitats are most likely to be affected by the invader.

Biology/Life History of Nonindigenous Species

Preliminary Results

- There is high genetic variability among Great Lakes zebra mussels.
- A second *Dreissena* species in the Great Lakes has been identified.
- There is a low level of genetic differentiation among Great Lakes zebra mussel populations.

The Byssal Adhesive of Zebra Mussels, *Dreissena polymorpha*

J. Herbert Waite, University of Delaware

Program: Delaware Sea Grant College Program

Project Number: R/B-26

Date: 9/1/91 to 8/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To purify the substance that is the precursor of zebra mussels' byssal adhesive.
- To determine the sequence and physical properties of this substance.
- To localize this substance immunochemically.

Preliminary Results

- Several families of DOPA-containing precursor proteins have been purified from zebra mussel byssal threads.
- DOPA content in zebra mussel proteins is lower and more variable than in other marine DOPA proteins.
- DOPA-containing precursor proteins in zebra mussels have no extended sequences in common with other marine mussel glues.

Influences of Temperature and Diet on Physiological Energetics of Growth and Reproduction of *Dreissena polymorpha*

David W. Garton, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-10

Date: 2/1/92 to 1/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine how water temperature and food quantity and quality affect growth and reproduction in zebra mussels.
- To identify environmental factors that limit mussel distribution.
- To identify "weak links" in the zebra mussel life cycle — periods when resistance to environmental stress is low or when reproduction could be reduced.

Preliminary Results

- Zebra mussels are genetically diverse and can adapt to local temperature regimes.
- Thermal tolerances of "northern" mussels may not accurately predict thermal tolerances of "southern" mussels.
- Greatest shell growth occurs with low temperatures and abundant food.
- Body mass is greatest at low temperatures.
- Highest oxygen consumption occurs with high temperatures and abundant food.
- Participation in spawning decreases as temperature increases.
- High temperatures and abundant food retard reproductive effort.
- Temperature — rather than food — appears to be the driving force behind zebra mussel reproduction.

Biology/Life History of Nonindigenous Species

Genetic Variability and Environmental Tolerances of the "Quagga" Mussel: A New Dreissenid Invader of the Great Lakes

Edward L. Mills, Cornell Biological Field Station, and Bernie May, Cornell University

Program: New York Sea Grant Institute

Project Number: R/CMB-5

Date: 8/1/92 to 5/31/93

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To measure the quagga's genetic variability and its natural hybridization with the zebra mussel.
- To determine the quagga's tolerance to salinity and heat.

Preliminary Results

- No evidence of hybridization between zebra and quagga mussels has been observed.
- A mussel from the former Soviet Union — previously identified as a zebra — has been shown to be a quagga; this provides a place to start in searching for the quagga's origins.

Species Identities and Relationships of North American and European *Dreissena* (*Bivalvia: Dreissenidae*)

Gary Rosenberg, Academy of Natural Sciences of Philadelphia

Program: New Jersey Marine Sciences Consortium Sea Grant Program

Project Number: R/E-30-ZM

Date: 9/1/92 to 8/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To confirm that a second *Dreissena* species is present in North America.
- To evaluate genetic variability in European *Dreissena* and compare it with North American populations.
- To quantify how many existing *Dreissena* species occur in Europe.
- To determine whether it's possible to identify *Dreissena* species by shell and anatomy alone (as opposed to genetic gel tests).

An Investigation of the Larval Development and Shell Morphology of the Zebra Mussel, *Dreissena polymorpha* (Pallas)

Gail M. Lima, Illinois Wesleyan University

Program: Illinois-Indiana Sea Grant Program

Project Number: ZM/3

Date: 9/1/92 to 9/1/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine the maximum time zebra mussel veligers can remain planktonic.
- To determine whether veligers can delay metamorphosis and which environmental factors could influence this.
- To describe larval and post-larval zebra mussel shell morphology.
- To propose control techniques that interfere with larval settlement and metamorphosis.

Ecosystem Effects of Nonindigenous Species

Osmoregulatory Physiology of the Zebra Mussel

Robert L. Preston, Illinois State University

Program: Illinois-Indiana Sea Grant Program

Project Number: ZM/2

Date: 11/1/92 to 10/31/95

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To characterize how zebra mussels osmoregulate at the cellular level.
- To test the hypothesis that ion balance is regulated by membrane processes that are potentially sensitive to chemical agents.
- To test specific agents that disrupt osmoregulation in zebra mussels.

Ecosystem Effects of Nonindigenous Species

Interactions Between Newly-Introduced Zebra Mussel, *Dreissena polymorpha*, and Pelagic Communities

David W. Garton and David A. Culver, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-15

Date: 11/15/88 to 8/31/92

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To examine whether zebra mussels have diverted a significant amount of energy from the open-water food web to the lake bottom.
- To determine whether zooplankton growth slows as zebra mussel production increases.

Historical and Recent Changes in the Diet of the Alewife in Lake Ontario: Significance and Implications for Ecosystem Change

Edward L. Mills, Cornell Biological Field Station

Program: New York Sea Grant Institute

Project Number: R/FBF-4-PD

Date: 1/1/89 to 12/31/89

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To examine the seasonal diet of alewives in Lake Ontario.
- To compare information on dietary changes with data gathered before *Bythotrephes cederstroemi* colonized the lake.

Results

- In spring 1988, *Bythotrephes cederstroemi* (spiny water flea) was an important food source for alewives and was the only detectable change in alewife diet since 1972.
- Considerable numbers of *Bythotrephes* enter Lake Ontario from Lake Erie.
- *Bythotrephes* spines appear to cause no obvious stomach injury in alewives.
- Any changes in abundance of microzooplankton in Lake Ontario will affect both the alewife community and the salmonine population it supports.

Ecosystem Effects of Nonindigenous Species

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The implications of a nonindigenous species invasion for the ecosystem, especially in terms of competition for food with other species, may be far-reaching. Any new organism introduced to an existing 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 species. In addition, some invading organisms can influence — and possibly significantly change — both a lake's water quality and its productivity. Therefore, it is a high priority to identify and evaluate the effects and changes the invader is likely to produce at each stage in its life history. Such information helps natural resource managers determine how to minimize the impacts invading organisms have on established biota and habitats.

Ecosystem Effects of Nonindigenous Species

The Effects of Zebra Mussels on Pelagic Communities

David A. Culver, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-17-PD

Date: 12/1/89 to 6/30/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To determine the impact of zebra mussels on the phytoplankton in the western basin of Lake Erie.

Results

- Water clarity and algal abundance changed seasonally in both 1988 and 1989. Spring algal blooms were followed by a clear water phase in early July, followed by a resurgence of algae in August. *Daphnia* was most abundant in late June and declined in mid-July both years. Zebra mussels increased in abundance from 1988 to 1989.
- Grazing estimates suggested that *Daphnia* could explain the decline of phytoplankton during the clear water periods. The resurgence of phytoplankton after *Daphnia* declined both years suggests that zebra mussels were not responsible for the clear water periods, because zebra mussels were still present in August when the resurgence occurred.

Grazing Rates of Zebra Mussels

David A. Culver, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-21-PD

Date: 4/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To evaluate the grazing rate of zebra mussels as a function of body size to enable estimates of grazing rates in the field from size frequency and density measurements.
- To examine the effects vertical mixing rates of the western basin of Lake Erie have on the growth rate of zebra mussels suspended at various depths near and above the bottom.

Results

- Grazing rates varied significantly with body size and with added clay particles to simulate the effect of silt with low food quality. Analyses of an extension data set are continuing at this time.
- Zebra mussels in cages near the bottom grew only one-third as fast as those two meters above the bottom. This shows that either existing communities of zebra mussels on the bottom decrease the amounts of algae there relative to further up in the water column, or higher turbulence above the bottom increases the delivery rate of algae to zebra mussels, or both. Clearly, zebra mussels on the lake bottom do not have unlimited access to all algae in the water column.

Concentration of Hydrophobic Carcinogens by Zebra Mussels: Effects on Aquatic Food Chains

Susan W. Fisher, The Ohio State University, and Paul C. Baumann, U.S. Fish and Wildlife Service National Contaminant Research Center

Program: Ohio Sea Grant College Program

Project Number: R/PS-6-PD

Date: 4/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To make toxicokinetic and physiological measures to examine the movement and importance of contaminants passing through zebra mussels into the greater Great Lakes food web. ▽

Ecosystem Effects of Nonindigenous Species

Results

- Accumulation rates drop by a factor of two for each 10°C change in temperature.
- Zebra mussels are likely to concentrate contaminants at a level 100 times greater than would be expected in fish.
- Bioconcentration of contaminants in zebra mussels depends on environmental temperature and the contaminant's affinity for water.

Impact of *Dreissena polymorpha* on the Zooplankton of Western Lake Erie

Alfred M. Beeton, GLERL at NOAA, and John R. Hageman, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-25-PD

Date: Regular monitoring as of 4/1/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To follow changes in zooplankton as the zebra mussel population grows.
- To determine the effects of mussel competition and predation on community structures.

Preliminary Results

- Major decrease in copepod abundance.
- Major population fluctuations for cladocera.
- Almost total disappearance of some rotifers.

The Fate of Phytoplankton Following Processing by the Zebra Mussel

Rex L. Lowe, Bowling Green State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-22-PD

Date: 5/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To determine which algal species become zebra mussel feces and pseudofeces.
- To determine the survival of algae following zebra mussel planktivory.
- To identify the implications of zebra mussel planktivory on the food web.

Results

- Few algae that pass through the zebra mussel gut survive.
- Lake-bottom algae are more likely than open-water algae to survive ingestion by zebra mussels, escape from zebra mussel pseudofeces and re-enter the plankton community.

Monitoring the Ecological Impact of Zebra Mussels in the Eastern Basin of Lake Erie

Howard P. Riessen, SUNY College at Buffalo

Program: New York Sea Grant Institute

Project Number: R/FO-1-PD

Date: 5/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To monitor and follow the population dynamics of veligers when zebra mussels first invaded the eastern end of Lake Erie.

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Results

- In 1989, veligers hit peak densities in September (300 to 3,000 per cubic meter) but were absent from the water column by November.
- In 1990, veligers were absent in May and June, hit peak densities in August (more than 100,000 per cubic meter) and declined rapidly during September.
- During the first year of zebra mussel colonization in this region, veliger densities increased by one to two orders of magnitude.

Trophic Interactions: The Relative Importance of *Dreissena* and *Daphnia* Grazing on Phytoplankton Abundance and Water Clarity

Joseph C. Makarewicz, SUNY College at Brockport

Program: New York Sea Grant Institute

Project Number: R/CMB-3-PD

Date: 6/1/90 to 12/31/90

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To test the ability of the pelagic organism *Daphnia* and the benthic organism, the zebra mussel *Dreissena polymorpha* to affect water clarity as a result of grazing on phytoplankton.

Results

- Zebra mussels excrete soluble reactive phosphorus (SRP) as they graze on phytoplankton but at much lower levels than when they graze on zooplankton.
- Low rate of phosphorus excretion by zebra mussels suggests that they could be inhibiting phytoplankton growth, thus resulting in greater water clarity.

Epilithic Benthos in the Western Basin of Lake Erie

Jerry H. Hubschman, Wright State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-23-PD

Date: 4/4/91 to 12/31/91

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To characterize the macroinvertebrate fauna of zebra mussel *Dreissena polymorpha* beds in western Lake Erie.

Results

- Aggregations of zebra mussels provide excellent habitat for benthic invertebrates.
- Amphipods, turbellaria, gastropods and oligochaetes dominate the assemblage.
- This interstitial community is both large and rich in species. Fifty-three macroinvertebrate taxa have been identified in samples.

Exotic Species Invasions: Population Dynamics and Community Consequences of the Zebra Mussel, (*Dreissena polymorpha*)

D.K. Padilla and S.I. Dodson, University of Wisconsin-Madison

Program: Wisconsin Sea Grant Institute

Project Number: R/LR-41

Date: 8/1/91 to 7/31/93

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To develop models to predict zebra mussel abundance, distribution, population dynamics and

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ecological effects in North America.

- To determine which factors are most important in predicting population performance.
- To predict areas likely to be invaded and how zebra mussels might change those ecosystems.

Preliminary Results

- Hard-water, mesotrophic lakes with rocky substrates are likely to be ideal habitat for zebra mussels.
- Zebra mussels are likely to reduce large phytoplankton (blue-green algae).
- Zebra mussels are likely to have small effects on nanoplankton and herbivorous zooplankton.
- Based on European lakes, there appear to be thresholds in pH and calcium ion concentrations that will determine whether zebra mussels can establish populations in lakes.
- Other lake physical characteristics are not likely to affect their ability to support populations of zebra mussels.

The Impact of Zebra Mussels (*Dreissena polymorpha*) on Lower Food Web Dynamics in a Large Freshwater Lake

Donald J. Stewart, SUNY College at Stony Brook, E.L. Mills and J.L. Forney, Cornell Biological Field Station, and M.J. Mitchell, SUNY College at Stony Brook

Program: New York Sea Grant Institute

Project Number: R/CE-3

Date: 8/1/91 to 7/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To test the hypothesis that open-water production of zooplankton will decline in response to colonization by zebra mussels.
- To create a computer model of nutrient-plankton interactions to predict Oneida Lake's response to invasion by zebra mussels.
- To gauge how zebra mussels might affect nutrients, phytoplankton, zooplankton and larval fish.

Preliminary Results

- Zebra mussel filtration rates depend on mussel size and amount of available food.
- Zebra mussels remove phytoplankton of the size most preferred by *Daphnia*.
- *Daphnia* respond to reduced phytoplankton with reduced clutch size and reduced survival.

Influence of Zebra Mussel Invasion on Carbon and Phosphorus Dynamics in Plankton Communities: A Mesocosm Study in Saginaw Bay

Robert T. Heath, Kent State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-6

Date: 9/1/91 to 8/31/92

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To test the hypothesis that zebra mussels alter carbon and phosphorus dynamics at the base of the food web by grazing selectively on phytoplankton and bacterioplankton.
- To determine whether these effects are related to the trophic state of the community and zebra mussel density.

Preliminary Results

- Mussels prefer to graze on diatoms and small chlorophytes.
- Bacteria are smaller in the presence of zebra mussels, though their numbers do not change significantly.

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- Release of dissolved organic phosphorus is greatly reduced in the presence of zebra mussels.
- Bacterial productivity is reduced by 60 to 70 percent in the presence of zebra mussels.
- Phosphate uptake in bacteria is greatly reduced in the presence of zebra mussels.
- Oligotrophic, mesotrophic and eutrophic communities all appear to be susceptible to this effect.
- Communities with large portions of large, inedible, blue-green algae seem less affected.

Accumulation and Trophic Transfer of Organic Xenobiotics by the Zebra Mussel, *Dreissena polymorpha*: The Role of Route of Exposure and Lipid Content

Susan W. Fisher, The Ohio State University, and Peter F. Landrum, GLERL at NOAA

Program: Ohio Sea Grant College Program

Project Number: R/ZM-1

Date: 10/1/91 to 9/30/93

Primary Source of Funds: Pass-through from EPA

Objectives

- To measure lipid content and production of pseudofeces when zebra mussels are fed two types of algae or sediment.
- To compare the assimilation rates of contaminants into zebra mussels via three types of particulates.
- To use radioactive tracers to measure trophic transfer from pseudofeces to the aquatic invertebrate *Gammarus*.

Preliminary Results

- Mussels exposed to contaminated algae assimilate the contaminant more efficiently than mussels exposed to the same contaminant in sediments.
- Exposure through algae plays a greater role in zebra mussel contamination.

Zebra Mussel: Fish Relations and Their Effects on Nutrient/Energy and Contaminant Dynamics

Konrad Dabrowski, The Ohio State University, and Paul C. Baumann, U.S. Fish and Wildlife Service
National Contaminant Research Center

Program: Ohio Sea Grant College Program

Project Number: R/ZM-4

Date: 10/1/91 to 9/30/94

Primary Source of Funds: Pass-through from EPA

Objectives

- To determine if various sizes of freshwater drum and yellow perch exhibit size-selective predation on zebra mussels.
- To determine prey handling times of various sizes of freshwater drum and yellow perch preying on various sizes of zebra mussels.
- To determine if lab-generated predictions of size-selective predation patterns by selected fish species on zebra mussels accurately predict actual predation patterns by fish in the field.
- To determine digestibility of different sizes of mussels as food for various sizes of freshwater drum and yellow perch.
- To determine the metabolic rates of oxygen consumption and ammonia excretion as a function of swimming speed in freshwater drum and yellow perch.
- To determine energy and protein balance in freshwater drum and yellow perch feeding on zebra mussels, as compared to reference diets.
- To estimate ecological significance of freshwater drum and yellow perch preying on zebra mussels in terms of energy flow in Lake Erie.



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- To document the presence of and determine the concentrations of PCB, dioxin and furan isomers in a wild population of zebra mussels from a contaminated location.
- To determine the ability of drum to bioaccumulate various polychlorinated aromatic isomers by feeding on environmentally contaminated zebra mussels.

Preliminary Results

- Zebra mussels sampled from Ashtabula Harbor did not exhibit extensive contamination; one sample site showed detectable contamination of Chrysene in the larger-sized mussels.
- Stomach and intestinal analyses of drum and perch collected in May 1992 showed that 26.5 percent and 37.3 percent contained zebra mussels, respectively. Drum less than 325 mm and perch less than 175 mm rarely consumed mussels.
- Stomach and intestinal analyses of drum and perch collected in July 1992 showed that 31.3 percent and 15 percent contained zebra mussels, respectively. Drum less than 265 mm and perch less than 200 mm rarely consumed mussels.
- Seasonally, more zebra mussels were consumed in the spring than in the summer.
- The predation on zebra mussels by freshwater drum and yellow perch does not appear to be gape limited.

The Impact of Zebra Mussel Filtering on Pelagic Food Webs

David A. Culver and Robert M. Sykes, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-3

Date: 2/1/92 to 1/31/95

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine how zebra mussel grazing affects open-water communities.
- To gauge how the benthic boundary layer affects the food available to zebra mussels.

Preliminary Results

- Zebra mussels near the lake bottom grow only one-fourth to one-third as much as mussels higher in the water column.
- There is less food available to zebra mussels at greater depths.
- The impact of zebra mussels on open-water communities may depend on the physical structure of the lake bottom and mussel settling depth.

Responses of Macrophytes and Associated Fish Larvae to Zebra Mussels in Saginaw Bay

Thomas G. Coon and Ted Batterson, Michigan State University

Program: Michigan Sea Grant College Program

Project Number: R/ZM-7

Date: 5/1/92 to 4/30/93

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To document how increased densities of zebra mussels affect water clarity and thus distribution, abundance and species composition of submersed macrophytes.
- To determine whether zebra mussels change densities and growth of yellow perch and common carp larvae.

Preliminary Results

- From 1991 to 1992, macrophytes in Saginaw Bay increased in occurrence and number.
- Species responding to increased water clarity included angiosperms, charophytes and attached chlorophytes.

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Zebra Mussel's Directed Trophic Transfer

Susan W. Fisher, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/PS-11-PD

Date: 6/1/92 to 12/31/92

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To test the hypothesis that PCBs are transferred along the food chain from contaminated algae to zebra mussels to gammarids and ultimately to many edible fish species.

Results

- Studies with uncontaminated algae show differential processing and production of pseudofeces as a function of algae species, mussel size and algal concentration.
- Zebra mussels accumulate PCBs and PAHs at levels about ten times higher than those typical of aquatic invertebrates.
- Determinants of bioconcentration in zebra mussels include mussel size and lipid content.
- Contaminated particles are a significant source of PCBs and PAHs for zebra mussels.
- When zebra mussels are exposed to contaminated particles, unassimilated materials pass through to feces and subsequently become a source of contamination for benthic invertebrates.
- Gammarids accumulate 90 to 100 percent of their body burden of PCBs and PAHs through ingestion of contaminated zebra mussel feces.
- Fish eating contaminated zebra mussels versus contaminated gammarids will receive five times the dose of chemical through consumption of gammarids due to food chain magnification.

The Areal and Vertical Distribution of *Cladocera glomerata* in Western Lake Erie and its Interaction with the Zebra Mussel (*Dreissena polymorpha*)

Mark E. Monaco, NOAA, Richard C. Lorenz, Columbus (Ohio) Division of Water, and

Charles E. Herdendorf, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ER-26-PD

Date: 6/1/92 to 12/31/92

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To determine how zebra mussels have influenced the areal and vertical distribution of *Cladophora glomerata* in western Lake Erie.

Results

- Biomass of the dominant benthic alga *Cladophora glomerata* has not increased.
- Water clarity has increased throughout the western basin. Secchi disk depths in 1992 ranged from 0.6 to 4.3 m, compared with 0.7 to 2.6 m for the same sites in the early 1980s.
- *Cladophora* colonization, which began with lush growth at the splash zone, is inversely related to zebra mussel colonization and begins declining after 1.5 m of depth.
- Based on minimal light requirements, *Cladophora* is capable of a mean maximum depth of growth to 8.35 m, compared with the mean maximum observed depth of 2.9 m.
- *Cladophora* colonization is limited by competition with zebra mussels for bedrock habitat at depths greater than 2 m, even when adequate light levels are available for colonization.
- Only trace amounts of *Cladophora* are found on substrates colonized nearly 100 percent by zebra mussels.
- The blue-green alga *Phormidium* is present at many of the sampling sites, often colonized directly on zebra mussels and rocks.

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Impact of *Dreissena polymorpha* on the Plankton Diatoms in Western Lake Erie and Lower Saginaw Bay, Lake Huron

Ruth Holland Beeton, University of Michigan

Program: Michigan Sea Grant College Program

Project Number: R/ZM-3

Date: 8/1/92 to 7/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objective

- To evaluate how zebra mussels affect the community structure of diatoms in western Lake Erie and Saginaw Bay.

Preliminary Results

- Between the 1980s and 1990s, planktonic diatoms in western Lake Erie declined by more than 85 percent.
- During the same period, water transparency increased by more than 76 percent.
- Concentrations of major nutrients have either remained essentially the same or increased in the waters of Hatchery Bay (near Put-in-Bay, Ohio) since the establishment of *Dreissena polymorpha*.

Influence of Zebra Mussel Invasion on Nutrient Dynamics in Plankton Communities: Field Verification of Mesocosm Findings in Saginaw Bay

Robert T. Heath, Kent State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-7

Date: 8/1/92 to 7/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To test the hypothesis that planktonic nutrient dynamics observed in the field will show the same sensitivity in the presence of zebra mussels as seen in lab and mesocosm experiments.
- To confirm that changes in bacterial nutrient dynamics are caused by loss of labile dissolved organic carbon (carbon normally released by algae).

Preliminary Results

- Bacterial phosphate uptake in samples taken from oligotrophic sites were consistently more sensitive to zebra mussels than samples taken from eutrophic sites.
- Sensitivity of bacterial phosphate uptake was correlated with the extent to which zebra mussels grazed on phytoplankton at each site. Those sites at which algae were most heavily grazed were those at which bacterial phosphate uptake was most severely affected.
- Algal eutrophic sites that support large populations of zebra mussels develop communities of large-bodied cyanophytes and large colonial chrysophytes, which are not as edible to zebra mussels as diatoms or small-bodied chlorophytes found at oligotrophic sites.
- We tested the hypothesis that zebra mussels affect bacterial activities by depriving them of carbon substrate normally released by algae (i.e., labile dissolved organic compounds, LDOC) by comparing bacterial activities in samples incubated in ambient light intensities with those incubated in low intensity light and in the dark. We found that light deprivation of the community led to similar declines of bacterial activities as experienced by zebra mussel grazing, presumably because of a decrease in available LDOC photosynthate.

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Remote Sensing Studies of Zebra Mussel Impacts in Saginaw Bay

W. Charles Kerfoot and Ann L. Maclean, Michigan Technological University

Program: Michigan Sea Grant College Program

Project Number: R/ZM-6

Date: 9/1/92 to 8/31/93

Primary Source of Funding: Pass-through from Michigan DNR

Objectives

- To determine whether changes in water quality caused by zebra mussels can be detected, mapped and quantified using remotely sensed images.
- To use Advanced Very High Resolution Radiometer (AVHRR) techniques to monitor changes in water temperature, turbidity and chlorophyll *a* content.
- To test the hypothesis that the impact of zebra mussels on Saginaw Bay is strongly related to water depth and interactions between inshore and offshore water masses.

Preliminary Results

- Developed automated procedures for generating temperature and reflectance contour maps of Lake Huron, Lake St. Clair and western Lake Erie using satellite data.
- Preliminary maps provide excellent detail of horizontal temperature and reflectance patterns in the study sites.
- Marked thermal gradients of approximately 10°C appear during mid-summer in Saginaw Bay (July 4, 1983 image).
- The maps show that shallower bay waters may be successively closed off from the offshore water masses due to density gradients; under these conditions, the effect of zebra mussel filtering activity may be tracked using satellite data.
- Zebra mussel impacts on water quality may be more difficult to track when flushing occurs (e.g., spring and fall) (September 4, 1987 image).

Direct Experimental Assessment of the Impact of *Dreissena polymorpha* on Unionid Growth, Mortality and Condition in Lake St. Clair

R. Douglas Hunter, Oakland University

Program: Michigan Sea Grant College Program

Project Number: R/ZM-4

Date: 9/1/92 to 8/31/93

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To provide direct experimental evidence that zebra mussels cause the death of unionids in Lake St. Clair.
- To evaluate whether zebra mussels also cause reduced growth and emaciation in Lake St. Clair unionids.

Preliminary Results

- Massive *Dreissena* colonization of *Lampsilis soliquoidea* and *Anodonta grandis* causes starvation and tissue degrowth, as evidenced by increase in shell:tissue mass ratio.
- In a survey of five species of unionids, those that were colonized by zebra mussels suffered higher mortality rates than those not colonized.
- There were interspecific differences in mortality rates.
- Most unionids will recover if attached zebra mussels are removed.
- Unionids cleaned of zebra mussels had survival rates equal to those of unionids that were uncolonized.
- Species with relatively massive shells had lower percentage of mortality than species with relatively thin and fragile shells.

Ecosystem Effects of Nonindigenous Species

Phosphorus Budget of a Zebra Mussel Population

Joseph C. Makarewicz, SUNY College at Brockport

Program: New York Sea Grant Institute

Project Number: R/CE-4

Date: 9/1/92 to 8/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine a phosphorus budget for a zebra mussel population.
- To compare phosphorus cycling in zebra mussels with down stream transport of phosphorus in the Erie Canal.

The Impact of Zebra Mussels on the Dynamics of Heavy Metals

Peter C. Fraleigh, University of Toledo

Program: Ohio Sea Grant College Program

Project Number: R/ZM-2

Date: 9/1/92 to 8/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine whether zebra mussels increase biodeposition of heavy metals to the lake bottom.
- To test whether zebra mussels increase flux of heavy metals from the water column to the lake bottom.

The Impact of Zebra Mussels on the Benthic Food Web in Saginaw Bay, Lake Huron

Rex L. Lowe, Bowling Green State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-5

Date: 9/1/92 to 8/31/95

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine how increased densities of zebra mussels affect the structure and function of benthic algae communities.
- To test whether zebra mussel feces and pseudofeces increase nutrients available to benthic algae and increase growth.
- To test whether increased light penetration increases growth of benthic algae and leads to changes throughout the food web.

Preliminary Results

- Light availability to benthic algae has increased in Saginaw Bay following the zebra mussel invasion.
- Benthic algal growth in Saginaw Bay has increased following the zebra mussel invasion.
- Benthic algal community structure has shifted following the zebra mussel invasion in Saginaw Bay.
- Benthic algal biomass was not limited by nitrogen or phosphorus in Saginaw Bay following the zebra mussel invasion.

Nutrient Regeneration by Zebra Mussels and its Impact on Phytoplankton

Michael J. Vanni, Miami University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-15

Date: 9/1/92 to 8/31/95

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Ecosystem Effects of Nonindigenous Species

Objectives

- To quantify the amount and proportion of nitrogen and phosphorus consumed, assimilated and released by zebra mussels and the fraction available to phytoplankton.
- To determine the effect of nutrient release on phytoplankton nutrition, growth and community structure.
- To create a computer model that predicts the effects of zebra mussel nutrient cycling on the whole ecosystem.

Preliminary Results

- Body and shell C and N content are constant across all size classes (only mussels collected in June analyzed so far).
- Small mussels have more P/mg dry weight in their shells than larger mussels; but less P/mg dry weight in their soft tissue (only mussels collected in June analyzed so far).
- Overall N:P excretion rates are below the Redfield 7:1 molar ratio, and therefore favor blue green algae growth.
- There is a significant effect of month ($P < .05$) on P excretion but not on N excretion or N:P ratio.
- There is a significant effect of mussel size ($P < .05$) on P excretion and N:P ratio but not on N excretion.

The Effects of Zebra Mussels on the Invertebrate Communities of Wetlands in Saginaw Bay, Michigan

Thomas M. Burton, Michigan State University

Program: Michigan Sea Grant College Program

Date: 4/1/93 to 3/31/96

Primary Source of Funds: Pass-through from EPA

Objectives

- To determine which sizes and species of the most abundant zooplankton in wetlands are most susceptible to filtration by zebra mussels.
- To observe how zebra mussels affect the invertebrate community in a *Scirpus americanus* wetland.
- To investigate the dynamics of zebra mussel colonization of the dominant vegetation in a *Scirpus americanus* wetland.

The Influence of Zebra Mussels on the Recruitment of Saginaw Bay Fishes

David J. Jude, University of Michigan

Program: Michigan Sea Grant College Program

Project Number: R/ZM-5

Date: 9/1/92 to 8/21/95

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine which environmental factors are most important in fish year-class strength.
- To test whether zebra mussel and zooplankton abundances affect fish hatching, growth and mortality.

Socio-Economic Analyses: Costs and Benefits of Nonindigenous Species

Date: 8/1/91 to 7/31/93

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To survey Ohio and Michigan licensed drivers about their current and future recreation activities on Lake Erie and costs incurred as a result of zebra mussels.
- To estimate the economic value and impact of Lake Erie tourism and recreational fishing and how zebra mussels have affected it.

Preliminary Results

- About 25 percent have responded to the survey as of April 1993.

Environmental and Economic Benefits from Zebra Mussel Harvesting Through Contaminant Reduction and Product Development

Joe M. Regenstein, Cornell University, and Susan Goldhor, Center for Applied Regional Studies

Program: New York Sea Grant Institute

Project Number: R/SWM-1

Date: 9/1/91 to 8/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine contaminant levels in Great Lakes zebra mussels.
- To compost and hydrolyze ground zebra mussels.
- To test ultrasound as a way to reduce or destroy contaminants in zebra mussels.
- To evaluate the economic feasibility of different methods of harvesting zebra mussels.
- To evaluate and develop markets for zebra mussel products (compost, liquid fertilizer, liquid protein).

A Policy Framework for Nonindigenous Species in the Great Lakes

Alan J. Randall, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-14

Date: 9/1/92 to 8/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To develop policy approaches that are appropriate for accidental introductions, purposeful private introductions and purposeful public introductions of exotic species.
- To develop a method to identify the costs and benefits of both accidental and planned introductions of exotics.
- To complete a cost-benefit analysis of an introduction that has already occurred in the Great Lakes.

Control and Mitigation of Nonindigenous Species

Control and Mitigation of Nonindigenous Species

Temporary measures may mitigate the effects of invading organisms. But the only truly effective means of control will be identified through long-term research. One example of this approach is the successful control of sea lamprey populations in the Great Lakes. Future success in controlling invading species depends on a research strategy that addresses all physical, chemical and biological requirements of each invading species. Only through understanding each organism's behavior, physiology and genetic and immunological characteristics can scientists devise innovative, effective and selective control techniques. From a base of general biology and life history, researchers can investigate a variety of control measures: engineering (redesigning water intake pipes, etc.), physical (scrapping, filtering, etc.), chemical (antifoulants, biocides, etc.) biological (parasites, predators, etc.), and physico-chemical (heat, pH, etc.). These lines of investigation should be parallel and should

Control and Mitigation of Nonindigenous Species

Testing of Mechanical, Molluscicidal, Antiattachment, Antibiofouling Agents on the Zebra Mussel

Susan W. Fisher, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/PS-8-PD

Date: 4/1/90 to 3/31/91

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To test a variety of different agents for their ability to control zebra mussels.

Results

- Environmentally safe chemicals kill adult mussels in short periods of time at concentrations averaging 150 parts per million.
- These chemicals are effective under a wide variety of environmental conditions.

Control of Zebra Mussels with Lemmatoxins, A Natural Molluscicide from *Phytolacca dodecandra*

Harold H. Lee, The University of Toledo

Program: Ohio Sea Grant College Program

Project Number: R/PS-7-PD

Date: 12/1/90 to 6/15/91

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To determine the efficacy of Endod, a natural molluscicide from *Phytolacca dodecandra*, in zebra mussel control.

Results

- Lemmatoxin (Endod) doses of 15 mg/L are lethal to adult mussels, while lower doses prevent mussel adhesion and reduce adhesion and aggravation.
- Endod is recommended for use as a control agent in tandem with other mechanical and chemical means in water intake pipes.

Evaluation of Molluscicides for Zebra Mussel Control

Susan W. Fisher and Jeffrey M. Reutter, The Ohio State University

Program: Ohio Sea Grant College Program

Date: 5/10/91 to 9/30/93

Primary Source of Funds: Pass through from U.S. Fish and Wildlife Service

Objective

- To evaluate a series of candidate molluscicides.

Preliminary Results

- Determined the toxicity of 12 molluscicides to adult zebra mussels.
- Determined the toxicity of five molluscicides to veligers, plantigrade and adult zebra mussels.

Control and Mitigation of Nonindigenous Species

Application of Underwater Robots to Perform Inspection, Cleaning and Maintenance of Intake Pipes

Samuel E. Landsberger, Cornell University

Program: New York Sea Grant Institute

Project Number: R/EMS-4

Date: 7/1/91 to 6/30/93

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To develop a prototype robot that will clean and inspect water intake pipes.
- To design and test technology for underwater robots that will perform work in constrained environments.

Preliminary Results

- Scientists have developed a strategy for building a robot that propels itself along a cable within infested intake pipes.
- Scientists have designed a robot that can perform pipe inspections, cleaning and maintenance; work on a prototype has begun.
- The Erie County (N.Y.) Water Authority has installed guide cable in its two pipes to accommodate the new robot.

include both short- and long-term control and mitigation methods. Finally, all proposed control strategies must be ecologically acceptable and socially responsible. Research on proposed biocides, in particular, should include considerations of the toxicity to other organisms, persistence in the environment and bioaccumulation potential.

Effect of Ultraviolet-B Radiation (280-320 nm) on Survivorship of Zebra Mussel (*Dreissena polymorpha*): A Potential Control Strategy

Linda Chalker-Scott, Howard Riessen and James D. Scott, SUNY College at Buffalo

Program: New York Sea Grant Institute

Project Number: R/EMS-3

Date: 8/1/91 to 7/31/92

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine which zebra mussel life stages are sensitive to UV-B radiation.
- To determine minimum dose needed for significant mortality.
- To develop a UV-B prototype for use in water intake pipes and other vulnerable areas.

Results

- Adult mussels survive higher UV-B radiation doses than do larvae.
- UV-B radiation is lethal to adult mussels when it is applied constantly.
- Larvae are killed after relatively short exposure to UV-B radiation; older larvae are less sensitive.

Nonpolluting Control of Biosurface Fouling

Robert E. Baier and Anne E. Meyer, SUNY College at Buffalo

Program: New York Sea Grant Institute

Project Number: R/EMS-2

Date: 8/1/91 to 7/31/93

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine how zebra mussel attachment and settling relate to the surface energy of the substrate and other substrate characteristics.



Control and Mitigation of Nonindigenous Species

- To test the hypothesis that the strength of the adhesive bond between zebra mussel and substrate is related to the initial events in the exposure cycle and the substrate's surface energies.
- To identify coatings that prevent attachment without harming the environment.

Approaches to Zebra Mussel Control Through Intervention in Reproduction

Jeffrey L. Ram and Peter Fong, Wayne State University

Program: Michigan Sea Grant College Program

Project Number: R/ZM-1

Date: 8/1/91 to 7/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To determine internal and external spawning triggers in male and female zebra mussels.
- To determine the chemical structure of spawning inducers.
- To develop inhibitors to zebra mussel spawning.
- To identify a field site for testing spawning inducers and inhibitors.

Preliminary Results

- Viable gametes can be produced through serotonin-induced spawning.
- Hydrogen peroxide weakly stimulates spawning.
- Several pharmacological agents inhibit serotonin-induced spawning.
- Dopamine inhibits serotonin-induced spawning in zebra mussels, while indomethacin reduces spawning intensity.
- Serotonin produces no significant change in zebra mussel ECGs, but toxic doses of potassium inhibit heart activity in zebra mussels.
- Several agents inhibit zebra mussel fertilization.
- Specific cell-surface sugars may play an important role in fertilization and embryonic development of zebra mussels.

The Use of Potassium in Control of the Zebra Mussel, *Dreissena polymorpha* Pallas

Susan W. Fisher and Paul C. Stromberg, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-11

Date: 2/1/92 to 1/31/94

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To evaluate potassium salts as molluscicides.
- To determine whether low levels of potassium deter zebra mussel attachment.
- To measure potassium's toxicity to nontarget animals.

Preliminary Results

- Potassium is highly toxic to adult mussels.
- Potassium chloride (KCl) is the most economical and environmentally compatible form.
- Potassium appears to have no adverse effects on other aquatic animals—even at 10 times the dose used to kill zebra mussels.
- Low levels of potassium prevent zebra mussel larvae from settling onto hard surfaces.
- Pulses of potassium administered every two hours appear to be just as effective as a continuous feed.
- Potassium inhibits both heart and respiratory activity in zebra mussels.

Control and Mitigation of Nonindigenous Species

Developing Mass Culture Techniques for Rearing Larvae of the Zebra Mussel, *Dreissena polymorpha*

David W. Garton, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-8-PD

Date: 5/1/92 to 12/31/92

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objective

- To develop mass culture techniques for rearing zebra mussel larvae for application in basic research and applied toxicology.

Results

- Veligers survive longer in aquaria with gentle flow systems than in static aquaria.
- Unfed veligers survive about 10 days in culture.
- Fed larvae survive no longer than unfed larvae, although the fed larvae grow and develop more rapidly.
- Egg quality among adult female mussels declines over time.
- Larvae collected from lake water survive longer than lab-spawned larvae and begin to settle.

Carbon Dioxide as a Narcotizing Pre-Treatment for Chemical Control of *Dreissena polymorpha*

William Elzinga, Environmental Science and Engineering, Inc.

Program: Illinois-Indiana Sea Grant Program

Project Number: ZM/4

Date: 9/1/92 to 12/31/93

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine the amount of carbon dioxide needed to kill zebra mussels in a closed system and the amount necessary to simply drug the mussels.
- To determine whether using chlorine and carbon dioxide together increases control effectiveness.
- To test how length of application, temperature and mussel size influence the control effectiveness of chlorine and carbon dioxide.

Preliminary Results

- Lethal effects have been observed with carbon dioxide at more than 190 mg/l for 24-hour application.
- Narcotizing effects have been observed at lower concentrations (100-150 mg/l) over the same time period.
- Narcotizing effects have been observed within four hours of the initiation of the treatment.

New Approaches to Control of Zebra Mussels by Targeted Microbial Products

Ralph Mitchell, Harvard University

Program: Massachusetts Institute of Technology Sea Grant College Program

Project Number: RT-35

Date: 9/1/92 to 8/31/95

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To isolate bacteria that inhibit attachment or cause disease in zebra mussels.
- To isolate specific substances from these bacteria and evaluate their potential as environmentally safe control measures.

Preliminary Results

- Several bacteria that can kill adult mussels in less than five days have been identified.

Prevention of Introduction of Nonindigenous Species

Prevention of Introduction of Nonindigenous Species

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Scientists can predict the spread of an established nonindigenous species (a viable reproducing population) by analyzing the species' environmental requirements and its dispersal mechanisms—vectors that allow it to reach areas where environmental conditions are favorable for growth and reproduction. Most nonindigenous species have been introduced and spread by human activities (ship ballast, boats, pet industry, etc.). However, dispersal mechanisms are often unique to each species and are usually determined after geographic range extensions occur. To predict likely future dispersal mechanisms, scientists couple their knowledge of a species' biology and life history with reports of past modes of dispersal. Once dispersal mechanisms are identified for individual invading species, scholars and policy makers can develop safeguards and international protocols to prevent and/or slow the spread to uninfested areas. Such safeguards and protocols may also prevent the spread of new, not-yet-established, nonindigenous species. Analysis and identification of past and possible future dispersal mechanisms enhances our ability to mitigate the effects of invading species on the ecosystem.

The Use of Acoustic and Hydrodynamic Techniques to Control Zebra Mussel Infestation

Dimitri M. Donskoy, Stevens Institute of Technology

Program: New Jersey Marine Sciences Consortium Sea Grant Program

Project Number: R/E-29ZM

Date: 9/1/92 to 9/30/95

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To test how adults and veligers respond to varying frequencies, intensities and duration of sound and vibration.
- To study ultrasound and hydrodynamic cavitation effects on zebra mussels.
- To develop acoustic and vibrational methods for measuring zebra mussel populations in tanks and pipes.
- To evaluate the feasibility of converting hydrodynamic energy to acoustic energy to enhance the efficiency of the control technique.

Application of Wide-Range Ultraviolet Radiation for Zebra Mussel Control

Linda Chalker-Scott, SUNY College at Buffalo

Program: New York Sea Grant Institute

Project Number: R/EMS-6

Date: 9/1/92-8/31/94

Primary Source of Funds: Fiscal Year 1992 Zebra Mussel Federal Appropriation

Objectives

- To determine the minimum level of ultraviolet exposure necessary to prevent larval settling and the minimum chronic level necessary to kill existing populations.
- To gauge the effects of ultraviolet light on veliger behavior.
- To develop a prototype instrument that will deliver ultraviolet radiation in restricted locations.

Preliminary Results

- Adult mussels demonstrate a limited ability to move away from UV exposure.
- While wide-range UV will eventually kill off adult populations, the killing time is so long as to be of doubtful use as a control mechanism for existing populations (using our existing UV source).
- Higher intensity UV sources show more promise in killing adults.
- Quagga mussels appear to be more resistant than zebra mussels.
- Planktonic larvae show a negative directional response to UV radiation and are killed rapidly (~2 hrs.), even under our existing UV source.

Prevention of Introduction of Nonindigenous Species

Ship Operational & Safety Aspects of Ballast Water Exchange at Sea

John B. Woodward, Michael G. Parsons & Armin W. Troesch, University of Michigan

Program: Michigan Sea Grant College Program

Project Number: R/ZM-2

Date: 8/1/91 to 7/31/92

Reducing the Spread of Established Nonindigenous Species

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To analyze how hull bending stresses change during at-sea ballast water exchanges.
- To describe the consequences of ballast exchange during bad weather.
- To determine whether slowing or rerouting may result from ballast exchange in bad weather.
- To make ballast exchange recommendations to the U.S. Coast Guard.

Preliminary Results

- Ballast water exchange is not likely to affect metacentric height — a measure of ship stability.
- Ballast water exchange during storms that produce a significant wave height of 10 feet appears to be safe — it creates bending and shear values still within American Bureau of Shipping safety guidelines.
- Ballast water exchange during storms that produce a significant wave height of 20 feet can create hull slamming and should be avoided.

Reducing the Spread of Established Nonindigenous Species

The Significance of Spreading Vectors in the Zebra Mussel Invasion: Experimental and Observational Studies on Dispersal Mechanisms of *Dreissena polymorpha*

James T. Carlton, Williams College

Program: Connecticut Sea Grant Program

Project Number: R/ES-5

Date: 7/1/91 to 6/30/93

Primary Source of Funds: Fiscal Year 1991 Zebra Mussel Federal Appropriation

Objectives

- To quantify the role of sport boats, commercial craft and sport fishing in dispersing zebra mussels in the Great Lakes basin.
- To conduct experiments to test how vessels and sport fishing affect zebra mussel dispersal.
- To conduct preliminary investigations on natural dispersal vectors, especially aquatic birds.

Preliminary Results

- More than 50 percent of boaters using Great Lakes waters in eastern Michigan also use their boats in inland waters.
- Transit times between Great Lakes and inland waters averaged five days but were occasionally as short as a day.
- Veligers were frequently found in all types of water contained in boats, including engine cooling systems, bilges, live wells and bait buckets.
- Adult mussels were found only on vegetation entangled on boat trailers; however, on some days, 30 percent of the boat trailers transported mussels in this way.
- Based on reported destinations, larger inland lakes are predicted to be invaded first.

Reducing the Spread of Established Nonindigenous Species

Once introduced and established in an open aquatic system, nonindigenous species have proven impossible to eliminate. Though effective control methods are eventually found, in most cases, little can be done to minimize ecosystem impacts and the resulting resource losses. Emphasis, therefore, is on preventing introductions of new invaders. First, scientists identify the means of introduction. Then they attempt to develop cost-effective, realistic methods of prevention. For example, ballast water discharge is an important vector for introducing nonindigenous species in the Great Lakes. Strategies to eliminate this source of introduction — without imposing undue hardships on the shipping industry — must be developed. Strategies for eliminating other vectors (intentional releases, canal openings, accidental releases, etc.), must be developed in a similar fashion. In addition, not all invading species become widespread and abundant. By examining life history characteristics and past dispersal patterns in other aquatic environments, scientists can identify those species most likely to colonize the Great Lakes and other systems.

Reducing the Spread of Established Nonindigenous Species

Prediction and Early Detection of Zebra Mussel Invasions of the Inland Waters of Michigan

Ladd E. Johnson and James T. Carlton, Maritime Studies Program

Program: Michigan Sea Grant College Program

Project Number: R/ZM-8

Date: 2/8/93 to 10/31/93

Primary Source of Funds: Local Sea Grant program from federal and nonfederal sources

Objectives

- To determine the likely rate, direction and pattern of the spread of zebra mussels to Michigan's inland waters.
- To test the hypothesis that recreational boat traffic between the Great Lakes and inland waters is responsible for initial invasions.
- To detect the early stages of zebra mussel invasion of Michigan's inland lakes.

Newly funded research projects

initiated in 1993 by the National Sea Grant College Program

Biology/Life History of Nonindigenous Species

Swimming and Settlement Behavior in the Quagga Mussel

Victor S. Kennedy, University of Maryland

Program: Maryland Sea Grant College Program

Project Number: NA

Date: 1/1/94 to 12/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To observe the behavior of the quagga mussel to determine possible options for preventing fouling at industrial water delivery systems.
- To refine protocols for culturing and rearing quagga mussel larvae.
- To study how gravity, temperature, salinity and dissolved oxygen content affect quagga swimming behavior.
- To determine how light and substrate orientation affect settling behavior in quagga pediveligers.

Assessing the Spatial and Temporal Distribution of Zebra Mussel Larvae in Saginaw Bay, Michigan, Using the Video Plankton Recorder

Scott M. Gallager and Cabell S. Davis, Woods Hole Oceanographic Institution

Program: Massachusetts Sea Grant College Program

Project Number: R/B-119-PT

Date: NA

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To modify the Video Plankton Recorder for use on a small vessel in shallow, turbid water for survey and experimental work in the Great Lakes.
- To determine the temporal and spatial distribution and abundance of zebra mussel larvae in Saginaw Bay, relative to the physical dynamics of the water column.
- To evaluate the extent of diel vertical migration of mussel larvae and its potential importance as a transport mechanism.

Species Identification of Early Life History Stages of Dreissenid Mussels and Other Co-occurring Bivalves in Freshwater and Oligohaline Habitats

Richard A. Lutz and Brad S. Baldwin, Rutgers University

Program: New Jersey Marine Sciences Consortium Sea Grant Program

Project Number: R/E-45ZM

Date: 7/1/93 to 6/30/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To develop a practical way to identify larval and postlarval stages of *Dreissena polymorpha*, *D. bugensis* (quagga mussel), *Mytilopsis leucophaeata* (dark false mussel) and other co-occurring bivalve species and freshwater and oligohaline habitats by using SEM and other routine optical microscopic examination of shell and hinge form and structure.
- To develop routine methods for rearing zebra and quagga mussel larvae through to post-larval stages.
- To determine whether shell morphological features used for identification purposes are altered by environmental conditions or differ with respect to the geographic location of parental source populations.

Newly funded research projects

Genetics of the Zebra and Quagga Mussels: A Comparative Analysis of Mitochondrial DNA Sequence Data

Carol A. Stepien, Case Western Reserve University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-9

Date: 9/1/93 to 8/31/96

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To determine genetic differences between zebra and quagga mussels and develop rapid screening methods for assessing the relative abundance and genetic variability of both veligers and newly settled mussels.
- To determine whether there are additional cryptic species in this North American nonindigenous complex.
- To test whether there are differences in both overall genetic variation and base substitution frequencies in both species of mussels from the "Old" and "New" Worlds.
- To pinpoint the original European source of mussel parental stocks.
- To determine whether different mussel genetic strains and/or subpopulations exist in North America and, if so, which are most successful in various habitats and on various invasive fronts.

Preliminary Result

- The first DNA sequence data for dreissenid mussels has recently been obtained.

Ecosystems Effects of Nonindigenous Species

Zebra Mussel and Sediment Interactions: Is There an Effect on Nitrogen and Phosphorus Regeneration Ratios?

James B. Cotner, Texas A & M University

Program: Texas A & M University Sea Grant College Program

Project Number: R/ES-60

Date: 9/1/93 to 8/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To determine whether zebra mussels change the dissolved nitrogen/phosphorus supply ratio in areas of Lake St. Clair where they are abundant.
- To test the hypothesis that mussels directly affect microbial sediment oxygen demand by increasing the flux rate of reduced carbon and other nutrients to the sediments.
- To test the hypothesis that increased benthic microbial activity results in lower nitrogen/phosphorus ratios.

Foodchain Contamination of Edible Fish Through Zebra Mussel Directed Trophic Transfer

Susan W. Fisher, The Ohio State University, and Peter F. Landrum, GLERL at NOAA

Program: Ohio Sea Grant College Program

Project Number: R/ZM-21

Date: 9/1/93 to 3/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To quantify the amount of trophic transfer at each level of an aquatic foodchain.
- To assess how biological variables affect trophic transfer.
- To determine how the nature of the chemical being transferred affects each step of trophic transfer.

Newly funded research projects

Remote Sensing Studies of Zebra Mussel Impacts in Saginaw Bay

W. Charles Kerfoot and Ann Maclean, Michigan Technological University

Program: Michigan Sea Grant College Program

Project Number: R/ZM-9

Date: 9/1/93 to 8/31/96

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To determine whether changes in water quality caused by zebra mussels can be detected, mapped and quantified using remotely sensed images.
- To determine whether computer-assisted image and analysis procedures that use spectral information can be used to quantify spatial and temporal changes in water quality variables.
- To map and model spatial and temporal changes in water quality, caused either directly or indirectly by zebra mussels in Saginaw Bay.

Shifts in Southwestern Lake Michigan Benthic Food Web Dynamics Since the Invasion of the Zebra Mussels

Nancy C. Tuchman, Loyola University of Chicago

Program: Illinois-Indiana Sea Grant Program

Project Number: NA

Date: 8/1/93 through 7/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To determine how the 1992 zebra mussel invasion of the rock reef in southwestern Lake Michigan will affect the dynamics of the benthic food web.
- To compare pre-1992 data on benthic algal, macroinvertebrate and crayfish composition and crayfish diet, abundance and size class distribution with post-1992 data.
- To determine the relative contribution of the benthic and the limnetic littoral communities on total littoral zone primary production.

Preliminary Results

- Light penetration to the lake-bottom community has increased significantly since the 1992 zebra mussel invasion.
- The benthic algal community has become dominated by green filamentous algae since the 1992 zebra mussel invasion.

Socio-Economic Analyses: Costs & Benefits of Nonindigenous Species Present and Expected Economic Costs of Zebra Mussel Damages to Water Users with Great Lakes Water Intakes

Leroy J. Hushak, The Ohio State University

Program: Ohio Sea Grant College Program

Project Number: R/ZM-12

Date: 9/1/93 to 8/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To survey industries with Great Lakes water intakes about the annual costs associated with zebra mussels (damage, maintenance, control, full or partial plant shut-down, plant design modifications, research costs).
- To survey public organizations and researchers about annual spending on zebra mussel control research.
- To survey researchers at public and private institutions about the feasibility of zebra mussel control research resulting in annual cost reductions for industry.
- To estimate the expected annual rate of return of investment in zebra mussel control research to industries with Great Lakes water intakes.

Newly funded research projects

Control and Mitigation of Nonindigenous Species

The Role of Continuous Introductions in Establishing Zebra Mussel Colonies in Areas Where Environmental Factors May Be Limiting

Mary Balcer, University of Wisconsin

Program: Wisconsin Sea Grant Institute

Project Number: R/LR-47

Date: 7/1/93 to 6/30/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To determine whether zebra mussels can survive, grow and reproduce under the pH, calcium and water temperature conditions of Duluth-Superior harbor in western Lake Superior.
- To estimate how many zebra mussel veligers and juveniles are introduced yearly to Duluth-Superior harbor from ballast water discharge and boat hull transport.
- To explore how continuous introductions help mussel populations reach the numbers necessary for self-sustaining population growth.

Preliminary Result

- Wisconsin Sea Grant's Zebra Mussel Watch program has documented the presence of zebra mussels in Duluth-Superior harbor but has recorded only low densities of mussel veligers and juveniles.

Chlorine Minimization and Boundary Layer Injection for Control of Zebra Mussel Fouling in Hudson River Water Intakes

Vincent Guida, Lehigh University

Program: New Jersey Marine Sciences Consortium Sea Grant Program

Project Number: R/E-44ZM

Date: 7/1/93 to 6/30/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To assess both the environmental impact and the economic viability of using staged boundary layer injection technology to place chlorine only along intake walls, where fouling occurs.
- To determine the optimal level of continuous chlorine necessary to control zebra mussel settlement in a Hudson River water intake.
- To test the degree of control, chlorine consumption and chlorine discharge associated with boundary layer chlorination.

Control of Zebra Mussel Veligers in Water Treatment Plants by Chemical Coagulants

John E. Van Benschoten and Joseph F. Atkinson, SUNY College at Buffalo

Program: New York Sea Grant Institute

Project Number: NA

Date: 8/1/93 through 7/31/95

Primary Source of Funds: Fiscal Year 1993 Zebra Mussel Federal Appropriation

Objectives

- To characterize how coagulants affect veliger behavior.
- To characterize the particle stability characteristics of both veliger and non-veliger particulates.
- To identify how adding coagulants at water intakes affects solid-liquid separation processes.
- To measure particle aggregation/disaggregation characteristics of veligers at varying coagulant doses and turbulence levels.
- To develop a model predicting how coagulant additions would affect different water intakes.

Sea Grant outreach

THE SIX GREAT LAKES SEA GRANT programs working as a unified team are the primary source of Great Lakes information for the general public and water users. The extension component of these programs includes more than 30 agents and specialists who cover the U.S. Great Lakes shoreline. These extension professionals are the primary liaisons with the public. They translate scientific discoveries and technological developments and transfer them to waters users, ensuring that society receives the maximum benefit from research efforts. Also, through their interactions with the public and businesses and industries that use the lakes, these agents identify critical research needs and issues for their programs. This guarantees that Sea Grant research remains focused on the real issues affecting society and that the research results obtained represent practical, "real world" solutions to problems.

Each Great Lakes Sea Grant program began education and public information efforts on zebra mussels in 1989. However, the zebra mussel population explosion in Lake Erie in 1989 — in one year densities reached over 30,000 per square meter — and the associated clogging of everything from large electric power plant cooling systems to engines in small private boats created a near-panic in the Great Lakes community. Sea Grant's agents and communication specialists put all their energy into providing the most current zebra mussel information possible. This information took many forms: videos,

news releases, fact sheets, conferences, seminars, network television spots, newsletters, displays and one-on-one sessions. By mid-1990, Ohio Sea Grant agents and researchers alone had conducted more than 200 seminars and conferences on zebra mussels.

The six programs in the Great Lakes Sea Grant Network carefully coordinated their efforts to prevent duplication and to provide accurate information to as many people as possible. In this brief report, it is impossible to describe all programs and activities undertaken. Instead, we have described 13 efforts that illustrate the breadth and scope of Sea Grant's zebra mussel outreach efforts. These are outlined briefly below and in greater detail in the pages that follow.

- ▼ The programs have produced many important fact sheets and videos. However, more than 300,000 copies of two fact sheets produced by Ohio Sea Grant were printed by Brunswick Marine and have been distributed widely by Sea Grant programs and 100 other agencies.
- ▼ New York Sea Grant, in response to many information requests from surrounding states, has conducted more than 125 one- or two-day regional training sessions since 1990, primarily in New England and the mid-Atlantic states. This would not have been possible without strong support from U.S. Fish and Wildlife Service as the co-sponsor of the program.
- ▼ In 1990, Ohio Sea Grant hosted the first zebra mussel research conference to enhance communication among interested scientists and to provide a forum for recent research results. This conference has become a very important annual event. As of the 1993 conference, it is now hosted by a Sea Grant program or a Canadian sponsor.
- ▼ In 1990, New York Sea Grant, with a great deal of private sector support, created the Zebra Mussel Information Clearinghouse — part library and part public information office. With its "800" number and its newsletter, this office provides one-stop shopping for anyone interested in the most current research information on zebra mussels.
- ▼ In 1991, Michigan Sea Grant instituted an annual conference on zebra mussels for municipal and industrial water users. This provides a forum for gathering and sharing information on problems and solutions about zebra mussels and water intakes.
- ▼ To slow the spread of the mussel and to document the spread as it occurs, the public needs to know how to identify mussels and report them when observed. To address this need, Wisconsin Sea Grant developed a color, wallet-sized identification card for zebra mussels. Since 1990, more than one million cards have been produced, including a version in French for the Ontario Ministry of Natural Resources.



- ▼ Photographs and slides of exotic species are in great demand for educational purposes. To meet this need, Michigan Sea Grant created the Nonindigenous Species Graphics Library in 1991. Since then, they have distributed more than 1,200 photographs, slides and illustrations of exotic species.
- ▼ Illinois-Indiana Sea Grant has developed an exceptional education program, using 130 Illinois high schools and almost 10,000 students to monitor river systems throughout the state for zebra mussels. The results are reported to Illinois Natural History Survey.
- ▼ Recognizing that the nation's

In fiscal years 1992 and 1993, outreach projects were awarded to the programs in the Mid-Atlantic and New England Sea Grant Networks. The Mid-Atlantic Network includes programs in Delaware, Maryland, New Jersey, North Carolina and Virginia. The New England Network includes programs in Connecticut, Massachusetts, Maine, New Hampshire and Rhode Island.

science writers at the largest newspapers can reach more people than our programs can reach with seminars and fact sheets, Ohio Sea Grant coordinated a special zebra mussel information session at the

- 1992 conference of the Scientists' Institute for Public Information, co-sponsored by the Society for Environmental Journalists in Toronto. Major newspapers, public television stations and network affiliates were present.
- ▼ Sea Grant's development of educational displays is exemplified by Minnesota Sea Grant's *Exotic Aquatics of the Great*

Lakes Region display at the Bell Museum of Natural History. This comprehensive interactive display was created by the Bell Museum, with Sea Grant as science advisor, and funding from the state. Three copies are available for travel.

- ▼ In an effort to provide concrete information to Wisconsin industries facing a possible zebra mussel infestation, Wisconsin Sea Grant developed its Zebra Mussel Watch program in 1990. With assistance from municipalities, power plants, industries and four Wisconsin colleges and universities, this project monitors zebra mussel populations and reports the results in the periodic newsletter *Zebra Mussel Update*.
- ▼ Surveys of user needs are a regular component of Sea Grant activities. Illinois-Indiana's 33-question survey on the information needs of municipal and industrial water users is a good example of Sea Grant's efforts to address real issues and provide real world solutions.
- ▼ Transferring the knowledge gained in the Great Lakes region has been a major effort of Sea Grant. Minnesota Sea Grant's conference for upper-Mississippi water users in 1992 is a good example. With support from a dozen agencies from Arkansas to Wisconsin, the two-day conference with 250 participants was successful in letting the users know what to expect and how to deal with the problem when it arrives. ▲

Just the facts

WHAT ARE ZEBRA MUSSELS? How did they get here? What will they do to Lake Erie? And what will they do to my boat?

It was summer 1989 — just a year after the first zebra mussel was discovered in Lake Erie — and such questions were pouring in to Ohio Sea Grant.

“People called and wanted us to tell them everything we knew about zebra mussels,” says Maran Hilgendorf, Ohio Sea Grant communicator. “We were glad to do it, but it meant hours on the phone for the extension agents.”

“We were also receiving many requests for speakers,” she says. “We wanted to find some way to provide a service without taxing the same people again and again.”

So Hilgendorf and her colleagues posed a question: Wasn't there a more efficient way to meet public demand for zebra mussel information?

Today, the answer is clearly “yes.” Ohio Sea Grant's solution is two informative fact sheets and a video called *Too Much Mussel*.

Together, the three pieces form a package. One fact sheet details the invasion and its implications — for both the Great Lakes ecosystem and the economy. The other tells boaters how to keep zebra mussels off their boats and out of inland waters. And the five-minute video provides pictures to accompany the words — striking visual evidence of the zebra mussel's impact on Lake Erie.

Best of all, the information pieces are meeting a need, both

within and outside the Great Lakes. Hilgendorf reports that Ohio Sea Grant has distributed more than 300,000 general zebra mussel fact sheets and 30,000 of the boaters' version since 1989. In 1992 alone, she says, Ohio Sea Grant handled more than 800 requests for the fact sheets from people in 43 states. She also notes that prominent television programs — including PBS's “Scientific American Frontiers” and TNN's “Fishing with Roland Martin” — have incorporated Sea Grant's zebra mussel video footage into their shows.

Hilgendorf says the information pieces began when Ohio extension agent Fred Snyder wrote the first version of a zebra mussel fact sheet in late 1989. Ohio Sea Grant printed and distributed the first copies — to an overwhelming response. Ultimately, the demand for copies became so great that Hilgendorf made a plea; could anyone help Sea

Ohio Sea Grant Director Jeffrey M. Reutter shows zebra mussel shells found in such quantities on Lake Erie they create windrows. (photo by Jay Rendall)



Every Sea Grant program produces resource material, such as fact sheets, videos and newsletters, frequently in cooperation with other agencies, associations and businesses. For example, New York Sea Grant and PBS joined forces to produce a 30-minute video on the zebra mussel that has been aired by a number of East Coast PBS stations. A list of Sea Grant resources begins on page 69.

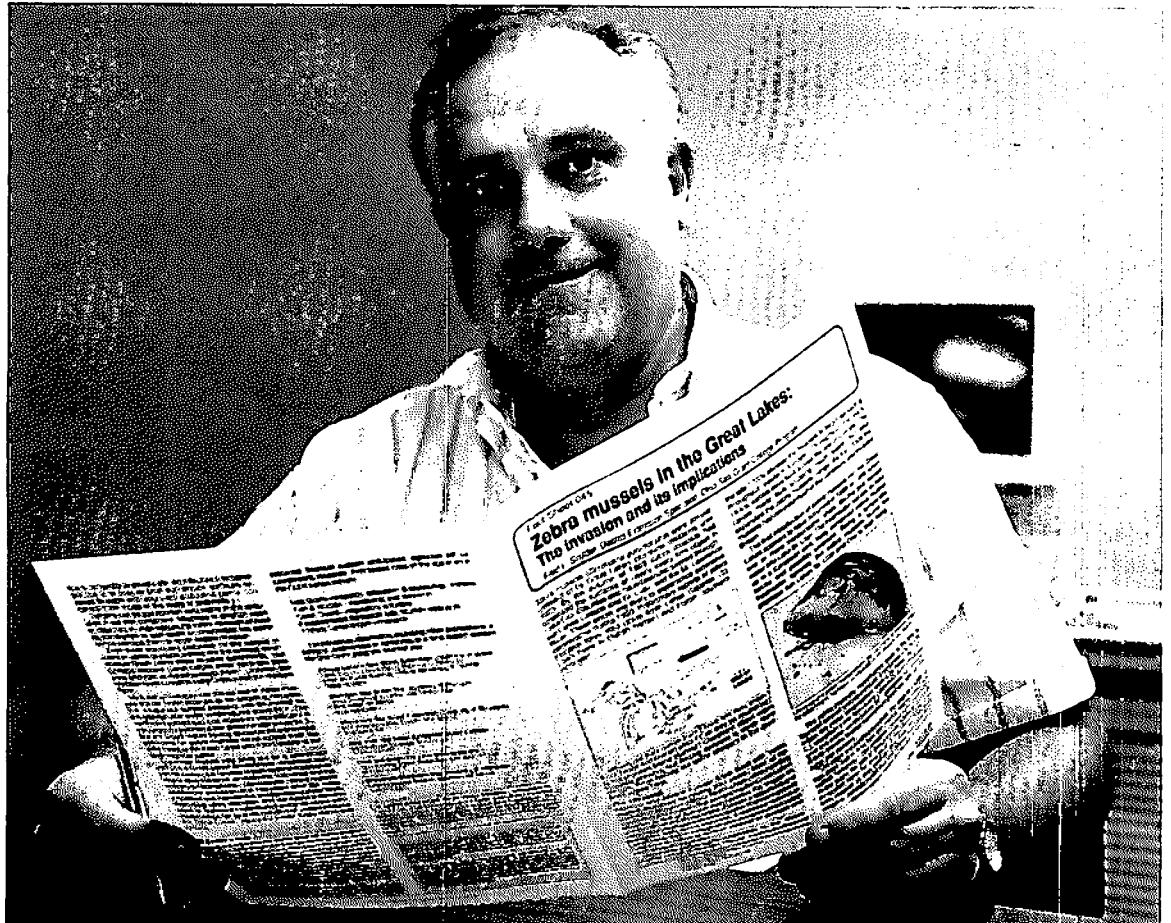
Grant print zebra mussel fact sheets?

Brunswick Marine responded. To date, the company has printed 250,000 of the 300,000 general zebra mussel fact sheets in circulation and thousands of copies of three other publications — a gift worth about \$25,000, Hilgendorf says.

“Brunswick’s generosity allowed us to better serve our audience, but also helped clear the way for other zebra mussel projects — including the fact sheet for boaters (written by extension agent Dave Kelch) and the video (produced by Ohio State University Extension),” Hilgendorf says.

Today, Hilgendorf is pleased about the benefits of the zebra mussel information pieces — for Ohio and the entire Great Lakes region.

“We’ve raised public awareness about zebra mussels. And we’ve filled an information need for the other states in the region and many inland states,” she says. “But probably the best outcome is that people have become more knowledgeable about the value of Lake Erie. Seeing this threat to it makes them appreciate the value Lake Erie has for them.” ▲



Don Thurke looks over a copy of the report that was printed at Mercury Marine. (photo from *PROFILE* magazine, Brunswick Corporation’s employee magazine.)

Mussel busters

THE OLD JOKE ON TOURS OF Europe is that if it's Tuesday, it must be Brussels. Apparently the pace on these tours is so frenetic that the only way to know where you are is to ask what day it is.

Let it be known that travelers on whirlwind tours of Europe have nothing on Chuck O'Neill. He may be in Baltimore instead of Brussels, but the schedule is just as crazy. He's up and down the East Coast, in North Carolina one week, in Connecticut the next. He's on a plane to Philadelphia, to Nashville, to New Orleans. From Lake Champlain to Chesapeake Bay, his fame is growing. He's fast becoming one of the country's favorite traveling mussel busters.

It's a tough job. O'Neill, an extension specialist with New York Sea Grant, has a serious charge: to bring the people in the five major

river basins outside New York state up to speed about zebra mussels. To accomplish this, he and fellow agent Dave MacNeill travel far and wide. They cover Lakes Erie, Ontario and Champlain, as well as the Connecticut, Susquehanna, Delaware and Allegheny rivers and the eastern portion of the Mississippi River basin. They also conducted a workshop in Tulsa for those in Arkansas, Oklahoma, Texas and Kansas to cover the western portion of the Mississippi and the Arkansas rivers. There, at the states' request, they teach diverse audiences about zebra mussels — everyone from Sea Grant staff to natural resources workers to representatives from industrial and municipal plants.

"Dave tells them about the critter, and I tell them what the critter can do and how to control it," O'Neill says.

O'Neill and MacNeill started

conducting these one- to two-day regional training sessions in 1990. The format is simple, but effective. They devote the first day to basic questions about zebra mussels: what are they? what can they do? will they get into my river? They also present control options, "everything from keeping mussels off a boat to keeping them out of a nuclear power plant," O'Neill says.

If the session continues for a second day, O'Neill and MacNeill teach the group such things as how to tell the difference between zebra and quagga mussels and how to test for zebra mussels in rivers and lakes — basic topics in identification and monitoring. They cram as much information as they can into the time available and even bring in other expert speakers.

"It really is a 'know your enemy' type of approach," O'Neill says.

He estimates that he and MacNeill did 125 sessions that ranged from a few hours long to the full two-day workshops in 1990 and 1991, reaching 5,000 people in the mid-Atlantic states and northeast.

It's this kind of impact that's so essential in winning the battle against zebra mussels, O'Neill says. In fact, it was the need for more zebra mussel information in the mid-Atlantic and northeast that got the project started in the first place.

"We didn't see all the water users — the small-town industries, the engineers from bigger industries — making it to the major conferences," he says. "And we didn't see people



New York Sea Grant Extension Specialist Dave MacNeill examines a vial of zebra mussels. (photo by Scott Weston)

New York Sea Grant has recently entered an agreement with the USDA Extension Service to provide "teach the teacher" training for inland state Cooperative Extension Services to "pass the baton" from Sea Grant to Extension as the mussel moves further inland.

outside the Great Lakes basin teaching people about the mussel and why they should be concerned."

But O'Neill doesn't take full credit for the idea. The National Sea Grant office also recognized the need and encouraged New York Sea Grant to pursue it, he says.

"They wanted us to provide information that wasn't getting to people from within their own areas."

For New York Sea Grant, the question was how to get regional training sessions going. The answer lay with the U.S. Fish and Wildlife Service. O'Neill and MacNeill proposed the project, and the Fish and Wildlife Service signed on as a co-sponsor, agreeing to make presentations at the sessions and to pay for outside speakers and any printed materials.

"This is a unique, strong collaboration," O'Neill says. "It's important that we're doing these

sessions with the Fish and Wildlife people, even though we're not from the same parent agency."

Today, O'Neill reports that the training sessions are working out well for all involved.

"We're working very closely with the mid-Atlantic and New England Sea Grant networks and we're bringing them up to speed fast," he says.

Fast indeed. In March, O'Neill trained members of the mid-Atlantic network; in April of 1992, he trained New Hampshire/Maine Sea Grant and Louisiana Sea Grant. He's confident that because they've learned from the Great Lakes' experience, they'll know what to do about zebra mussels when the time comes.

"They won't have the headache of having to figure out what to do. They can just act."

Nancy Balcom, extension educator in fisheries and aquaculture with Connecticut Sea Grant, agrees.

"The sessions are great," she says. "In terms of time and value, many of our participants said it was the best workshop they'd ever been to. It bumps you up the learning curve real fast."

O'Neill sees New York Sea Grant benefiting, too.

"We're reaching an audience that didn't know Sea Grant existed, forging a lot of good linkages," he says. "Media and federal agencies are getting to know us better. They're starting to realize that Sea Grant has so much good information to give them." ▲



Chuck Pistis and Steve Stewart of Michigan Sea Grant Extension provide information about the zebra mussel's life cycle. (photo provided by Michigan Sea Grant Extension)

Musseling in on research

ABOUT THE SAME TIME EACH YEAR, it happens: the invasion of the zebra mussel people. Their experiments and projects temporarily tucked away, scientists, graduate students, business executives and resource managers from California to Connecticut converge by the hundreds for an intensive week of zebra musseling — everything from the ins and outs of spawning to zapping the bothersome bivalves with ultraviolet light. The occasion? The annual International Zebra Mussel Research Conference — sponsored, in part, by the Great Lakes Sea Grant Network.

For those interested in zebra mussels — both researchers trying to understand them and industries trying to get rid of them — it's the major event of the year.

"The conference is the main network for getting results of zebra mussel research," says Indiana University-Kokomo biologist Dave Garton. "It's very valuable."

And it's growing. The first conference, hosted in December 1990 by Ohio Sea Grant, drew an audience of nearly 200 from 20 states and Canada and included 34 presentations on zebra mussel biology, ecology and control by nearly 90 authors. Audience members included prominent scientists from Canadian and American universities, as well as a member of the Ohio legislature and a writer from *Time* magazine.

The second conference, hosted in November 1991 by New York

Sea Grant, drew an audience of 361 from 29 states, the District of Columbia and Canada and included 70 presentations by nearly 150 authors.

For Ohio Sea Grant extension agent Fred Snyder, who helped organize the first conference, these numbers prove what many suspected all along: that zebra mussel research warrants its own forum.

He says Ohio Sea Grant initiated the first conference to ensure that there would be such a gathering.

"There was no forum for researchers to exchange their findings about zebra mussels," he says. "It was a big problem."

Snyder says it was no easy job solving this problem. It took some ▶



Dr. David Garton (left), Anna Stanczykowska-Piotrowska (center) and John Hageman, at Stone Lab December of 1990 observing zebra mussels. Anna was a speaker at the Ohio Zebra Mussel Research Conference.

Dial-A-Mussel

IT'S A TYPICAL DAY AT THE Zebra Mussel Information Clearinghouse. Dr. Dan Molloy is visiting from the New York State Museum at Albany, wading through a hefty stack of journal articles, scanning papers for that elusive something from someone else's research that might help him with his own. Administrative assistant Jeanine Munn is taking requests for inter-library loans and journal article copies on the 1-800 line. And director Chuck O'Neill is reviewing submissions for the upcoming issue of *Dreissena polymorpha Information Review*, the clearinghouse's research-oriented newsletter.

This is the hybrid known as the Zebra Mussel Information Clearinghouse—part library, part public information office. For its part, the library features a collection of 1,400 zebra mussel research papers from peer-reviewed journals, including nearly 400 in Cyrillic. And for its part, the bimonthly *Dreissena polymorpha Information Review* is the only place in the Great Lakes to find preliminary zebra mussel research findings. It has 500 subscribers in 40 states, four Canadian provinces, The Netherlands and Hong Kong.

If it seems that the clearinghouse leads a bit of a double life, it's no wonder—even its office is cut in two. The site is the old library at SUNY-Brockport, the biggest and oldest building on campus. Half is in its original state, complete with stacked shelves and crowded reading tables. The other half has been

converted to offices bustling with publishing and information operations, telephones ringing, printers whirring.

Fortunately, the Zebra Mussel Information Clearinghouse and its small corps of employees see plenty of activity on both sides, says director Chuck O'Neill. Since it began in 1990, the clearinghouse has tripled the number of research papers in its collection and has distributed 14,000 copies of *Dreissena polymorpha Information Review*. Further, in 1991, it handled nearly 900 information requests from people in 37 states and four Canadian provinces; in 1992, the clearinghouse served 1,000 people from 40 states and five provinces.

People who use the clearinghouse are "folks of all stripes," O'Neill says. The largest user groups are consulting engineers, researchers and government employees, followed closely by industrial employees. There's a lot of diversity, even within categories.

"We work with everyone, from the guy who's got a cottage on Lake Erie and is concerned about zebra mussels to officials with EPA, the U.S. Army Corps of Engineers, Eastman Kodak and Xerox," says O'Neill who characterizes the clearinghouse as a liaison.

"We act as a broker, putting researchers in touch with each other, putting industry and utility researchers in touch with a basic theoretical scientist," he says. "We also try to help smaller operations gain exper-

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Dreissena
I N F O R M A T I O N R E V I E W
ZEBRA MUSSEL INFORMATION CLEARINGHOUSE
polymorpha



tise. We put the consulting engineer who just designed a power plant in touch with the engineer for a power plant that pumps just six hours a day."

According to O'Neill, there was a real need for the clearinghouse, even before it began. Researchers were frustrated by how little they knew about zebra mussels and how difficult it was to find good, current information.

"They could only find a few things easily, and those were written in 1954 and didn't say much," O'Neill says.

Seeing a potential need that Sea Grant could fill, New York Sea Grant approached the Empire State Electric Energy Research Corporation and asked its scientists whether their zebra mussel research information was adequate. They gave a resounding no.

"They said they had a pressing need for more information, and that if we wanted to start a technical library, they'd help bankroll it," O'Neill says.

Sea Grant accepted. Additional grants from Eastman Kodak, the Monroe County Water Authority, the Great Lakes Sea Grant Network and New York Sea Grant helped the zebra mussel clearinghouse become a reality.

Today, the benefits of the clearinghouse are clear.

"There's a lot of collaboration going on between researchers and engineers. I don't think that happens unless there's a clearinghouse," O'Neill says.

The U.S. Fish and Wildlife Service, for example, has used clearinghouse information on zebra mussel sightings to develop its own computerized geographic information system map of zebra mussel sightings.

The New York State Museum's Dan Molloy, for one, is enthusiastic in his praise for the clearinghouse.

"I can't speak well enough of it," he says. "It's extraordinary in how it pulls all the zebra mussel literature together. It's personally saved me an inordinate amount of research time and has speeded up general communication about zebra mussels."

O'Neill emphasizes that the clearinghouse benefits people outside New York as well.

"We're putting researchers in touch with each other, but it's more than that," he says. "Our providing this service means that each Sea Grant program can use the money it's receiving on things that are important to the people of the state. They don't have to spend a major chunk reinventing the wheel."

O'Neill relishes the role New York Sea Grant plays in providing a service for the region. He's even taking steps to improve it. Currently, O'Neill and company are creating an electronic form of the ever-expanding zebra mussel research bibliography. It is now available to U.S. and Canadian electric utilities on EPRINet and they hope to have it available to Internet users early in 1994. They're also creating a master list of all zebra mussel research that's been funded by Sea Grant, the government or private sources. And O'Neill has a scientist formerly associated with the Ukrainian Academy of Sciences translating a Cyrillic bibliography into English.

People who use the clearinghouse are "folks of all stripes," O'Neill says. The largest user groups are consulting engineers, researchers and government employees, followed closely by industrial employees.

For O'Neill, it's all part of running a good clearinghouse.

"Scientific research without an outlet to user audiences is research only partially appreciated," he says.

▲

Zebra mussels & the bottom line

EACH JANUARY SINCE 1991, Warren Isaacson has taken out an insurance policy. It has no deductible, no terms, no promise of compensation. But for Isaacson, water department superintendent for the city of Escanaba, Mich., it's a keeper. His insurance policy is a presentation about minuscule microbes that could someday become tiny zebra mussel assassins. It's an update on government regulations on molluscicides; it's a helpful chat with colleagues over drinks. It's Michigan Sea Grant's zebra mussel conference for municipal and industrial water users.

No conference can completely ensure against zebra mussel infesta-

"At the conferences, peers talk to each other about what they're doing. If one has a proven track record in dealing with a certain problem, just sharing that with others saves money."

tion. But for Isaacson and about 200 others annually, the conference does ensure that they have the latest information on key issues.

The format is straightforward. Scientists, resource managers and government officials come from

around the country to speak to an audience of water managers from both private industry and city facilities. The crowd includes such big names as Detroit Edison, Morton Salt Co., Michigan Department of Natural Resources and Exxon. They all gather at the Kellogg Center on the Michigan State University campus for two days of give and take, discussing new findings in zebra mussel biology, monitoring and control techniques and regulatory implications. Some participants are already facing zebra mussel infestation; others, like Isaacson, are there to prepare for it.

The speakers include experts from within Sea Grant, but also prominent researchers from other organizations, says Chuck Pistis, Michigan Sea Grant extension agent. Renata Claudi from Ontario Hydro, Wayne Weiner from Maryland Sea Grant and Dan Molloy from the New York State Museum are just a few who have been featured since the meetings began in 1991.

Pistis says the conference is simply a local, more convenient variation on the standard professional meeting. The need for a conference with a local spin occurred to him, he says, after he came back from a zebra mussel conference in Rochester, N.Y. He knew the big conferences were valuable, but also knew that local Michigan water users didn't have the time or the money to get there. Responding to what he saw as an "educational need," he

and fellow Sea Grant agent Steve Stewart proposed a zebra mussel conference for Michigan. The first one was held in January 1991.

That meeting was well-received, as were the next two, Pistis says. Participants rated the 1992 and 1993 conferences a 3.35 on a scale of 1-4, 1 meaning *poor* and 4 meaning *excellent*.

Pistis says the biggest reason for the high marks is that the conferences save people money.

"At the conferences, peers talk to each other about what they're doing. If one has a proven track record in dealing with a certain problem, just sharing that with the other saves money," he says.

Isaacson echoes that sentiment.

"The value of these conferences is that we all stay up-to-date. As a result, we don't spend money on something that's not worthwhile."

Beyond the dollars saved, Pistis also sees intangible benefits for the entire region. Sea Grant included. The conferences serve almost as mixers, ways of introducing participants to Sea Grant people and services from all the Great Lakes states.

Pistis says the result is an enhanced image of Sea Grant and more healthy dialogue about zebra mussels.

"Because of these conferences, the people in Michigan and the region involved with zebra mussels talk to each other a lot more," he says. "There's great value in that." ▲

May I see some I.D., please?

THEY'RE ENTRENCHED IN THE Great Lakes. They're spreading into the mid-Atlantic region. Soon they may be in California.

If you guessed zebra mussels, you're right—kind of. These fast-spreaders are Wisconsin Sea Grant's zebra mussel information cards. They're 4.5- by 3.5-inch flier-type cards small enough to fit in a wallet. Though tiny, they're full of information. On the outside, two-color photographs show the mollusk's tell-tale markings: the brownish-yellow striped pattern and D-shaped shell. Inside, readers learn about the multi-billion-dollar threat zebra mussels pose, how to identify them and how to report sightings.

Best of all, these cards have spread even faster than the mussels themselves. Wisconsin Sea Grant communicator Stephen Wittman reports that nearly one million cards have been printed since the project began in 1990. In 1992 alone, Wisconsin Sea Grant pro-

duced more than 580,000 cards, including more than 110,000 for other Sea Grant programs in the Great Lakes (customized for each state) and almost 8,000 for the Nashville office of the U.S. Army Corps of Engineers.

Wisconsin Sea Grant provides these cards to any group that's interested, at cost. Most card carriers reside in the Great Lakes region, but Wittman reports that he's also filled sizable orders for programs in the Mid-Atlantic Sea Grant Network, the Lake Champlain Basin Program and the Tennessee Shell Company, the nation's leading exporter of commercially harvested freshwater mussels. Wisconsin Sea Grant has even produced a version in Canadian French for the Ontario

Ministry of Natural Resources.

According to Wittman, the cards sprang from a need for fundamental public awareness about zebra mussels—both how to identify them and why it is important to do so. The idea took root after Wisconsin Sea Grant graphic designer Christine Kohler saw a Lyme tick identification card produced by the Wisconsin Department of Natural Resources and asked "why not zebra mussels?"

Four years and thousands of copies later, the cards are a clear success. Wisconsin Sea Grant has printed more cards than almost all previous publications combined, and total distribution is among the largest of all Sea Grant zebra mussel publications. Also, Wittman

continues to receive dozens of inquiries about the card from industries and government agencies as far away as California, Arkansas and Connecticut.

"We're pleased the cards have turned out to be so popular," Wittman says. ▲

Zebra Mussel Alert

The barnacle-like zebra mussel poses a multibillion-dollar threat to industrial and public drinking water supplies and may become a costly nuisance to shippers, boaters, commercial fishermen, anglers and beach-goers as well—far more costly in human terms than all previous Great Lakes invaders combined.

Public assistance in reporting zebra mussel sightings at new locations is essential to help prevent its spread to our inland lakes and rivers!

How to Identify It

► Zebra mussels look like small clams with a yellowish and/or brownish "D"-shaped shell, usually with alternating dark and light bands of color (thus the name "zebra").

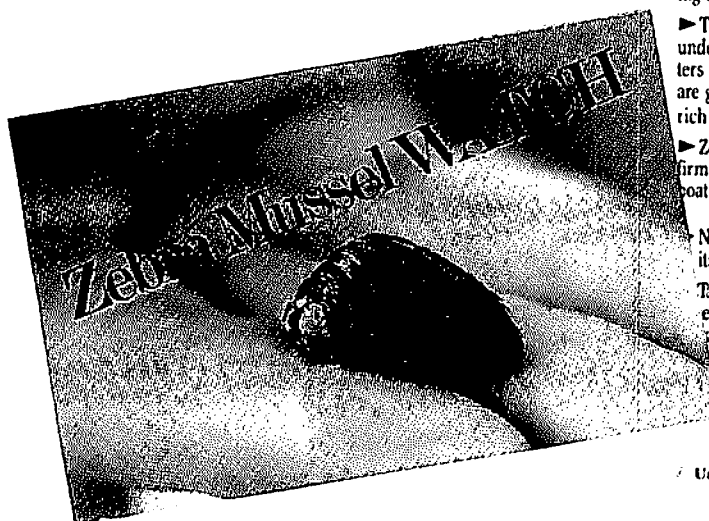
► They can grow up to two inches long, but most are under an inch long. Zebra mussels usually grow in clusters containing numerous individuals (see photo), and are generally found in shallow (6 to 30 feet deep), algae-rich water.

► Zebra mussels are the ONLY freshwater mollusk that firmly attaches itself to solid objects, including rocks, boat hulls, etc.

Note the date and precise location where the mussel its shell(s) were found;

Take the mussel with you (several, if possible) and rub in rubbing alcohol (in any case, DON'T throw it in the water), and

IMMEDIATELY contact the nearest Ohio Sea Grant Advisory Service field office in Elyria, Painesville or Port Clinton, or phone (614) 292-8949.



A picture is worth . . .

LOOK INSIDE BOXES AT MICHIGAN Sea Grant and you'll find zebra mussels, ruffe, spiny water fleas, sea lamprey, shoots of Eurasian water milfoil, stalks of purple loosestrife, tube-nosed goby and alewives.

There's no genetic tinkering going on here, and it's not an aquatic exotic species convention. These inhabitants are photographs, slides and illustrations, some of the members of Great Lakes Sea Grant Network's Nonindigenous Species Graphics Library.

According to Carol Allaire, a Michigan Sea Grant writer and editor who helped develop the collection, Michigan Sea Grant has distributed more than 1,200 photographs, slides and illustrations of exotic species since the graphics library began in 1991. Because most people who call the library want camera-ready graphics of the zebra mussel, the collection is zebra mussel-heavy. It includes more than 100 shots of zebra mussels encrusting everything from an unsuspecting crayfish to a Lake Michigan shipwreck.

Most requests come from government agencies, industries and other Sea Grant programs, Allaire says. The U.S. Army Corps of Engineers, for example, has used slides in staff training presentations, and a Cleveland-based BP Oil executive has used slides and photos in presentations at corporate headquarters in London.

Though they're not the largest user group, prominent museums and

media organizations also use the service. Library graphics have appeared at the Kohl Children's Museum in Wilmette, Ill., the Bell Museum of Natural History at the University of Minnesota and in *Science* and *National Fisherman* magazines.

Requesters can borrow the graphics from Michigan Sea Grant and return them after a two-week lending period or can purchase copies for a nominal fee. To get the word out about the library, Michigan Sea Grant distributes library catalogs and color promotional brochures at various conferences and meetings.

For Allaire, the creation of the graphics library was an example of Sea Grant at its best. She says the Great Lakes Sea Grant Network saw the spread of zebra mussels and the accompanying media stories and presentations about it, anticipated a need and began filling it.

"We just asked ourselves how we could best meet this need and began doing it."

For Roland Hamborg, an environmental resources specialist with the U.S. Army Corps of Engineers, this decision came just in time.

"Before I heard about the graphics library, I couldn't find any source of

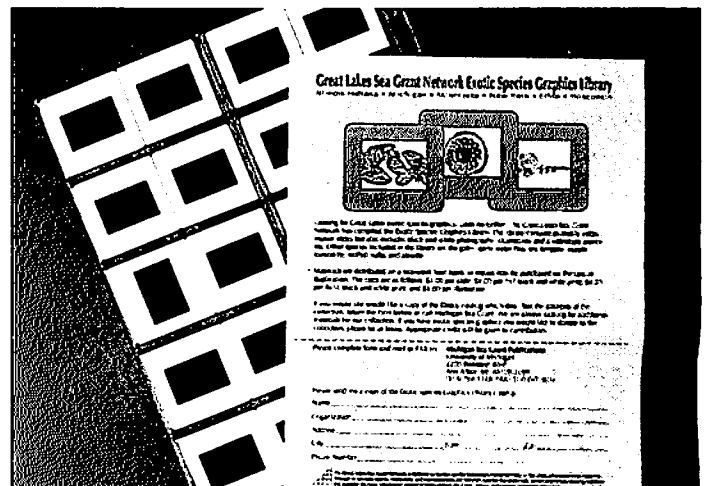
graphics," he says. "It looked like the only option I had was to make copies from a few magazine articles, which wouldn't have worked well at all. The graphics library made everything work very smoothly."

Allaire is pleased about the graphics library's benefits, for the public and for Sea Grant.

"The public can actually use our graphics to get a good look at nonindigenous species and identify them," she says. "And for us, the graphics library provides a good opportunity to make contacts, contacts that give us a chance to promote other Sea Grant services and programs," she says.

"In this way, we're not only helping inform people about nonindigenous species, but we're also helping people learn about other Sea Grant services and products they can use." Δ

The collection of photographs in the Nonindigenous Species Library are used by several agencies and businesses. (photo provided by Michigan Sea Grant)



Zebra mussels 101

IT'S A SUNNY DAY IN MAY, AND Leslie Kilver and Michelle Smith from Janet Franklin's 10th-grade biology class are on a barge that's permanently anchored at the Central Illinois Power System facility on the Illinois River. Notebooks and sampling jars in hand, they look like two typical, young, field scientists. Tension builds as they reel in about four feet of rope and pull up a curious-looking contraption — a series of four successively larger layers of plastic plates attached to a steel cable. They huddle to inspect the plates. The evidence is clear. One girl smiles; the other groans. They've discovered zebra mussels.

54

Franklin's students from Meredosia-Chambersburg High School in Meredosia, Ill., are some of the youngest soldiers in the battle against zebra mussels. They're part of the Illinois Rivers Project, an effort that involves 130 Illinois high schools and almost 10,000 students in gathering data on the Mississippi, Illinois and other major rivers and lakes in the state.

Though the project has been around for three years, the zebra mussel monitoring component is a new addition. Credit, in part, belongs to Illinois-Indiana Sea Grant research coordinator Glenn Stout for suggesting the idea and to Illinois-Indiana Sea Grant for providing financial support.

According to Cindy Bidlack, project coordinator for the Illinois Rivers Project, the zebra mussel monitoring effort is pretty straight-

forward. School groups set monitoring devices out in late March. Then over the course of the next eight months, they visit the sites every two weeks. When zebra mussels are found, students notify Bidlack or Doug Blodgett, associate biologist with Illinois Natural History Survey's long-term resource monitoring program. Some students also send preserved mussel samples to Blodgett. The cycle ends in November, as weather conditions dictate.

The project is young, but Bidlack emphasizes that it has produced some significant results for both scientists and students. Ten

schools, including Meredosia-Chambersburg, reported mussel sitings to Illinois Natural History Survey in 1992. In addition, Illinois schools have embraced the project, she says, and have worked it into student life in many different ways. At some schools, the entire first-year class goes monitoring for zebra mussels; at others, only upper-level biology students participate. Franklin's students at Meredosia-Chambersburg, for example, try to culture the little mollusks in aquaria and ultimately hope to capture the zebra mussel's entire life history on videotape.



Students conduct water quality tests during the River Curriculum Project. This student is on the Illinois River at East Peoria.

In Bidlack's view, this project is providing a real service. Government agencies facing stiff cutbacks need help where they can get it, "people to act as their eyes."

At the same time, says Bidlack, students need to gain an awareness about water quality and all the other environmental issues that they will be voting on as adults.

Franklin, too, is enthusiastic.

"It's good for students to realize that things they learn in school have a bearing on the real world. It's

been a very good experience for them."

It was a vision of these kinds of benefits that led Stout to suggest the project. The idea hit him while he was attending the second International Zebra Mussel Research Conference in Rochester, N.Y., he says. Talks he heard there confirmed his evaluation that zebra mussels would spread down the Illinois River from Chicago to St. Louis. He knew high schools in the area were already doing water quality sampling. Why

couldn't they keep an eye on zebra mussels, too?

Stout admits he was excited about the prospect.

"I called the Illinois Rivers Project from Rochester," he says. "I couldn't wait."

Things moved pretty quickly after that. Materials to build the monitoring devices were distributed—two sets per school—at the Rivers Project's student meeting in March. Doug Blodgett came

to the weekend meeting to train the teachers attending how to use the devices correctly. The schools took it from there.

Today, Stout and Bidlack see many of their hopes for the project coming true. It's been favorably received at meetings and symposia from Sweden to Japan and was recently included in a feature story in *National Geographic*. Students continue to gather helpful information for Illinois Natural History Survey.

"They fill in the holes that can't be attended to by staff," Blodgett says.

And student interest remains high. At last year's student meeting of the Illinois Rivers Project, Janet Franklin's two 10th-graders presented a short videotape about potential infestation sites within the Central Illinois Power System facility. The response was very positive, Franklin says.

The next step is to increase zebra mussel monitoring efforts throughout the region. Indiana is next. Bidlack reports that a fledgling effort, Water Watchers of Indiana, is currently underway. Illinois-Indiana Sea Grant plans to provide financial support.

"We've seen it work before," Stout says. "It's just a good investment." Δ



Glenbrook South teacher Jim Sheppard and student Tania Aglikin with zebra mussel monitoring device.

Getting the scoop

“NEW INVADERS MENACE LAKES”
“Tiny foreign clams
loom large in Lake Erie’s
future”

“Uninvited guests crash Lake
Erie parties”

It was 1991 — three years after
such headlines heralded the zebra
mussel invasion of the Great Lakes.
For Maran Brainard Hilgendorf,
Ohio Sea Grant communicator, it
was a crucial time. Zebra mussel
research was beginning to yield
results, with many findings disprov-
ing early concerns. What was the
best way to let the public know?

For Ohio Sea Grant, an informa-
tion session for science journalists
proved to be the key.

The format was simple, but ef-
fective. The Scientists’ Institute for
Public Information (SIPI) and the
Society for Environmental Journal-
ists provided the writers — promi-
nent science journalists attending a
workshop on Great Lakes environ-
mental reporting. Ohio Sea Grant
provided the zebra mussel know-
how — Ohio Sea Grant director Jeff
Reutter, researcher David Garton
and Ontario Hydro scientist Renata
Claudi.

Together, the two groups met
in Toronto in mid-April 1992, ex-
changing questions and answers
for a couple hours on a Sunday
morning. The discussion was broad,
including such topics as Canadian
and American zebra mussel regula-
tions, ongoing research and the
invasion’s effects on the Great
Lakes ecosystem and economy.

Major newspapers — such as the
Minneapolis Star-Tribune and *The
Buffalo News* — public television
stations and network affiliates were
represented at the session.

This was just what Hilgendorf
was hoping for.

“There was just so much new in-
formation about zebra mussels com-
ing out. We needed a vehicle to
distribute new research findings to
established science reporters,” she
says.

Hilgendorf
says the science
writers’ session
became reality
only after about
two years of
planning. She
proposed the
project to the
Great Lakes Sea
Grant Network
and the National

Sea Grant office in 1990. Then in
August, funding for the session se-
cured, Hilgendorf started consider-
ing people to lead it.

In the end, Reutter, Garton and
Claudi seemed the best choices.

“Those three made the most
sense,” Hilgendorf says. “Under Jeff
Reutter, Ohio Sea Grant was leading
the nation in zebra mussel research.
Dave Garton was *the* zebra mussel
expert. And Renata Claudi brought
the perspective of being a scientist
with the largest business that uses
Great Lakes water.”

Ultimately, the hard work it took
to plan the session was worth it,
Hilgendorf says.

“In just about two hours, jour-
nalists were able to get a greater un-
derstanding of the zebra mussel
issue and were also able to ask ques-
tions about infestations in their spe-
cific regions,” she says.

Dean Rebuffoni, who attended
the session from the *Minneapolis
Star-Tribune*, agrees.

“The zebra mussel session was
extremely informative,” he says. “It
was useful not only to members of

the media in the
Great Lakes re-
gion, but also to
the scientists.
We found out
we really can
speak the same
language. I left
with a notebook
full of contacts
and ideas. I’d
love to do an-
other one,” he

*“We were able to
establish relationships
with good science
reporters — relationships
we can build on in the
future.”*

says.

Hilgendorf adds that the Sea
Grant programs in the Great Lakes
region also benefited from the ses-
sion.

“We were able to get more cov-
erage of an important issue,” she
says, pointing to stories that ap-
peared in the *South Bend Tribune*
and *Minneapolis Star-Tribune*.

“And we were able to establish rela-
tionships with good science report-
ers — relationships we can build on
in the future.”

“It was a very successful and
very productive effort,” Hilgendorf
says. ▲

An exotic exhibit

“WHO SUCKED THE LIFE BLOOD from Great Lakes fisheries?” asks a boldly lettered sign above a display panel at the University of Minnesota’s Bell Museum of Natural History. A pretty obvious clue is the sea lamprey hanging from the panel, its suction cup-like mouth affixed to an unfortunate fish.

Fortunately for museum visitors, this sea lamprey is no blood-sucker; it’s a puppet, and its prey is a photograph. Along with a trophy stuffed carp and dozens of paintings, photographs, cartoons and diagrams, it’s part of the Bell Museum’s new exhibit titled “Exotic Aquatics of the Great Lakes Region.”

The display, which opened to the public in July 1992, is the result of cooperation among the Minnesota legislature, the Bell Museum, the Science Museum of Minnesota, the Minnesota Department of Natural Resources, several other state agencies and two zoos. And Minnesota Sea Grant.

Four museum staff worked full time for a year to create it, says Don Luce, the Bell Museum’s curator of exhibits. The finished product is a series of 12 panels on different exotics topics.

The form may sound familiar, but this is no ordinary display. “Exotic Aquatics” includes sliding panels that kids can move back and forth to show a lake scene, both before and after exotics. It has a magnetic map of the Great Lakes region, complete with little boats

and cartoon characters that kids can move around to show how exotics spread. And it even has a giant marsh ecosystem jigsaw puzzle with two different solutions: a complex one with cattail at the base of the food chain and a simpler one that can be solved with purple loose-strife.

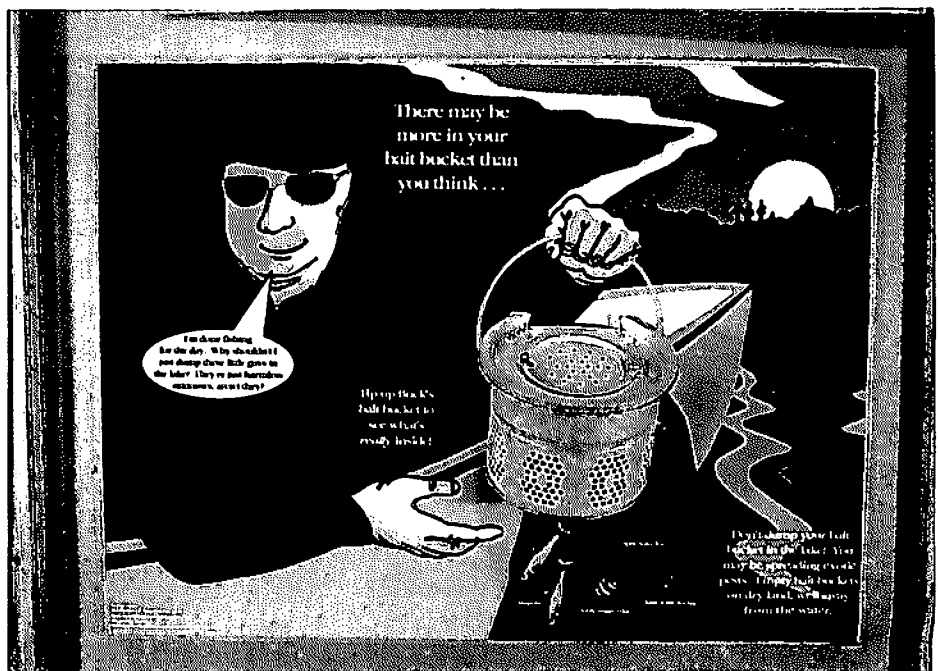
All these bells and whistles belie a single, simple goal—to teach, says Minnesota Sea Grant writer Mike McLean. The main thrust of the display is to teach people that introductions and infestations of exotic species don’t happen merely by chance or accident—that they happen and succeed partly because of environmental neglect, he says.

“One of the reasons exotics are here is because the natural environment has been perturbed. If you

take a plow and dig up a field, weeds take advantage of that open space. There’s really no difference between a weed and an exotic that takes advantage in a lake.”

For McLean, the display was just what Minnesota needed to get its environmental groups working toward a common goal.

“One after another, an exotic would become a problem, the different groups would try to deal with it, and they’d come up with the same advice,” he says. “The idea was to put together a comprehensive exhibit to educate people about the interrelationships between these problems.”



One panel in a series of 12 on different exotic topics, located at the Bell Museum. (photo provided by Don Luce)

Thanks to a \$500,000 grant from the Legislative Commission on Minnesota Resources, money made available from lottery ticket proceeds, the idea came to life. Or at least still-life. Minnesota Sea Grant's involvement first came when it joined the consortium of environmental groups that proposed the display to the legislature. Later, Minnesota Sea Grant served as an adviser for the display's creators at the Bell Museum, providing expertise for the display panels on zebra mussels, sea lamprey, exotic species

travel—one that can be wall-mounted and two that can be displayed free-standing.

"It's geared for easy setup and easy maintenance," McLean says. The display is booked at the Bell Museum, the Science Museum of Minnesota, state parks and visitors centers until July 1993. After that, it will be available for loan throughout the Great Lakes region. McLean says that some Great Lakes Sea Grant programs have proposed to cover transport costs to bring the display to their states but that final decisions on this are still pending.

movement and control options.

Planning the exhibit was a pleasant experience and beneficial for Minnesota Sea Grant, McLean says.

"It really was a very good cooperative effort. Minnesota's a pretty small state, and the consortium was a pretty small group. Most people knew each other, and working relationships became stronger."

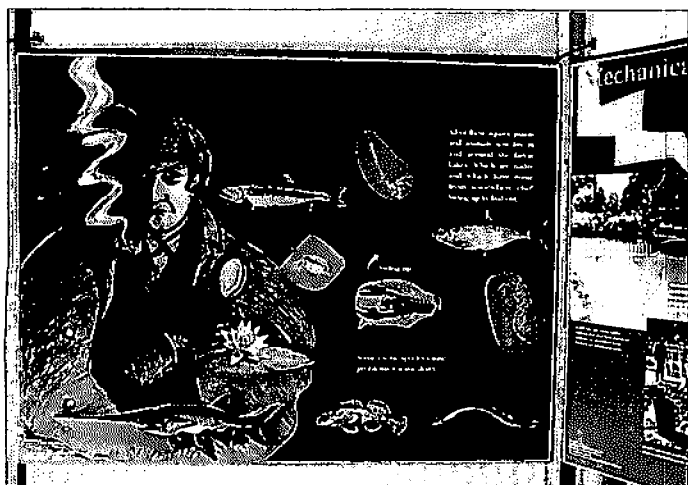
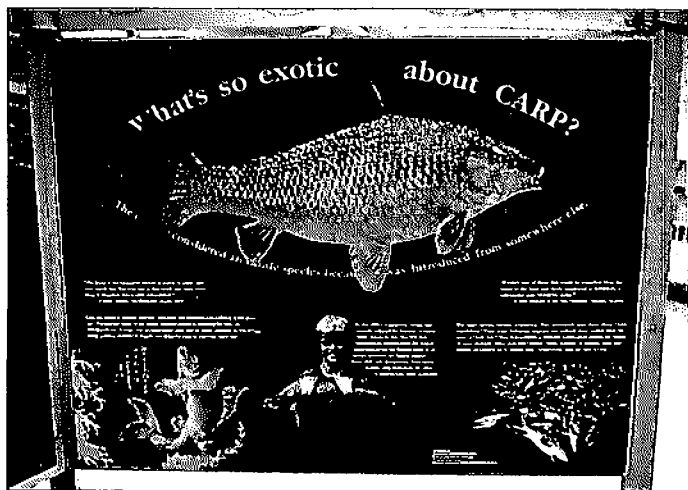
Ultimately, three copies of the display will be available to

travel—one that can be wall-mounted and two that can be displayed free-standing.

There are high hopes riding on this display among all the consortium members, McLean says. The official goal is that one million Minnesotans will see and learn from it. For McLean, this seems likely. "This display will be beneficial because students will be able to take a basic biological problem out of the textbook and see its application to principles in the real world," he says. "As for adults, it will help them understand that the problems at their dock may be related to the way they've treated their lakeshore, that these problems aren't always caused by some far-off shipper." McLean doesn't see these lessons as limited to Minnesota.

"This display will benefit all the Great Lakes states simply because there's a lot of common information," he says. Δ

Two panels (below) from the "Exotic Aquatics of the Great Lakes Region" display located at the Bell Museum. (photo provided by Don Luce)



On the lookout

AFTER THREE YEARS, IT'S BECOME something of a ritual. Every week from late June through November, John Babinec, a water intake specialist with Wisconsin Electric Power Co. in Milwaukee, pumps 1,000 liters of unfiltered Lake Michigan water through a 55-gallon steel drum. But this is no ordinary drum; inside is a funnel-shaped mesh net with a tiny bucket attached at the tip. The water through the drum, Babinec rinses the net, retrieves the bucket and carefully pours its contents into a sample bottle. Later, with the help of a stereo-microscope with a polarized lens, he'll see the fruits of his labor: zebra mussel veligers swimming around in the water intake sample, wriggling around under the microscope, plain as day.

This is Wisconsin Sea Grant's zebra mussel watch in action. Begun in spring 1990, it's a sampling and analysis project that involves 16 municipal water intake facilities, 11 power plants, five industries and four Wisconsin colleges and universities, all with the goal of determining how many zebra mussel veligers and young adults are present in Wisconsin's Great Lakes waters.

It's a big job. To tackle it, Wisconsin Sea Grant divides it into categories—harbors and water intakes.

Four Sea Grant researchers and their students handle Wisconsin's 10 major harbors. They sample at 28 different sites every two weeks, using a mesh net to snag veligers and plexiglass pyramids to collect young adults.

At the same time, industrial and municipal technicians sample at their own water intakes, recording data about zebra mussel quantity, size and density, much the way the scientists do. The end result of both efforts is a mass of helpful information about where zebra mussels are, how fast they're growing and reproducing, and how dense the colonies really are. Wisconsin Sea Grant compiles this information and gets it out to the people who need it, both in person and through the periodic newsletter *Zebra Mussel Update*.

Al Miller, project director and assistant director for advisory services with Wisconsin Sea Grant, says the project began because Wisconsin industries facing zebra mussel infestation needed sound information about what was actually happening in Lake Michigan and Lake Superior, not merely newspaper stories and unconfirmed reports.

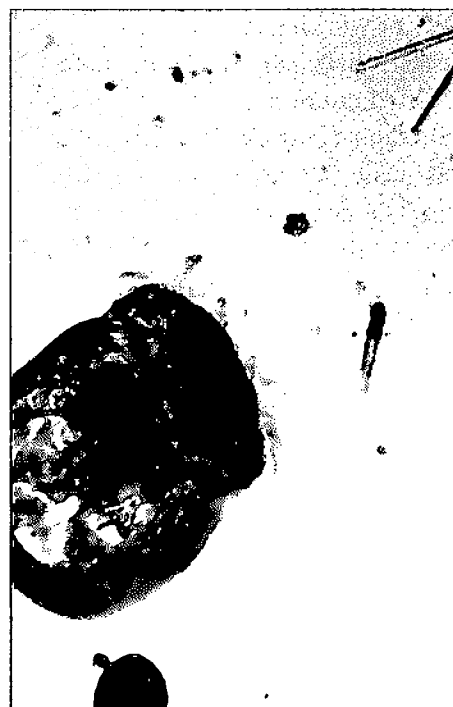
"Businesses don't make decisions based on newspaper stories," he says. "They weren't going to spend \$300,000 on control measures until there was more scientific information about what was really happening with zebra mussels."

According to Miller, the Wisconsin Department of Natural Resources also was hesitant to begin taking steps to control zebra mussels prematurely.

"They didn't want to put a lot of chlorine into the lakes if it wasn't necessary," he says.

Dave Michaud, senior scientist in Wisconsin Electric Power Co.'s environmental department, says

The fertilized eggs hatch and become veliger larvae. This stage lasts approximately three to five weeks, during which time they are invisible to the naked eye. (photo provided by the Ontario Ministry of Natural Resources)



there was also a tremendous need in industry for information about how to conduct a systematic zebra mussel watch program.

"In 1990, not many companies had biologists on staff who were even trained in identifying zebra mussels," he says. "No one really knew what they were looking for."

Recognizing these needs, Wisconsin Sea Grant responded. Miller and colleague Cliff Kraft, zebra mussel watch coordinator, identified the Wisconsin harbors

and nearshore areas most likely to be exposed to zebra mussels, got a list of water users in those areas and got to work contacting them. The response was positive.

“We talked to various industries, and they said they’d like to have us analyze samples in their plants,” Miller says.

In working with these industries, Wisconsin Sea Grant soon shifted out of active sampling and into an advising role. Seeing that the water intake technicians were already doing many water quality tests, Miller and Kraft decided that the best use of Sea Grant’s time would be to teach the technicians how to identify veligers and adults. More than 200 trained technicians later, Wisconsin Sea Grant is now nearly out of the intake sampling and analysis business; the technicians have taken over.

Kraft says he’s pleased with the way intake technicians have responded and that he has full confidence in their ability.

“Anybody who’s doing water quality tests in a plant is certainly able to identify juvenile and adult zebra mussels,” he says.

Miller is pleased with the positive response the zebra mussel watch has received among Wisconsin industries, offering recent grants from Wisconsin industries totaling over \$40,000 as an example.

“Without a doubt, the feedback has been very positive,”

he says. “The water user community is very pleased with what they’re getting, and they’re very willing to provide financial support to see that it continue.”

Proof of this comes from Michaud.

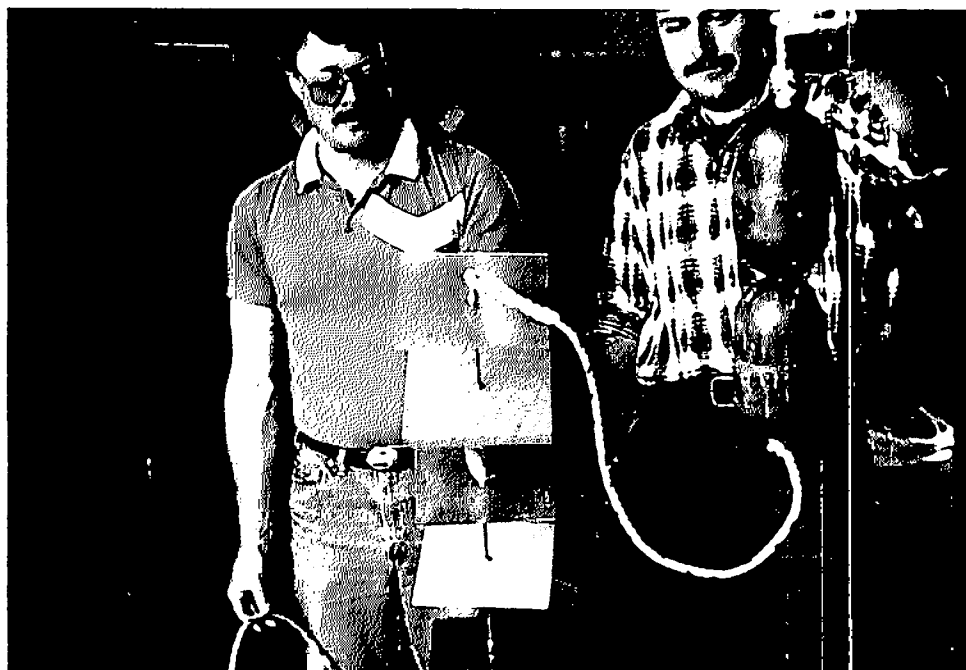
“When we were asked to help fund the program this year, it was no big deal,” he says. “Sea Grant has been very helpful in providing us with baseline data that we’re confident with and doing it relatively quickly. They’ve saved us money by producing some pretty amazing results for a tiny number of dollars. I don’t think a private firm could have done it.”

But Miller emphasizes that the rewards aren’t all financial.

“Probably the most positive thing to come out of this project is that it has opened the door between Sea Grant and industry in the state,” he says. “Our previous relationships with industry were not that strong. Now that we’re into the zebra mussel issue, communications have opened and we’re now talking about other issues.”

For Miller, the Great Lakes region also benefits from the zebra mussel watch.

“Sea Grant has taken on new life because of the zebra mussel effort. One program’s accomplishment enhances Sea Grant’s image in the whole region,” he says. “It carries over.” Δ



Researchers have found that mussels will attach to almost all solid surfaces, natural or man-made. This multi-material sampler was placed in the western basin of Lake Erie in May of 1989. (photo provided by the Ontario Ministry of Natural Resources)

Q & A

HOW MANY CITY AND BUSINESS water users along lower Lake Michigan have seen zebra mussels? Where? What are they doing about them? Do water users know enough about combating the pesky mollusks?

Robin Goettel wanted answers—answers that weren't readily available.

"We didn't know what the area water users were doing about zebra mussels, and we didn't know if they were getting the information they needed," says Goettel, communications coordinator for the Illinois-Indiana Sea Grant Program.

So Goettel, Illinois-Indiana Marine Advisory Service leader Joe O'Leary, former communications assistant Kimberly Meenen and University of Illinois decision data specialist Gail Snowdon set out to remedy the situation.

The remedy was a 33-question "information needs" survey. The Illinois-Indiana Sea Grant team began work in June 1991, determining topics, writing questions, selecting a random sample. Five months later the survey was ready and was mailed to 29 municipal and industrial water users in Illinois and Indiana's lakeshore counties. According to Goettel, most of the organizations surveyed were medium-sized municipal water treatment plants, but the group also included Chicago Water Works, Commonwealth Edison and the Great Lakes Naval Station.

The goal of the survey was twofold: to gather data on the ever-increasing spread of zebra mussels and

to act as a sort of report card—a gauge of how well Illinois-Indiana Sea Grant was meeting the area's information needs.

Thanks to a 93 percent response rate, Goettel and her colleagues got the data they wanted. Survey results showed that 74 percent of municipal and industrial water users have seen zebra mussels at their plants in Lake Michigan and that 80 percent of these sightings are the result of industry-run monitoring programs. The results further showed that 50 percent of respondents treat the water as a means of controlling zebra mussels, mainly with chlorine.

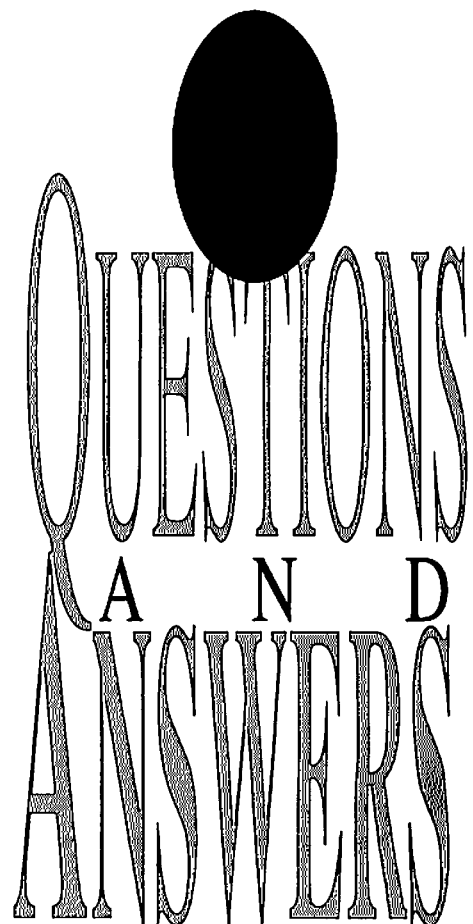
"These findings were very helpful because they allowed us to get a better handle on the scope of the infestation in lower Lake Michigan," Goettel says.

She says that data about the area's information needs also were valuable. Survey results showed that respondents prefer to get their information about zebra mussels from workshops and newsletters, and that 73 percent think their information needs are being met.

According to Goettel, information like this was just what Sea Grant needed.

"Many of our efforts were reinforced and verified, but we also learned about areas we should emphasize more to most effectively educate the water users," she says.

As one example, Goettel notes that several respondents asked for more information about ways to control zebra mussels and how



much these methods cost. As a result, Illinois-Indiana Sea Grant included journal articles and a list of publications about zebra mussel control with the summary of results it sent to each respondent. Future follow-up plans include a slide show about control methods that will be available throughout the Great Lakes region.

Goettel says the slide show, to be written by prominent zebra mussel scientist Ellen Marsden of the Illinois Natural History Survey, will become a feature of future industry workshops. The emphasis will be

on teaching industry leaders how to choose the most appropriate, environmentally friendly and least expensive control technologies from among the 50 available. Goettel says Marsden also hopes to show industry leaders how to implement their chosen methods.

Goettel says she hopes the slide show will help people both within and beyond the bounds of the Hoosier and Illini states deal more effectively with zebra mussels.

"Our goal is always to ask the questions that need to be asked and then get information out to those who need it," she says. ▲

zebra mussels
information
CONTROL
& COST



Zebra mussels (below) Dreissena polymorpha were accidentally introduced into the Great Lakes in the mid-1980s. Quagga mussels (top) Dreissena bugensis, an East European relative of the zebra, was found in the colder depths of Lake Ontario in 1991 and across the bottom of Lake Erie in 1992. (photo by J. Ellen Marsden)

Mussels and the Mississippi

THEY WERE COMING — NO DOUBT about it. It was early winter 1992 and zebra mussels were already in the Illinois River. It was just a matter of time before they made it to the Mississippi.

Fortunately, Minnesota Sea Grant was ready with the age-old defense — information. If the spread into the Mississippi couldn't be prevented, it could at least be understood in time. The race was on.

It was close, but thanks to the Upper Mississippi River Basin Association, Minnesota Sea Grant and more than a dozen other agencies from Arkansas to Wisconsin,

the upper Mississippi water users got the head start they needed in the race against zebra mussels—an introduction to them from the people who know them best — the Great Lakes water users. In early April 1992, the two camps, 250 strong, converged in suburban Minneapolis for a conference. What followed were two days of straight talk about what zebra mussels are, how much damage they can do and what can be done about them. (For the record, zebra mussels were discovered in the Mississippi just two months later.) ▶



Students from Alton (Illinois) High School conduct water quality tests on the Mississippi River at Lock & Dam #26.

Researchers

This list includes only the first researcher listed on every project. For a complete list of researchers, see the project description. Students are not included.

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Resource list

This list includes material that is distributed by the six Sea Grant programs in the Great Lakes Sea Grant Network as of December 1993. Many of the other Sea Grant programs are producing material about the zebra mussel, too. For example, Rhode Island (401/792-6842), Virginia (804/924-5965) and North Carolina (919/515-2452) Sea Grant programs all currently have material available. Other U.S., state and Canadian agencies also have material available.

To order any item in this resource list, complete and mail the order form for the program distributing the material. Free items are for *single copies only* unless specified otherwise. For prices on bulk orders, contact the program that is distributing the material. Please prepay all orders.

Resources on zebra mussels

The first three publications provide information on how this species was introduced into the Great Lakes, areas colonized in the lakes, what methods of eradication exist, provides tips on what you can do to slow the mussel's spread, and the impact zebra mussels will have on industry, recreation and the Great Lakes ecosystems.

- Zebra mussels in the Great Lakes: The invasion and its implications. December 1993. *Fred L. Snyder, David W. Garton, and Maran Brainard*. 4 pp. OHSU-FS-045. Free for any size order. **OH**
- Zebra mussels: A 1992 Great Lakes overview. 1992. *Avery Klauber*. 8 pp. Free; multiple copies are \$.10 each. **NY**
- Zebra mussels in the Great Lakes. 1992. 2 pp. MICHU-SG-92-700. Free. **MI**

Mid-Atlantic zebra mussel fact sheet. Reprinted January 1994. *Barbara Doll*. 6 pp. Explores the possible routes of entry the zebra mussel might take and examines the environmental characteristics that would make this area a hospitable host, including the expansive estuaries and freshwater rivers and lakes. Free. To order, write N.C. Sea Grant, Box 8605, N.C. State University, Raleigh, NC 27695-8605.

Zebra mussel: An unwelcome visitor. 1993 *Karin A. Tammi*. 2 pp. Describes the biology, impact and history of zebra mussels in the United States along with identification information and help to Rhode Islanders to prevent their introduction into the state. \$.50 To order, write R.I. Sea Grant Information Office, URI Bay Campus, Narragansett, RI 02882, 401/792-6842.

Zebra mussels in Virginia's future. March 1993. 2 pp. Includes the zebra mussel's physical requirements and a list of its potential range in Virginia's waters. Free. To order, write Virginia Institute Marine Science, Gloucester Point, VA 23062.

- New concerns emerge as zebra mussel spreads. 1992. 2 pp. MICHU-SG-92-702. Free. **MI**
- The zebra mussel (*Dreissena polymorpha*): An unwelcome North American invader. 1991. *Charles R. O'Neill, Jr. and David B. MacNeill*. 12 pp. NYSGI-G-91-013. \$1.00 **NY**
- Boaters—Slow the spread of zebra mussels and protect your boat, too. 1993. *David O. Kelch*. 2 pp. OHSU-FS-054. Free for any size order. **OH**
- Identification of juvenile *Dreissena polymorpha* and *Mytilopsis leucophaeata*. 1992. *David B. MacNeill*. 3-fold brochure includes diagrams, glossary and references for the zebra mussel and dark false mussel. NYSGI-G-92-001. Free **NY**
- Zebra mussel information needs survey for municipal and industrial water users—Summary report. 1992. *Robin Götzel and Gail Snowdon*. 8 pp. A survey of 29 southern Lake Michigan municipal and industrial water users provided findings on what types of zebra mussel information were most needed and in what form the information could best be delivered. Free. **IL-IN**
- Control of zebra mussels in residential water systems. 1993. *Charles R. O'Neill, Jr.* 8 pp. \$1.00 **NY**
- Zebra mussels may clog irrigation systems. 1993. 2 pp. MICHU-SG-93-701. Free. **MI**
- Engineering Notes. 1992. *Philip Keillor*. Free. **WI**
 - #1: Case studies of constructed filter bed intakes. A description of 10 such systems in the western Great Lakes that range from one to 100 years old. Included is information on operational experience and whom to contact (plant operators and design engineers) for further information, plus commentary from marine contractors and design engineers. 16 pp.
 - #2: Infiltration intakes for very large water supplies: Feasible? A review of four 20-year-old papers that considered design feasibility as a means of protecting larval organisms from entrainment in power plant and water diversion project intakes. 11 pp.
 - #3: Zebra mussel (*Dreissena polymorpha*) distribution: Reported size, depth and temperature variables. A summary of relevant data about zebra mussels intended for project design engineers. 7 pp.
 - #4: Using filtration and induced infiltration intakes to exclude organisms from water supply systems. A literature review plus an overview of slow sand filtration and infiltration systems. 13 pp.
- Sand filter intakes could safeguard vital water-supply systems from zebra mussels. 1991. *Philip Keillor*. 4 pp. WIS-SG-91-428-13. Free. **WI**
- Don't let these invaders hijack your boat! is a 17"x22" humorous cartoon poster telling boaters what to do to slow the spread of zebra mussels. Perfect for fishing/bait shops. Pub X6. Free. **MN**
- Don't pick up hitchhikers! Stop the zebra mussel is a 3 pp. flier and 11"x17" poster. One or two copies of the flier and poster are free. **NY**

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Resources

- Zebra mussel watch identification card. *Christine Kohler and Stephen Wittman*. Wallet-sized cards have a color picture of the zebra mussel with text describing their appearance and what to do if you find a mussel. Free; 20 cards for \$1.00. Available from each program. Order customized cards from Wisconsin. WI
- Zebra mussel distribution map from the latest issue of *Dreissena polymorpha information review*. Free. NY
- Zebra mussel distribution in Michigan. Free. MI
- Zebra mussels: From spawning to settlement.** January 1994. 20-minute video shot through a microscope shows mussels spawning naturally and induced. Voice-over provides details. \$15.00. OH
- Zebra mussels. 1993. Produced by New York Sea Grant and PBS-affiliate WLIW, Long Island as 30-minute show. \$12.00. NY
- Protecting your boat from zebra mussels. Revised 1993. This 15 minute video gives pointers on how to prevent damage to your recreational boat and tips on preventing the spread of the mussel to inland waters. \$10.00. NY
- Too much mussel. January 1991. This 5.5 minute video (VHS format) provides an overview of the impact of zebra mussels to Lake Erie. \$15.00. OH
- Zebra mussel features. Collection of 90 second feature stories produced by Outreach Communications TV at Michigan State University. Contact Carol Swinehart at MSU 517/353-9723. \$10.00.
- Nonindigenous Species Graphics Library contains slides, photographs and illustrations of zebra mussels and other aquatic nuisance species. Also includes a videotape resource list. Contact Michigan Sea Grant at 313/764-1138 for more information.

Resources on other species

- A field guide to aquatic exotic plants and animals. 1992. Developed by MN Sea Grant, MN DNR and Bell Museum of Natural History. 10-page, four-fold, color brochure describes eleven common exotics in the Great Lakes region. Pub X9. Free. MN
- Biology and potential impacts of the rudd in the Great Lakes. October 1993. *David MacNeill*. 4 pp. Free. NY
- The Ruffe invasion, *Gymnocephalus cernuus*. 1993. *Mike McLean*. Describes the aggressive, perch-like fish found in Lake Superior. This invader was first identified in the St. Louis River in 1987. It is now the most numerous forage fish in the estuary and its range is expanding. PUB X7. Free. MN
- Effects of spiny tailed *Bythotrephes* on Great Lakes fish. 1993. *D. Rae Barnhisel*. Explains affect of *Bythotrephes* on fish predation. 2 pp. MICHU-SG-93-704. Free. MI
- Don't let exotics ride with you. 1992. A simple card explaining four major exotics that threaten our lakes and rivers and what boaters and anglers can do to prevent their spread. 2 pp. Free for any quantity. Available from each program. OH

- The spiny water flea, *Bythotrephes*: A newcomer to the Great Lakes. 1991. *David J. Berg*. 2 pp. OHSU-FS-049. Free. OH
- Spiny tailed *Bythotrephes*: Its life history and effects on the Great Lakes. 1990. *Carla E. Caceres and John T. Lehman*. Explains the anatomy, reproductive cycle and behavior of *Bythotrephes* and how this exotic may affect the Great Lakes ecosystems. 7 pp. MICHU-SG-90-700. Free. MI
- Pacific Salmon in the Great Lakes: The history and future. 1986. *Warren Downs*. 5 pp. WIS-SG-86-149. Free. WI
- Sea Lamprey: Invader of the Great Lakes. 1982. *Warren Downs*. 8 pp. WIS-SG-82-138. \$.50. WI
- Is it a white bass or a white perch? Reprinted 1991. *Fred L. Snyder*. 1 p. OHSU-FS-005. Free. OH
- Getting to know your catch: Lake Erie Salmonid identification. Reprinted 1991. *David O. Kelch*. 2 pp. OHSU-FS-031. Free. OH

Scientific publications on zebra mussels

- "Biology of recent invertebrate invading species in the Great Lakes: The spiny water flea, *Bythotrephes cederstroemi* and the zebra mussel, *Dreissena polymorpha*" by *David W. Garton, David J. Berg, Ann M. Stoeckmann and Wendell R. Haag* reprinted from *Biological Pollution: The Control and Impact of Invasive Exotic Species*, *Bill McKnight* (ed.), pp. 63-84, 1993. OHSU-RS-165. Free. OH
- "Reduced survival and fitness in native bivalves in response to fouling by the introduced zebra mussel (*Dreissena polymorpha*) in western Lake Erie" by *Wendell R. Haag, David J. Berg, David W. Garton and J.L. Farris* reprinted from *Can J Fish and Aquat Sci* 50(1):13-19, 1993. OHSU-RS-157. Free. OH
- "Changes in planktonic diatoms and water transparency in Hatchery Bay, Bass Island Area, Western Lake Erie since the Establishment of the zebra mussel" by *Ruth E. Holland* reprinted from *J Great Lakes Res* 19(3):617-624, 1993. MICHU-SG-93-306. Free. MI
- "Effects of deionized water on viability of the zebra mussel, *Dreissena polymorpha*" by *J.L. Ram and J.U. Walker* reprinted from *Comp Biochem Physiol* 105C(3):409-414, 1993. MICHU-SG-93-304. Free. MI
- "The zebra mussel (*Dreissena polymorpha*), a new pest in North America: Reproductive mechanisms as possible targets of control strategies" by *J.L. Ram, P. Fong, R.P. Croll, S.J. Nichols and D. Wall* reprinted from *Invertebrate Reproduction and Development* 22:1-3 (1992) 77-86. MICHU-SG-93-303. Free. MI
- "Spawning in the zebra mussel (*Dreissena polymorpha*): Activation by internal or external application of serotonin" by *J.L. Ram, G.W. Crawford, J.U. Walker, J.J. Mojares, N. Patel, P. Fong and K. Kyojzuka* reprinted from *J Experimental Zoology* 265:587-598, 1993. MICHU-SG-93-300. Free. MI

Resources

- Attitudes of 1990, 1991, and 1992 Mid-America Boat Show and 1991 Fairport Symposium patrons concerning the zebra mussel (*Dreissena polymorpha*), Lake Erie, and Great Lakes pollution" by **Frank R. Lichtkoppler, David O. Kelch and M. Annie Berry** reprinted from *J Great Lakes Res* 19(1):129-135, 1993. OHSU-RS-158. Free. OH
- Seasonal reproductive cycle and settlement patterns of *Dreissena polymorpha* in western Lake Erie" by **David W. Garton and Wendell R. Haag** reprinted from *Zebra Mussels: Biology, Impacts and Control*, Thomas F. Nalepa and Donald W. Schloesser (eds.), pp. 111-128, 1992. OHSU-RS-159. Free. OH
- Investigations of the toxicokinetics of hydrophobic contaminants in the zebra mussel" by **Susan W. Fisher, Duane C. Gossiaux, Kathleen A. Bruner and Peter F. Landrum** reprinted from *Zebra Mussels: Biology, Impacts and Control*, Thomas F. Nalepa and Donald W. Schloesser (eds.), pp. 465-490, 1992. OHSU-RS-160. Free. OH
- The use of endod to control the zebra mussel" by **Harold H. Lee, Akilulu Lemma and Harriett J. Bennett** reprinted from *Zebra Mussels: Biology, Impacts and Control*, Thomas F. Nalepa and Donald W. Schloesser (eds.), pp. 643-656, 1992. OHSU-RS-161. Free. OH
- Early detection of the zebra mussel (*Dreissena polymorpha*)" by **Clifford Kraft** reprinted from *Zebra Mussels: Biology, Impacts and Control*, Thomas F. Nalepa and Donald W. Schloesser (eds.), pp. 705-714, 1993. WISCU-R-93-001. Free. WI
- Multivariate model for predicting population fluctuations of *Dreissena polymorpha* in North American Lakes" by **Charles W. Ramcharan, Dianna K. Padilla and Stanley I. Dodson** reprinted from *Can J Fish Aquat Sci* 49(1):150-158, 1992. WIS-SG-92-944. Free. WI
- Models to predict potential occurrence and density of the zebra mussel (*Dreissena polymorpha*)" by **Charles W. Ramcharan, Dianna K. Padilla and Stanley I. Dodson** reprinted from *Can J Fish Aquat Sci* 49(12):2611-2620, 1992. WISCU-R-92-032. Free. WI
- Bioenergetics model of zebra mussel, *Dreissena polymorpha*, growth in the Great Lakes" by **Daniel W. Schneider** reprinted from *Can J Fish Aquat Sci* 49(7):1406-1416, 1992. WISCU-R-92-017. Free. WI
- Synchronous spawning in a recently established population of the zebra mussel, *Dreissena polymorpha*, in western Lake Erie, USA" by **Wendell R. Haag and David W. Garton** reprinted from *Hydrobiologica* 234:103-119, 1992. OHSU-RS-151. Free. OH
- International zebra mussel research conference (1991) proceedings sponsored by the Great Lakes Sea Grant Network and hosted by New York Sea Grant. 52 pp. \$8.00. NY
- Heterozygosity, shell length and metabolism in the European mussel, *Dreissena polymorpha*, from a recently established population in Lake Erie" by **David W. Garton and Wendall R. Haag** reprinted from *Comp Biochem Physiol* 99A(1/2):45-48, 1991. OHSU-RS-140. Free. OH
- Molluscicidal activity of potassium to the zebra mussel, *Dreissena polymorpha*: Toxicity and mode of action" by **Susan Warwick Fisher, Paul Stromberg, Kathleen A. Bruner and J. Denise Boulet** reprinted from *Aquatic Toxicology* 20:219-234, 1991. OHSU-RS-146. Free. OH
- Zooplankton grazing and phytoplankton abundance: An assessment before and after invasion of *Dreissena polymorpha*" by **Lin Wu and David A. Culver** reprinted from *J Great Lakes Res* 17(4):425-436, 1991. OHSU-RS-149. Free. OH
- Methods for evaluating zebra mussel control products in laboratory and field studies" by **Susan Warwick Fisher and Dennis Bernard** reprinted from *J Shellfish Res* 10(2):367-371, 1991. OHSU-RS-150. Free. OH
- International zebra mussel research conference (1990) proceedings sponsored by the Great Lakes Sea Grant Network and hosted by Ohio Sea Grant. 32 pp. OHSU-TS-019 also available as "Abstracts of technical papers presented at the International Zebra •Mussel Research Conference Columbus, Ohio 1990" reprinted from *J Shellfish Res* 10(1):243-260, 1991. OHSU-RS-144. Both are free. OH

Scientific publications on other species

- Embryonic and postembryonic development in *Bythotrephes cederstroemi*" by **P.M. Yurista** reprinted from *Can J Fish Aquat Sci* 49(6):1118-1125, 1992. MICHU-SG-92-307. Free. MI
- Zooplankton *Bythotrephes cederstroemi* spine induces aversion in small fish predators" by **D. Rae Barnhisel** reprinted from *Oecologia* 88:444-450, 1991. MICHU-SG-92-303. Free. MI
- Causes and consequences of cladoceran dynamics in Lake Michigan: Implications of species invasion by *Bythotrephes*" by **John T. Lehman** reprinted from *J Great Lakes Res* 17(4):437-445, 1991. MICHU-SG-92-302. Free. MI
- Genetics and ecology of an invading species: *Bythotrephes cederstroemi* in western Lake Erie. 1991. **David J. Berg**. 164 pp. TD-030. On loan from the Sea Grant Depository, Pell Library Building/Bay Campus, University of Rhode Island, Narragansett, Rhode Island 02882. (All items listed in this publication can be borrowed from the Depository.)
- Occurrence of *Bythotrephes cederstroemi* (Schoedler 1877) in Lake Superior, with evidence of demographic variation within the Great Lakes" by **David W. Garton and David J. Berg** reprinted from *J Great Lakes Res* 16(1):148-152, 1990. OHSU-RS-138. Free. OH
- Thermal tolerances of the predatory cladocerans *Bythotrephes cederstroemi* and *Leptodora kindtii*: Relationship to seasonal abundance in western Lake Erie" by **David W. Garton, David J. Berg and Robert J. Fletcher** reprinted from *Can J Fish Aquat Sci* 47(4):731-738, 1990. OHSU-RS-125. Free. OH
- The white perch and its interaction with yellow perch in Lake Erie. 1989. **Donna L. Parrish**. 137 pp. TD-021. \$15.50. OH

Resources

Newsletters

• *Dreissena polymorpha* information review. Summaries of research, meetings, legislation and sitings of the zebra mussel for the interested professional. Bimonthly. \$60.00 annual subscription rate includes other benefits. Contact Zebra Mussel Clearinghouse at 800/285-2285.

• *Zebra mussel update* reports on the status of the zebra mussel invasion in the region, zebra mussel-related research, upcoming conferences, new publication, etc. Written by Clifford Kraft. Published irregularly; Free. WI

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- *The HELM*, issued quarterly by Illinois-Indiana. Free.
- *Upwellings*, issued quarterly by Michigan. Free.
- *The Seiche*, issued quarterly by Minnesota. Free.
- *Coastlines*, issued quarterly by New York. Free.
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