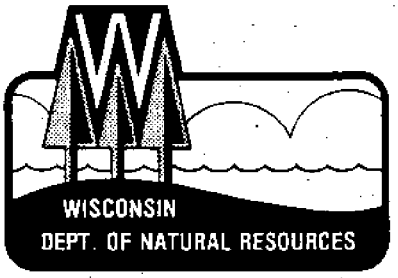
Protecting Wisconsin Waters from Exotic Invaders



University of Wisconsin Sea Grant Institute

A Zebra Mussel Report to the Legislature

December, 1994

Printed on 100 percent, post-consumer, unbleached paper

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Preface

On April 29, 1992, Governor Thompson signed the budget adjustment bill (Act 269) into law. Section 9142 requires the Wisconsin Department of Natural Resources, in consultation with the Aquatic Nuisance Control Council, to prepare a report to the Legislature on zebra mussels by June 30, 1994. The Governor directed WDNR and the Council to examine additional staffing needs for zebra mussel activities and to develop recommendations on an appropriate funding level and potential non-general purpose revenue funding sources for consideration in the 1995-97 budget bill.

Specifically the report was to identify the following key issues related to zebra mussels:

- The current and potential economic and environmental impacts;
- The potential control strategies;
- The geographical areas, public facilities or activities which need technical or financial assistance to reduce the environmental, public health or safety risk caused by this species; and
- The adequacy of existing state resources and staffing to address the problems posed by zebra mussels.

This report was compiled to meet those requirements.

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EXECUTIVE SUMMARY

Zebra mussels are small, fresh water, fingernail-sized mussels native to the Caspian Sea region of Asia. They were first discovered in North America in Lake St. Clair near Detroit in 1988. Tolerant of a wide range of environmental conditions, zebra mussels have now spread to portions of all the Great Lakes and the Mississippi River drainage system. In Wisconsin, zebra mussels are found in the nearshore areas of Lake Michigan from Racine to Washington Island, Green Bay, Superior Harbor, the Mississippi River, and a few other inland waters (see page 2).

Zebra mussels have already had a major financial impact on surface water users in Wisconsin.

Zebra mussels concern surface water users because they clog the water intake pipes of power plants and water treatment facilities. They can also taint and contaminate potable water supplies and inhibit commercial navigation and recreational boating by encrusting the hulls of boats and ships.

Of particular concern are the effects zebra mussels will likely have on the environment. Aquatic communities will be transformed when zebra mussels invade. Although scientists cannot accurately predict the environmental impacts, the effects on biodiversity and community structure will, in many cases, alter the ecosystem in undesirable ways. Lake St. Clair, for example, has seen a decline in its walleye population, and the primary plankton productivity in Lake Erie has been reduced significantly, thereby reducing the amount of food available lower in the food chain.

Zebra mussels also have the potential to cause species extinction; in particular they threaten native mussels.

Zebra mussels have already had a major financial impact on surface water users in Wisconsin, but facilities have learned to live with the problems by developing appropriate control strategies. Chemical control has been the most common treatment method used by water utilities and power plants. No effective toxicant, like the chemical TFM used against sea lampreys, has been developed to selectively control zebra mussels in the environment. Although certain species of fish and diving ducks prey on zebra mussels, they have not demonstrated their effectiveness in helping to control this invader.

The goals of Wisconsin's zebra mussel program are:

- To protect our native flora and fauna;
- To slow, and if possible, prevent the spread of zebra mussels;
- To provide technical assistance to surface water users

for developing long-term, cost-effectiv
environmentally safe solutions;

- And to inform and educate recreation
that it is important to maintain clean
our waters against unwelcome invade
mussel.

The funding recommendations in this rep
vide the resources necessary for enhanced
education efforts, additional monitoring ca
creased technical assistance to private faci
sources would also be used for policy man
developing environmental controls and reg
the spread of zebra mussels. It includes th
projections of the resources needed to ade
the problems zebra mussels pose.

Efforts by the Wisconsin Department of Na
sources and the University of Wisconsin Se
tute have focused on monitoring, technical
water treatment facilities and information a
activities. Existing resources do not adequa
the problem. WDNR and UW Sea Grant Ins
cated roughly 1.5 full-time employees (FTEs
$30,000 annually for zebra mussel activities
three years. To effectively deal with the curr
Wisconsin, it will require a minimum of 4.0
$580,000 in annual funding.

I.

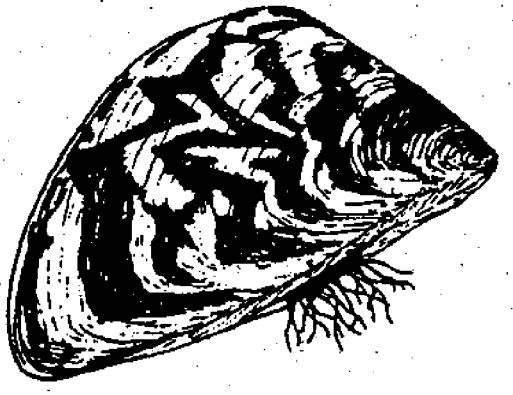
BACKGROUND AND INTRODUCTION

What Is A Zebra Mussel?

Zebra mussels, *Dreissena polymorpha*, are small, freshwater, bivalve mussels native to the Caspian Sea region of Asia. They have alternating dark and light stripes on their shells that range in color from brown to black and white to yellow. Adults vary in length from .03 to 2 inches with the average mussel usually about one half inch (13 mm). The zebra mussel has up to 200 "byssal threads," or elastic fibers that are formed one-by-one, at the base for attachment to a structure. The zebra mussel can attach to almost any hard surface such as rocks, wood, boats, docks, pipes, other aquatic species with hard shells or exoskeletons, or semi-hard surfaces like plants.

Why Are Zebra Mussels A Problem?

Zebra mussels pose a major problem primarily for raw water users and dam operators. The mussels can obstruct intake and distribution pipes, screens, and condensers at municipal water treatment and power plant facilities and other industries using raw water. Thick accumulations of mussels can corrode steel and cast iron pipes. They can also taint and contaminate potable water supplies, encrust hulls of boats and ships, and foul commercial fishery trap nets.



Zebra Mussel (Enlarged)

In harbors, zebra mussels create a nuisance to boat operators by coating the rungs of ladders that lead down the side of docks and tires fastened to the docks as boat bumpers. Zebra mussels also colonize concrete bridge pillars, greatly increasing the erosion of these structures and reducing their life expectancy.

After zebra mussels die, their sharp shells wash ashore and accumulate on beaches where they can injure unprotected skin and produce noxious odors. Using the shells of native clams and crayfish as anchors, zebra mussels can also accumulate in large numbers and suffocate the host animals. Research shows zebra mussels can harm many native species of mussels.

Through filter feeding, zebra mussels reduce the amount of phytoplankton (microscopic plants and many types of algae) in the water column. This can lead to declines in other species that depend upon phytoplankton for food. Zebra mussels are likely to transform aquatic ecosystems, in particular the fisheries, but the effect and magnitude of those changes are difficult to predict.

Where Did Zebra Mussels Come From And Where Are They Now?

The zebra mussel is native to the Black, Caspian, and Aral seas. Through the 1700s and 1800s it invaded the European inland waterways. Zebra mussels appear to have been introduced to the Great Lakes in 1985 or 1986, although they went undiscovered until June, 1988, when they turned up in Lake St. Clair between lakes Huron and Erie. Zebra mussels were transported in the ballasts of ships originating from European fresh water ports, and were discharged with the ballast water into the Great Lakes.

By 1991, three years after their initial discovery, zebra mussels had spread throughout the Great Lakes, including the connecting channels. Figure 1, with information compiled by New York Sea Grant, shows the present range of the zebra mussel in North America as of September 27, 1994. In Wisconsin, zebra mussels are found in Lake Michigan including Green Bay, and in the Mississippi River. Small numbers have also been observed in the Superior Harbor but do not appear to be a reproducing population. In August 1993, a small population of zebra mussels was discovered on the Flambeau River about 3 miles northeast of Ladysmith, but subsequent field investigations in the summer of 1994 revealed no zebra mussels at this site.

Also in the summer of 1994, zebra mussels made their first significant move into inland Wisconsin lakes. Adult zebra mussels turned up in Elkart Lake in Sheboygan County, Silver Lake in Kenosha County and Racine Quarry in Racine County. Veligers, the zebra mussel larvae, were discovered in a plankton sample from Okauchee Lake in Waukesha County but subsequent surveys failed to turn up adult mussels.

In addition, Zebra mussels turned up in three large rivers in Wisconsin. Veligers occurred in samples collected from the Fox River several miles above its confluence with Green Bay. A moderate density of veligers, 1,500 per cubic meter, was collected in a "plankton tow" south of the De Pere Dam on the Fox River. In a plankton tow, an extremely fine net is pulled through the water to collect the microscopic free-swimming larvae. Reports of cooling system blockages at facilities along the Milwaukee River also indicate that zebra mussels have successfully colonized the river several miles upstream from Lake Michigan. In addition, in the summer of 1994, zebra mussels were found attached to several isolated boat hulls in the lower St. Croix at Hudson, Wisconsin and at Afton, Minnesota.

How Can They Spread And Where Are They Likely To Go In The Future?

Zebra mussels can be transported from infested waters both naturally and by humans. The spread of veligers from waterbody to waterbody is enhanced by the release of ship and barge ballast water, boat trailers and live bait containers taken from infested waters. Larvae can also spread by currents and perhaps, to a lesser extent, by attaching themselves to waterfowl or other wildlife. Adult mussels can transport themselves by attaching to boat and

barge hulls.

Zebra mussels will likely inhabit most areas of North America south of central Canada and north of the Florida panhandle where conditions are suitable for their growth. Wisconsin is included in the future habitat range of zebra mussels although not all state waters may be conducive to mussel populations.

What Is Unique About The Zebra Mussel's Biology And Ecology?

The life span of adult zebra mussels averages about two years within a range of one to five years. Their reproductive system is unique to freshwater mussels. Unlike native mussels, zebra mussels do not require a host fish to complete their life cycles, thus enhancing their reproductive potential. Frequently, native mussels may have only one or several fish species for hosts, which means the abundance of the native mussels is proportional to the host fish populations..

Zebra mussels have extremely high fecundity rates, varying from 30,000 to 40,000 eggs per female per year, with reports as high as one million eggs per year. The species is separately sexed with reproduction occurring when water temperatures reach and maintain about 12°C (54°F).

Over two to three days, eggs hatch into larvae called veligers. The free swimming veligers develop quickly, and over a span of 8 to 12 days, have the rudiments of a shell and start developing a foot. Over several weeks, the shell becomes heavy enough that the veligers slowly sink. Upon settling, the juvenile's foot further develops, and they are able to crawl on hard structures, or substrate. After the shell becomes fully formed, the young zebra mussel will produce elastic attachment fibers, known as byssal threads. At this point they become sedentary.

Adults can attach to any hard surfaces and densely colonize areas. It is not uncommon to see more than 100,000 zebra mussels per square meter in European lakes or the Great Lakes. In the summer of 1993 Green Bay experienced densities of more than 200,000 per square meter of settled veligers. By July, 1994, suspended samplers that provide structure for the mussels to colonize had densities of settled veligers that peaked at 350,000 per square meter in southern Green Bay, indicating that the zebra mussel population there was still expanding.

In contrast to Green Bay, zebra mussel densities have stabilized in Lake Michigan. In August, 1994, veliger concentrations were observed at 55,000 per cubic meter at the Pleasant Prairie Power Plant and 30,000 per cubic meter at the Point Beach Nuclear Power Plant. Concentrations of adults found on the suspended substrate samplers in Lake Michigan were actually lower in 1994 compared to the last few summers.

What Is Their Preferred Habitat?

In general, zebra mussels require well-oxygenated water with high levels of suspended organic material and a rea-

sonably hard substrate, the structure upon which they settle. Various physical characteristics such as substrate availability or water current, and chemical parameters such as low levels of dissolved oxygen in the water, temperature, pH or calcium, can limit the spread of the mussels.

Zebra mussels are generally found attached to rocks or other hard surfaces in 6 to 30 feet of water, but actual colonization depths vary depending on light intensity, water temperature and the availability of food. They prefer water temperatures between 20°C and 25°C (68°F and 77°F) and water currents slower than 6 feet per second.

Zebra mussels require calcium for shell development. Calcium concentrations greater than 15 parts per million are needed for proper growth. Recent data show that pH levels are very important in zebra mussel physiology. Zebra mussels have difficulty growing and reproducing in waters with pH levels below 6.5, suggesting that their distribution may be limited in northern Wisconsin lakes that have naturally lower pH and calcium levels.

How Are Zebra Mussels Transported?

There are a number of potential ways, either through natural or human means, that zebra mussels may be transported to a new aquatic environment. The spread of zebra mussels into Wisconsin's inland water bodies is most likely due to factors listed in Table 1 (Carlton, 1993) under "human-mediated" mechanisms. While all of these dispersal mechanisms are possible, not all are equally probable. This is particularly true of natural transport by birds and other animals, regarded as unlikely dispersal mechanisms (Johnson, L., 1994).

The dispersal mechanisms listed in Table 1 under "vessels/navigation" are the most likely methods of transport to inland water bodies. Recreational boats, crafts and commercial vessels, such as ships and barges, have been responsible for most zebra mussel infestations into the navigable water bodies of North America since their introduction into Lake St. Clair. Small recreational or pleasure boats can unintentionally transport zebra mussels from infested to uninfested waters; this is one of the more probable modes of dispersal. Similarly, work boats and barges used by industrial contractors are another probable transport method, as well as diving equipment used by contractors and recreational divers.

Standing water in wet wells, bilges and other compartments of small boats can maintain zebra mussel veligers. Anchor systems may also preserve small mussels in a moist environment as can navigation buoys, fishing and diving equipment, stocking water and bait buckets. These are all potential vectors, or mechanisms, for short- and long-distance transport of zebra mussels because the veligers can survive in any residual water source or in moist conditions for up to 14 days. Adult zebra mussels can also live out of water for several days in moist places, and

they can survive for up to two weeks in any compartment containing standing water.

Natural vectors are those over which humans have little or no influence. Examples of natural vectors include dispersing larvae downstream via water currents and waterfowl or animals. Recent studies have shown that ducks can transport veligers short distances over land (Johnson et. al., 1994), but waterfowl are probably not a major mechanism for zebra mussel transport. The natural dis-

Table 1. Potential Dispersal Mechanisms for the Different Life Stages of Zebra Mussels (*Dreissena polymorpha*) (Carlton, 1993)

Dispersal Mechanisms	Life Stage		
	Planktonic	Sedentary	
	Eggs and Larvae	Juveniles	Adults
Natural			
1. Currents[1]	X	X	X
2. Birds[2]	X?	X	X
3. Other animals	X?	X	X
Human-Mediated			
Waterways			
4. Canals[1]: vessels, irrigation	X	X	X
Vessels/Navigation			
5. Ballast water[2]	X	X	
6. Vessel exteriors[1]		X	X
7. Vessel interiors	X	X	
8. Fishing vessel wells	X	X	
9. Navigation buoys[3]		X	X
10. Marina/boat yard equipment[3]		X	X
Fisheries			
11. Fishing equipment		X	X
12. Fish cages[3]		X	X
13. Fish stocking water	X	X	
14. Bait and bait-bucket water	X	X	X
Other Industry			
15. Commercial products[1]		X	X
16. Marker bouys and floats[3]		X	X
17. Firetruck water	X	X	X
Other			
18. Intentional movements[1]		X	X
19. Aquarium releases[1]	X	X	X
20. Amphibious planes	X?	X	X
21. Recreational equipment		X	X
22. Litter (garbage)[3]		X	X
23. Scientific research	X	X	X

Note: ? = Uncertain whether this life stage would be associated with the indicated mechanism

[1] Dispersal by this mechanism has been documented

[2] Dispersal by this mechanism is suspected to have occurred

[3] Zebra mussels known to occur on the animal or object

persal mechanisms listed under 1-3 in Table 1 are not considered controllable. Many of the human transport mechanisms, however, are more manageable and consequently have been the focus of public awareness efforts to slow the spread of zebra mussels.

What Is A Quagga Mussel?

A second mollusk, closely related to the zebra mussel, was discovered in Lake Erie in 1992. This new species, *Dreissena bugensis*, was named Quagga after an extinct African relative of the zebra. The Quagga mussel and zebra mussel look similar and are difficult to distinguish to the untrained eye. The main physical difference between the two species is that the zebra mussel has a flat ventral, or bottom, surface, unlike the quagga which rounder.

Quagga mussels have been found in lakes Erie and Ontario, in the Erie Canal and in the upper St. Lawrence River. The two species are often found in the same habitat, although the Quagga mussels appear to be more tolerant of salinity than zebra mussels and have been found at greater water depths. An earlier study on Lake Erie showed that Quagga mussels inhabit the deeper, softer layer of sediments. More recent studies on Lake Erie, however, found Quagga mussels coexisting with zebra mussels in shallower waters. By contrast, zebra mussels have only been found to inhabit hard surfaces in shallower areas. If, as early research seems to indicate, Quagga mussels have the ability to survive and grow in the soft sediments of deeper waters, it would certainly not bode well for the native benthic, or bottom-dwelling, organisms in the Great Lakes. Many commercially and recreationally important species such as chubs and lake trout depend on these benthic organisms for food during all or part of their development.

The Quagga is still something of a mystery to researchers who continue to explore the differences between the two species. Subtle biological differences between the two bivalves may be crucial to determining whether control methods used against zebra mussels will be as effective against Quaggas. Yet, given the similarity between the two mussels and recently completed research, scientists expect that existing control strategies will be effective in controlling both species.

II.

CURRENT WISCONSIN EFFORTS

Monitoring

Monitoring is being accomplished through a network of volunteers.

UW Sea Grant Institute and several potentially affected water and electric utilities and industrial facilities initiated monitoring for adult zebra mussels and veligers in 1990. Since then, monitoring has continued at numerous locations along the Wisconsin coasts of lakes Michigan and Superior. With the detection of zebra mussels in the Mississippi River in September 1991, the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service began an inland monitoring program the following summer at all locks and dams and in some of the major tributaries to the Mississippi.

To date, monitoring has revealed a rather dramatic increase in zebra mussel densities in Lake Michigan and the Mississippi River. Increases in zebra mussel populations at these locations have raised concerns among water users, especially "raw water" users whose intakes draw water directly from surface waters, to the possibility that inland waters may soon be infested. As a result, a cooperative monitoring program for Wisconsin's inland waters was established in 1993 for sampling the rivers, lakes and streams facing the greatest threat of infestation via boat traffic from the Great Lakes or the Mississippi River.

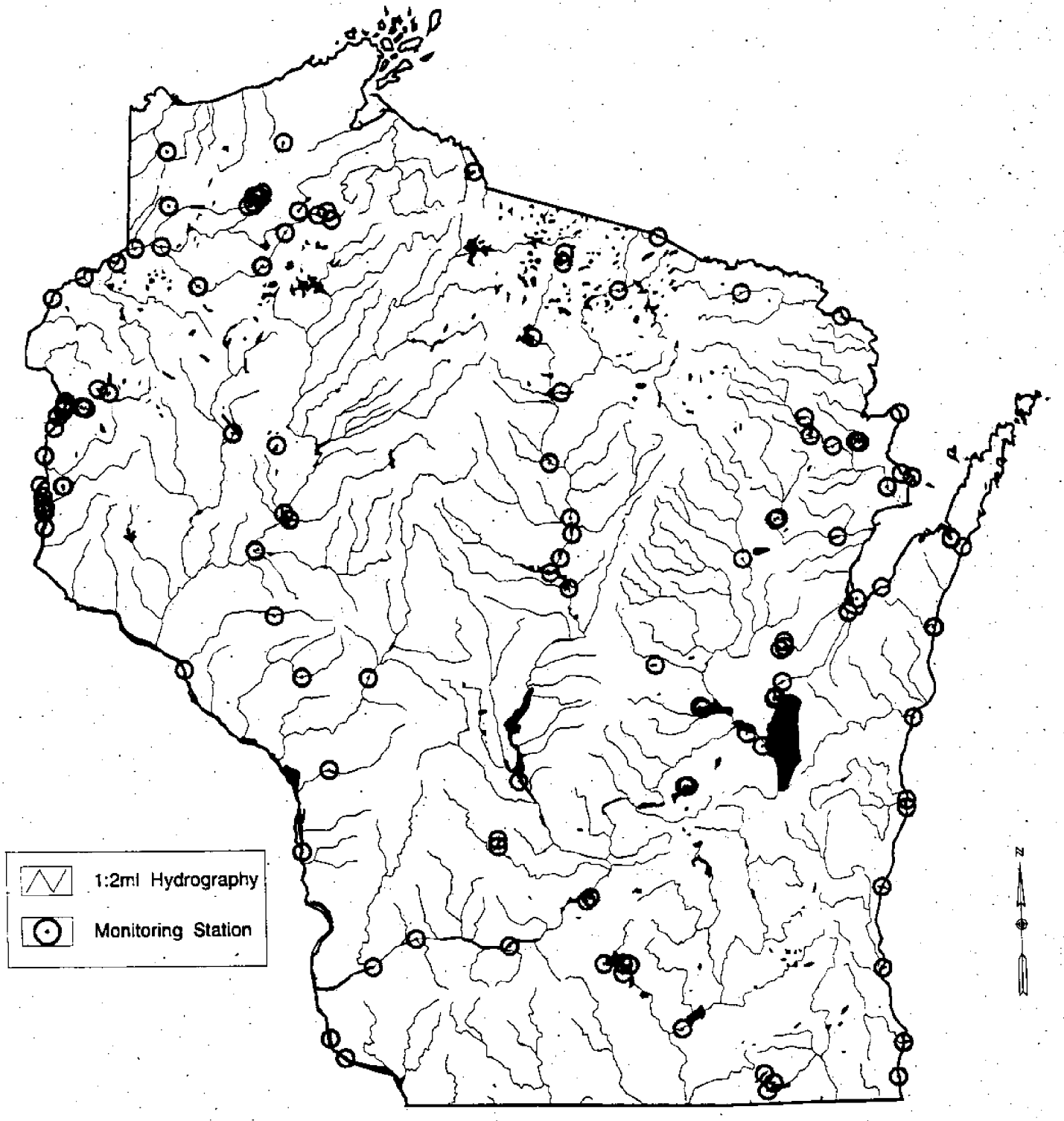
The inland monitoring program is being accomplished through a network of various agencies and volunteers including WDNR, the U.S. Fish & Wildlife Service, UW Sea Grant Institute and the National Park Service. In addition, volunteers from lake associations, the Hydro Users Group, Wisconsin Valley Improvement Corporation member companies and water utilities are also participating in the sampling program. In 1993, 112 sites were sampled statewide for settled zebra mussels. Figure 2 shows the location of the zebra mussel monitoring sites in Wisconsin.

The purpose of monitoring is to track the spread of zebra mussels and document which waters are infested with this invader. Monitoring also provides an advance warning system for raw water users. There is about a 6- to 12-month lead time from when zebra mussels are first sighted to when control devices need to be in place to prevent water supply problems.

Data from the inland monitoring program is recorded on reporting forms and then entered into the Geographic Information System (GIS) computer network so information can be readily analyzed and provided to those who are interested. Key information on the exact location of where the sample was collected, as well as the size and number of zebra mussels observed, is stored in this system. Cur-

Figure 2. (Following Page) Location Of Zebra Mussel Monitoring Stations In Wisconsin

ZEBRA MUSSEL MONITORING STATIONS



0 30 60 90 120 Miles

0 30 60 90 120 150 180 Kilometers

Nominal Scale 1:2638257

Wisconsin Department of Natural Resources

Bureau of Water Resources Management

Meg2.aml
Plotted:11/16/94

rent and historical data on the Great Lakes stations are available though UW Sea Grant Institute.

Two substrate samplers are deployed at each sampling location and are regularly inspected during the May through October sampling season to determine the presence or absence of zebra mussels. Population densities are estimated by careful inspection of the substrate samplers. Guidelines for zebra mussel monitoring are contained in the "Zebra Mussel Monitoring Handbook for Inland Waters" published by the UW Sea Grant Institute in 1992.

Information and Education

In conjunction with the Great Lakes monitoring effort, the UW Sea Grant Institute also initiated a campaign to alert industries and the public about the mussels and their potential impacts on water users. Press releases, media interviews and public presentations complemented the wide distribution of wallet-sized zebra mussel identification cards. About one million cards have been produced and distributed throughout the eastern United States. Contacts for federal and state agencies are listed on the card, as well as several industries. In Wisconsin, the card lists both UW Sea Grant Institute and WDNR staff contacts.

In the fall of 1990, UW Sea Grant Institute, WDNR and the state's Coastal Management Program held regional meetings in Ashland, Manitowoc and Milwaukee, apprising more than 200 local officials of the pending mussel infestation and possible problems for water treatment facilities and community industries. Radio and television public service announcements and paid advertisements aired in the state in the fall of 1992 in a cooperative venture between UW Sea Grant Institute and WDNR.

Information and education efforts are aimed at slowing the spread of this invader.

WDNR prepared a three-fold pamphlet warning boaters about zebra mussles and instructing them on how to clean their boats and fishing gear to minimize transporting the mussels to inland waters. Similar plastic boater advisory signs were produced for public and private marinas and launch ramps and distributed around the state in counties adjacent to the Great Lakes. Like the identification card, the advisory pamphlets and plastic signs identify both UW Sea Grant Institute and WDNR as contacts for further information.

A wealth of general information is available through the Great Lakes Sea Grant Network, including fact sheets, videos and slide sets. A Sea Grant graphics library exists as a source for slides, photos, illustrations, etc., available for users such as the news media. Two newsletters serve national audiences: *Dreisenna polymorpha Information Review*, published by the New York Sea Grant program, targets the research community; and the *Zebra Mussel Update*, a free newsletter produced by UW Sea Grant Institute, reports on sightings and other information of a more general interest. The *Review* also includes a map showing current documented distribution in the United States and Canada.

More technical information is available as researchers in industry, government labs and academia complete initial research. Much of the available information on zebra mussels is related to their biology, impacts and controls. The Great Lakes Sea Grant Network also maintains a research clearinghouse that is accessible for a small fee and that can be reached by dialing (800) 285-2285. A listing of the more popular publications, as well as the conference proceedings from recent years, are listed in Appendix A.

Information is readily available to Wisconsin citizens. Through cooperative efforts of the UW Sea Grant Institute, WDNR, industries such as the Wisconsin Electric Power Company and the West Shore Water Producers Association, information has been freely exchanged and shared. These organizations are to be commended for their collective cooperative efforts.

The major focus now is to assure the public that efforts in cleaning boats can make a difference.

Most of the information to date has focused on the Great Lakes where zebra mussels have gained notoriety. As the mussels continue to move into inland waters, educational efforts will need to be adjusted to address this new audience and possible new problems, such as mussel effects on locks and dams. The U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service and WDNR can expect to assume a greater role in this effort.

The major focus now is to assure the public that efforts in cleaning boats **can** make a difference. Because of extensive media coverage, many people believe that zebra mussels are everywhere, or soon will be. The public reaction to requests for owners to clean boats and gear has often been that these individual efforts would make little difference, so why take the time. Public information, as well as information to policy makers, must be factual. It should focus on the idea that zebra mussel migration can be slowed or limited by public actions.

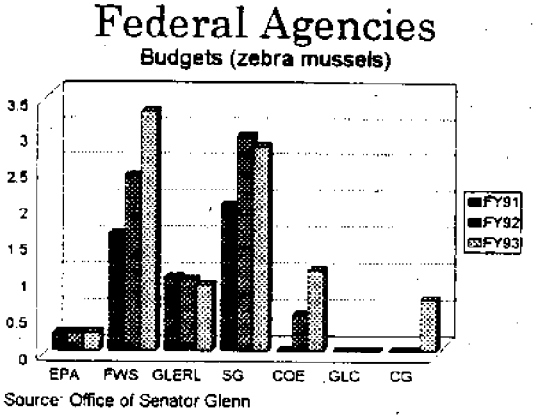
In the future, additional funding will be necessary to adequately educate boaters and the general public on this issue.

Research And Development

The first research response came from the electric power industry. In the late 1980s, when zebra mussels were discovered in the Midwest, Electric Power Research Institute (EPRI) quickly established a Zebra Mussel Advisory Group consisting of member companies throughout the Great Lakes, on both sides of the border. The first products were intended to alert companies to the potential problems they might face as zebra mussels spread throughout the Great Lakes and eventually to inland waters. Studies were also quickly initiated to evaluate alternative control methods. Similarly, the American Water Works Association Research Foundation, the research arm of municipal water utilities, initiated studies of control methods suited for its members. In addition to these industry-wide efforts, individual power and water utilities and regional consortia of both utilities, also conducted numerous studies of control

options and made that information available to associates.

In 1990, Congress authorized increases for zebra mussel research and outreach in several agencies' budgets (see adjacent illustration). Perhaps the most important factor in university research is the process used to set the research agenda. Sixteen organizations were involved in reviewing and prioritizing 1992-93 proposals and establishing the direction for 1993-94 research. Sea Grant, and other organizations such as the U.S. Environmental Protection Agency (EPA) and the Cooperative Institute for Limnology and Ecosystem Research (CILER), have all used this vehicle to select projects for funding.



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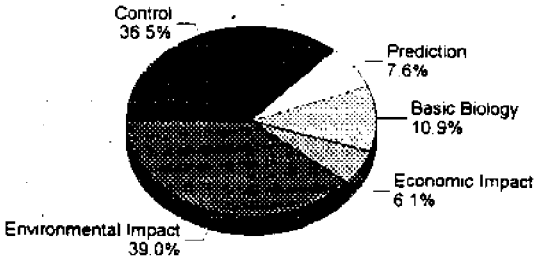

Funding Level of NOAA Sea Grant funded projects

During the first two years, 31 applied research projects, valued at $5,107,861, including $1,955,429 in matching state and university funds, have been supported through the national Sea Grant College Program. More than 20 universities are involved in this research effort; a major focus has been environmental impacts and zebra mussel control. While these are by no means the only university research projects under way, they represent the research stimulated through special Congressional funding in response to the zebra mussel infestation.

It is likely that research on the biology and control of zebra mussels will continue at the current pace both in industry and academia because of the tremendous economic impact the mussels have on power plants, water works, certain industries, locks and dams, and the environmental impacts to Wisconsin waters and fisheries. It is less likely that special federal funding will continue in light of the budget deficit and other domestic demands, such as 1993 flood relief.

Comparing Wisconsin's Efforts To Other States And The Federal Government

The response of state governments at this time has been somewhat limited. With scores of other tasks facing them, state management agencies have been hesitant to commit major resources to the zebra mussel issue — or to the

State Governments

Boater Advisories

CN, DE, MD, MI, MN, NJ, VA, WI

Nonindigenous Committees

CN, MN, OH, WI

Statewide Action Plans

NY

One-time Research Funding

MI

Legislation Prohibiting Transport

NY, MN

Statewide Monitoring

IL, PA, WI

broader question of non-native species — without a legislative mandate. And state legislatures, troubled by financial woes of their own, are cautious about authorizing new programs. Many view the zebra mussel infestation as inevitable and believe current efforts are satisfactory.

The major action of states has been to produce boater's advisories — as radio and television public service announcements, through one-page handouts, and as signs posted at launch ramps and marinas, encouraging boaters to thoroughly clean their boats after leaving infested waters. With cooperation from boating and fishing clubs, this information has been widely disseminated in the United States and Canada. The slow pace at which mussels are moving into inland lakes and rivers, compared to the speed at which navigable waterways are being infested, suggest that these advisories are having a positive effect.

Minnesota recently passed legislation making it illegal to transport zebra mussels and other nuisance exotics. Though state actions to date are limited, there is considerable cooperation between Wisconsin's management agencies and the water users on permitting, and joint ventures with Sea Grant to produce and distribute information.

III.

FINANCIAL AND TECHNICAL IMPACTS

Economic Effect On Water Utilities

Total costs to Wisconsin utilities for controlling zebra mussels in estimated to be $6.46 million based on 1993 figures.

Wisconsin has 20 water systems operating 21 surface water treatment plants. Seven surface water treatment plants have had chemical addition systems installed in their water intake for the control of zebra mussels. The capital costs to these plants are as follows:

Green Bay	$350,000
Oak Creek	$200,000
Port Washington	$225,000
Milwaukee (2 plants)	$2,500,000
North Shore Water Commission	$400,000
Appleton	$200,000
South Milwaukee	$200,000
TOTAL	$4,075,000

The average capital cost excluding Milwaukee was approximately $265,000. Nine of the remaining 13 surface water treatment plants in Wisconsin may need to install water intake chemical addition systems in the future. Those water treatment plants are: Ashland, Kenosha, Manitowoc, Sheboygan, Two Rivers, Marinette, King Veteran's Home in Waupaca, Neenah, and Oshkosh. Using an average capital cost figure of $265,000, the total additional cost to these nine treatment plants would be $2,385,000.

Based on funds expended at seven facilities and projected costs at nine others, the total capital cost for chemical treatment for water utilities (based on 1993 figures) is estimated to be $6.46 million dollars. In addition to capital costs, there will be annual operation and maintenance expenses.

Cudahy, Racine and Kenosha have two or more water intakes. These utilities inspect their intakes in the fall and switch to secondary intakes when they close down their main intake. They then cover the intake openings, introduce chlorine or sodium bisulfite, retain the chemical in the intake for 30 or more days and then reopen the main intake. Racine performs this with sodium bisulfite twice a year. Kenosha did not treat during the winter of 1992-93. The chemically treated water is drawn through the plant. The exception is Cudahy where it is pumped through industrial cooling water pipes. Racine and Cudahy currently

have no long-term plans to install permanent zebra mussel treatment control measures. The annual operation and maintenance costs to all three facilities is $24,000.

Another likely utility expenditure will be for inspection by divers. Assuming water plant intakes will be inspected in the spring and fall at a cost of $2,000 per dive, the yearly diving expenses would be $76,000 for the utilities. This figure also assumes that Menasha and Superior will not require diving inspections. Actual expenditures could vary significantly because of the variable nature of the diving work involved.

Economic Effect On Power Plants

A number of power plants, particularly those along Lake Michigan and the Mississippi River, have accurate cost estimates available for zebra mussel controls. These costs include dollars spent on cleaning and inspection, chemical additions, and operation and maintenance. The 1993 costs incurred are listed below for each facility where the information is available:

Dairyland Power Cooperative

Flambeau Hydro Station	$10,000
Alma	$75,000
Genoa - LaCrosse Boiling	$25,000
Genoa III	$75,000
Cassville - Stoneman Station	$25,000
TOTAL	$210,000

Wisconsin Public Service Corporation

Kewaunee	$40,000
Pulliam	$100,000
TOTAL	$140,000

Wisconsin Electric Power Company

Pleasant Prairie	$52,000
Oak Creek	$87,000
Point Beach	$437,000
Port Washington	$46,000
Valley Power Plant	$18,000
TOTAL	$640,000

Manitowoc Public Utilities

$9,000

The cost for zebra mussel control in 1993 for these power companies was approximately $1 million.

The cost for zebra mussel control in 1993 for these power companies was approximately $1 million. In addi-

tion, capital cost outlays for zebra mussel control were expended for two facilities in 1991-92. Pulliam spent $900,000 and Oak Creek $800,000. Although projected costs are not available for 1994 and beyond for zebra mussel prevention and control for all the facilities, estimates are higher than 1993 figures. Cost estimates were not readily available for the Wisconsin Power & Light Edgewater facility because many of the expenditures incurred for zebra control were internal to the operation.

Northern States Power's French Island facility on the Mississippi River has not expended any funds yet on zebra mussel controls because the mussels were first discovered at the plant in late 1993. However, the facility is considering warm water circulation and will likely incur some costs to control zebra mussels in 1994 and beyond.

Economic Effect on Industrial Facilities

No cost estimates are available for industrial facilities in Wisconsin because they have been largely unaffected by zebra mussels, to date. The majority of the industrial facilities are located inland or on large river systems like the Fox and Wisconsin where zebra mussels have either not infested or not become a problem yet. Expenditures for prevention and control of zebra mussels at the industrial facilities are likely to be similar to those for the power companies.

Effect On Locks And Dams

The U.S. Army Corps of Engineers (COE) operates 10 major locks and dams on the Mississippi River bordering Wisconsin. COE's St. Paul district operates Lock and Dams 3, 4, 5, 5A, 6, 7, 8, 9 and 10 while the Rock Island district of the COE operates Lock and Dam 11. In September, 1991, the first zebra mussel in the river was discovered, attached to a native pig toe mussel in the Mississippi River near La Crosse. Another specimen was discovered at Lock and Dam 8 in January, 1992, during a routine inspection of the dewatered lock.

By 1993, thick layers of zebra mussels were observed at a number of the lock and dam structures on the Mississippi River, indicating a dramatic increase in zebra mussel densities.

The Corps of Engineers has initiated a program to control zebra mussels in and around public facilities. As part of this effort, the St. Paul district began monitoring for zebra mussels in 1992 to track their spread through the upper Mississippi River. Monitors were installed at each lock and dam between the Lower St. Anthony Falls at Minneapolis and Lock and Dam 10 at Guttenberg, Iowa. In addition, divers looked for zebra mussels during routine yearly inspections of the lock and dams.

Monitoring results from 1992 indicated the presence of zebra mussels at all COE locks and dams on the Mississippi River except the Upper St. Anthony Falls Dam at Minneapolis. By 1993, thick layers of zebra mussels were observed at a number of the lock and dam structures, indicating a dramatic increase in zebra mussel densities.

To date, no dollars have been spent for zebra mussel control or cleanup at COE facilities. The only monies spent were approximately $15,000 dollars in 1992-93 for zebra

mussel monitoring efforts at both the St. Paul and the Rock Island districts. The funding level continued at about $15,000 for mussel monitoring efforts in 1994.

The Waterways Experiment Station (WES) of the COE has been actively involved in researching zebra mussel control and cleanup techniques. This research has identified a number of potential effects on lock and dam structures, including:

- ✓ Critical components of water level gauging stations - intake, stilling well and float.
- ✓ Raw water systems - fire prevention systems, screens, cooling systems.
- ✓ Measurement systems - transducers, gauge wells, piezometers.
- ✓ Large gates and valves - miter gates, vertical lift gates, control gates, culvert valves.
- ✓ Lock chamber - concrete surfaces, lock culverts, chamber walls.
- ✓ Navigation aids - buoys and trash booms, mooring bitts, ladders.
- ✓ Submersible racks and gates - trash racks, wicket-type gates.
- ✓ Special devices - air vents, bubbler systems.

Potentially, all underwater lock and dam components are susceptible to infestation. Cleaning of infested components would be labor intensive, costing possibly millions of dollars for complete or partial dewatering of a lock and dam structure to remove the attached zebra mussels.

In addition, COE vessels and dredges are also susceptible to zebra mussel infestation. Hulls, ballast tanks or sea chests, piping systems, keel coolers and dredging systems are all potential areas for zebra mussel colonization. Cleaning and prevention measures will likely be expensive.

Economic Effect On The Clamming Industry

Early research from Lake St. Clair and Lake Erie, where zebra mussels have been established for a longer time, indicates that the native mussel species are being severely affected. This does not bode well for Wisconsin waters because zebra mussels are expected to do well in most river systems in the state where native mussels are abundant.

Likely to be particularly hard hit is the clamming industry on the Mississippi River. The mussel harvest from the Mississippi in 1992 was worth about $828,000, with Wisconsin's share $326,000, or 39 percent of the total. The 1992 figures are down considerably compared to the last five years. From 1988-92, the mussel harvest on the Mississippi was worth an average of $2.85 million. Wisconsin's share of the average over that same period was $451,000, or 16 percent.

Only the Mississippi River remains open for commercial clamming; all inland Wisconsin waters were closed for clamming in 1990 due to the potential threat of overharvesting native mussel populations.

Commercial clamming provides a livelihood for a number of harvesters in Wisconsin and the upper Midwest. This could change if zebra mussels become well established and severely affect or eliminate native mussel populations. Three possibilities exist: 1) zebra mussels could eliminate native mussels from clamming sites until none remain for harvest; 2) zebra mussels could reduce native populations until harvesting would be limited to preserve the species, making commercial clamming unprofitable; or 3) zebra mussels could become established, but at low levels that would not harm the native mussel populations or the clamming industry.

Based on available research from the eastern United States, the prognosis for the clamming industry in Wisconsin is not good. It will probably be hit hard by the zebra mussel invasion.

Effect On Commercial And Recreational Fishing

Most of the data addressing effects on fisheries have been derived from Lake Erie studies. Within two years of becoming established in western Lake Erie, zebra mussel densities on spawning reefs exceeded 100,000 per square meter. The concern was that walleye would not spawn over zebra mussels or that their eggs would not survive incubation due to the suffocating effects of waste produced by the mussels. Actual survey data has not shown this to be the case. In fact, zebra mussels may be providing a good spawning substrate.

Although the short-term observation is that there have not been any negative effects on walleye spawning on Lake Erie, the long-term verdict on walleye populations is still out. Data results indicate that walleye patterns were affected in Lake Erie due to increased water clarity; the walleye moved from shallow, nearshore areas to deeper water habitat.

Yellow perch is an important component of the Canadian commercial fishery in Lake Erie. There is concern that fall-spawning fish, such as lake trout and whitefish, may be affected because they have a longer egg incubation period and are more sensitive to spawning substrate requirements. Lake Erie data over a five-year period from 1989 to 1993 indicated that the commercial catch for yellow

perch had declined, possibly due, in part, to the zebra mussel invasion. The Canadian commercial harvest of yellow perch declined from 11.8 million pounds in 1989 to 3.9 million pounds in 1993. Quotas, which are based on the projected availability of yellow perch,, declined over the same period. The quota dropped significantly from 6.9 million pounds in 1993 to 3.7 million pounds in 1994 (Paine, 1994). The trend in declining perch abundance has resulted in a reduction of the economic contribution of an important commercial fish species in Lake Erie.

Data from Lake St. Clair suggests that zebra mussels may be causing a shift in the lake's fish community from perch and walleye to bass and pike (Griffiths, 1994).

Data from Lake St. Clair suggests zebra mussels may be causing a shift in the lake's fish community from perch and walleye to bass and pike (Griffiths, 1994). Lake St. Clair is also clearer, with fewer phytoplankton and more aquatic plants due to the zebra mussel invasion. This, in turn, may favor a population of bass and muskellunge that prey on walleye. The fisheries of many hard water, inland Wisconsin lakes may be susceptible to similar changes if infested, particularly those lakes similar to Lake St. Clair.

Several other changes to the ecosystem resulting from the invasion of zebra mussels could have undesirable effects on fish species' composition and abundance. Through their efficient filter feeding systems, zebra mussels can remove much of the seston, the minute living and non-living floating particles in the water, increasing water clarity. This allows new stands of aquatic plants to form in areas that were historically devoid of them. In addition, there is a tendency to shift from "pelagic," or free floating, organisms to bottom dwelling invertebrates. The pelagic, or open water zone of a lake, is dominated by plankton, such as phytoplankton and zooplankton, microscopic plants and animals. By contrast, the benthic, or bottom zone of a lake, is typically inhabited by aquatic insects, flatworms and crustaceans such as crayfish. Reductions in phytoplankton as a result of zebra mussel filter feeding have apparently caused declines in zooplankton upon which young fish feed, but this has not, as yet, reduced the growth of young-of-the-year walleye in Lake Erie. In many cases, fishery impacts will be difficult to assess unless adequate data are available on fish species composition and abundance prior to the invasion of the zebra mussel.

The multi-million dollar, commercial and sport fishing industry in lakes Michigan and Superior may be affected by zebra mussels.

In 1988, the U.S. Fish & Wildlife Service projected future economic losses to the Great Lakes fisheries in the range of $400 million per year with most of the impacts accruing to Lake Erie. These projected financial impacts are highly speculative, and have not been realized thus far.

Several species of fish, including fresh water drum, whitefish, sunfish and lake sturgeon, are likely to feed on zebra mussels. The extent that these species will be able to control zebra mussel populations is unknown; it is not likely they will be effective in controlling them.

Based on what has happened in Lake Erie and Lake St. Clair, it is likely that zebra mussels will transform the fisheries and aquatic ecosystems in many inland Wis-

consin waters and the nearshore area of Lake Michigan and possibly Lake Superior by altering the native community structure and species composition. What remains unclear is how these changes will affect annual fish yields harvested by commercial and sport fishermen and what the economic impact will be. In all likelihood, the most productive fishing areas are those most likely to be severely affected since zebra mussels will colonize extensively in those areas due to the food availability. Thus, areas such as Green Bay and Lake Winnebago, with abundant fisheries, may be at a greater risk. Monitoring results from Green Bay in 1993 and 1994 indicated a major zebra mussel invasion was under way. It is, however, still too early to assess the potential effects on the Green Bay fishery.

Costs And Concerns With Disposal

There are several options for the disposal of zebra mussels including disposal at a municipal solid waste landfill, disposal by landspreading or composting. Each of these options has advantages and disadvantages.

Options for disposal of zebra mussels include landfilling, landspreading, composing, consumptive uses and non-consumptive uses.

Many of the larger power plant facilities such as Detroit Edison and Ontario Hydro are landfilling zebra mussels. There are a number of concerns associated with landfilling including: 1) proper shipment to eliminate odors; 2) waste dewatering; 3) acceptance by the landfill owner or operator; 4) requirements for covering to suppress odors; and 5) analytical tests to ensure that contaminant levels in the mussels are acceptable for landfilling. Disposal costs will range from $15 to $30 per cubic yard, and analytical costs will be in the range of a flat fee of $100 to $300 to determine if the waste is acceptable. Another potential cost is a $600 review fee that WDNR would charge if a plan modification is necessary in order for the landfill to accept the waste.

Another option for disposing zebra mussels is landspreading, which will likely be considered by facilities already landspreading water treatment plant sludge. There are several concerns for landspreading: 1) temporary storage; 2) purchase or lease of the property to be used; 3) purchase or lease of the equipment needed to operate the landspreading operation; 4) assessment of the potential environmental impacts including acceptable soil loading rates; 5) transportation costs to the site; 6) odor control measures; and 7) closure and long-term care of the facility. Many of the costs associated with landspreading would be variable. For example, preparation of an adequate environmental impact statement could cost in the range of $5,000 to $10,000. Testing requirements to ensure acceptable soil loading rates could range from $300 to $1,000 with a WDNR review fee of $600.

Waste composting, another disposal option, creates several other concerns and costs: 1) rental or purchase of land for composting operations; 2) rental or purchase of composting equipment which is likely to be variable in cost; 3) transportation costs to the site; and 4) draining of

the wastes of all liquids and covering immediately to prevent odors. The finished product could be given away, sold or landspread. If the finished product is landspread, the previously mentioned costs apply.

Possible uses for composted zebra mussels include consumptive uses, such as in chicken or cattle feed, or in non-consumptive uses such as fertilizer, soil conditioner, cement or road construction. The volume of the wastes and the level of contaminants in the waste would affect the consumptive uses.

State and federal agencies, as well as the private sector, are investigating options for the disposal of zebra mussels. Waste disposal is not only a concern for utilities and industries that may choose mechanical control options for removing mussels, but also for owners of fishing vessels or barges who may need to dispose of mussels scraped off hulls.

WDNR already has rules in place that would address zebra mussel disposal. Large quantities of zebra mussel waste have not yet been generated in Wisconsin primarily because of efforts by WDNR and UW Sea Grant to alert water treatment facilities early of potential problems and because of an active treatment program by surface water users.

Recreational Concerns

Shore Use

Reports from Ohio in 1990-91 described wind rows of zebra mussels washed on shore as waves dislodged the mussels from nearshore colonies. Shoreline fouling causes two problems to shore users and local governments. First, rotting mussels on the shore produce offensive odors. In addition, colonies in the Great Lakes typically have been composed of animals about a half inch long. The shells are small and sharp. The potential is high for beachgoers to cut their feet on washed-up shells, and the small size of the shells may make beach cleanup difficult. It is also possible that nearshore colonies in public swimming areas could endanger swimming because of the sharp edged shells.

On the positive side, zebra mussels remove some unwanted materials from the water column. To shore users this could mean the water is clearer and more attractive for shoreline activities. Swimmers and boaters will be able to see to greater depths, enhancing the aesthetics of the resource.

In Wisconsin, the most dramatic impacts are likely to occur within Lake Michigan harbors and in Green Bay. As mussels move into inland waters, water clarity, especially in small water bodies, will markedly improve. While this may enhance some recreational uses, the mussels will also filter the water of the food needed to support other organisms in the food chain, which in turn support fish species sought by recreational anglers.

Marina Operations

Docks and other in-water structures, such as ladders or tires fastened to docks, provide suitable surfaces for mussels. Depending on the physical conditions of the water body, encrustation of such structures is probable. Like other nearshore areas, marinas will likely see improved water clarity at the expense of sharp shells on structures, ramps and rocks. Dense colonies of mussels could affect the buoyancy of floating structures. WDNR has received few reports, however, of problems with flotation equipment. Increased costs in maintenance are probable because mussels must be removed from structures. This may result in the decreased useful life of items in contact with the water, such as ropes, docks, and buoys. For example, the chemistry of the zebra mussel's byssal thread is highly corrosive to metal piping and can create holes in pipes if left unchecked. Erosion of concrete structures is also greatly increased when colonized by zebra mussels.

Boaters

Boats provide hard surfaces for mussels to attach to and foul hulls and possibly affect boat performance. Some paints, waxes or other coatings can reduce the amount of settling. More frequent cleaning or on-land storage are other options for controlling this problem.

Another concern for boaters is young mussels settling in the small orifices of an engine cooling system or inside the seachest. Within a few months, the settled mussels could grow large enough to block the flow of water and cause irreparable engine damage. Only a few isolated cases have been reported over the past three summers in the Great Lakes region, and routine engine use, along with hot water flushing, can control settling mussels.

Fresh water boaters have been free of many of the problems common to salt water boaters. As zebra mussels infest more fresh water areas, that difference will diminish. It is likely that the time and dollars spent in maintaining a boat will increase.

Summary Of Economic Costs

Aside from water utilities and power plants, there have been no significant financial impacts from zebra mussels, to date. Projected costs are more difficult to quantify, and in most cases, are unknown. The long-term costs, however, especially to the environment, are likely to be greater than the short-term costs now experienced by surface water users. Table 2 summarizes the actual and projected costs to Wisconsin surface water users and to the aquatic environment as a result of the zebra mussel invasion.

Wisconsin's water utilities and power plants have spent about $5 million from 1990 through 1993 on capital equipment to control zebra mussels. The projected expenditures for 1994 and beyond are likely to be greater than $5 million. Industrial facilities have been unaffected to date because they are located on uninfested, inland Wisconsin rivers. Future costs to industrial facilities for the installation of capital equipment to control zebra mussels are

Table 2. A Summary Of The Actual And Projected Financial Impacts Of Zebra Mussels On State Water Users And The Aquatic Environment.

likely to be very similar to current expenditures for power plants.

Locks and dams on the Mississippi and Fox rivers are also susceptible to zebra mussel infestations. The costs could run into the millions of dollars to dewater a single lock and dam and remove and dispose of encrusted zebra mussels.

Although there have not yet been zebra mussel effects on

Water User Sector Affected	Actual Costs	Projected Costs
Surface Water Users		
Water Utilities	$4,075,000[1]	$2,385,000[2]
Power Plants	$999,000[1]	>$1,000,000[2]
Industrial Facilities[3]	0	>$1,000,000
Lock & Dam Operations[4]		
Mississippi River	0	unknown
Fox River	0	unknown
Clamming Industry—Mississippi R.	0	$451,000[5]
Resource Users[6]		
Sport Fishing	0	unknown
Commercial fishing	0	unknown
Boaters	0	unknown
Marina operators	0	unknown
Disposal of Zebra Mussel Wastes[7]	0	unknown
Environmental[8]	0	unknown
TOTAL	$5,074,000	>$4,836,000

[1]These figures are based on costs incurred from 1990-93 for capital improvement for Wisconsin facilities.

[2]These figures are projected expenditures for 1994 and beyond based on the average capital improvement costs to date and/or best available estimates.

[3]Industrial facilities are located inland primarily on large rivers and have not been affected yet by the invasion of zebra mussels. Projected expenditures are similar to the power companies.

[4]Underwater lock and dam components are susceptible to infestation. Although figures are not available, cleaning of infested components would be labor intensive potentially costing millions of dollars for complete or partial dewatering for a single lock and dam structure in order to remove the attached zebra mussels.

[5]This is an average of Wisconsin's annual share of the native mussel harvest from 1988-92. Projections are that commercial clamming will no longer be profitable when zebra mussel become established in the Mississippi River. In the worst-case scenario, Wisconsin could lose about $451,000 per year from clamming based on the latest figures available.

[6]In 1988 the U.S. Fish & Wildlife Service projected a multi-million dollar impact to the commercial and sport fishery industry of the Great Lakes as a result of the zebra mussel invasion. Any attempt to estimate the financial impact to Wisconsin's fishery would be highly speculative. Maintenance costs for marina operations and boaters will almost certainly increase, but it is impossible to project what those costs might be.

[7]At present, no large loads of zebra mussels have gone to a landfill anywhere in the state. The current waste disposal tipping fee in Wisconsin is about $30-$35 per ton. Without knowing the volume of zebra mussel wastes that could be generated, it is impossible to project what the costs may be. A proactive treatment program by surface water users in the state could avert most, if not all the costs, that may be associated with disposal of the mussels.

[8]Many aquatic communities will be transformed as a result of the invasion of the zebra mussel. The effects on biodiversity and community structure will, in many cases, alter the ecosystem in undesirable ways. Although scientists have not learned to quantify the financial impacts to the environment, they are no less real and may end up being more costly in the long run.

Wisconsin's water utilities and power plants have spent about $5 million from 1990 through 1993 on capital equipment to control zebra mussels.

Based on Wisconsin's share of the native mussel harvest over the last six years, the state could lose $430,000 annually if the native clam populations were devastated and the clamming industry was forced to shut down.

the clamming industry on the Mississippi River, this is likely to change soon. Based on Wisconsin's share of the native mussel harvest over the last six years, the state could lose $430,000 annually if the native clam populations were devastated and the clamming industry forced to shut down.

Financial effects on the fisheries of Lake Michigan or the Mississippi River where zebra mussel populations have been established for several years have not yet been documented. While projected cost estimates remain speculative, the multi-million dollar commercial and sport fishing industry could potentially suffer serious financial consequences if, or when, fish populations shift or decline. As previously discussed, zebra mussels have the potential to dramatically change the ecology of aquatic communities, including the fisheries, in ways that scientists cannot predict. Certainly boaters and marina operators will incur increased maintenance costs in waters infested with zebra mussels. Boaters are already beginning to experience some increase in maintenance costs in certain areas along Lake Michigan where zebra mussels have been established since 1990.

In Wisconsin, to date, no costs were incurred for zebra mussel disposal since no large quantities of zebra mussels needed to be landfilled. This situation could certainly change in the future. The costs for landfilling zebra mussels would be around $30 to $35 per ton and the disposal costs would rise significantly if landfilling is not an option due to high contaminant levels in the mussel tissue.

Scientists have not yet learned how to quantify the environmental impacts in dollar values, but this does not make them any less real. In the long term, environmental costs may be much higher than the short-term costs of maintaining existing standards for water users.

A recent report by the U.S. Congress, Office of Technology Assessment (OTA), estimated that cumulative losses nationwide from selected harmful, nonindigenous species between 1906 and 1991 were $96 billion, more than $1.2 billion per year. Fish and aquatic invertebrates accounted for $1.67 billion of this total. These are costs associated with nonindigenous species control and lost opportunities (Office of Technology Assessment, 1993).

Less tangible are costs associated with the decline of indigenous species, species extinction and loss of biodiversity, all of which are expected impacts from zebra mussel proliferation. Invasions of zebra mussels will likely lead to dramatic changes in the ecological functioning of aquatic communities in terms of predation, prey availability, and competition between species (Carlton, 1994).

Research scientists already report declines in native unionid populations in the Illinois (Blodgett, 1994), St. Lawrence (Riccardi, 1994), and Mississippi rivers (Jennings, 1994) and Lake St. Clair is beginning to show declines in walleye populations (Griffiths, 1994).

The National Biological Survey (Madenjian, 1994) estimated that zebra mussels are consuming 39 percent of the primary plankton production in western Lake Erie, greatly reducing available food at the low end of the food chain. Besides filtering food out of the water column, zebra mussels use native clams as substrate, which is a cause for concern for native clam populations.

Of particular concern is the endangered Maple Leaf and Higgins-Eye clams on the St. Croix River. Out of this concern arose a detailed zebra mussel response plan for the St. Croix River, which serves as a border between Wisconsin and Minnesota above the confluence of the Mississippi. A multi-agency task force that includes staff from the U.S. Fish & Wildlife Service, the National Park Service, and the Minnesota and Wisconsin Departments of Natural Resources, developed a specific action plan in 1993 to protect the St. Croix National Scenic Riverway from the threat posed by a zebra mussel infestation. The efforts are aimed at reducing the risk of extinction to three federally endangered native mussels including the Higgins' eye pearly mussel, the fat pocketbook mussel, and the winged mapleleaf mussel, as well as protecting more than 40 other species of native mussels.

Specific elements of the plan include:

- An aggressive zebra mussel monitoring program;
- An information and education program;
- An inspection program involving all watercraft entering the St. Croix River at, or above the Arcola Sandbar; and
- A remediation program that includes mobile equipment for boat washing to decontaminate vessels that have been in infested waters.

The zebra mussel response plan on the St. Croix was an interim program that was reviewed for effectiveness by all the involved agencies in late 1993. It was decided at that time that the program should remain in effect at least through 1994.

In September, 1994, zebra mussels were discovered on boat hulls in the lower St. Croix. This will lead to a reevaluation of the existing program by the multi-agency task force. This could lead to more restrictions on navigation in order to provide additional protection for the native mussels in the upper St. Croix River.

The OTA reports that nonindigenous species have been a factor in listing 26 percent, or 160 of the 613 species identified as threatened or endangered under the Endangered Species Act. Zebra mussels could certainly increase the number of endangered and threatened species in the future.

As noted in Table 2, many of the financial impacts cannot

be readily quantified, particularly those to the aquatic environment. However, this does not make them any less costly to deal with in the longer term.

Zebra mussels are likely to transform aquatic ecosystems, in particular the fisheries, but the effect and magnitude of those changes are difficult to predict.

Environmental Effects

Fishery Impacts

Griffiths predicts that the Thames River walleye stock may be gone by 1997 as a result of the zebra mussel invasion, which could cause as much as a 50-percent decline in the walleye population in Lake St. Clair.

As stated earlier, zebra mussels are very efficient filter feeders, removing small particles out of the water column like phytoplankton, small zooplankton such as rotifers and water fleas, and detritus, bits of organic debris. Zebra mussels can also filter and consume their own veligers. Since plankton and detritus are major food sources in aquatic ecosystems, fisheries-related effects could result from zebra mussel filtration activity.

By removing phytoplankton and detritus from the water column, zebra mussels can cause a decline in the abundance of zooplankton that feed on them. Further up the food chain, larval fish of all species preying upon zooplankton could face survival challenges as mussel populations expand. Reduced larval fish populations and other food web alterations could mean fewer predatory fish.

Zebra mussel infestations may also adversely affect fish populations through alteration of habitat and interference with fish spawning and recruitment. Increased water clarity due to filter feeding by zebra mussels may weaken the ability of larval fish to escape predation and can make zooplankton more visible to fish predators. Certain species of fish such as walleye, that like more turbid conditions, will likely seek new habitat in deeper waters.

To date, research data from western Lake Erie has not shown a perceptible effect on walleye spawning success despite zebra mussel densities on spawning reefs that exceed 135,000 per square meter. Continued monitoring of walleye spawning areas is, however, necessary to document whether there are any future zebra mussel effects. Recruitment of larval fish species may decrease because of less available food and increased predation, as shown by declines in yellow perch populations in 1992 in Lake Erie. Research in this area is far from complete.

Data from Lake St. Clair (Griffiths, 1994) indicate larval walleye disappear from two to six weeks after they enter Lake St. Clair from the Thames River because zebra mussels have so radically altered the environment. Due to the filter feeding of zebra mussels, Lake St. Clair is now clearer, has fewer phytoplankton, has an increased abundance of aquatic plants and a larger population of bass and pike that prey on the walleye. Griffiths predicts that the Thames River walleye stock may be gone by 1997 due to the zebra mussel invasion, which could cause as much as a 50-percent decline in the walleye population in Lake St. Clair.

Although there is no research data available on smaller inland waters, the potential effect on the fisheries is may be

as severe, or more severe than to the Great Lakes because the inland systems are less diverse and thus may have less resilience to change.

Effects On Biodiversity And Community Structure

As is frequently the case with other non-native species that successfully adopt new surroundings, zebra mussels will likely change the structure of many of the aquatic communities in which they are introduced. This could mean that zebra mussels may out-compete some native species and force them from their environment altogether, shrink the niches of other species, or be responsible for the arrival of new species.

One group of organisms zebra mussels will likely affect are native mussels. The sheer numbers of zebra mussels, especially in areas of high infestation, may compete for food and space and crowd out the approximately 50 species of native mussels. Early research indicates that native unionid mussel populations in Lake St. Clair and Lake Erie are rapidly disappearing where excessive numbers of zebra mussels have become established. Zebra mussels have the potential to substantially reduce native mussel species from Wisconsin's lakes and streams and possibly drive some of these species to extinction.

Water clarity will be increased in Wisconsin waters that are infested with zebra mussels, but productivity of those same waters will likely decline.

Other organisms, such as certain species of diving ducks that eat zebra mussels, may become more abundant in certain areas because of the readily available source of food. Organisms such as algae, zooplankton, aquatic insects, native clams, forage fish and certain species of sport fish could all potentially decline if zebra mussel densities increase significantly. In other cases, there may be a shift in dominance and species composition. For example, aquatic plants will likely grow to greater depths due to increased water clarity while open-water, or pelagic algal species may decline. In other cases, algae and fish dominance may shift from pelagic forms to bottom-dwelling, or benthic forms.

Table 3 summarizes some potential effects zebra mussels may have on various aquatic organisms. It is impossible to accurately predict how various species in an aquatic ecosystem will react to a zebra mussel invasion. Zebra mussels probably will, however, alter the aquatic environment in ways we are not accustomed to and that are not necessarily desirable.

Effects On Water Clarity

Laboratory studies indicate that zebra mussels can efficiently filter food particles down to 0.7 microns. Under optimal conditions, adult mussels can filter between one and two liters of water per day. As previously discussed, studies have shown that this filtration ability can significantly increase water clarity. Since zebra mussels were introduced in the western basin of Lake Erie, researchers have noted a two- to three-fold increase in water clarity and a significant decrease in the amount of chlorophyll present. Chlorophyll content is an indicator of the productivity of

Table 3. Impacts Of Zebra Mussels On Aquatic Ecosystems (Simplified)

ORGANISMS AFFECTED	PROJECTED IMPACTS		
	OVERALL ABUNDANCE	SPECIES COMPOSITION (Shift in Dominance)	RECRUITMENT (Addition of new individuals)
PRIMARY PRODUCERS: algae	Decline	Algal dominance may shift from floating, pelagic forms (decline) to attached, benthic forms (increase)	Decline - pelagic forms Increase - benthic forms
macrophytes (aquatic plants)	Increase	Macrophytes will likely increase in dominance and grow to deeper depths due to increased water clarity	Increase
PRIMARY CONSUMERS: zooplankton	Decline	Zooplankton dominance may shift from more pelagic forms to benthic forms	Potential decline in pelagic forms. Potential increase in benthic forms
native mussels	Decline	Native mussels are likely to decline substantially because they will not be able to successfully compete	Decline
SECONDARY CONSUMERS: forage fish	Unknown	A likely shift in species composition to forage fish species that can benefit from zebra mussels	Forage fish populations may be reduced by delays in recruitment or declines in reproduction potential
aquatic insects and invertebrates	Unknown	Dominance of certain species will likely shift	Unknown
TOP LEVEL CONSUMERS: fish	Overall abundance may be the same but the composition of species will likely shift.	Dominance may shift from pelagic fish to benthic fish	Possibly lower; zebra mussels might limit spawning habitat and interfere with fish egg and fry development

an aquatic ecosystem, and it provides a measure of the amount of algae present.

The extent that zebra mussels can change the water clarity and productivity of Wisconsin waters will depend, in part, on the degree of infestation and the trophic conditions of a particular water body. The amounts of water filtered may be different for rivers than for lakes; consequently, the impacts are likely to be different as well.

Increased water clarity, as a result of zebra mussel filtering, will allow greater light penetration thus providing the opportunity for aquatic plants to grow to increased depths. Relatively shallow lakes, like Lake Winnebago, could be affected significantly as an increase in water clarity would likely augment aquatic plant growth and undesirable attached algal species.

Effects on the food chain from water clarity and productivity changes are described in Table 3.

Accumulation Of Toxins

Because zebra mussels can filter large volumes of water in a relatively short time, they have the ability to build up, or bioaccumulate toxic contaminants, as they ingest phytoplankton and dissolved organic carbon. Once zebra mussels have accumulated toxins, they can redistribute the contaminants in the environment. This may mean increased trace metals and toxic organic compounds in the sediment where zebra mussel colonies are established.

The build up of contaminants in zebra mussels, or bioaccumulation, will likely occur along the Lake Michigan shoreline, Green Bay, the lower Fox River and tributaries where there are known toxic hot spots.

Toxic assessment data from lakes Erie, Michigan and Huron (Kreis, 1994) have shown that zebra mussels bioaccumulate polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), some heavy metals (lead and cadmium) and a few pesticides (DDT and dieldrin). The greatest concentration of these contaminants occurs in mussel tissue, not in shells. The data from the Great Lakes show an average bioaccumulation rate inthe mussel tissue of about 0.5 parts per million for PCBs, which will vary somewhat based on the time of year and location. The actual bioaccumulation of toxins in the tissue of zebra mussels will depend on the contaminant's concentration in the water, sediment and food, and the animal's physiological state.

In Wisconsin, zebra mussels will likely accumulate some PCBs and other contaminants in areas along the Lake Michigan shoreline, Green Bay and the lower Fox River, and tributaries where there are known toxic hot spots. Zebra mussels could affect the cycling of contaminants in some of the shallow areas along the Lake Michigan shoreline and in Green Bay due to their high filtration rates, bioaccumulation potential and fecundity rates. In inland Wisconsin waters, zebra mussel exposure to contaminants will, in general, be less. Therefore, there is less of a concern that zebra mussels will bioaccumulate toxins, compared to some areas within the Great Lakes. Toxic assessments for zebra mussels will need to be conducted on Wisconsin waters in the future to document where problems are occurring.

Figure 1. North American Range Of The Zebra Mussel As Of September, 1994, Follows. Copyright 1994, New York Sea Grant. Reprinted With Permission.

IV.

EFFECTIVE CONTROL STRATEGIES FOR RAW WATER USERS

Raw water users in Wisconsin are mainly power plants and water utilities. Some other industries, mainly paper companies, draw surface water, but their use is relatively low and other, more expensive, sources are usually available. The recommended control strategy for raw water users is to treat for mussel veligers rather than the adults. This eliminates concerns and costs associated with fouling at the facilities and mussel disposal.

Regardless what chemical is used to control zebra mussels, treatment must be provided to meet water quality standards at the point of discharge.

Power utilities use large quantities of water for cooling systems, passing the water through the plant and discharging it back to the same water body, a process called once-through cooling. For a large electric power plant like the Point Beach facility near Two Rivers, more than 900 million gallons per day are used in large and small heat exchangers. Water flow to this equipment is critical to the safe and efficient operation of the plant and the continued power distri-

Oxidizing Chemicals

Chlorine (Cl)—A familiar, relatively inexpensive chemical and a preferred option with the least environmental effects. Most effective in summer when temperatures are above 59°F (15°C). Not 100 % effective, corrosive to stainless steel and can produce trihalomethanes.

Sodium Hypochlorite (NaOCl)—An effective oxidizer that will kill all adult zebra mussels in 4-5 days at levels of 2.5 ppm. Highly corrosive.

Potassium Permanganate (KMnO4)— Effective at killing zebra mussels without adversely affecting non-target species. Produces fewer trihalomethanes than chlorine. Turns water pink at higher concentrations.

Chloramine—Not effective on veligers at lower concentrations (1.5 ppm produces 90% mortality).

Chlorine dioxide (ClO2)—Less effective than chloramines but does not produce trihalomethanes. Three times as expensive as chlorine.

Ozone—The most effective oxidizer. Can improve water taste and control odors. Has high capital, operation and maintenance costs; is technically difficult to control; and can form disinfection by-products.

bution to several million people.

By comparison, the city of Milwaukee uses about 150 million gallons per day to supply residential and industrial users. Water in municipal supplies must be both potable and palatable. Off-odors, tastes, or colors are unacceptable to residential users. Chemicals must be added or treatment provided to remove odors. Chemicals used to control zebra mussels must be approved by the National Sanitation Foundation for use in drinking water and must be compatible with the water treatment process for each utility.

In an extreme case in 1989, zebra mussels plugged the water intake of Monroe, Michigan, and shut down the city's water. Monroe is on the western shore of Lake Erie.

Chemical Control

To date, chemical treatment has been the most common zebra mussel control method due to its cost effectiveness and familiarity. Initially, chemicals used at oceanside communities to deal with other mollusks were sought as a quick response to the problems caused by zebra mussels in Lake Erie. Molluscicides, developed specifically for mollusks, were investigated by the power industry as well as general chemicals, like chlorine and potassium permanganate. Regardless what chemical is used to control zebra mussles, treatment must be provided to meet water quality standards at the point of discharge.

Chemicals can be used to deter settling, or to achieve some desired mortality. They can be fed into a water intake system intermittently at high levels during and after the breeding season, or continuously at low levels throughout the reproductive season. In some cases, facilities use chemical feed throughout the year.

In Wisconsin, as is the case in many other states and provinces, some chemical treatments are simply not environmentally acceptable

While a variety of chemicals can be used for control, each has its strengths and weaknesses. Thus far, the least expensive chemical option for utilities in the United States and Canada is chlorine. But even chlorine has problems. Water clarity, improved by the filtering action of zebra mussels, can reduce chlorine demand. For power plants this may result in high enough doses to kill the mussels, but that requires removal prior to discharge so no residual chlorine remains in the waste stream.

Although the zebra mussel is a simple organism, it is able to sense undesirable substances and close its siphons for up to two weeks at a time, suggesting that continued low doses are more effective for total mortality. Chemicals can also be employed with other strategies to increase the effectiveness. In Wisconsin, however, as is the case in many other states and provinces, some chemical treatments are simply not environmentally acceptable. Currently, seven of Wisconsin's municipal water utilities use chemical control options at an average capital cost of $265,000. Milwaukee spent a total of $2.5 million to install chemical treatment systems in its two water treatment plants (Hahn, 1993).

Chemical treatment, even if it were environmentally friendly and 100-percent effective, does not completely

Physical And Mechanical Controls

solve the problem. Dead mussels can break loose individually or in clumps and still block intake filters or heat exchanges. Mussels must be periodically removed from the outside part of the intake structures which are not chemically treated.

Coatings

Coating surfaces with various materials is an approach used to deter settling of mussels. Various paints and waxes have been used on surfaces like boat hulls. Coatings can be applied to a number of in-water uses. The advantage of coatings is low maintenance costs, but the initial outlay may be quite expensive and some substances may also be toxic. Applied research continues in this area, but as is the case for other control strategies, no completely effective, low-cost coating has been found.

Sand Filters

Some of the most desirable long-term solutions to zebra mussel problems are physical controls. One option is to filter the incoming water through a bed of sand. The initial cost is high, but sand filtration not only eliminates zebra mussels, it also filters out other impurities as well.

Sand filtration is an old idea. The city of Superior installed such a system in 1899 drawing water through a horizontal layer of sand on the bed of Lake Superior. The cities of Manitowoc, Wisconsin Rapids and Biron use a vertical filter called a Ranney Well; other configurations also exist. While larger systems are feasible, sand bed filters are usually employed by communities with withdrawal rates of less than 10 million gallons per day, which includes nine of the 14 Wisconsin Great Lakes communities. Lake bed geology and relatively higher capital costs will likely limit practical installation for most Wisconsin communities.

Heat

Water hotter than 100°F will kill zebra mussels. Water temperatures near 130°F will cause instantaneous death, whereas temperatures around 100°F require longer exposure time to kill zebra mussels. Some power utilities can reroute discharge water back into the plant and raise temperatures high enough to kill both veligers and adults within the raw water systems. The Wisconsin Electric Power Company (WEPCO) in Milwaukee is one example. By periodically recycling discharge water, WEPCO is able to keep two of its power plants free of mussels. This approach is environmentally friendly. However, not all plant designs allow for water recirculation.

Oxygen Deprivation

The cities of Cudahy, Racine and Kenosha all take advantage of having multiple intakes. By alternating between intake pipes, these cities are able to close one intake, treat the water with chlorine or sodium bisulfite and leave the pipe sealed for 30 days or more. Sodium bisulfate removes oxygen from the water. Chlorine causes zebra mussels to close their siphons. In either case, the mussels

eventually die from lack of oxygen. The pipe must be flushed to remove dead animals before going back on line. The cost is about $24,000 for operation of these three plants.

Scraping Or Pigging

A simple approach at power plants is to periodically scrape intake wells using high pressure hoses and manual tools. Within intake pipes, cylindrical "pigs," or balls or sponges that can be forced through the pipe under high pressure to scrape the pipe walls, much as one does with a household drain. However, pigging may not be suitable for some intakes where the pipeline design or obstructions in the pipe may trap the pig. Like almost all control options, plant managers must also deal with the zebra mussel waste from these operations. Finding a suitable disposal site for dead, decomposing zebra mussels can be a problem.

Micro-filtration

One of the most promising control options is mechanical in-line filters. In 1993, reports at the 3rd International Zebra Mussel Conference by Ontario Hydro and the New York Power Authority provided positive test results using 15, 20 and 40 micron filters. Using both intermittent and continuous backflushing approaches, the tests removed 99 percent of settling size veligers from the intake and service water system (EPRI, 1993).

Disposable Substrates

Fish netting and other materials can be deployed near the entrances to intake pipes as alternate substrate for young mussels to settle. Once encrusted the nets can then be disposed of. This technique has been widely discussed but few technical papers are available to evaluate its effectiveness. It appears to be an appropriate option in areas with native clam populations where it offers an alternative substrate for attachment.

Microbes And Pathogens

The identification of bacteria or other micro-organisms that selectively attack zebra mussels, but not other organisms, is an area of continued research. To date there are no reported successes in this field. The potential for workable solutions exists, but obviously careful laboratory study is necessary before solutions are applied in the field.

Electric Shock, Acoustics, Ultra-violet Radiation and Others

These control options currently have practical application in limited situations but overall are presently more experimental than practical. A presentation at the 1st International Zebra Mussel Conference in 1991 discussed placing a small amount of explosive in the center of an intake pipe and crushing settled adults with the explosion. The author, a college professor, was trying to stimulate creative thinking to demonstrate that even seemingly unconventional methods can work. It is hoped a breakthrough in one of these areas will provide a practical, economic solution.

V.

ENVIRONMENTAL AND BIOLOGICAL CONTROLS

No selective toxicant has been developed to control zebra mussel populations in the environment. To date, TFM, also known as "lampreycide," for sea lamprey control has been the only chemical successfully used to control a pest. Research continues to develop selective chemical pesticides that would be effective in controlling zebra mussels, and which would also pose little or no environmental risk to other aquatic biota. If a selective pesticide is developed that proves effective for environmental control of this animal, it is likely to be years in the future.

Biological control agents could be effective in certain areas in helping to curb this invader. Zebra mussel larvae are preyed upon by young fish and zooplankton, but by itself this type of predation may not be very effective. Adult zebra mussels are eaten by rough fish species such as sheepshead of 18 inches or longer or carp, or by waterfowl such as certain species of diving ducks. The effectiveness of these species to control zebra mussel populations depends on the number of these predators, their willingness to feed more exclusively on zebra mussels, and upon the density and reproductive rate of the mussels.

In Europe, ducks have been important predators of zebra mussels.

Some research is under way to identify species that may be capable of functioning as a biological control for zebra mussels. Data from Lake Erie (French and Bur, 1993) has shown that the freshwater drum have changed their food habits since the invasion of the zebra mussel. Zebra mussels have become an important component of the drum diet because they are so abundant in the lake and because the drum have learned to eat them. Large adult fresh water drum may actually reduce zebra mussel populations in some habitats of Lake Erie. The high reproductive rate of zebra mussels in Lake Erie, however, reduces the likelihood that the drum could act as an effective predator in controlling mussel populations. Although present in Wisconsin waters, fresh water drum populations are relatively low and thus will probably not act as a significant control.

In Europe, ducks have been important zebra mussel predators. A recent study from the Cook Nuclear Plant in Bridgman, Michigan (Mitchell & Carlson, 1993), was the first published account of ducks eating zebra mussels in North America. Migrating scaup were first observed eating zebra mussels from the water intake structures at the Cook Nuclear Plant in the summer of 1991. Scaup and other diving ducks seem to search out new feeding locations during migration or winter to consume zebra mussels when available. Diving ducks are likely to selectively

Other biological control techniques under consideration include the release of sterile males, habitat enhancement for endemic natural predators, the introduction of natural enemies and the release of microbial agents.

prey on zebra mussels only during certain times of the year and then only at specific locations. Consequently, diving ducks are not expected to be effective in controlling zebra mussel populations in North American waters.

Other biological control techniques under consideration include the release of sterile males, habitat enhancement for endemic natural predators, the introduction of natural predators and the release of microbial agents. Several research labs are investigating naturally occurring pathogens, as opposed to genetically engineered strains, to control zebra mussels. Molloy et. al. (1994) presented preliminary survey results on the pathological effects of parasitic organisms on zebra mussels at the 4th International Zebra Mussel Conference. The intent of such research efforts is to isolate a microbe or "super bug" that will selectively control zebra mussels without adversely affecting other aquatic organisms. This approach was successfully used to control black flies in the Appalachians.

Biological control agents can themselves become pests and therefore must be screened carefully before introduction. Any technique used to control this animal in the ecosystem in the future, whether it is chemical or biological, is likely to have some adverse side effects.

Realistically, a combination of chemical use and biological methods may prove, from an environmental standpoint, to be the best control approach. Based on past efforts to control exotic species that have become widespread, however, much success in controlling zebra mussels where they have become established in the environment is unlikely.

VI.

EXISTING RESOURCES TO DEAL WITH THE ZEBRA MUSSEL PROBLEM

Wisconsin's efforts to combat zebra mussel problems, as described in Section II, were accomplished over the last several years through the equivalent of one half-time staff person at WDNR. No state dollars have been specifically targeted for zebra mussel activities since their original discovery here in 1990. There has been, however, some minor realignment in priorities within the agency to focus additional resources on zebra mussel problems.

In addition to WDNR efforts, UW Sea Grant Institute has devoted roughly one full-time staff person over the last several years to focus primarily on zebra mussel monitoring and information and education efforts. Funding for UW Sea Grant Institute activities has come from National Oceanic and Atmospheric Administration (NOAA) appropriations under the Aquatic Nuisance Prevention and Control Act. UW Sea Grant Institute and WDNR have worked closely together to establish a state zebra mussel program. The primary goal of that program has been controlling the spread of this aquatic invader.

At the federal level, the Nonindigenous Aquatic Nuisance Prevention and Control Act (Public Law 101-646) was enacted in 1990 in response to the zebra mussel infestation and other concerns about nonindigenous aquatic species introductions. The act provides an intergovernmental mechanism for the development of a cooperative national program to:

- Reduce the risk of, or prevent the unintentional introduction and dispersal of nonindigenous aquatic species that may be nuisances;
- Ensure prompt detection of the presence of, and monitor changes in the distribution of nonindigenous aquatic species; and
- Control established aquatic nuisance species in a cost-effective, environmentally-sound manner.

An Aquatic Nuisance Species Task Force was established to coordinate efforts related to nonindigenous aquatic species in the United States. The task force consists of seven federal agency representatives and eight ex officio members that represent non-federal governmental entities. The task force has established a national zebra mussel program to ensure coordination among the wide range of gov-

ernment interests and other entities. The national program addresses zebra mussel infestation through prevention, detection and monitoring and control efforts that also include protection of native species and ecosystems likely to be adversely affected.

Table 4. Estimates Of The Total Funds Spent On Zebra Mussels, Per Fiscal Year , By Agency Via The 1990 Aquatic Nuisance Prevention And Control Act (In Millions Of Dollars).

National funding for zebra mussel activities has been provided since 1990 when the Act was passed. Table 4 provides an estimate of the funding by each agency for zebra mussels under the Nonindigenous Aquatic Nuisance Prevention and Control Act. Funding has ranged from about $1 million in fiscal year (FY) 1990 to about $10 million in fiscal year 1993 although not all the monies were specifically targeted for zebra mussel activities. The majority of dollars have been appropriated to Sea Grant and the U.S. Fish and Wildlife Service.

AGENCY	FY90	FY91	FY92	FY93	FY94	FY95
U.S. Environmental Protection Agency	0.1	0.25	0.25	0.25	0.25	0.25
National Oceanic & Atmospheric Administration (NOAA): Great Lakes Environmental Research Laboratory (GLERL)	0.1	1.0	1.0	0.9	0.9	0.9
NOAA: Sea Grant	0.4	2.0	3.0	2.8[1]	2.8	2.8
Department of Interior, U.S. Fish & Wildlife Service	0.2	1.6	2.4	3.3	1.5[2]	1.5[3]
Department of Interior, Bureau of Reclamation	0	0	0.2	0.1	0.05	0.05
Department of Transportation,U.S. Coast Guard[4]	0.1	0.2	0.7	0.7	0.7	1.0
Department of Defense, U.S. Army Corps of Engineers	0	0.1	0.5	1.1	2.0	2.0
Tennessee Valley Authority	0	0.1	0.8	1.2	1.0	1.0[5]
TOTALS	0.9	5.25	8.85	10.35	9.2	9.5

[1]Only $2.4 million of the $2.8 million appropriated to Sea Grant in FY93 was actually spent. The balance of $0.4 million carried over to FY94.

[2]In FY94, $3.8 million was appropriated to the U.S. Fish and Wildlife Service for the nonindigenous species program of which $1.5 million was specifically targeted for zebra mussel activities.

[3]In FY95, $4.1 million was appropriated to the U.S. Fish and Wildlife Service for the nonindigenous species program, of which $1.5 million was targetted for zebra mussel activities.

[4]The U.S. Coast Guard expenditures do not reflect funds spent only on zebra mussel activities. Their efforts have been focussed on the development of a ballast water and shipping initiative to control the introduction of nonindigenous species into the Great Lakes.

[5]The FY95 doallars for the Tennessee Valley Authoriuty are projected expenditures.

Under the provisions in the 1990 act, grants can be made available to states with completed aquatic nuisance species implementation plans which the task force has approved. Plans must identify management practices and measures that will be undertaken to reduce infestations of aquatic nuisance species. The federal cost-share assistance to the states under this section of the act would not exceed 75 percent of the cost of implementing the plans.

As of fiscal year 1994, no federal funds had been appropriated for this purpose nor had any states requested fund-

ing under the 1990 act. In fiscal year 1995, sp,e addo- topma; fimdomg was appropriated for controls under the act. The Aquatic Nuisance Species Task Force would like to use a portion of these monies to provide some funding in fiscal year 1995 to states with approved implementation plans.

Legislatures from two Great Lakes states, Minnesota and New York, have directed their respective natural resource management agencies to develop management plans for aquatic nuisance species as specified in the federal act. The New York Department of Environmental Conservation completed a Nonindigenous Aquatic Species Comprehensive Management Plan in December, 1993. The Minnesota Department of Natural Resources is now developing a similar plan that is expected in late 1994. Several other states have expressed interest in this process but have not yet initiated development of the plans. The task force approved the New York plan in March, 1994, and that state delegation can now request funding for implementation of its plan as part of the federal budget.

The WDNR is the agency responsible for developing Wisconsin's implementation plan on aquatic nuisance species. WDNR will soon be developing such a plan to guide state actions in this area. The Eurasian water milfoil report submitted to the Legislature in 1993 and this report will provide the basis for developing a comprehensive Wisconsin plan for nonindigenous aquatic species.

VII.

GOALS, RECOMMENDATIONS AND RESOURCE NEEDS FOR WISCONSIN'S ZEBRA MUSSEL PROGRAM

Philosophy

The philosophy of Wisconsin's zebra mussel program has been to slow the spread of this aquatic invader from infested to uninfested waters. Detecting the presence and monitoring the distribution and density of zebra mussels is essential in implementing effective control strategies. Information and education efforts and technical assistance are also essential in order to successfully slow the spread of zebra mussels.

Goals

- Protect our native aquatic flora and fauna by reducing the threat that a zebra mussel invasion poses to the natural balance of our aquatic environments.
- Slow, and to the extent possible, prevent the spread of zebra mussels.
- Provide technical assistance to raw water users to develop long-term, cost-effective and environmentally safe solutions for controlling nuisance zebra mussel populations.
- Inform and educate recreational boaters of the importance of maintaining clean boats to protect our waters against unwelcome invaders like zebra mussels.

Recommendations

- ☑ Education
- ☑ Monitoring
- ☑ Technical assistance
- ☑ Controls
- ☑ Integration
- ☑ Regulation

Education

Education efforts will focus on increasing public awareness of the zebra mussel problem in Wisconsin and precautions that should be taken to prevent the mussel's spread and to control the animal when it does become established. Education will also concentrate on improving the public's understanding of the function of native species of aquatic animals and plants.

The following are examples of activities to be included as part of an enhanced zebra mussel education program:

- Increased emphasis on public service announcements,
- Billboard signs to alert boaters to follow good boat-cleaning techniques,
- Development of videos for use by special interest groups,
- Information packets for incorporation into school curriculum,
- Signs at all the major boat landings, and
- Pamphlets and brochures for recreational boaters and fishers.

Through our current information and education efforts, a number of these activities are already being accomplished to some degree. An augmented program will mean increased public awareness on the zebra mussel issue.

Education efforts so far have relied almost exclusively on the Department of Natural Resources and UW Sea Grant Institute to disseminate information on zebra mussels. This needs to change. In the future, the emphasis should shift to a network system that includes sharing the burden for an educational program. This means fishing clubs, sporting organizations, lake associations, diving clubs, utilities, schools, etc. will be part of a zebra mussel education network. WDNR and UW Sea Grant Institute will coordinate distribution of education materials such as pamphlets, brochures and videos to various groups and organizations who, in turn, will assist in disseminating information. This will result in a more effective public education program on zebra mussels.

Monitoring

The purpose of the monitoring program is to document the arrival of zebra mussels, track their spread in Wisconsin waters and determine their population growth and seasonal abundance. Monitoring is important because it confirms where zebra mussels are found and it can alert facilities or other affected parties of potential problems.

Current monitoring efforts are being accomplished through a network consisting primarily of volunteers. This monitoring network of trained volunteers enhances the

Current data management efforts to track and document the spread of zebra mussels will need to expand to include evaluation of impacts to native species and the effects of control strategies.

state's ability to track the spread of zebra mussels, since professional staff time and funding are limited.

Professional monitoring efforts will be needed to supplement the volunteer sampling program. Monitoring by professional biologists from WDNR, UW Sea Grant Institute, U.S. Fish and Wildlife Service, and the U.S. Corps of Engineers will follow more structured guidelines contained in the latest scientific sampling methodologies and will include sampling of both adults and veligers (larvae). This more rigorous approach to sampling on a number of select waters by professional staff will increase confidence in the sampling results. Professional biologists will also verify new infestations identified through the volunteer program.

Objectives of the monitoring program are to:

- ✓ Improve the likelihood of early detection through a network of volunteer and professional sampling efforts,
- ✓ Monitor the spread of zebra mussels and the effects of their population expansion on native species and ecosystems and on human facilities and activities,
- ✓ Provide timely notification to appropriate entities of the detection and dispersal of zebra mussels and the potential effects of the mussels, and
- ✓ Assess appropriate management and control techniques based on population levels and determine the effectiveness of control strategies once they are in place.

One means of accomplishing these objectives is through a database network. Monitoring information is already being entered into the state's Geographical Information System (GIS). Current data management efforts to track and document the spread of zebra mussels will need to expand to include evaluation of impacts on native species and the effects of control strategies. It will also be important for Wisconsin to network with national monitoring efforts and those of other states where zebra mussels are a problem.

Another component of the monitoring programs is evaluation of toxins. Zebra mussels need to be collected and analyzed for toxins to determine whether contaminants are building up, or bioaccumulating in zebra mussel tissues, and if so, where the problems are occurring. An additional need is to conduct follow-up tissue monitoring of zebra mussels at those sites where bioaccumulation of toxins has been identified. The monitoring data, collected over a longer time, would be important in assessing trends related to bioaccumulation of contaminants in zebra mussels.

Technical Assistance

WDNR will continue to serve in a networking capacity for

water utilities, power plants, industrial facilities and dam operators. As a conduit for information, WDNR will facilitate private sector efforts to develop environmentally sound and cost-effective controls for dealing with zebra mussels. WDNR, through its contacts with other states, provinces and universities in the Great Lakes region and at the national level, will provide information in the form of literature references and technical contacts to municipalities, utilities and industries requesting this type of assistance. This approach will aid the private sector in developing cost-effective, long-term solutions to problems caused by zebra mussels.

The policy of the state should be to not provide financial assistance to facilities for mitigating the impacts of the zebra mussel infestation, limiting its efforts to providing technical assistance, unless the invasion of an exotic species has far-reaching consequences on the private sector, including agriculture or industry.

Controls

A number of effective control strategies for raw water users are available and in use as described in Section IV. Additional state dollars are not needed to conduct further research on chemical, mechanical or physical treatment technologies. The private sector and other governmental agencies in the United States and Canada are already spending sufficient funding and efforts to develop zebra mussel controls for raw water users.

What is needed is funding to develop controls for zebra mussels in the aquatic environment. This effort should be similar to the research that went into developing TFM for sea lamprey control. Wisconsin should not undertake this effort alone. The state needs to pool its resources with other states and provinces to examine various effective treatment options to limit or control zebra mussel populations in the wild.

Integration

An effective zebra mussel control program must include an integrated approach on how to respond to unintentional introductions of nonindigenous species in the state and in turn how to control and manage them. This will likely include administrative rules and internal WDNR guidance that will form the basis of a consistent policy on nonindigenous species. This means that the overall policy, and application of that policy, would be similar for all nonindigenous species regardless whether it is zebra mussels, Eurasian water milfoil, the ruffe or any other species that the agency is trying to control.

This is not to say that the management plans developed for individual nuisance species would be the same. The focus in terms of policy implications for management of the various nuisance species would, however, be similar. For example, any control program would have to minimize harm to the environment and the public health and welfare. In addition, any management controls would have to

safeguard recreation and other human activities while avoiding long-term, expensive control technologies at the taxpayers' expense.

Regulations

There are currently no statutory regulations or administrative rules in place that control or limit the spread of zebra mussels. Other states, such as Minnesota, have enacted rules on exotic species. The effectiveness of those regulations should be carefully examined. To the extent possible, Wisconsin's rules should be crafted similarly so they are integrated with other states, particularly in the Great Lakes region. Minnesota regulations are attached to this report in Appendix B as an example of model legislation on exotic species.

The key to a successful zebra mussel control program is preventing their spread. Laws that prohibit the launching of watercraft or trailers with zebra mussels attached could certainly enhance efforts to slow the spread of this animal and should be seriously considered. But consideration also has to be given to enforcement. In many cases, zebra mussels are likely to be transported from one water body to another in the larval form. Regulations that would make it unlawful to transport the veligers may be difficult, if not impossible, to enforce.

Any future laws in this area need to have a strong education component in order to gain public acceptance. In addition, any penalties should be reasonable based on the seriousness of the violation.

The desired course of action is for the Natural Resources Board and Legislature to consider legislation that would regulate the possession, transportation and introduction of not only zebra mussels, but all harmful aquatic nonindigenous species.

The desired course of action is for the Natural Resources Board and Wisconsin Legislature to consider legislation that would regulate the possession, transportation and introduction of not only zebra mussels, but all harmful aquatic nonindigenous species.

Funding Recommendations

The funding recommendations contained in this section represent a statewide assessment for all Wisconsin waters and are not limited to just infested waters or affected facilities. It includes the best available projections of the resources needed to adequately address the problems posed by zebra mussels in Wisconsin.

Based on best available estimates, the WDNR and UW Sea Grant Institute are devoting about 1.5 full-time employees (FTEs) and $30,000 per year to zebra mussel activities. This falls short of the annual projected level needed of 4.0 FTEs and $580,000 annually to implement the goals and recommendations detailed in this report. Of the total level of effort needed, 3.0 FTEs and $530,000 are recommended for WDNR and 1.0 FTE and $50,000 are recommended for UW Sea Grant Institute. Table 5 contains an assessment of the available resources and the additional needs required for dealing effectively with the zebra mussel problem in Wisconsin.

The additional resources needed for technical support,

which includes information and education, monitoring and technical assistance, are 1.5 FTEs and $400,000. For policy management, which includes controls, integration and regulation, the additional resources necessary would be 1.0 FTE and $150,000.

These estimated requirements for staffing and funding are based on the best available projections of the resources necessary to deal with the problems posed by zebra mussels. As reflected in Table 2 in Section III, many of the financial impacts are unknown, particularly to the environment. Even though the financial impacts to the environment cannot yet be determined, they are no less real and may end up being more costly in the long run. At some future time, if or when these impacts can be quantified, the level of effort and resource requirements, as contained in Table 5, will need to be reassessed.

Suggested Funding Sources

In order to deal effectively with the problems posed by zebra mussels, funding from both the private and public sectors is essential. The assessment of resource needs in Table 5 reflects only the public funding needed. The private sector has already invested considerable monies in controlling zebra mussels.

Wisconsin's water utilities and power plants have spent about $5 million on controlling zebra mussels through 1993, with the future costs likely to increase (see Table 2). State funds are not recommended for mitigation of the impacts of zebra mussels for these facilities. In addition to developing controls at their facilities, the private sector will be responsible for a number of other activities including: research into and development of control options for raw water users, monitoring at their facilities, contaminant evaluations if mussel disposal occurs and assistance and participation with the public sector on information and education efforts.

Although there are no cost figures available to the private sector for implementing these specific activities, the financial burden could significantly outweigh public funding that will be required. Wisconsin will need an additional $725,000 annually in public funding, which includes money for staffing, to deal effectively with zebra mussel problems. The suggested source for state dollars would be 50 percent general purpose revenue (GPR) and 50 percent segregated funds. It is recommended that GPR monies be replaced by federal funding if they are available after the state implementation plan is completed and approved as required by the 1990 Aquatic Nuisance Prevention and Control Act (see Section VII). Federal funding is not likely to be available before fiscal year 1996, which means state GPR funding would be necessary for at least several years.

Table 5. (Next Page) Assessment Of The Available Resources And Additional Level Of Effort Required To Deal Effectively With The Zebra Mussel Problem In Wisconsin

Category	Program Elements	% Staff Effort Needed[1]	Existing Resources Available[2]		Total Level of Effort Needed[3]		Additional Resources Required	
			Staffing	Funding	Staffing	Funding	Staffing	Funding
Technical Support (1.5 FTEs + $400,000)	Information and Education/Outreach	30	0.5	$25,000	1.0	$325,000	0.5	$300,000
	Monitoring							
	-Water Users	5	0	$2,500	0.1	$10,000	0.1	$7,500
	-Waterbodies	30	0.5	$2,500	0.8	$10,000	0.3	$7,500
	-Toxic Evaluations	5	0	0	0.1	$85,000	0.1	$85,000
	Technical Assistance	30	0.5	0	1.0	0	0.5	0
Policy/Management (1.0 FTE + $150,000)	Controls							
	-Raw Water Users[4]	—	—	$5M	—	—	—	—
	-Aquatic Environment	20	0	0	0.2	$100,000	0.2	$100,000
	Integration[5]	50	0	0	0.5	$50,000	0.5	$50,000
	Regulation	30	0	0	0.3	0	0.3	0
	TOTALS	—	1.5	$30,000	4.0	$580,000	2.5	$550,000

[1]The percent of total staff effort needed by specific category, either Technical Support or Policy Management.

[2]WDNR has reallocated one half-time staff person for zebra mussel activiteis over the last several years and UW Sea Grant Institute has devoted roughly one full-time staff person and $25,000 over the same period. The dollars spent on information and education are part of UW Sea Grant Institute's funding under the Aquatic Nuisance Prevention and Control Act.

[3]The total level of effort needed includes three full-time staff equivalents and $530,000 for WDNR and one full-time staff equivalents and $50,000 for UW Sea Grant institute.

[4]Raw water users, which include primarily water utilities and power plants, spent about $5 million on controlling zebra mussels through 1993, with the future costs likely to increase (refer to Table 2). It is not recommended that state funds be used to mitigate the impacts of zebra mussels on these facilities (refer to the discussion on technical assistance in Section VIII). Thus, the funding and staffing for raw water users is not reflectied in the total resources needed.

[5]This effort involves developing an integrated approach for responding to unintentional introductions of nuisance aquatic exotic species in the state as well as coordination with other states and federal agencies, including the Aquatic Nuisance Species Task Force.

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APPENDIX B

Selected Minnesota Exotic Species Statutes

M.S. 18.317 UNDESIRABLE EXOTIC AQUATIC PLANTS OR WILD ANIMALS.

Compiled by the Minnesota Department of Natural Resources - Exotic Species ProgramRevised May 4, 1994

Subd.1. Transportation prohibited. Except as provided in subdivision 2, a person may not transport Eurasian or Northern water milfoil, myriophyllum spicatum or exalbescens, zebra mussels, or undesirable exotic aquatic plants or wild animals identified by the commissioner of natural resources on a road or highway, as defined in section 160.02, subdivision 7, or on forest roads.

Subd.1a. **Placement Prohibited.** A person may not intentionally place undesirable exotic aquatic plants or wild animals into public waters within the state.

Subd. 2. **Exception.** A person may transport Eurasian or Northern water milfoil, myriophyllum spicatum or exalbescens, or other undesirable exotic aquatic plants or wild animals identified by the commissioner of natural resources for disposal as part of a harvest or control activity conducted under a permit or as specified by the commissioner.

Subd. 3. **Launching of watercraft with Eurasian or Northern water milfoil or other Harmful Species prohibited.**

(a) A person may not place a trailer or launch a watercraft into waters of the state if the trailer or watercraft has attached to it Eurasian or Northern water milfoil, zebra mussels, or other undesirable exotic aquatic plants or wild animals identified by the commissioner of natural resources. A conservation officer or other licensed peace officer may order the removal of Eurasian or Northern water milfoil, zebra mussels, or other undesirable exotic aquatic plants or wild animals identified by the commissioner of natural resources from a trailer or watercraft before being placed or launched into waters of the state.

(b) For purposes of this section, the meaning of watercraft includes a float plane and "waters of the state" has the meaning given in section 103G.005, subdivision 17.

(c) A commercial harvester shall clean aquatic plant harvesting equipment of all aquatic vegetation at a suitable location before launching the equipment in another body of water.

Subd. 3a. Inspection of Watercraft and Equipment. Watercraft and associated equipment including weed harvesters, that are removed from any waters of the state that the commissioner of natural resources identifies as being contaminated with Eurasian water milfoil, zebra mussels, or other undesirable exotic aquatic plants or wild animals identified by the commissioner of natural resources, shall be ran-

domly inspected between May 1 and October 15 for a minimum of 10,000 hours by personnel authorized by the commissioner of natural resources. Beginning in calendar year 1994, a minimum of 20,000 hours of random inspections must be conducted per year.

Subd. 4. **Enforcement.** This section may be enforced by conservation officers under sections 97A.205, 97A.211, and 97A.221, subdivision 1, paragraph (a), clause (1), and by other licensed peace officers.

Subd. 5. **Penalty.** A person who violates subdivision 1, 1a, 3, or 3a is guilty of a misdemeanor. A person who refuses to obey the order of a peace officer or conservation officer to remove Eurasian or Northern water milfoil, zebra mussels, or other undesirable exotic aquatic plants or wild animals from a trailer or watercraft is guilty of a misdemeanor.

Ecologically Harmful Species

M.S. 84.966 CONTROL OF PURPLE LOOSESTRIFE.

Subd. 1. **Definition:** For the purpose of this section, "purple loosestrife" means Lythrum salicaria, Lythrum virgatum, or combinations thereof.

Subd. 2. **Establishment of Control Program:**

The commissioner of natural resources shall coordinate a control program to curb the growth of purple loosestrife. The commissioners of agriculture and transportation must aid and corporate with the commissioner of natural resources to establish, implement and enforce the control program.

M.S. 84.967 ECOLOGICALLY HARMFUL SPECIES; DEFINITIONS.

Subdivision 1. Scope. For the purposes of sections 84.967 to 84.9692, the following terms have the meanings given them.

Subd. 2. **Ecologically Harmful Exotic Species.** "Ecologically harmful exotic species" means non-native aquatic plants or wild animals that can naturalize, have high propagation potential, are highly competitive for limiting factors, and cause or may cause displacement of, or otherwise threaten, native plants or native animals in their natural communities.

Subd. 3. **Limited Infestation of Eurasian Watermilfoil.** "Limited infestation of Eurasian water milfoil" or "limited infestation" means an infestation of Eurasian watermilfoil that occupies less than 20 percent of the littoral area of a waterbody up to a maximum of 75 acres, excluding water bodies where mechanical harvesting is used to manage Eurasian watermilfoil or where no Eurasian watermilfoil control is planned.

M.S. 84.968 ECOLOGICALLY HARMFUL SPECIES: MANAGEMENT PLAN; REPORT

Subdivision 1. Management Plan. (a) By January 1, 1993, a long-term statewide ecologically harmful exotic species management plan must be prepared by the commission of natural resources and address the following:

(1) coordinated detection and prevention of accidental in-

troduction;

(2) coordinated dissemination of information about ecologically harmful exotic species among resource management agencies and organizations;

(3) a coordinated public awareness campaign regarding ecologically harmful exotic animals and aquatic plants;

(4) a process, where none exits, to designate and classify ecologically harmful exotic species into the following categories:

(i)undesirable wild animals that must not be sold, propagated, possessed, or transported; and

(ii) undesirable aquatic exotic plants that must not be sold, propagated, possessed, or transported;

(5) coordination of control and eradication of ecologically harmful exotic species on lands and public waters; and

(6) develop a list of exotic wild animal species intended for nonagricultural purposes, or propagation for release by state agencies or the private sector.

(b) The plan prepared under paragraph (a) must include containment strategies that include:

(1) participation by lake associations, local citizen groups, and local units of government in the development and implementation of lake management plans;

(2) a reasonable and workable inspection requirement for boats and equipment participating in organized events on the waters of the state.

(3) allowing access points infested with ecollogically harmful exotic species to be closed, for not more than a total of seven days during the open water season, for control or eradication purposes, and requiring posting of signs

(4) provisions for reasonable weed-free maintenance of public accesses to infested waters; and

(5) notice to travelers of the penalties for violations of laws relating to ecologically harmful exotic species.

Subd. 2. **Report .** The commissioner of natural resources shall be January 1 each year submit a report on ecologically harmful exotic species to the legislative committees having jurisdiction over environmental and natural resource issues. The report must include

(1) detailed information on expenditures for adminsitration, education, eradication, inspections, and research;

(2) an analysis of the effectiveness of management activities conducted in the state, including chemical eradication, harvesting, educational efforts, and inspections;

(3) information on the participation of other state agencies, local government units, and interest groups in control efforts;

(4) information on management efforts in other states;

(5) information on the progress made by species;

M.S. 84.969 COORDINATING PROGRAM, GRANTS, AND REGIONAL COOPERATION

(6) an estimate of future management needs.

Subd. 1. **Coordinating Program.** The commissioner of natural resources shall establish a statewide coordinating program to prevent and curb the spread of ecologically harmful exotic animals and aquatic plants.

Subd. 2. **Grants.** The coordinating program created in subdivision 1 may accept gifts, donations, and grants to accomplish its duties and must seek available federal grants through the federal Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. A portion of these funds shall be used to implement the plan under section 10.

Subd. 3. **Regional Cooperation.** The governor may cooperate individually and regionally, with other state governors in the midwest for the purposes of ecologically harmful exotic species management and control.

M.S. 84.9691 RULEMAKING

(a) The commissioner of natural resources may adopt emergency and permanent rules restricting the introduction, propagation, use, possession, and spread of ecologically harmful exotic species in the state, as outlined in section 84.967. The emergency rulemaking authority granted in this paragraph expires July 1, 1994.

(b) The commissioner shall adopt rules to identify bodies of water with limited infestation of Eurasian watermilfoil. The areas that are infested shall be marked and prohibited for use.

(c) A violation of a rule adopted under this section is a misdemeanor.

M.S. 84.9692 CIVIL CITATIONS AND PENALTIES.

Subdivision 1. **Authority to issue.** After appropriate training, conservation officers, peace officers, and other staff designated by the commissioner may issue warnings or citations to persons who:

(1) unlawfully transport ecologically harmful exotic species on a public road;

(2) place a trailer or launch a watercraft with ecologically harmful species attached into waters of the state;

(3) operate a watercraft in a marked Eurasian water milfoil limited infestation area; or

(4) damage, remove, or sink a buoy marking a Eurasian water milfoil infestation area.

Subd. 2. **Penalty Amount.** A citation issued under this section may impose up to the following penalty amounts:

(1) $50 for transporting visible Eurasian water milfoil on a public road in each of the following locations:

(i) the exterior of the watercraft below the gunwales including the propulsion system;

(ii) any surface of a watercraft trailer;

(iii) any surface of a watercraft interior of the gunwales;

(iv) any water container including livewells, minnow buckets, or coolers which hold water; or

(v) any other area where visible Eurasian water milfoil is found not previously described in items (1) to (4);

(2) $150 for transporting visible zebra mussels on a public road;

(3) $300 for transporting live ruffe or live rusty crayfish on a public road;

(4) for attempting to launch or launching into noninfested waters a watercraft with visable Eurasian water milfoil or adult zebra mussels attached, $500 for the first offense and $1,000 for a second or subsequent offense;

(5) $100 for operating a watercraft in a marked Eurasian water milfoil limited infestation area other than as provided by law;

(6) $150 for intentionally damaging, moving, removing, or sinking a milfoil buoy; or

(7) $150 for launching or attempting to launch into infested waters a watercraft with visible Eurasian water milfoil or visible zebra mussels attached .

Subd. 3. **Payment of Penalty.** If not appealed under subdivision 4, civil penalties are payable to the commissioner no later than 30 days after issuance. Fines collected under this section must be credited to the water recreation account.

Subd. 4. **Appeals.** Citations may be appealed under the procedures in section 116.072, subdivision 6, if the person requests a hearing by notifying the commissioner within 15 days after receipt of the citation. If a hearing is not requested within the 15-day period, the citation becomes a final order not subject to further review.

Subd. 5. **Enforcement of Field Citations.** Field citations may be enforced under section 18.317.

Subd. 6. **Cumulative Remedy.** The authority of conservation officers to issue field citations is in addition to other remedies available under law, except that the state may not seek penalties under any other provision of law for the incident subject to the citation.

Licences

M.S. 86B.401 WATERCRAFT LICENCES.

Subd. 11. Suspension for not removing water milfoil or other undesirable exotic species. The commissioner , after notice and an opportunity for hearing, may suspend for a period of not more than one year the license of a watercraft if the owner or person in control of the watercraft or its trailer refuses to comply with an inspection order of a conservation officer or other licensed peace officer or an order to remove Eurasian or Northern water milfoil, myriophyllum spicatum or exalbescens, zebra mussels, or other undesirable exotic aquatic plants or wild animal species identified by the commissioner from the watercraft or its trailer as provided in section 18.317, subdivision 3.

M.S. 86B.415 LICENSE FEES.

Subd. 7. Watercraft surcharge. A surcharge is placed on each watercraft licenses under subdivisions 1 to 5, for control, public awareness, law enforcement, monitoring, and research of nuisance aquatic exotic species such as zebra mussel, purple loosestrife and Eurasian water milfoil in public waters and public wetlands. The surcharge is $5 until December 31, 1996, and $3 there after.

103G.617 EURASIAN WATER MILFOIL EDUCATION AND MANAGEMENT.

Subd. 1. Definition. For the purposes of this section, "Eurasian water milfoil" means myriophyllum spicatum.

Subd. 2. **Inventory.** The commissioner shall inventory and monitor the growth of Eurasian water milfoil on lakes in the state. The commissioner may use volunteers to aid in the inventory effort.

Subd. 3. **Education.** The commissioner shall publish and distribute informational materials to lakeshore owners and boaters on the control problems of Eurasian water milfoil.

Subd. 4. **Management.** The commissioner shall coordinate a control program to manage the growth of Eurasian water milfoil with appropriate local units of government, special purpose districts, and lakeshore associations. Technical assistance may be provided by the commissioner upon request.

Subd. 5. **Research.** The commissioner shall initiate cooperative research with the University of Minnesota and other public and private research facilities to study the use of nonchemical methods, including biological control agents, for control of Eurasian water milfoil.

Ecologically Harmful Exotic Species Emergency Rules

Minnesota Rules Chapter 6216 (effective Aug. 12, 1993)

6216.0100 DEFINITIONS.

Subpart 1. **Scope.** The terms used in chapters 6216.0100 through 6216.0700 have the meanings given to them in *Minnesota Statutes* , sections 84.967 and 97A.015, unless otherwise noted.

Subp. 2. **Applicant.** "Applicant" means any person who applies for a permit pursuant to parts 6216.0100 to 6216.0700.

Subp. 3. **Aquatic plant.** "Aquatic plant" means a plant, including any part or seed of a plant, that can grow in water or on a substrate that is at least periodically deficient in oxygen as a result of water content.

Subp. 4. **Commissioner.** "Commissioner" means the commissioner of natural resources or a designated employee.

Subp. 5. **Department.** "Department" means the Department of Natural Resources.

Subp. 6. **Escape.** "Escape" means an accidental introduction or escape of a species from the control of the owner or responsible party.

Subp 7. **Exotic species.** "Exotic species" means a species that enters or is introduced into an ecosystem beyond its

historic range, except through a natural range expansion, including any such organism transferred from another country into the state, unnaturally occurring hybrids, cultivars, non-Minnesota genetic lineage or subspecies, genetically engineered species or strains, or other genetically altered species.

Subp. 8. **Exotic species importation and release permit.** "Exotic species importation and release permit" means a permit issued by the commissioner to allow the importation and release of an exotic species in the state.

Subp. 9. **Infested waters.** "Infested waters" means bodies of water with populations of zebra mussels, Eurasian water milfoil, ruffe, spiny water flea, or white perch.

Subp. 10. **Limited infestation of Eurasian watermilfoil.** "Limited infestation" means an infestation of Eurasian watermilfoil occupying less than 20 percent of the littoral area of a water body up to maximum of 75 acres, excluding water bodies where mechanical harvesting is used to manage Eurasian watermilfoil or where no Eurasian watermilfoil control is planned.

Subp. 11. **Littoral area.** "Littoral area" means those areas of a water body 15 feet or less in depth.

Subp. 12. **Native species.** "Native species" means any species present in an ecosystem within its historic range, or naturally expanded from its historic range, in the state.

Subp. 13. **Naturalize.** "Naturalize" means to establish a self-sustaining population of exotic species in the wild.

Subp. 14. **Release.** "Release" means an intentional introduction or release of a species from the control of the owner or responsible party.

Subp. 15. **Transport.** "Transport" means causing or attempting to cause undesirable aquatic plants and wild animals to be carried or moved by a device and includes, but is not limited to, accepting or receiving undesirable aquatic plants or wild animals for transportation or shipment. Transport does not include the incidental movement of undesirable aquatic plants or wild animals within a contiguous water body.

Subp. 16. **Undesirable exotic aquatic plant.** "Undesirable aquatic plant" means the following ecologically harmful exotic species:

A. Eurasian watermilfoil (*Myriophyllum spicatum*);

B. curly leaf pondweed (*Potamogeton crispus*);

C. flowering rush (*Butomus umbellatus*);

D. any variety, hybrid, or cultivar of purple loosestrife (*Lythrum salicaria, Lythrum virgatum*, or combinations thereof);

E. water chestnut (*Trapa natans*); and

F. hydrilla (*Hydrilla verticillata*).

Subp. 17. **Undesirable exotic aquatic plant or wild animal permit.** "Undesirable exotic aquatic plant or wild ani-

mal permit" means a permit issued by the department to transport, possess, sell, purchase, import, take, or propagate undesirable exotic aquatic plants or undesirable exotic wild animals.

Subp. 18. **Undesirable exotic wild animal.** "Undesirable wild animal" means the following ecologically harmful exotic species:

A. white perch (*Morone americana*);

B. ruffe (*Gymnocephalus cernua*);

C. grass carp (*Ctenopharyngodon idella*);

D. zander (*Stizostedion lucioperca*);

E. any strain of nutria (*Mycocastor coypu*);

F. European rabbit (*Oryctolagus cuniculus*);

G. Asian raccoon dog, also known as finnraccoon (*Nyctereutes procyonoides*);

H. Eurasian wild pigs and their hybrids (*Sus scrofa subspecies and Sus scrofa hybrids*), excluding domestic hogs (*S. scrofa domesticus*) ;

I. rusty crayfish (Orconectes rusticus);

J. zebra mussel species(all species of the genus *Dreissena*);

K. spiny waterflea (*Bythotrephes cederstroemi*);

L. asiatic clam (*Corbicula fluminea*);

M. mute swan (*Cygnus olor*);

N. Sichuan pheasant (Phasianus colchicus strauchi);

O. sea lamprey (*Petromyzon marinus*);

P. common carp (*Cyprinus carpio*);

Q. tilapia species (all species of the genus*Tilapia*);

R. rudd (*Scardinius erythrophthalmus*);

S. tubenose goby (*Protererorhinus marmoratus*); and

T. round goby (*Neogobius melanostomus*)

6216.0200 POSSESSION, TRANSPORTATION, PURCHASE, SALE, OR IMPORTATION OF UNDESIRABLE EXOTIC SPECIES.

Subpart 1. Prohibition. A person may not transport, possess, sell, purchase, import, propagate, or release undesirable exotic plants and animals in this state except as provided in subparts 2 to 4, and part 6216.0300, subpart 5, or:

A. under an aquatic nuisance control permit;

B. under an undesirable exotic aquatic plant or wild animal permit,

C. under a transportation permit as provided in Minnesota Statutes 17.4985,

D. as provided by law; or

E. when these species are transported, in direct passage, through Minnesota in according to appropriate state and federal regulations.

Subp. 2. Control Activities. A person authorized by a permit issued by the commissioner may transport Eurasian water milfoil or other water transmitted harmful exotic species identified by the commissioner for disposal as part of a permitted harvest or control activity as specified in *Minnesota Statutes* 18.317. Subd. 2.

Subp. 3. Possession and transportation of dead undesirable exotic species. A person may possess and transport dead undesirable exotic species to the department to report their occurrence and for identification.

Subp. 4. Common Carp. A person may possess, transport, buy, or sell common carp as provided by the game and fish laws.

6216.0300 PERMIT REQUIREMENTS FOR UNDESIRABLE EXOTIC SPECIES.

Subpart 1. **Permits.** Before a person may transport, possess, purchase, sell, import, take, or propagate an undesirable aquatic plant or animal specified in part 6216.0100 for scientific, research, education, control, or exhibition purposes, a permit must be obtained from the commissioner.

Subp. 2. **Revocation of permit.** Permits issued under this part may be revoked by the commissioner if the conditions of the permit are not met by the permittee or for any act or omission, including release or escape, that threatens native plant and animal populations in the state.

Subp. 3. **Expiration date.** All permits shall expire on December 31 of each year, except permits issued less than 90 days before December 31 shall expire on December 31 the following year.

Subp. 4. **Application period.** Persons possessing undesirable exotic wild animals on the effective date of parts 6216.0100 to 6126.0700 must apply for an undesirable exotic aquatic plant or wild animal permit under subp. 5 within 60 days of the effective date of parts 6216.0100 to 6216.0700.

Subp. 5. **Commercial purposes.** The following species may be possessed, sold, exported, taken, or transported live for commercial purposes under an undesirable exotic aquatic plant or wild animal permit, a game farm license, a commercial fishing license or permit, a commercial crayfish harvest permit, commercial crayfish importation permit, or aquatic farm or private fish hatchery license issued by the commissioner:

A. rusty crayfish;

B. common carp;

C. wild pigs;

D. Sichuan pheasant; and

E. tilapia.

Subp. 6. **Inspection of permitted sites.** Facilities for holding undesirable exotic wild animals and aquatic plants for research, exhibition, education, or commercial pur-

poses are subject to inspection at any reasonable time by the commissioner.

Subp. 7. **Contingency plans.** Permittees must prepare written contingency plans for eradication or recapture of released or escaped species as specified in their undesirable exotic aquatic plant or wild animal permit.

6216.0400 NOTIFICATION, RECAPTURE, AND DESTRUCTION OF RELEASED UNDESIRABLE EXOTIC SPECIES.

Subpart 1. Notice; actions to recapture or destroy. In the event of an escape or a release of an undesirable exotic wild animal or aquatic plant species, the owner must immediately notify a conservation officer and is personally responsible for the recovery or destruction of the plants or animals. The owner of an escaped undesirable wild animal or accidentally introduced aquatic plants must immediately implement the actions specified in the contingency plan required by an undesirable exotic aquatic plant or wild animal permit. If the owner is unable to recapture or otherwise destroy the released or escaped plants or animals within ten days of the escape, the escaped plant or animal may be captured or destroyed by the department at the owner's expense.

Subpart 2. **Department action.** Released, escaped, or other unconfined undesirable exotic wild animals or accidentally introduced aquatic plants, that have not been reported to the department as provided in subpart 1, may be captured or destroyed at any time by the department to avoid potential establishment of naturalized populations.

6216.0500 RESTRICTED ACTIVITIES ON INFESTED WATER BODIES.

Subpart 1. Prohibition on entry. Entry by boaters, anglers, or other water users and their associated equipment into infestations of Eurasian water milfoil marked with yellow buoys according to part 6216.0600, on waterbodies identified with limited infestations under part 6216.0600, is prohibited, except for emergencies.

Subp. 2. **Exceptions.** Enforcement, emergency, resource management, and other government personnel or contractors are exempt from this part when performing official duties or authorized work as prescribed in part 6110.1200, Subpart 2, item D, subitem. (3). Owners or leasees of land adjacent to the control area, that do not have an alternative route for their watercraft from their property to reach waters may use the shortest and most direct route through the limited infestation when traveling to and from their property. They shall also operate their watercraft in a manner that would least disturb the aquatic plants in the marked area.

Subp. 3. **Prohibition on taking bait from infested waters.** The taking of minnows for bait purposes from all infested waters in Minnesota is prohibited.

Subp. 4. **Commercial fish nets used in infested waters.** Commercial fish nets that are used in infested waters in Minnesota may only be used in other infested bodies of water with the same species designation. In addition to the

information required under Minnesota Statutes, section 97C.351, commercial fish nets used in infested waters must be marked with the species designation of the infested body of water.

Subp. 5. **Transporting water from infested waters.** Owners or operators of watercraft leaving waters of the Mississippi River downstream of St. Anthony Falls, Minnesota waters of Lake Superior including waters of the St. Louis River downstream of the Fond du Lac dam, waters of the Minnesota River downstream of Shakopee and Island Lake in St. Louis County, must drain livewells, bait containers, other boating related equipment holding water, and bilges by removing the drain plug before transporting the watercraft on public roads. This subpart does not apply to ballast water utilized by documented commercial vessels engaged in interstate or international commerce.

Subp. 6. **Fish hatchery or aquatic farms in infested waters.** Infested waters will not be licensed for private fish hatcheries or aquatic farm use.

Subp. 7. **Designation of infested waters.** Infested waters shall be designated by the commissioner by publishing an official notice in the state register and posting all public access points. Water bodies may be removed from designation by the commissioner by publishing an official notice in the state register and removal of posting at public access points.

6216.0600 IDENTIFICATION AND MARKING OF LIMITED INFESTATIONS OF EURASIAN WATER MILFOIL .

Subpart 1. **Publication.** The commissioner shall identify bodies of water having limited infestations of Eurasian water milfoil by publishing the names of those bodies of water in the state register and a local newspaper. At any time the commissioner may amend the list as additional limited infestations are discovered or water bodies are determined to no longer have limited infestations.

Subp. 2. **Marking.** Infestations of Eurasian water milfoil on bodies of water determined to be limited infestations, shall be marked by the department according to part 6110.1500 subpart. 7. The commissioner will mark areas were Eurasian water milfoil control is planned. The markers will be removed after control actions are completed and Eurasian water milfoil plants are no longer a threat to fragment or transport by boaters, anglers, or other water users and their associated equipment

6216.0700 IMPORTATION AND RELEASE, OF EXOTIC WILD ANIMALS AND AQUATIC PLANT SPECIES.

Exotic species of wild animals or aquatic plants may not be imported for release, or released unless they meet one or more of the following conditions:

A. it is authorized to be released from a licensed shooting preserve according to the conditions of the shooting preserve license; or

B. it is a ringnecked pheasant, gray (Hungarian) partridge, or Chukar partridge, or quail;

C. it is an exotic bird permitted for falconry under a state falconry permit and registered by submitting a Federal Form 3-186A (Migratory Bird Acquisition/Disposition Report);

D. it is a biological control that has been thoroughly tested by United States Department of Agriculture, and approved by the Minnesota Department of Agriculture, and the Department of Natural Resources;

E. released according to a plan approved by the commissioner;

F. it is imported and released according to Chapter 17.4981 to 17.4997 and Commissioner's Order 2450, section 1, chapter 6250, or its successor;

G. it is a game fish already present in Minnesota and released according to a fish stocking permit issued by the department; or

H. for an exotic species that is not an undesirable exotic wild animal or aquatic plant, or not exempted in this part, all the following steps must be completed to the satisfaction of the commissioner:

(1) the applicant applies for an exotic species importation and release permit ;

(2) the applicant must submit health information and history for the animals to be imported:

(3) the applicant must prepare an environmental assessment worksheet including data verifying that the proposed introduction does not have the characteristics of an ecologically harmful species and indicating for what reasons species native to the state are not an acceptable alternative to the proposed release;

(4) the commissioner determines it is in the best interest of the state to release the species from captivity; and

(5) the commissioner issues an importation and release permit to the applicant.

References to Statutes or Rules

Ecologically harmful non-native species. "Ecologically harmful exotic species" is defined in *Minnesota Statutes* 84.967. *("ecologically harmful exotic species" means non-native aquatic plants or wild animals that can naturalize, have high propagation potential, are highly competitive for limiting factors, and cause displacement of, or otherwise threaten, native plants or native animals in their natural communities.)*

Minnows. "Minnows" is defined in Minnesota Statutes 97A.015, Subdivision 29.

Possession. "Possession" is defined in *Minnesota Statutes* 97A.015, subdivision 36.

Private aquatic life. Private aquatic life is defined in *Minnesota Statutes* chapter 17.

Wild animal. "Wild animal" is defined in Minnesota Statutes 97A.015, subdivision 55. *("Wild animal" means all*

living creatures, not human, wild by nature, endowed with the sensation and power of voluntary motion, and includes but is not limited to mammals, birds, fish, amphibians, reptiles, crustaceans, and mollusks.)]

Minn. Rules 6110.1500 Subp. 7. ***Milfoil areas.*** *Buoys or signs indicating an area that is infested with Eurasian water milfoil may be marked using a solid yellow sign or buoy. If a buoy is used, it shall be no less than four inches in diameter and extend at least 30 inches above the surface of the water. The words "Milfoil" or "Milfoil Area" must appear on opposing sides of the buoy in at least two-inch high black letters. If a sign is used, it shall be no more than 12 inches in width or more than 18 inches in height and extend 30 inches above the surface of the water at normal water level. The words "Milfoil" or "Milfoil Area" must appear on the sign the sign in at least two-inch high black letters.*

SIGHTINGS

North American Range of the Zebra Mussel

as of 30 September 1994

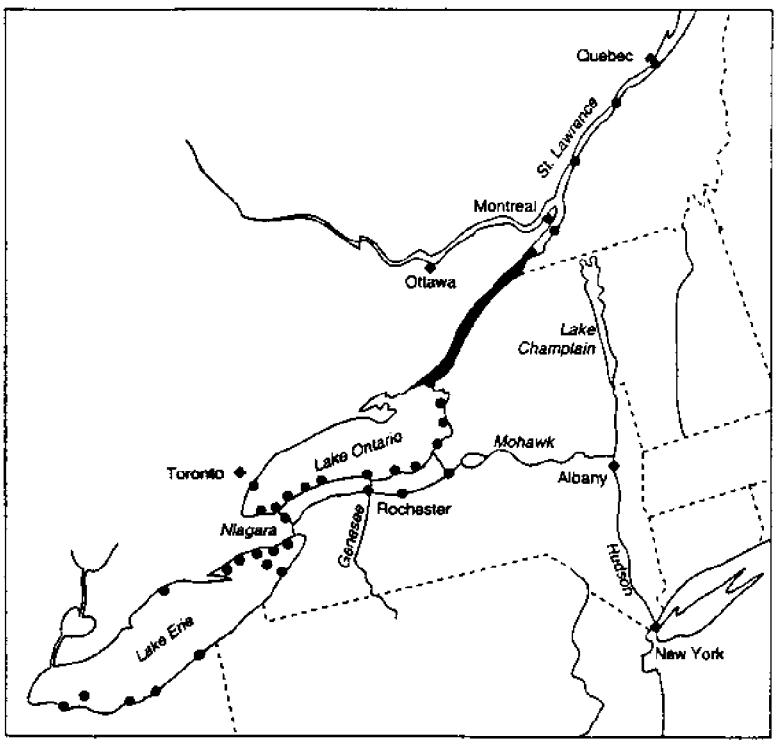
Compiled by New York Sea Grant with information from: Empire State Electric Energy Research Corp., Fisheries and Oceans Canada, Great Lakes Sea Grant Network, Illinois Natural History Survey, Ontario Hydro, Ontario Ministry of Natural Resources, Tennessee Valley Authority, US Army Corps of Engineers, US Fish & Wildlife Service, and Utilities and others throughout North America.

Sitings:

1. Big Elkhart Lake, WI
2. Okauchee Lake, WI
3. Mississippi River, Davenport, IA.
4. Onondaga Lake, Syracuse, NY
5. Cayuga Lake – entire lake
6. Canandaigua Lake – entire lake
7. Keuka Lake, Penn Yan, NY
8. Tippecanoe Lake, IN
9. Allegheny River, river mile 45.7 (lock7), Kittanning, PA,
10. Green River, river mile 74, Livermore, KY
11. Mississippi River, Pool 11, river mile 586, Dubuque, IA

North American Range of the Quagga Mussel

as of 30 September 1994




Lake Manitoba
Winnipeg
Rainy
Lake Superior
Sault Ste Marie
Duluth
Bismarck
Mississippi
St Croix
Wisconsin
St Paul
Minnesota
Pierre
Sioux Falls
Missouri
Lake Michigan
Lake Huron
Muskegon
Lansing
Detroit
Madison
Chicago
Mississippi
Des Moines
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Platte
Lincoln
Illinois
Springfield
Wabash
Indianapolis
Maumee
Sandusky
Little Miami
Columbus
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Charleston
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Topeka
Kansas City
Jefferson City
St Louis
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Ohio
Cumberland
Nashville
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Oklahoma City
Canadian
Arkansas
Little Rock
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Tennessee
Tenn - Tom
Black Warrior
Alabama
Tombigbee
Montgomery
Atlanta
Chattahoochee
Savannah
Broad
Wateree
Columbia
Little Tennessee
Greensboro
Raleigh
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Allegheny
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Harrisburg
Philadelphia
Trenton
Baltimore
Delaware
Hudson
New York
Delaware Bay
Washington
Shenandoah
Richmond
James
Chesapeake Bay
Augusta
Montpelier
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