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U.S. Fish & Wildlife Service

Sherburne National Wildlife Refuge

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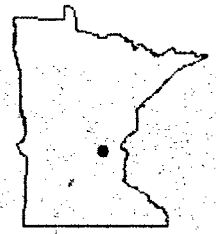

Sherburne National Wildlife Refuge consists of 30,665 acres of Federal land dedicated to the conservation, management, and where appropriate, restoration of fish, wildlife, and plant resources and their habitats for the benefit of present and future generations of Americans.

Sherburne, one of ten National Wildlife Refuges in Minnesota, is located in the east central region of the state, approximately 50 miles northwest of the Minneapolis/St. Paul metropolitan area and 30 miles southeast of St. Cloud.

The primary mission of the Refuge is to represent a diverse biological community characteristic of the transition zone between tallgrass prairie and forest. Established in 1965 to protect and restore the habitats associated with the St. Francis River Valley for migratory birds and other wildlife purposes, the focus of the Refuge today is on the restoration of oak savanna, wetland and big woods habitats.

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Sherburne NWR Fact Sheet

BOBBY APPROVED
Sherburne NWR Website is Bobby Approved for accessibility as of October 2001

Sherburne National Wildlife Refuge
17076 293rd Ave
Zimmerman, MN 55398
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Phone: 763.389.3323
Fax: 763.389.3493
TTY users may reach the Refuge through the Federal Information Relay Service 1-800-877-8339

U.S. Fish & Wildlife Service

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History

The St. Francis River Valley, the basis for the formation of the Sherburne National Wildlife Refuge, was originally settled in the 1870s under the Homestead Act, although humans lived in the area for over 10,000 years. American Indian village sites discovered on the Refuge date back to 1300 A.D. Historically, the St. Francis River Basin was known as one of the finest wildlife areas in the state. Tremendous numbers of ducks, muskrats, beaver and mink were supported on small lakes, and marshes near the river which were abundant with wild rice and other wetland plants. The surrounding upland was primarily oak savanna which provided habitat for elk, bison, and timber wolves.

By the early 1940s, several developments had severely reduced the value of wildlife habitat in the basin. A ditch system, built in the 1920s, enhanced drainage to increase agricultural acreage. This resulted in fewer wetlands holding water throughout the year. In the early 1940s carp invaded the lakes and streams in the basin. The feeding activities of these fish resulted in the uprooting of submerged vegetation important to aquatic wildlife. In addition, the native oak savanna upland habitat was converted to agriculture or home sites through logging and/or plowing. Protection from fire allowed the oak savanna to convert to dense woodlands.

In the early 1940s, local conservationists and sportsmen became interested in the possibility of restoring the former wildlife values of the St. Francis River Basin. The Minnesota Conservation Department now the Department of Natural Resources, conducted studies with the intention of managing the area as a state wildlife area. By the early 1960s it had become apparent that the magnitude of the project was beyond the funding capabilities of the Minnesota Conservation Department, as over 300 individual land holdings, comprising over 30,000 acres, would need to be purchased. Therefore, the State of Minnesota formally requested the U.S. Bureau of Sport Fisheries and Wildlife, now known as the U.S. Fish and Wildlife Service, to consider the area for a National Wildlife Refuge.

The Bureau took on the task and began seeking approval for the Refuge from various local, state and federal authorities. Final approval of the Refuge was received from Migratory Bird Conservation Commission on May 18, 1965, and land was purchased with Federal Migratory Bird Hunting Stamp (Duck Stamp) funds.

Since that time, Refuge management has been directed towards achieving the following goals:

- To provide resting, nesting and feeding habitat for waterfowl and other migratory birds.
- To provide habitat for resident wildlife.
- To protect endangered and threatened species.
- To provide for biodiversity through restoration and maintenance of native vegetation and wildlife.
- To provide the public with wildlife-oriented opportunities in interpretation, recreation and outdoor classrooms when compatible with the resource and other Refuge objectives.

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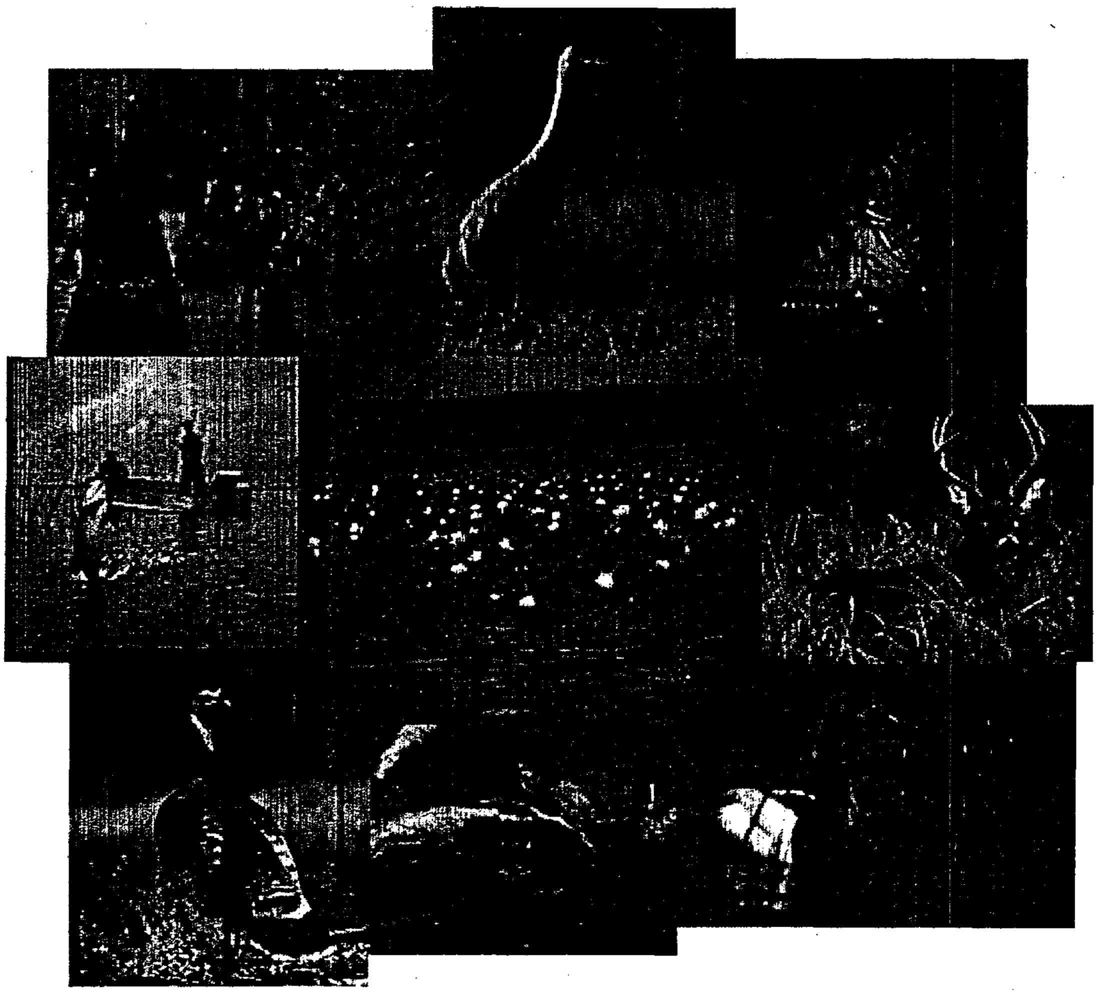
Sherburne
National Wildlife Refuge



Contacting the Refuge:

Refuge Manager: Anne Sittauer
e-mail: anne_sittauer@fws.gov

17076 293rd Avenue
Zimmerman, MN 55398
Phone: 763-389-3323
Fax: 763-389-3493
TTY: 1-800-877-8339 (Federal Relay)

Located four miles west of Zimmerman, Minnesota

Sherburne NWR Homepage

Refuge Facts

- Established: 1965
- Acres: 30,700
- Administers Crane Meadows NWR
- Supported by a large volunteer program

Financial Impact of Refuge

- 14-person permanent staff, five seasonal
- 120,000 visitors annually
- FY 2004 Budget: $1,357,527

Natural History

- Refuge lies in the transition zone of deciduous hardwood forest and tallgrass prairie
- Located in the St. Francis River Valley, which is known as one of the finest wildlife areas in the state
- Historic wetland, oak savanna habitat was degraded by settlement practices of fire suppression and farming
- Management emphasizes restoring the native habitat
- Important waterfowl area
- Bald eagles and sandhill cranes nest on the refuge

Highlight

Visit the 7.3-mile Prairie's Edge Wildlife Drive and discover the prairie, oak savanna and wetland habitats that support an astounding array of wildlife just as it may have been 150 years ago when the first settlers came to the area

Refuge Objectives

- Provide resting, nesting and feeding habitat for waterfowl and other migratory birds
- Provide habitat for resident wildlife
- Protect endangered and threatened species
- Provide for biodiversity through oak savanna restoration
- Provide public opportunities for outdoor recreation and environmental education

Priorities

- Improve and maintain public use facilities and services to provide a quality experience to nearly 120,000 visitors a year
- Pursue the necessary funding for construction of a new visitor center
- Provide additional services directed toward wildlife observation, hunting, environmental education and nature photography

Public Use Opportunities

- Hiking and cross-country skiing
- Hunting and fishing
- Environmental education and interpretation
- Wildlife observation and photography
- Auto tour route

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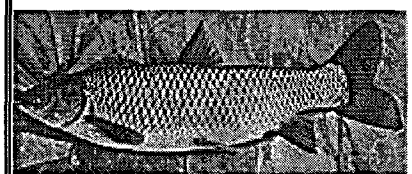
USGS 2004

USGS
Upper Midwest Environmental Sciences Center

Invasive Species

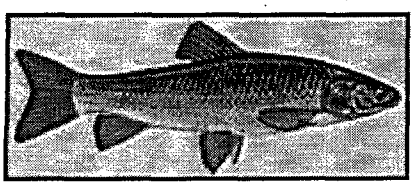
Asian Carp

- Fast Facts
- Ongoing Studies
- Fishery Drug Development
- Project Status Report 2000-05 November 2000 Asian Carp Invasion of the Upper Mississippi River System

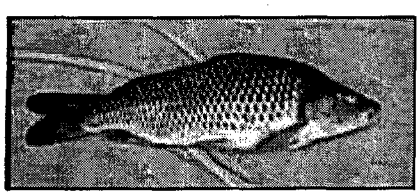


Asian Carps

Types: common, grass, bighead, silver and black carps



Black Carp
(Mylopharyngodon piceus)



Common Carp

Why are they a problem?

All four of the Asian carps that are established in the United States spread quickly after introduction, became very abundant, and hurt native fishes either by damaging habitats or by consuming vast amounts of food. Common and grass carps destroy habitat and reduce water quality for native fishes by uprooting or consuming aquatic vegetation.

Bighead and silver carps are large filter-feeders that compete with larval fishes, paddlefish, bigmouth buffalo, and freshwater mollusks (clams). In addition, boaters have been injured by silver carp because they commonly jump out of the water and into or over boats in response to outboard motors. Black carp, which consume almost exclusively mussels and snails, may further threaten our already imperiled native freshwater mussels should they become established.

Fast Facts

Origin: Eurasia
Preferred habitat: Large warm-water rivers and impoundments.
Size: Commonly 24–30 inches and 3–10 pounds, but individuals of all species can reach 50+ pounds.

Method of introduction: All species were introduced from multiple pathways. Common and grass carps were introduced by government agencies; bighead and silver carps escaped from aquaculture facilities. Black carp are not established; they remain only within aquaculture facilities.

How far have they spread?

Common carp and grass carp have spread or have been introduced legally or illegally into nearly every state in the United States. Bighead and silver carps are spreading rapidly but are found mainly in the Mississippi River drainage basin. Black carp have been collected in the Mississippi River but are not thought to have established reproducing populations at this time.

What are UMESC scientists doing to help?

USGS scientist Lynn Bartsch

Through partnership with the Long Term Resource Monitoring Program, UMESC scientists have detected and monitored the spread of Asian carps in the Upper Mississippi River. In a joint effort with the USGS Center for Aquatic Resources Studies in Florida, UMESC scientists are conducting a risk assessment for bighead and silver carp. This assessment will be used by the U.S. Fish and Wildlife Service to determine if these species should be listed as injurious wildlife in the Lacey Act. If listed, importation and interstate transportation of these species would be prohibited.

Ongoing Studies:

Principal Investigator	Project Title
Cindy Kolar	A Biological Synopsis and Risk Assessment of Asian Carps of the Genus *Hypophthalmichthys*

Last updated on November 30, 2004
Contact the Upper Midwest Environmental Sciences Center
http://www.umesc.usgs.gov/invasive_species/asian_carp.html
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Center home page

MDNR 2005

Invasive Species of Aquatic Plants and Wild Animals in Minnesota

Annual Report 2004

for the year ending December 31

Minnesota DEPARTMENT OF NATURAL RESOURCES

Minnesota Department of Natural Resources
Invasive Species Program
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Submitted to
Environment and Natural Resources Committees
of the Minnesota House and Senate

This report should be cited as follows:
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Preface

Each year, by January 15, the DNR is required to prepare a report for the Legislature that summarizes the status of management efforts for invasive species (aquatic plants and wild animals) under its jurisdiction. Minnesota Statutes, Chapter 84D.02, Subd. 3, specify the type of information this report must include: expenditures; progress in, and the effectiveness of, management activities conducted in the state, including educational efforts and watercraft inspections; information on the participation of others in control efforts; management efforts in other states; and an assessment of future management needs. Additional sections have been added to this report to provide a thorough account of DNR's Invasive Species Program activities and other activities related to invasive species of aquatic plants and wild animals.

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Invasive Species of Aquatic Plants and Wild Animals in Minnesota: Annual Report for 2004

Summary

Hot topics in 2004

Asian carp - Expanding efforts to prevent their spread into Minnesota
The Minnesota Department of Natural Resources (DNR) is working with other agencies to prevent the spread of Asian carp into the state. Bighead, silver, and grass carp are moving toward Minnesota. The closest known populations are in Iowa waters of the Mississippi River and its tributaries. There is also concern that these carp will enter the Great Lakes through the canal that connects the Illinois River with Lake Michigan. Unlike many invasive species that are spread primarily through human actions, these fish spread via connected waters. Three key actions undertaken by the DNR were:

- A feasibility study, funded by Minnesota DNR, U.S. Fish and Wildlife Service, and Wisconsin DNR, was completed in March 2004. The study focused on technology that could deter the spread of Asian carp, and the associated cost.
- DNR's Deputy Commissioner met with Congressional staff in Washington D.C. to discuss potential federal funding for the construction of two dispersal barriers; a key recommendation of the feasibility study.
- Minnesota is working with other Great Lakes states to help fund the installation of a new fish dispersal barrier in the canal between the Illinois River and Lake Michigan to prevent the spread of Asian carp and other invasive species. The DNR helped fund a required non-federal match for the $9 million project.

Lake Ossawinnamakee - Preventing the spread of zebra mussels within the state
Lake Ossawinnamakee, and the surrounding Brainerd area, was the focus of intensive efforts to prevent the spread of zebra mussels. In 2003, zebra mussels were discovered in this central Minnesota lake, creating a new source for spread into other central Minnesota water bodies. Three pathways of movement were targeted including 1) upstream movement via boat traffic, 2) downstream movement via natural waterflow, and 3) unintentional transport on trailered watercraft visiting Lake Ossawinnamakee. The DNR took actions to interrupt each of these potential pathways:

- Risk from boat traffic traveling upstream to Kimball Lake was eliminated by placing large boulders in Kimball Creek. Area DNR staff also worked with county commissioners to pass an ordinance prohibiting boat traffic through Kimball Creek.
- The DNR paid for weekly copper sulfate treatments during the summer and early fall to kill zebra mussel veligers (free-floating immature zebra mussels) in the bay that feeds Pelican Brook. This outlet stream provides a connection to the Mississippi River. By killing veligers, the DNR reduced risk that zebra mussels would establish in downstream waters including the Mississippi River.

- Public awareness and watercraft inspection efforts were increased in the Brainerd area. Watercraft access inspectors spent 183 hours on Lake Ossawinnamakee, inspecting 244 boats. In the Brainerd area as a whole, watercraft inspections were increased by 57% (to1,063 hours).

Curly-leaf pondweed - Improving management

There has been an increase in the number of lake residents and lake associations requesting assistance with problems caused by curly-leaf pondweed. In response, the DNR has increased its efforts to 1) provide technical assistance to lake residents and 2) research/develop new methods of managing curly-leaf pondweed. In 2004, the DNR provided technical assistance for numerous curly-leaf pondweed planning and management projects including a major project on Lake Benton (Lincoln County). Staff also presented information at three curly-leaf management workshops organized by University of Minnesota Extension Services and the Minnesota Lakes Association. The DNR has been actively supporting research into new curly-leaf pondweed management techniques since 1997. A key question is: Can we be more aggressive in controlling this plant without harming fish and wildlife habitat? During 2004, DNR staff continued to evaluate several methods of curly-leaf pondweed management including endothall herbicide, fluridone herbicide, and winter drawdown. As new methods of curly-leaf management become available, the DNR will evaluate their effectiveness in Minnesota lakes.

Status of Invasive Species in Minnesota: 2004

Aquatic Plants

- **Eurasian watermilfoil** was found in eight new water bodies, including Leech Lake in Cass County. This brings the total number of infestations to 160 water bodies (Figure 1).
- **Purple loosestrife** has been documented in more than 2,200 locations statewide. Management efforts are being carried out on nearly half of these locations with biological controls or herbicide applications.
- **Curly-leaf pondweed** is widespread; it is known to occur in 702 Minnesota lakes in 69 counties.
- **Flowering rush** is currently found in 16 lakes. The most problematic area of the state is near Detroit Lakes where the Pelican River Watershed District is leading ongoing management efforts.

Aquatic Animals

- No **Asian carp** (bighead, grass, silver, or black carp) were caught in Minnesota in 2003, a lone bighead carp (*Hypophthalmichthys nobilis*) was caught in Lake Pepin.
- No new **zebra mussel** infestations were discovered. To date, zebra mussels are found in two inland lakes, Lake Superior, the Mississippi River (below the Twin Cities), and the lower St. Croix River.
- **Spiny waterflea** were collected in four new lakes this year. Researchers from the University of Minnesota-Duluth found this non-native zooplankton in samples from Flour, Greenwood, McFarland and Pine lakes, all in Cook County. The

interconnections among many lakes in this area of the state may allow this species to spread quickly in northeastern Minnesota.

- No ***Daphnia lumholtzi*** were collected from Lake Pepin. However, in 2003, samples showed clear evidence of reproduction. Cooler water and higher flows may have prevented this sub-tropical invasive species from appearing this season.
- **Tubenose goby** populations are increasing in the St. Louis River estuary. The tubenose goby was first discovered in 2001 and was originally expected to be less invasive than the round goby.

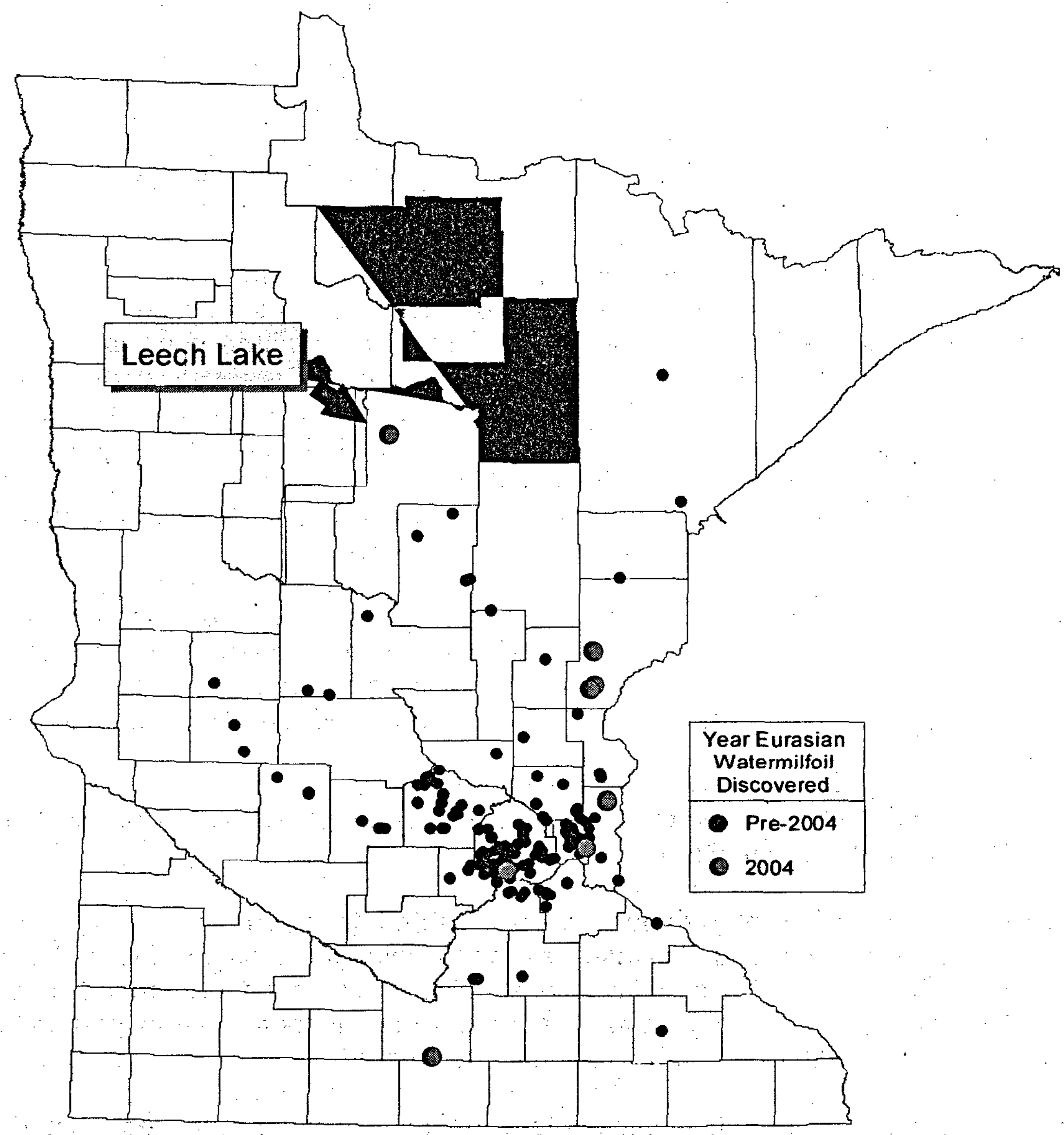

Figure 1. Eurasian watermilfoil infestations in Minnesota

The Problem

Invasive species have the potential to cause serious problems in Minnesota. Evidence from numerous locations in North America and from around the world demonstrates that these non-native species threaten the state's natural resources and local economies that depend on natural resources.

The Response

To address the problems caused by invasive species, the 1991 Minnesota Legislature directed the DNR to establish the Invasive Species Program and to implement actions to monitor and manage invasive species of aquatic plants and wild animals.

The three primary goals of the Invasive Species Program are to:

1. Prevent introductions of new invasive species into Minnesota;
2. Prevent the spread of invasive species within Minnesota;
3. Reduce the impacts caused by invasive species to Minnesota's ecology, society, and economy.

1. Prevent introductions of new invasive species into Minnesota

The best way to manage invasive species is to prevent their introduction into new habitats. Prevention efforts involve a variety of interrelated activities including: **risk assessment, education, regulations,** and **enforcement**. Risk assessments are focused on determining whether an invasive species will survive in Minnesota, the problems it might cause, and the pathways through which it might reach our state. Education efforts help explain the risks posed by invasive species and steps that people and businesses can take to prevent new introductions. Regulations help to prevent activities or practices that carry a high risk of introduction.

A new brochure, *Help Stop Aquatic Hitchhikers*, was produced. Designed for boaters, anglers, and other outdoor recreationists, the publication provides simple steps that individuals can take to help stop the spread of invasive plants and animals. Distribution efforts are ongoing through sport and outdoor shows, special events, information kiosks, and tourist information centers.

Several initiatives were carried out to prevent the spread of Asian carp into Minnesota (see Management of Asian Carp).

2. Prevent the spread of invasive species within Minnesota

Efforts to prevent the spread of invasive species within Minnesota are focused on people and their habits. Once an invasive species becomes established in Minnesota's lakes and rivers, a primary means for its spread is the unintentional transport on boats, trailers, and other water-related recreational equipment.

The DNR hired 40 watercraft inspectors to work at public water accesses, primarily on lakes and rivers already infested with invasive species. They inspect boats, inform owners about the problems invasive species can cause, and demonstrate actions that boaters can take to prevent spread. This year, inspectors worked more than 20,000 hours and inspected over 50,000 watercraft during the open water season. Inspections were conducted at 21 fishing tournaments and continued through October in order to reach waterfowl hunters. The DNR also worked cooperatively with five lake associations and citizen groups to increase inspection efforts. These citizen groups funded additional hours of inspection at specific accesses while the DNR provided training, equipment, and supervision. For example, the Lake Minnetonka Conservation District funded an additional 946 hours of inspection on five Lake Minnetonka accesses.

Conservation officers spent 2,396 hours enforcing the invasive species laws and rules. Statewide, a total of five civil citations, 20 written warnings, and three summons were issued to individuals for violations of invasive species laws and rules.

Several initiatives were carried out to prevent the spread of zebra mussels from Lake Ossawinnamakee in north central Minnesota (see Management of Zebra Mussels).

3. Reduce the impacts caused by invasive species
Current efforts to reduce the harmful effects of invasive species are primarily focused on the management of aquatic plants.

Eurasian watermilfoil. To reduce the problems caused by Eurasian watermilfoil (milfoil), the Invasive Species Program worked closely with lakeshore owners, lake associations, local units of government, and others to manage milfoil with herbicides and mechanical harvesting. The amount of funding offered to cooperators for control of milfoil was increased. There was an increase in the total amount of control costs reimbursed by the DNR, though the number of cooperators seeking reimbursement declined. The DNR has been conducting research to evaluate the feasibility of using fluridone herbicide to control milfoil in Minnesota lakes. Research completed in 2004 suggests that low rates of fluridone reduce milfoil abundance in nutrient rich lakes, but also cause decreases in beneficial native plants.

Purple loosestrife. Both herbicides and biological control methods (the use of insects that eat purple loosestrife) are being used to manage this invasive plant. Since 1992, more than eight million leaf-eating beetles have been released in 800 of the 2,200 known purple loosestrife infestations. Severe defoliation of purple loosestrife by the beetles was observed on more than 20% of sites monitored in 2004. These efforts have been supported in large measure with funding appropriated by the Minnesota Legislature as recommended by the Legislative Commission on Minnesota Resources (LCMR) and cooperation from local and county governments to rear and release the beetles statewide.

Coordination and cooperation among groups that manage invasive species

The successes achieved in preventing and managing invasive species results from cooperation among various organizations. Management of milfoil and purple loosestrife involves cooperation with local lake associations and local units of government. Efforts to prevent introductions of new invasive species into Minnesota often involve the participation of DNR staff in state and regional groups such as the Minnesota Invasive Species Advisory Council and the Mississippi River Basin Panel on Aquatic Nuisance Species. Involvement with these groups promotes partnerships, develops uniform messages in educational products, and ensures sharing of information about new and existing invasive species.

Revenue and Expenditures

The primary funding source for the Invasive Species Program is a $5 surcharge on watercraft registration of in Minnesota. This fee generates approximately $1.2 million per year. The 2003 Minnesota Legislature appropriated additional funding to the DNR ($380,000 in Fiscal Year 04 and $440,000 in Fiscal Year 05) to expand existing program efforts. Most of the funding (~70%) is spent on education, watercraft inspections, enforcement, and management/control efforts (Figure 2). Additional funding, primarily for research projects, was received from the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, and the Minnesota Legislature as recommended by the LCMR.

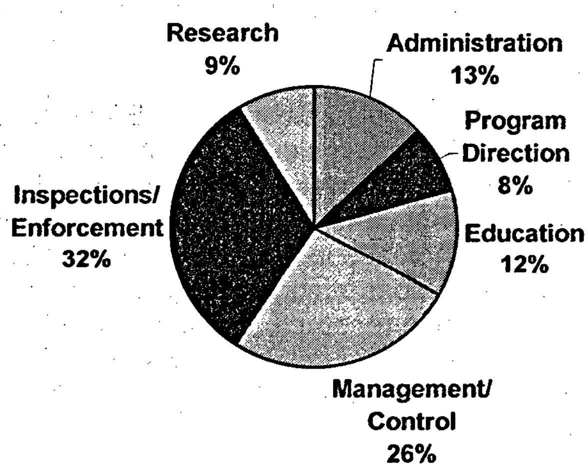

Figure 2. DNR's Invasive Species Program spending in fiscal year 04 by major categories.

Plans for the future

Continued investment in a comprehensive program to protect Minnesota's natural resources from future damage due to invasive species is paramount. The increase in funding provided by the 2003 Legislature has allowed prevention and management efforts to be expanded. The new funding is being used to:

- expand education efforts
- maintain the level of watercraft inspections at 20,000 hours
- increase grant funding to cooperators who are managing milfoil on infested lakes
- provide grants to improve curly-leaf pondweed management
- fund research to improve control efforts

The DNR plans to continue working with other agencies and groups who are members of the Minnesota Invasive Species Advisory Council to develop comprehensive strategies and actions that will position Minnesota to better address the multitude of invasive species issues.

Introduction

Overview of DNR's Invasive Species Program

Minnesota's Invasive Species Program was established in 1991 and was the first program of its kind in the nation. The Minnesota Department of Natural Resources (DNR) has responsibility to develop and coordinate a statewide program to prevent the spread of invasive species of wild animals and aquatic plants. This comprehensive program was preceded by single species programs. In 1987, the DNR was designated the lead agency for control of purple loosestrife, an invasive plant of particular concern for the state's wetlands. In 1989, the DNR was officially assigned a coordinating role for Eurasian watermilfoil control (Minnesota Statutes 84D.02, Subd. 2).

The Invasive Species Program addresses many invasive species that are present in Minnesota such as Eurasian watermilfoil, purple loosestrife, zebra mussel, and ruffe (see Table 1). The DNR Invasive Species Program also attempts to prevent the introductions of invasive species that have the potential to move into Minnesota such as hydrilla, water chestnut, and Asian carp. To do so, the program identifies potentially invasive species in other areas of North America and the world, predicts pathways of spread, and develops and implements solutions that reduce the potential for introduction and spread (see Risk Assessment). Prevention efforts are often undertaken with other states, agencies, and partners with similar concerns.

Other State Invasive Species Control Programs

The Minnesota Department of Natural Resources (DNR) and the Minnesota Department of Agriculture (MDA) administer prevention and control programs for other invasive species (harmful exotic species) in Minnesota. The DNR's Division of Forestry, working in cooperation with the MDA, is charged with surveying and controlling forest pests, including non-native organisms such as the gypsy moth and several bark beetles. A separate annual report is prepared by the DNR's Forest Health Protection Team. MDA is responsible for the state's noxious weed and seed regulations that apply primarily to terrestrial plants, although as of 2003, the implementation of the noxious weed law is the responsibility of local agencies. Information about control, prevention, and regulatory programs for several terrestrial invasive species, plant pests, and noxious weeds may be obtained from the MDA. University of Minnesota Sea Grant Extension has an Invasive Species Information Center in Duluth. The Center promotes education and outreach to prevent the spread of aquatic invasive species in the state.

Program Staff and Other DNR Support

Most activities of the Invasive Species Program are conducted or directed by a nine-person staff from DNR's Division of Ecological Services. Up to 40 seasonal watercraft inspectors are hired each year to inspect boats at public water accesses. Current program staff, their principal areas of responsibility and activity, and their phone numbers are listed in Appendix A. Staff from the DNR Division of Fish and Wildlife, Division of Enforcement, as well as the Bureau of Information and Education contribute significantly to the implementation and coordination of invasive species activities.

Table 1. DNR's Invasive Species Program efforts that address specific invasive species.
A = public information and education, B = watercraft inspections to prevent spread,
C = population surveys and monitoring, D = control to reduce nuisance,
E = control to reduce populations/escapes, F = research on biology and management,
G = regulations

Invasive Species of Aquatic Plants and Wild Animals in Minnesota	Efforts of DNR's Invasive Species Program						
	A	B	C	D	E	F	G
Aquatic Plants							
Flowering rush (*Butomus umbellatus*)	X	X	X	X	X	X	X
Purple loosestrife (*Lythrum salicaria*)	X		X		X	X	X
Eurasian watermilfoil (*Myriophyllum spicatum*)	X	X	X	X	X	X	X
Other non-native aquatic plants	X		X		X	X	X
Curly-leaf pondweed (*Potamogeton crispus*)	X	X	X	APM		X	X
Animals							
Common carp (*Cyprinus carpio*)			F		F/W	W	X
Ruffe (*Gymnocephalus cernuus*)	X	X	F/O		NIF	X	X
Round goby (*Neogrobius melanstromus*)	X	X	F/O		NIF		X
Spiny waterflea (*Bythotrephes longimanus*)	X	X	F				X
Zebra mussel (*Dreissena polymorpha*)	X	X	X			X	X
Rusty crayfish (*Orconetes nusticus*)	X						X
Mute swan (*Cygnus olor*)			X		X		X

APM - Individuals or groups apply for aquatic plant management permits
F - DNR Fisheries monitors this species
F/O - DNR Fisheries and other agencies monitor this species
F/W - DNR Fisheries and/or Wildlife occasionally manage this species at priority sites
NIF - Inland waters will be addressed as outlined in a Nonindigenous Fish (NIF) plan
W - DNR Wildlife is involved with research on this species

Divisions of Ecological Services and Fish and Wildlife

Pesticide enforcement specialists from Ecological Services and Aquatic Plant Management Specialists in DNR Fisheries assist with the management of various invasive plants including purple loosestrife, Eurasian watermilfoil, and flowering rush. In addition to these staff, other individuals from the Division of Fish and Wildlife and the Division of Ecological Services contribute by providing biological expertise, assisting with control efforts, conducting inventory and public awareness activities, and providing additional avenues for public input.

Division of Enforcement
Conservation officers are responsible for enforcing the state regulations regarding invasive species of aquatic plants and wild animals. A regional enforcement supervisor acts as invasive species enforcement coordinator within the Division of Enforcement to assist in scheduling, executing, and reporting on enforcement activities related to invasive species. A chapter describing enforcement activities is included in this report (see Enforcement).

Bureau of Information and Education
Susan Balgie and other staff from the Bureau of Information and Education provide support for the Invasive Species Program's public awareness activities (see Education and Public Awareness).

Participation in Statewide, Regional, and National Groups

The DNR Invasive Species Program and other agencies in the state participate in statewide groups such as the Minnesota Invasive Species Advisory Council, the Noxious Weed Potential Evaluation Committee, and the Weed Integrated Pest Management Group.

The DNR Invasive Species Program and others in the state participate in regional and federal activities regarding harmful invasive species. The increasing number of national and regional entities and activities related to invasive species have made it much more difficult to represent Minnesota's interests at the regional and national level.

Minnesota's representative to the Great Lakes Panel on Aquatic Nuisance Species is Jay Rendall, the Invasive Species Program Coordinator. Doug Jensen from Minnesota Sea Grant is the alternate member and represented the state at Great Lakes Panel meetings in 2004. Participation on this regional panel helps keep Minnesota informed of regional and federal efforts regarding harmful invasive species and provides a voice for Minnesota interests. The Mississippi Interstate Cooperative Resources Association (MICRA) convened a Mississippi River Basin Panel on aquatic nuisance species. Jay Rendall was selected by MICRA to chair the new panel during its initial year. Jay represented the panel at the ANS Task Force meeting and Asian Carp Work Group meeting in May 2004.

Program staff are also involved with the following statewide or regional groups: Gary Montz and Jay Rendall - the St. Croix River Zebra Mussel Task Force (see Appendix B); Luke Skinner - national garlic mustard biocontrol working group.

Expenditures

Funding Sources

Funding for activities conducted by the Invasive Species Program comes from a variety of state, federal, and local sources.

State Funds

The primary funding source is a $5 surcharge on the registration of watercraft in Minnesota. "Surcharge" receipts are deposited in the Water Recreation Account and appropriated by the Legislature. Surcharge receipts currently generate sufficient funds to allow an annual appropriation of approximately $1,200,000 (Table 2). The 2003 Legislature, at the Department's request, expanded funding for the Invasive Species Program by appropriating additional funding from the Water Recreation Account. This funding was from the "regular" watercraft license receipts (Table 2). Funding was increased by $380,000 in FY04 and $440,000 in FY05.

Table 2. State and local funding (in thousands of dollars) received by the Invasive Species Program, fiscal years 2003, 2004, and 2005.

Fiscal Year	Water Recreation Account		Legislative Commission on Minnesota Resources[1]	Local Contributions	Total
	Surcharge	Regular			
2003	1,191	0	45	11	1,247
2004	1,202	380	55	19	1,656
2005	1,201	440	54	17	1,712

[1] State appropriations, as recommended by the LCMR, from the Environment and Natural Resources Trust Fund or the Minnesota Resources Fund or both.

Over the last decade, significant support for invasive species research has been appropriated by the Minnesota Legislature from the Environment and Natural Resources Trust Fund and the Minnesota Resources Fund as recommended by the Legislative Commission on Minnesota Resources (LCMR). Recommendations by the LCMR are based on results of a competitive process. During the FY04/05 biennium, funding has been provided for a project focused on European buckthorn species, two high-priority terrestrial invasive plants. This project is a joint effort by DNR and the Minnesota Department of Agriculture (MDA).

Federal Funds

The DNR seeks funding from federal sources for a variety of program activities. Recent projects that have been funded are shown in Table 3. For example, funds from the U.S. Fish and Wildlife Service (USFWS) support the implementation of the St. Croix Interstate Management Plan for aquatic invasive species. A portion of DNR's public awareness efforts and zebra mussel monitoring dives on the St. Croix River are paid from these funds. Two grants have been approved by the U.S. Environmental

Protection Agency (USEPA) to support research on the biological control of European buckthorn. Funding from the U.S. Forest Service (USFS) was also obtained to initiate a garlic mustard biological control project. These federally-funded projects often operate on timelines that are different from the state's fiscal year.

Table 3. Recent proposals submitted by the Invasive Species Program that received federal funding.

	Federal Grant			
Category	**Federal Fiscal Year[1] Grant Awarded**	**Calendar Year(s) Used**	**Grant Amount (1000's of $)**	**Source**
Implement St. Croix management plan for aquatic nuisance species				
	1998	1999	20	USFWS
	1999	2000	19	USFWS
	2000	2001	85	USFWS
	2001	2002	85	USFWS
	2002	2003	80	USFWS
	2003	2004	60	USFWS
	2004	2005	71	USFWS
Research on biological control of European buckthorn				
	2001	2002-03	75	USEPA
	2003	2004-05	50	USEPA
Research on biological control of garlic mustard				
	2003	2004-06	105	USFS
	2004	2004-06	65	USFS

[1] The federal fiscal year begins on October 1 and ends on September 30.

Local Funds

Local groups work with the DNR to manage invasive aquatic species and, in some cases, provide funds to expand planned efforts (Table 2). During 2004, the Bay Lake Association, Plantagenet Lake Association, Pike Lake Association, Kandiyohi County, and the Lake Minnetonka Conservation District provided funding so that the number of watercraft inspections on specific lakes could be increased. See the Watercraft Inspections and Awareness Events chapter for a more detailed account of these cooperative efforts.

Timeframe

This report covers activities in calendar year 2004, which includes the last half of the Minnesota fiscal year 2004 (FY04), Jan. 1 - June 30, 2004, and the first half of fiscal year 2005 (FY05), July 1 - Dec. 31,2004. To provide a comprehensive review of expenditures that occurred during calendar year 2004, we report both expenditures that were incurred in FY04 and those planned in FY05.

Cost Accounting

The DNR has a detailed cost accounting system that is used to track how funds are spent. All staff time and expenditures are coded. The coding allows us to sort work/expenditures by the type of activity being undertaken (e.g., management activities, public awareness efforts) and/or by what invasive species the work is focused on.

Minnesota Statute (M.S. 84D.02 Subd. 6) identifies five expenditure categories that must be reported. Those categories are Administration, Education/Public Awareness, Management/Control, Inspections/Enforcement, and Research. A sixth category, Program Direction, has been added to cover a variety of program-wide or "big-picture" activities that do not fit easily into the reporting categories required by statute. Expenditures within each category are subdivided to reflect the program activities described in the following chapters.

Administration

Administration includes *Support Costs* assessed by the Division of Ecological Services for general office supplies, office rent, telephones, postage, workers' compensation fees, computer support fees, and the state accounting system fees. *Clerical* costs and *Administrative Support* costs that fund administrative staff that work for the divisions of Fish and Wildlife and Ecological Services are shown separately. Administration also includes *Other Work*; staff time spent by invasive species program staff when they participate in activities that are not related directly to program work, e.g., training or assistance provided to other division or department projects, and a prorated portion of the salary of division staff that serve on regional management teams. Finally, all *Staff Leave Time* used for holidays, sick leave, or vacations (slightly more than 4% of the budget shown in Table 4) is included as an administrative expense.

Program Direction

This category includes a variety of activities and expenditures. *State coordination* includes general program planning, preparation of state plans and reports, and attendance at public meetings. Program staff meet with groups such as the Minnesota Lakes Association (MLA) and Lake Minnetonka Conservation District (LMCD) to discuss state activities and to coordinate efforts. Program staff also are members of state-level coordinating groups, such as the Minnesota Invasive Species Advisory Council (MISAC), which are included here. Expenditures primarily represent staff time spent on these activities. *Regional and federal coordination* includes staff time and out-of-state travel expenses to work with regional and federal partners on invasive aquatic species issues. Examples from 2004 include: the Great Lakes and Mississippi River Basin panels on Aquatic Nuisance Species (ANS), the Council of Great Lakes Governors' ANS Initiative, the Natural Areas Association's Invasive Species Workshop, and a Midwest Regional Workshop on ANS Regulations and Enforcement. Finally, *Equipment* *and Services* includes fleet costs not assigned to a specific activity and the cost to purchase and repair boats, trailers, computers, and similar items.

Education/Public Awareness
Expenditures in this category include staff time, in-state travel expenses, fleet charges, mailings, supplies, printing and advertising costs, and radio and TV time to increase public awareness of invasive aquatic species. The costs of developing and producing pamphlets, public service announcements, videos, and similar material are included, as are the costs of developing and maintaining invasive species information on the DNR's Web site.

Management/Control
Expenditures in this category include staff time, in-state travel expenses, fleet charges, commercial applicator contracts, and supplies to survey the distribution of invasive aquatic species in Minnesota and to prepare for, conduct, supervise, and evaluate control activities. When the management activity is focused on a specific invasive aquatic species, e.g., Eurasian watermilfoil, purple loosestrife, or zebra mussels, detailed expenditure information for that species is shown. Funds provided to local government units and organizations to offset the cost of Eurasian watermilfoil management efforts are also included.

Inspections/Enforcement
Expenditures in this category include the costs that conservation officers incur enforcing invasive species rules and laws, the costs of implementing watercraft inspections at public water accesses, and staff time and expenses associated with promulgation of rules, development of legislation, conducting risk assessments, and other efforts to prevent the introduction of additional invasive species into Minnesota.

Research
Expenditures in this category include staff time, travel expenses, fleet charges, supplies, and contracts with the University of Minnesota and other research organizations to conduct research studies. These studies include efforts to develop new or to improve existing control methods, better understanding of the ecology of invasive species, develop better risk assessment tools, and evaluate program success. When research is focused on a specific invasive species, such as Eurasian watermilfoil, purple loosestrife, or curly-leaf pondweed, detailed expenditure information for that species is shown.

Fiscal Year 2004 (FY04)

Expenditures on invasive species activities during FY04 (July 1, 2003 - June 30, 2004) totaled $1,797,000 (Table 4). Expenditures from the Water Recreation Account, the largest single source of funding, are listed along with spending from other accounts. For this report, spending from the "Surcharge" and "Regular" portions of the Water Recreation Account have been combined into a single column.

The Invasive Species Program manages other accounts that also support program activities. An example is revenue from the sale of public awareness material. This revenue is deposited in a "Publications Account" and is used to fund future public awareness efforts. Grants received from various state or federal funding sources, such as LCMR recommended appropriations and the USFWS are other examples. As is shown in Table 4, most program activities focused on the management of non-native, invasive terrestrial plants are funded by grants from other organizations.

The final expenditure category reflects work by non-Program staff in the divisions of Ecological Services, Fish and Wildlife, and Enforcement who occasionally do invasive species work as part of their regular DNR jobs. In FY04, major expenditures in this category included $32,000 of invasive species work coded to the Game and Fish Fund (primarily reflecting the work of aquatic plant management specialists in DNR Fisheries); $26,000 to the Division of Enforcement (reflecting enforcement efforts that were not reimbursed by Invasive Species Program funds); and $22,000 provided by the Division of Ecological Services to help support buckthorn research. This summary may not reflect the contribution of all DNR staff that provide assistance to manage non-native invasive aquatic plant and wild animal species.

The $1,497,000 of "Water Recreation Account" expenditures by the Invasive Species Program during FY04 (Table 4) was slightly less than the $1,582,000 available. FY04 funds remaining at the end of year "roll over" and will be spent during FY05. Figure 3 provides a broad outline of how the $1.497 million was spent; a detailed breakdown of spending by category is shown in Table 4. As in past years, the Inspections/ Enforcement category ($478,000) and Management/Control category ($390,000) represent the two largest segments of the budget; these two categories accounted for 58% of "Water Recreation Account" funds expended in FY04. Also as in past years, the invasive species that received the largest focus (based on dollars spent) was Eurasian watermilfoil ($194,000 of targeted spending). Other invasive species that received substantial funding included: zebra mussels ($108,000), purple loosestrife ($77,000), and curly-leaf pondweed ($63,000). Individual chapters of this report provide details on the activities accomplished with those funds.

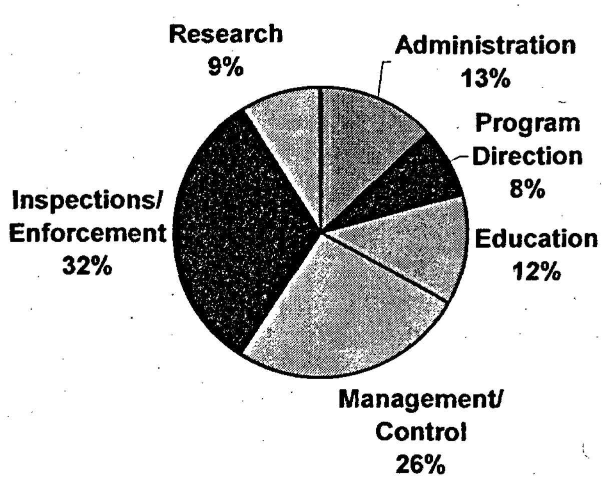

Figure 3. Invasive Species Program spending (Water Recreation Account only) in FY04 by major categories.

The Department sought the increase in watercraft license funding that occurred in FY04 to meet specific objectives. Those objectives included:

1) expanding grants offered to local groups/communities to offset the cost of managing invasive aquatic plants;
2) increasing funding available to the DNR's Division of Enforcement so that 2,000 hours of Enforcement effort is focused on invasive species activities each year;
3) allowing the Department to continue to conduct 20,000 hours of watercraft inspection efforts annually even though the number of lakes and the geographical area where inspections occur are expanding;
4) expanding the amount of technical assistance provided to lake groups that are managing invasive aquatic plants; and
5) expanding funding on research efforts targeted specifically at improving control options.

The increased funding available in FY04 allowed the Program to implement a number of those activities. Specific accomplishments included:

1) increasing public awareness efforts while continuing to provide 20,000 hours of watercraft inspections;
2) hiring an additional staff person in Brainerd to provide technical assistance to lake groups;
3) responding aggressively when zebra mussels were discovered in Lake Ossawinnemakee in Crow Wing County (spending on zebra mussel management and research efforts increased);
4) taking steps to identify and evaluate options designed to slow the movement of Asian carp into Minnesota waters (FY05 funds will help fund a dispersal barrier to limit Asian carp spread into the Great Lakes);
5) increasing research and management efforts targeted at curly-leaf pondweed.

Two of the objectives originally identified when the new funding was proposed were not achieved in FY04. Although the amount of grant funding offered to lake groups that manage Eurasian watermilfoil was increased, the amount of funding actually spent did not rise. The Eurasian watermilfoil chapter in this report provides a more in-depth discussion of this topic. Restructuring the current grant program may be necessary to meet the original objective. In addition, the Department decided that it was not appropriate at this time to reallocate additional revenue to the Division of Enforcement.

Fiscal Year 2005 (FY05)

Since this report is due in the middle of FY05, projected expenditures for this year are also reported (Table 4). Expenditures in some categories will increase because of the additional funding appropriated by the 2003 Legislature (see Table 2) and the FY04 funding that carried over. The following chapters describe in detail the activities that were conducted during 2004 with FY04 and FY05 funds.

Table 4. Invasive species related expenditures in fiscal year 2004 (FY04) and projected expenditures in fiscal year 2005 (FY05) (in thousands of dollars).

	Water Recreation Account		Other Funding Sources	
Categories of Expenditures	**FY04**	**FY05**	**FY04**	**FY05**
Administration				
Division Support Costs	33	37	--	--
Other Work: Staff Time and Regional	55	50		
Representation	67	67		
Staff Leave Time (Vacation, Holiday, Sick)	--	15		
Clerical	41	41		
Administrative Support				
Subtotal	**196**	**210**		
Program Direction				
State coordination	80	80	[1]14	[1]7
Support regional/federal activities	13	13		
Equipment and services	22	22		
Subtotal	**115**	**115**	**14**	**7**
Education				
Radio spots, TV, Web Site development	183	214	--	[1]50
Subtotal	**183**	**214**	**0**	**50**
Management/Control				
General	68	70	[1]32	[1]30
Eurasian watermilfoil	126	200		
Purple loosestrife	60	60		
Zebra mussel	98	80		
Curly-leaf pondweed	29	60		
Flowering rush	3	3		
Asian carp	6	68		
Terrestrial invasive plants	-	-	[1]89	[1]141
Subtotal	**390**	**541**	**121**	**171**
Inspections/Enforcement				
Watercraft inspections	350	360	--	--
Enforcement - access checks	56	56	[1]26	[1]30
Prevention - laws/risk assessments	72	70		[1]1
Subtotal	**478**	**486**	**26**	**31**
Research				
General	9	10	-	-
Eurasian watermilfoil	68	60	9	-
Purple loosestrife	7	7	-	-
Zebra mussel	10	10	-	-
Curly-leaf pondweed	34	40	-	-
Flowering rush	2	7	-	-
Other invasive plants	--	--	-	-
European buckthorn	3	3	[1,2,3]90	[1,2,3]90
Garlic mustard	2	1	[1,2]40	[1,2]60
Asian carp	--	22		
Subtotal	**135**	**160**	**139**	**150**
Total	**1497**	**1726**	**300**	**409**

[1]Other DNR funding, [2]LCMR funding, [3]Federal funding

Education and Public Awareness

Introduction

Issue

Public awareness of invasive species is one of the key strategies used to limit their introduction and spread. Since 1992, the DNR's Invasive Species Program has made substantial efforts to create and maintain a high level of public awareness and understanding about invasive species. An annual communications plan is developed by Program staff to identify activities and priorities.

Goals

Public awareness efforts in Minnesota are designed to:

- Make the public and certain businesses aware of the negative environmental impacts caused by some invasives;
- Help these groups identify and report findings of specific invasive species;
- Outline actions that boaters, anglers, seaplane pilots, waterfowl hunters, water gardeners, riparian landowners, bait dealers, and others must do to reduce the spread of these invasives; and
- Enhance understanding of management options.

Progress in Public Awareness - 2004

Key components of this year's communication efforts included radio and television advertising, public service announcements, printed materials, press releases, media contacts, newspaper ads, information on DNR's Web site, staffing at sports shows and other major events, informational signs at public water accesses, and training.

Radio

Radio was used in 2004 to reach boaters and anglers in several ways. Paid advertising was used on major stations in the Twin Cities and Brainerd during the weeks preceding the Fishing Opener, Memorial Day, and Fourth of July. The stations were selected for their listener profiles which correspond with those of boat owners. Paid advertising was also used on Minnesota News Network (MNN), reaching an additional 73 affiliate stations throughout greater Minnesota. In late summer, a special effort was made in the Duluth market and southeastern Minnesota (Rochester and Winona) where zebra mussel infestations occur.

In addition, public service announcements (PSAs) were made available to Minnesota radio stations along with communication encouraging program managers to play these announcements. The PSAs are available in two audio formats from the DNR's Web site making them readily accessible to station managers at any time and eliminating the need to mail tapes each year (www.dnr.state.mn.us/news/psas/index.html).

Television, video, and informational materials

Paid television advertising was used this year in the Duluth market during July and August (WDIO-TV, an ABC-affiliate station) to remind viewers of the continuing concerns about zebra mussels in the area. Two spots aired during morning and evening newscasts leading into popular outdoors segments including "Sportsman's Notebook," "Gone Fishing'," "Up North," and "Pro's Pointers."

In addition, spots concerning zebra mussels and Eurasian watermilfoil were aired on metro area cable stations to coincide with outdoor programs and Twins baseball coverage.

A newspaper advertising campaign was completed in 2004. The ad design incorporated the "Stop Aquatic Hitchhikers" national campaign logo and listed four simple steps that boaters and anglers could take to help stop the spread of aquatic invasive species. The ad ran in the outdoor or recreation sections of newspapers in targeted areas of the state including Brainerd, Duluth, Rochester, Twin Cities, and Winona during July and August. In addition, the ads ran in several specialty newspapers reaching boaters and tourists.

A new brochure, *Help Stop Aquatic Hitchhikers*, was produced this year. The publication provides simple steps that recreationists can take to help stop the spread of aquatic hitchhikers. Distribution efforts are ongoing to sport and outdoor shows, special events, information kiosks, and tourist information centers.

The 2004 *Minnesota Fishing Regulations* included a section on harmful invasive aquatic species. Descriptions and illustrations of these harmful invasives were provided along with a summary of invasive species laws, a list of infested waters, and information about how to stop the spread of invasives. More than one million copies of the fishing regulations were printed and distributed.

The *Minnesota Boating Guide* also included a page of information on how to prevent the accidental transport of harmful invasive plants and animals. The guide is updated annually and was distributed this year to more than 300,000 boaters.

"Contain those Crawlers," a poster and postcard about the harmful effects of earthworms on Minnesota's forest floors and "Harmful Exotic Plants," fact sheets designed for aquatic plant sellers and water gardeners were distributed through a variety of channels including the Northwest Sportshow and the Minnesota State Fair. The earthworm materials were developed and/or distributed by DNR the Native Plant Society, and other partners.

Information about harmful invasive species was included in the 2004 edition of the *Explore Minnesota Fishing Guide*, a publication of the Minnesota Office of Tourism. The guide targets anglers traveling to Minnesota and is widely distributed throughout the Midwest at major outdoor sports shows including those held in Chicago, Milwaukee, Kansas City, Omaha, Des Moines, Sioux Falls, and Fargo. It is also distributed at travel information centers across Minnesota and some Minnesota outdoor retailers.

News releases

News releases alerting the public about harmful invasive species in the state were distributed throughout the year to all major media outlets in Minnesota. In addition, several interviews with Minnesota media resulted in expanded television, radio, and print coverage this year, helping to raise awareness about these issues. Major daily and weekly newspapers ran articles generated from the news releases and several of these articles were syndicated to other newspapers around the country.

The DNR also produced and distributed several video news releases (VNRs) to television stations in ten markets in greater Minnesota. The VNRs provided information on Asian carp and water gardening, for example.

DNR Web site
The DNR's Web site pages covering invasive species issues were updated (www.dnr.state.mn.us/ecological_services/invasive.html). The site includes an overview of the Invasive Species Program as well as information on individual programs and staff. A summary of Minnesota's invasive species laws, as well as lists of harmful invasive species and infested waters, and field guides to aquatic plants and aquatic invasive plants and animals are available online. The site also provides a list of publications and resource materials in addition to links to related web pages and sites for other partnering agencies.

Shows and fairs
Invasive Species Program staff participated in the Northwest Sportshow and the Minnesota State Fair to distribute literature and information. Watercraft inspectors staffed the invasive species display throughout the State Fair providing a venue for visitors to ask specific questions about invasive species while visiting the exhibit. An estimated 750,000 people visit the DNR's exhibits at the Northwest Sportshow and the Minnesota State Fair each year. Staff also participated in a number of additional events this year including the Minnesota Muskie Expo and the Minnesota Resort and Campground Association's fall conference.

Public water accesses
DNR watercraft inspectors completed 20,426 hours of inspection (see Watercraft Inspections and Awareness Events) providing boaters with information and tips on ways to reduce the spread of invasive species. The DNR attempts to place "Help Prevent the Spread" and "Stop and Remove" signs at all public water accesses. Additionally, "Exotic Species Alert" signs are placed at accesses to infested waters.

Presentations
Presentations were given to a variety of audiences including university classes, high schools, conferences, annual meetings, training sessions, service and professional organizations, and lake associations.

Effectiveness of Public Awareness Efforts

Background
The DNR and Minnesota Sea Grant have conducted several surveys to help assess the effectiveness of public awareness efforts conducted in Minnesota. In 1994, Minnesota Sea Grant conducted a survey of boaters in Minnesota, Wisconsin, and Ohio to evaluate and compare regional differences in educational and awareness programs. A report (Minnesota Sea Grant, 1994) summarizing the survey results said, "More effort has been expanded and a greater variety of techniques have been used in getting the [invasive] species message out in Minnesota than in the other two states

surveyed. Survey results indicate Minnesota boaters are more knowledgeable about [invasive] species issues and have already changed their behavior to a greater extent (to prevent the spread of [invasives]) than boaters in the other two states. This suggests that educational programs are effective."

In 1996, the DNR funded a follow-up survey of boaters in the Minneapolis/St. Paul metro area (DNR, 1996). Also in 1998, a survey of boaters in the Brainerd area was conducted (DNR, 1999). Both these surveys indicate that awareness about invasives has continued to increase. In 2004, watercraft inspectors (see Watercraft Inspections and Awareness Events) continued to find high levels of public awareness of invasives by boaters throughout Minnesota. Information from past surveys was used to guide development of annual public awareness efforts and maximize their effectiveness.

Effectiveness and boater survey results

A 2000-2001 mail survey coordinated by Minnesota Sea Grant, with cooperation from the Invasive Species Program and conducted through the University of Minnesota Research Center, was sent to 4,000 boaters in five states: Minnesota, Vermont, Ohio, Kansas, and California. Results from Minnesota show that signs at water accesses, information in fishing and boating regulation booklets, articles in newspapers, and news stories on TV, as well as regulations and enforcement efforts, are the most effective methods to inform boaters and to encourage them to take precautions. The survey results show that messages are translating into action. Ninety percent of Minnesota boaters responding to the question in the survey said they took action (Armson, 2001), an increase over a similar Sea Grant survey in 1994 when 70% of Minnesota boaters said they took action. The survey also showed considerable differences in the percent of boaters who took action in other states: 82% in Vermont; 46% in Ohio; 40% in California; and 30% in Kansas. These differences are proportional to the level of boater public awareness efforts and the variety of methods used in those states.

Comparatively, Minnesota has invested more in public awareness regarding harmful invasive species and results show that this investment is resulting in significant increases in public awareness and preventative actions taken. In another 2000-2001 survey question, 99% of Minnesota boaters said they were very likely or somewhat likely to take precautions.

Angler survey

Minnesota Sea Grant previously conducted a separate survey of Minnesota anglers (Doug Jensen, Minnesota Sea Grant). The survey found that nearly 97% of Minnesotans believe it is important to prevent the spread of aquatic nuisance species. Yet, while awareness is very high, Minnesota anglers still represent a significant risk for the spread of harmful invasive species–29% of surveyed anglers dump unwanted live bait into the lake or river after fishing and 25% of anglers who put bait buckets in the water, reuse those minnows on other waters.

Participation of Others in Public Awareness Activities

National "Stop Aquatic Hitchhikers!" Campaign

The national Aquatic Nuisance Species (ANS) Task Force, the U.S. Fish and Wildlife Service, and the U.S. Coast Guard are the primary sponsors of the "Stop Aquatic

Hitchhikers!" campaign. The national campaign was implemented in 2002 and includes a variety of marketing tools such as public service announcements, stickers, posters, magazine and newspaper articles, television, and radio programs to make the public aware of this issue. Most materials and announcements include a Web site address (www.protectyourwaters.net) that directs individuals to visit the site and learn about the steps they can take to stop the transport and spread of harmful aquatic hitchhikers. Beginning in 2003, the DNR began to use the national "Stop Aquatic Hitchhikers!" brand in its informational materials.

Minnesota partners
Other agencies and organizations in Minnesota have been cooperatively involved with public awareness activities in the state for more than a decade and continue to conduct public awareness efforts throughout the state.

In 2004, the Minnesota Invasive Species Advisory Council (MISAC), of which DNR is a member and co-chair, produced a 2005 invasive species wall calendar for distribution to natural resource, agricultural, highway, and other professionals in the state. It was a cooperative effort of the council members to raise awareness of all types of invasive species and to inform the recipients of the council's Web site—www.mda.state.mn.us/misac/.

Teachers throughout Minnesota can reserve educational "traveling trunks" that include hands-on activities for classroom instruction. The trunks contain a wide range of tools designed to teach youth about aquatic invasive species (AIS). In addition to the DNR, educators can obtain the trunks from several organizations including the University of Minnesota Sea Grant, Bell Museum of Natural History, Great Lakes Aquarium, and National Park Service. For a more detailed description of the trunks, visit: www.seagrant.umn.edu/education/ttea.html.

The University of Minnesota Sea Grant Extension Program's Aquatic Invasive Species Information Center is a leader in public education campaigns and programming. Sea Grant conducts research, outreach, and education often in collaboration with the DNR to avoid duplication of effort, leverage resources, and combine our expertise to effectively address AIS issues in Minnesota and beyond.

2004 Highlights of Minnesota Sea Grant's educational activities related to harmful aquatic invasive species in Minnesota:

- *Habitattitude*™ is a new national public education campaign launched in fall 2004 to prevent the release of unwanted aquatic plants and fish by aquarists and water garden owners. The campaign was created through a partnership of the Pet Industry Joint Advisory Council (PIJAC), the U.S. Fish and Wildlife Service (USFWS), and the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Sea Grant Network, led by Minnesota. Based on a two-year, $300,000 grant from NOAA-Sea Grant, the campaign leverages $100,000 from the USFWS, and more than $1.1 million from PIJAC and its members. The campaign features a new logo, "don't release" messages, and a Web site, www.habitattitude.net. It also promotes guidelines as alternatives to release that consumers should consider when dealing with unwanted aquatic plants and animals. *Habitattitude*™ prevention messages will appear on fish bags, new aquaria, brochures and other print media, and ads in hobbyist and trade magazines across the country. In 2005, campaign partners will continue to staff booths at trade shows and society meetings, give presentations at meetings, as well as meet with federal and state agencies throughout the Great Lakes and beyond to broaden campaign partnerships. Dozens of agencies and organizations have expressed strong interest in becoming campaign partners (including several foreign countries).

- Sea Grant worked with seven other university entities and the DNR to successfully eradicate goldfish, koi, and other unwanted fish from a two-acre pond on the University of Minnesota-Duluth campus—likely released by aquarists or water gardeners. The pond was pumped dry so that the infestations would not spread via the outflow into a designated trout stream that flows into Lake Superior. Sea Grant produced signs and fliers and led mass media efforts to raise awareness, which reached an estimated 1.5 million people across the region.
- Sea Grant worked with DNR staff to develop a model education program designed to prevent the spread of aquatic plants from water gardens and shoreline restoration efforts. Educational messages and materials are being developed in collaboration with Michigan Sea Grant, nursery and landscape professionals, consumers, and educators, including the University of Minnesota Master Gardener Program. Consumer surveys and focus groups provided input on messages, graphics, and draft materials. Educational materials will be produced and distributed in 2005 across Minnesota, Wisconsin, and Michigan.
- Sea Grant continues to promote AIS youth education by promoting and distributing lesson plans, traveling resource kits, and curricula to teachers and educators. Presentations at *River Quest*, a Duluth-Superior youth education environmental stewardship event, reached nearly 600 sixth graders in May 2004. Sea Grant also partnered with the Newspaper in Education (NIE) programs across the Great Lakes to produce AIS educational tabloids, which were distributed to 49,000 students. In Minnesota, Sea Grant worked with the *St. Paul Pioneer Press* NIE program to sponsor an essay contest, which helped high school students incorporate AIS learning into their education. This program won the Outstanding Program Award from the Great Lakes Sea Grant Network in fall 2004.
- Center staff provided 59 presentations about harmful AIS at conferences, workshops, meetings, and festivals in Minnesota, including presentations of *Aliens A-Z: A History of Non-Native Introductions in Lake Superior* in several North Shore communities as part of the Sea Grant-sponsored Liquid Science Speaker Series. Sea Grant supported DNR efforts to update the *1995 Fisheries Management Plan for Minnesota Waters of Lake Superior* by presenting an update on invasive species and highlighting habitat issues and concerns at a Lake Superior Fisheries Conference in December. Sea Grant and DNR staff were interviewed for a public broadcast television program in the Twin Cities.
- Sea Grant and DNR collaborated to produce a new *Zebra Mussel WATCH* identification card, produced by Wisconsin Sea Grant. Minnesota Sea Grant also reprinted more than 600,000 cards for Eurasian ruffe, round goby, Eurasian watermilfoil, purple loosestrife, rusty crayfish, spiny and fishhook waterflea, and European frogbit. Each card provides identification features, helps prevent the spread, and encourages public reports of new infestations. Originally produced in

2002-03, these cards have become the most popular AIS outreach products across Minnesota and the Great Lakes region.

- Sea Grant partnered with Duluth's Park Point Community Club to release purple loosestrife-eating beetles (*Galerucella*) on infestations along Superior Bay.
- Center staff participate on state, regional, and national task forces including the Minnesota Invasive Species Advisory Council's (MISAC) Communication and Education Committee (chair), Great Lakes Panel on ANS's Information and Education Committee (alternate Minnesota representative), St. Croix River Zebra Mussel Task Force, ANS Task Force's Recreational Activities Committee (National Sea Grant College Program representative), and the ANS Task Force's Communication, Outreach, and Education Committee.

Future needs for public awareness in Minnesota

- Maintain spending on paid public awareness radio/TV spots to reinforce high awareness of invasive species by watercraft users.
- Continue to make public awareness of zebra mussels in Minnesota near Brainerd, Lake Superior, the Mississippi, Zumbro, and St. Croix rivers a priority.
- Work cooperatively with specific industry groups to develop targeted public awareness efforts such as the aquaculture industry, live bait dealers, water garden and horticulture industry, and aquarium trade.
- Use the Minnesota Invasive Species Advisory Council (MISAC) and other multi-entity groups to enhance interagency communication on the status and progress of invasive species management efforts.
- Expand public awareness activities that are cooperative ventures with lake communities outside the metro area.
- Increase information about harmful invasive species available through the various communication channels such as the DNR Web site, publications, and media outlets.
- Continue to work collaboratively with Minnesota Sea Grant staff to pursue research and outreach funding through National Sea Grant and other sources.

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Enforcement

Introduction

Issue

In 1991, the Legislature directed the DNR Commissioner to establish a two-year program designed to check trailered boats. Roadchecks were initially designed to inspect boats and trailers for the presence of Eurasian watermilfoil fragments and to educate and inform boaters. As additional harmful invasive species (e.g., zebra mussels) have become established in Minnesota, roadchecks and boat inspections were expanded to detect illegal transportation of those organisms, as well as other aquatic plants.

The DNR supported changes in statute passed during the 1996 legislative session that prohibited the transport of all aquatic vegetation (rather than Eurasian watermilfoil exclusively). This change in law made enforcement less complicated. Instead of having to identify Eurasian watermilfoil, which can be difficult, officers and watercraft users only had to ensure that all vegetation was removed before transporting boats and equipment.

In 1999, the Division of Enforcement took steps to better focus enforcement efforts. An Invasive Species Enforcement Plan that allocated hours and prioritized invasive species enforcement needs in each district was initiated.

Activities in the statewide Invasive Species Enforcement Plan were included as a specific component of the FY02, FY03, and FY04 annual work plans for all Enforcement Division activities. These annual work plans describe in detail each enforcement district's responsibilities in meeting various responsibilities, including invasive species, and ensure that appropriate work activities and levels are accomplished.

Goals

One of the Department's goals related to enforcement is to prevent the spread of invasive species within Minnesota. Part of this goal is to lower the percentage of trailered boats transporting prohibited invasive species, aquatic vegetation, and infested water within the state. The second part is to respond quickly when reports are received that invasive wild animals have escaped from captivity.

Progress in Enforcement Efforts - 2004

Several types of enforcement activities have occurred to limit the introduction and spread of invasive species including: educational work and presentations, checks of trailered boats at water accesses, monitoring commercial bait harvest equipment, and follow up on illegally-released invasive animals. In 2004, conservation officers spent 2,396 hours enforcing the invasive species laws and rules. Statewide, there was a total of five civil citations, 20 written warnings, and three summons issued to individuals for violations of invasive species laws and rules. Officers spent many hours educating the public on the regulations.

The following paragraphs summarize some of the key enforcement initiatives that have been used to meet the goals listed above.

Roadchecks of trailered boats were not conducted in 2004 (Table 5). Beginning in mid-summer of 2002, roadchecks were suspended. The reasons for suspending roadchecks are described below.

> In 1994, the Minnesota Supreme Court decided the case of Ascher v. Commissioner of Public Safety. Ascher held that the police could not conduct sobriety checkpoints. The Court's reasoning was that these checkpoints constituted an unlawful invasion of privacy. The court held that law enforcement officials must have reasonable suspicion of a violation before stopping a motorist. In the years between 1994 and 2002, the Division of Enforcement maintained that the needs for resource protection outweighed individual privacy interests in the roadcheck scenario. Accordingly, we supported the use of game and fish roadchecks and invasive species roadchecks.
>
> Developments in our state's appellate courts during 2002 signaled that natural resource enforcement measures must comply with the same constitutional rules that govern general police "searches and seizures." These decisions clearly signal that the Ascher case applies to Enforcement's work as well.
>
> The Division of Enforcement discontinued the use of game and fish roadchecks and invasive species roadchecks as a result. Enforcement is hopeful that further litigation or legislative changes will help resolve this situation for the benefit of our natural resources.

Enforcement at water accesses

Enforcement near the Mississippi River

Conservation officers conducted invasive species enforcement activities along the Mississippi River, focusing on the transportation of zebra mussels and infested water. Boaters using the Mississippi River south of the Twin Cities must empty bilges, live wells, and bait buckets so that they do not transport zebra mussel infested water from the Mississippi. During the summer of 2004, officers spent time enforcing along the Mississippi and St. Croix rivers (including accesses near Hastings, Red Wing, Lake City, Kellogg, Winona, and LaCrescent).

Efforts also focused on educating the public on the laws relating to transporting water from the St. Croix River in live wells and bait buckets. Zebra mussel awareness cards were handed out to the public again this year. Time was spent educating the public at accesses in Stillwater, Bayport, and Afton.

Enforcement during the waterfowl hunting season

Conservation officers conducted invasives enforcement activities during the waterfowl hunting season to inform hunters about the laws prohibiting transportation of aquatic vegetation. Hunters must remove vegetation from their boats, decoys, and anchors before leaving the water access. There is an exception for the transport of shooting blinds, and emergent vegetation cut above the water line can be transported.

Table 5. Summary of trailered watercraft inspected by the DNR during roadchecks conducted between 1991 and 2002.

Year	Number of Roadchecks	Number of Watercraft Inspected	Number of Watercraft with Aquatic Plants	Number of Warnings[1]	Number of Written Citations
2003	Discontinued	N/A	N/A	N/A	N/A
2002	1	48	15 (31%)	10 (20.8%)	1 (2.0%)
2001	4	429	68 (15.9%)	66 (15.4%)	1 (0.002%)
2000	4	410	71 (17%)	69 (16.8%)	2 (0.5%)
1999	4	491	101 (21%)	95 (19.3%)	7 (1.4%)
1998	5	645	127 (20%)	117 (18.1%)	3 (0.5%)
1997	7	638	161 (25%)	152 23.8%)	2 (0.3%)
1996	3	595	138 (23%)	152 (23.8%)	2 (0.3%)
1995	3	202	N/A	9 (4.5%)	-
1994	7	775	N/A	35 (4.5%)	-
1993	37	982	N/A	63 (6.4%)	9 (0.9%)
1992	7	1412	N/A	14 (1.0%)	12 (0.8%)
1991	8	818	N/A	9 (1.1%)	5 (0.6%)
Total	**90**	**7445**	**681**	**791**	**44**

[1] Made assumption that between 1994 and 1996 all offenders were issued warnings

Conservation officers contacted hunters during the waterfowl hunting season at the following accesses along the Mississippi River: Verchota (Winona County), North Lake (Goodhue County), Dresbach (Houston County), Wilcox and Halfmoon (Wabasha County). Additional time was spent in Freeborn County, Otter Tail County, Beltrami County, and Mille Lacs County at several lakes frequented by waterfowl hunters. Statewide, additional efforts were made by officers to contact waterfowl hunters at their traditional access points.

Enforcement near Lake Ossawinnamakee

The Invasive Species Program provided special training for conservation officers in the Brainerd area because of elevated concern about spread of zebra mussels and Eurasian watermilfoil from Lake Ossawinnamakee. In addition, the Invasive Species Program Coordinator and DNR conservation officers held an invasive species training session for Crow Wing County Water Patrol members in Brainerd.

Responding to escaped invasive animals

In 2003, the DNR changed its procedures and did not respond to reported escapes of mute swans. This modification reflects changes in federal regulation (see Other Invasive Animal Species in Minnesota). There were reports to conservation officers of escapes of invasive deer and other invasive wild animals. In the Twin Cities metro area, conservation officers have visited several ethnic food markets to evaluate the possible trade in invasive species. As a result of the information gathered in these visits, an educational initiative is underway with Invasive Species Program staff and other DNR personnel to provide resource materials to the communities in their respective languages.

Goals for 2005

The DNR believes that enforcement plays a critical role in reducing the spread of invasive species, however, it is only part of the larger prevention effort. In order for the regulations on invasive species to be effective in reducing their spread, there must be: a balanced mix of public education and awareness efforts, voluntary compliance from the general public, and enforcement of the regulations. One measure of the effectiveness of enforcement efforts targeting trailered boats would be a long-term decrease in the percentage of boats carrying aquatic vegetation.

Participation of Others

The Invasive Species Program has worked to increase the participation of other peace officers to help look for violations and to enforce the state laws related to transport of prohibited invasive species on public roads. Recognition of invasive species, as well as being well versed in the laws that relate to them, aids in the enforcement efforts to stop the spread of invasive species.

Regulations and Proposed Changes

Introduction

Issue

Minnesota's regulations related to invasive species of aquatic plants and wild animals currently in Minnesota Statutes and Minnesota Rules are generally considered to be comprehensive. The state statutes related to these invasive species are found in Minnesota Statutes, Chapter 84D. The administrative rules related to invasive species are found in Minnesota Rules, Chapter 6216. Current versions of both statutes and rules are available at www.revisor.leg.state.mn.us. Summaries of annual changes in the regulations can be found in past DNR annual reports on invasive (harmful exotic) species.

The DNR is assigned responsibility for designating *infested waters* (see M.S. 84D.03). Water bodies are designated infested if they contain specific invasive species such as Eurasian watermilfoil, zebra mussels, ruffe, round goby, white perch, and spiny waterfleas. The current *infested waters* lists are found in Minnesota Rules, Chapter 6216 at www.revisor.leg.state.mn.us/arule/6216.

The DNR is also required to adopt rules (per Minnesota Statutes 84D.12) that place non-native aquatic plant and wild animal species into various regulatory classifications and prescribe how invasive species permits will be issued (per Minnesota Rules 6216.0265). The DNR is authorized to adopt other rules regarding infested waters and invasive species of aquatic plants and wild animals.

Goals

The future needs identified in the 2003 report, included:

- Continue to support efforts to integrate and improve the comprehensiveness, enforceability, and responsiveness of federal laws regarding noxious weeds, injurious wildlife, and other designations related to invasive species. Specifically seek reauthorization of the National Invasive Species Act (NISA) and designations of injurious wildlife such as the black carp.
- Continue to adopt rules that designate additional prohibited invasive species, regulated invasive species, and unregulated non-native species.

Progress in Regulations - 2004

Federal

At the national level, the following are key regulatory areas: 1) related to reauthorization of the National Invasive Species Act (NISA); 2) national ballast water regulations; and 3) U.S.Fish and Wildlife Service (USFWS) potential designation of injurious wildlife. Activity on these areas is described below:

Reauthorization of NISA

Little progress was made to pass the National Aquatic Invasive Species Act of 2004. Bills to reauthorize NISA introduced in the House and the Senate never made it to the floor for a vote. Therefore, the National Invasive Species Act of 1996 was not reauthorized in 2004.

National Ballast Water Regulations

Ballast exchange requirements are now mandatory nationwide. On June 14, 2004, the Coast Guard under the authority of the Nonindigenous Aquatic Nuisance Prevention and Control Act and the National Invasive Species Act, established penalty provisions in rule for vessels equipped with ballast water tanks which are bound for ports or places within the United States that fail to submit a ballast water management (BWM) reporting form. Penalties were also established for vessels bound for the Great Lakes or portions of the Hudson River that violate the mandatory ballast water management requirements and these regulations widen the reporting and recordkeeping requirements of vessels subject to the regulations. The final rule was published in the *Federal Register* initially on June 14 and corrected on July 7, 2004.

Designation of injurious wildlife

The USFWS is continuing to review information related to a proposal to designate black carp, silver carp, and bighead carp as an injurious wildlife species under the Lacey Act. The USFWS had not designated black carp, silver carp, and bighead carp as injurious as of December 31, 2004.

Injurious wildlife can only be imported by permit for scientific, medical, educational, or zoological purposes, or without a permit by federal agencies solely for their own use; permits are also required for the interstate transportation of injurious wildlife currently held in the United States for scientific, medical, educational, or zoological purposes. Designation of injurious wildlife prohibits interstate transportation of those species currently held in the United States for purposes not listed above. Violations could bring a $5,000 fine or six months in jail.

State statute changes

The DNR proposed statutory changes for consideration during the 2004 Legislative Session. The Legislature passed a bill that included modifications of definitions, additions and increases in civil and criminal penalties, revision of the mandate to conduct 20,000 hours of watercraft inspections of watercraft leaving waters of the state, and changes in restrictions related to use of commercial fishing equipment in infested waters. The changes to specific parts of state statutes that became effective on June 1, 2004, are listed below:

M.S. 17.4982

The word "restricted" was replaced with "regulated" which is the appropriate term. This was apparently an error when this chapter of statutes was modified in the past.

MS 18.78 Control of purple loosestrife

Biocontrol for purple loosestrife has become a viable control option in recent years. The 2004 bill clarified that an annual list of priority sites where purple loosestrife control will occur is only for prioritization of herbicide treatments as initially intended before biocontrol was available.

M.S. 84.027
The terms for prohibited exotic species, regulated exotic species, and unregulated exotic species were changed to new terms—prohibited invasive species, regulated invasive species, and unregulated non-native species so they match a similar change in M.S. 84D.

M.S. 84D.01 Definitions
- A definition of aquatic plants was added. The Commissioner is given authority to address aquatic plants and wild animals. This addition clarifies the scope of the term and of the DNR Invasive Species Program.
- The definition of Eurasian watermilfoil was modified to include "its hybrids". There are lakes with hybrid milfoil in the state and they should be included in infested waters and eligible for DNR management.
- The definition of harmful exotic species is replaced with a definition of the term "invasive species" to more closely match the federal definition. The old definition is repealed. This change is repeated throughout M.S. Chapter 84D and related rules.
- The term "exotic species" was replaced by the term "non-native species" throughout MS 84D and related rules.

MS 84D.02 Management Program
The statute was changed to more clearly state the scope of the program is limited to non-native aquatic plants and wild animals.

MS84D.02 Management Plan
The legislation removed a past completion date for a management plan and now requires the Commissioner to "continue to maintain" a long-term management plan for invasive species of aquatic plants and wild animals.

M.S. 84D.02 Management Program - Inspection of Watercraft
- Reduces the existing 20,000-hour watercraft inspection requirement to 10,000 hours in order to provide more agency flexibility. It adds training of watercraft inspectors to DNR responsibility, and clarifies that the purpose of the inspections is to look for aquatic plants and aquatic invasive species.
- Eliminates the requirement in the annual report to review and report on management efforts in other states.

M.S. 84D.03 Infested Waters
The revised statutes now provide more consistent restrictions on netting bait, fish, and other aquatic species in infested waters. Some of these were inadequately covered in rule or statute. This change now places most of the restrictions in the statutes.

M.S. 84D.05 Prohibited Species
These statutes now allow prohibited species to be legally transported as specified in a commercial fish license for disposal or processing. This addresses the fact that commercial fisheries operating in infested waters may need a way to dispose of Asian carp, sea lamprey, or other prohibited invasive species they may capture during their fishing operations.

M.S. 84D.08 Escapes
Reduces the amount of time a person has to contact the Commissioner (or other designated individual) when a prohibited, regulated, or unlisted non-native species escapes. It was reduced from 48 hours to 24 hours. This makes the reporting requirement for invasive species the same as the farmed cervidae requirement.

M.S. 84D.13 Enforcement Criminal Penalties - Civil Citations
The penalties were increased to a level more consistent with other penalties. It also adds civil penalties for some actions that previously only had criminal penalties.

- The penalty for certain violations of 84D.05 was increased from a misdemeanor to a gross misdemeanor.
- Increased the civil penalty, from $100 to $250, for transporting a prohibited invasive species and allows the penalty to be imposed for the possession of a prohibited species.
- Sets the civil penalty for failing to drain water from watercraft and equipment when leaving certain waters at $50.
- Sets the civil penalty for transporting infested water off of riparian property without a permit at $200.

MS 84D.14 Exemptions
The reference to Chapter 18G, which clarifies Department of Agriculture and DNR responsibilities, was updated.

Required Rulemaking
Provides direction to DNR to fix the rules that will be replaced by this bill.

Revisor's Instructions
The bill included instructions to the Revisor to make the terminology changes in rules to match those in this bill.

Emergency rulemaking
In 2003 and 2004, DNR adopted emergency rules to designate waters found to have Eurasian watermilfoil, zebra mussels, and spiny waterflea as infested waters, as well as redesignated infested waters for which the previous designation in emergency rule expired. Designation of Northern snakehead fish (*Channa argus*) as a prohibited invasive species was included in the same emergency rule.

Permanent rulemaking
New rules will be proposed in 2005 to designate infested waters that have been designated in emergency rule, but have not yet been designated in permanent rules. Northern snakehead fish (*Channa argus*), invasive earthworms, and other invasive animal and aquatic plant species will be assessed, classified, and proposed as additional prohibited and regulated invasive species in 2005. Some species such as water spinach, starlings, and English sparrows may be reclassified and redesignated into different categories.

Future needs

- The Department is proposing some minor changes to the commercial fishing and harvest related statutes in 2005.
- Continue to support efforts to integrate and improve the comprehensiveness, enforceability, and responsiveness of federal laws regarding noxious weeds, injurious wildlife, and other designations related to invasive species. Specifically seek reauthorization of the National Invasive Species Act (NISA) and designations of injurious wildlife such as the black carp.
- Continue to adopt rules that designate additional prohibited invasive species, regulated invasive species, and unregulated non-native species.

Watercraft Inspections and Awareness Events

Introduction

Issue

The potential for boaters to accidentally move aquatic invasive species from one lake to another is a clear threat to Minnesota's aquatic ecosystems. For this reason, the 1991 Minnesota Legislature mandated that DNR conservation officers conduct inspections of trailered boats on Minnesota highways. The purpose of these inspections was to look for Eurasian watermilfoil, issue citations to violators, and inform the public about the potential spread of harmful aquatic invasive species.

In 1992, the DNR, Minnesota Lakes Association, and angling groups proposed and supported legislation (adopted as M.S. 18.317, Subd. 3A, and recodified as 84D.02 subd. 4) requiring 10,000 hours of inspections of watercraft leaving infested water bodies containing harmful aquatic invasive species such as Eurasian watermilfoil, spiny waterflea, and zebra mussels. Subsequently, a watercraft inspection program was established by the DNR in 1992 to accomplish this mandate. In 1993, legislation was passed increasing the number of inspection hours to 20,000 starting with the 1994 boating season. In 1999, this statute was amended to allow inspections on both infested and uninfested water bodies to fulfill the 20,000-hour requirement. Effective June 1, 2004, the 20,000-hour requirement was lowered to 10,000 hours.

Goals

Watercraft inspections help to achieve the second goal of the Invasive Species Program: preventing the spread of invasive species within Minnesota. The inspectors also help to:

- Complete up to 20,000 hours of watercraft inspection at public water accesses across the state;
- Increase public awareness about invasive species and the potential for boaters to transport invasive species between water bodies;
- Reduce the percentage of trailered boats carrying invasive species;
- Increase educational efforts with citizen groups.

Progress in Watercraft Inspections - 2004

Complete required hours of watercraft inspection

In 2004, 40 watercraft inspectors worked through the summer providing information to the public on watercraft inspections and invasive species. Inspections began in late April and continued though mid October. Within this 25-week period, watercraft inspectors logged 20,426 inspection hours. A total of 49,952 watercraft/trailers were inspected.

During the inspection season, inspections were conducted at 21 fishing tournaments and continued through October in order to reach waterfowl hunters. Inspectors distributed more than 6,800 Exotic Alert Tags on vehicles with trailers at access points on infested waters. Inspectors also worked to clear aquatic plant fragments from the public water accesses (PWAs) at which they were stationed.

Inspection efforts were conducted across the state in rough proportion to the number of PWAs on infested water bodies, (Table 6 and Figure 4). The actual distribution of time reflects both the number of PWAs and the intensity of public use at those accesses. The percent of time that the program is spending in each region has stayed relatively stable from 2000 to 2004 with a slight decrease in time in Regions 1 and 4, and an increase in time in Region 2, (Figure 5). This change could be attributed to the new infestations in greater Minnesota in the past years.

Table 6. Number of watercraft inspections conducted by watercraft inspectors in 2000, 2001, 2002, 2003, and 2004. (*Totals are rounded values*).

Year	DNR Region				Total
	1	2	3	4	
2000	2,300	4,200	35,200	9,000	51,000
2001	1,700	4,000	27,200	5,800	39,000
2002	660	3,100	32,300	7,700	44,000
2003	760	5,600	29,700	5,500	42,000
2004	1,200	6,800	35,600	6,800	50,500

The watercraft inspection program has primarily focused on water bodies with infestations of aquatic invasive species. This approach was used because there were relatively few infested water bodies and so it was very efficient. While it is important to contact boaters leaving water bodies infested with aquatic invasive species, we feel it is also important to inform boaters on other popular recreation lakes in Minnesota. To allow more flexibility in the program, state statute was amended to include watercraft inspections on uninfested water bodies in order to meet the Department's 20,000-hour mandate (M.S. 84D.02, Subd. 4). During 2004, inspections on uninfested waters represented about 13.31% of the total inspections (6,718 inspections) and approximately 14.7% of the inspection hours (3,001.25 hours).

To determine which uninfested waters to visit, we used three criteria: 1) lakes or areas with a high level of boater activity, 2) lakes identified on program surveys as frequent destinations for boaters leaving infested water bodies, and 3) lakes with lake associations that desired to hold "Invasive Species Awareness Events."

Although the program has broadened to include inspections at uninfested waters, the majority of the inspections are still done at infested water bodies. Two relatively new infestations are of special concern. The lower 25 miles of the St. Croix River are infested with zebra mussels, discovered in 2000 (see Management of Zebra Mussels). Since this is a relatively new infestation, it is very important that watercraft users on the river are aware of the infestation and become educated on how to reduce the risk of

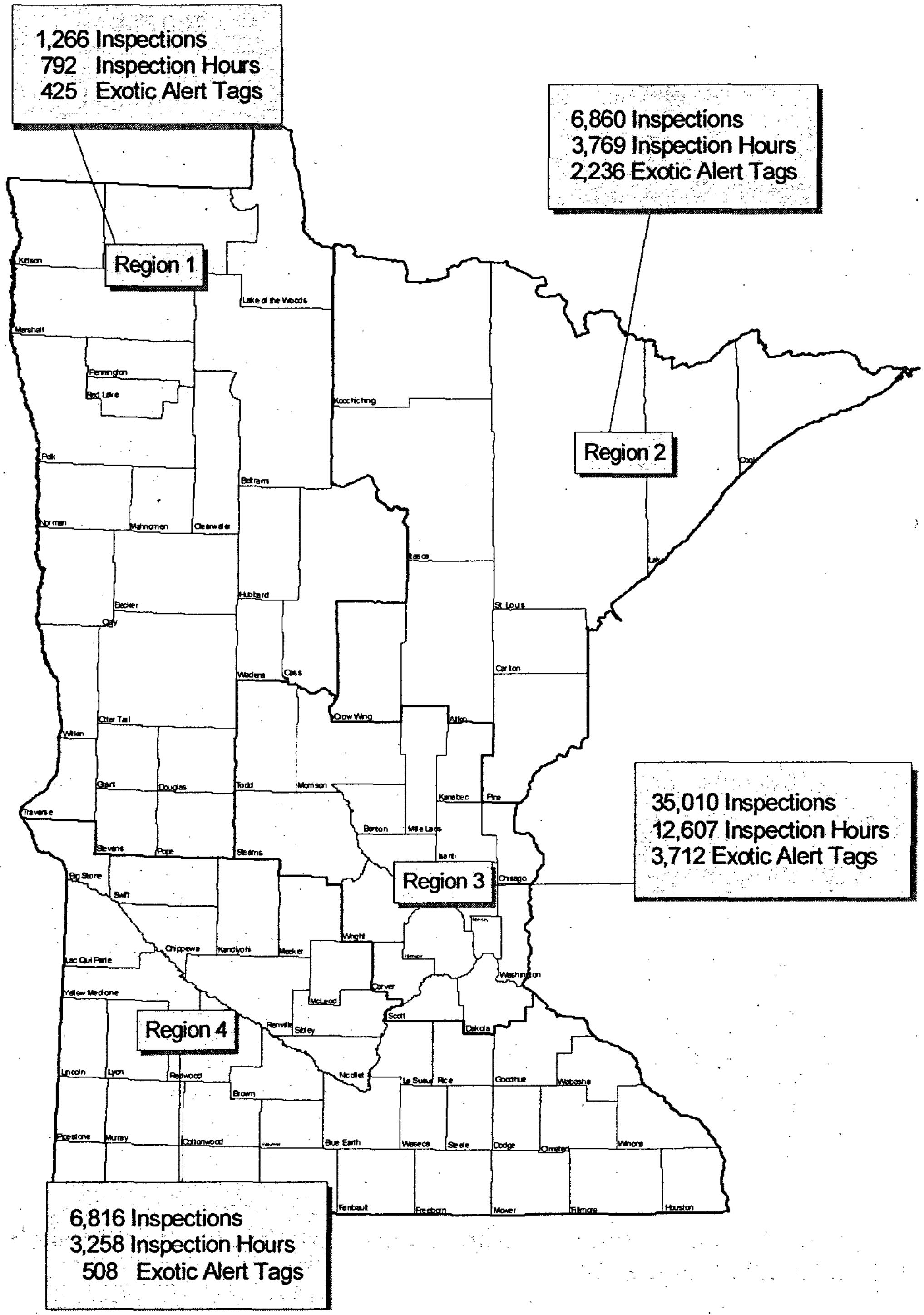

Figure 4. DNR watercraft inspections at public water accesses in 2004.

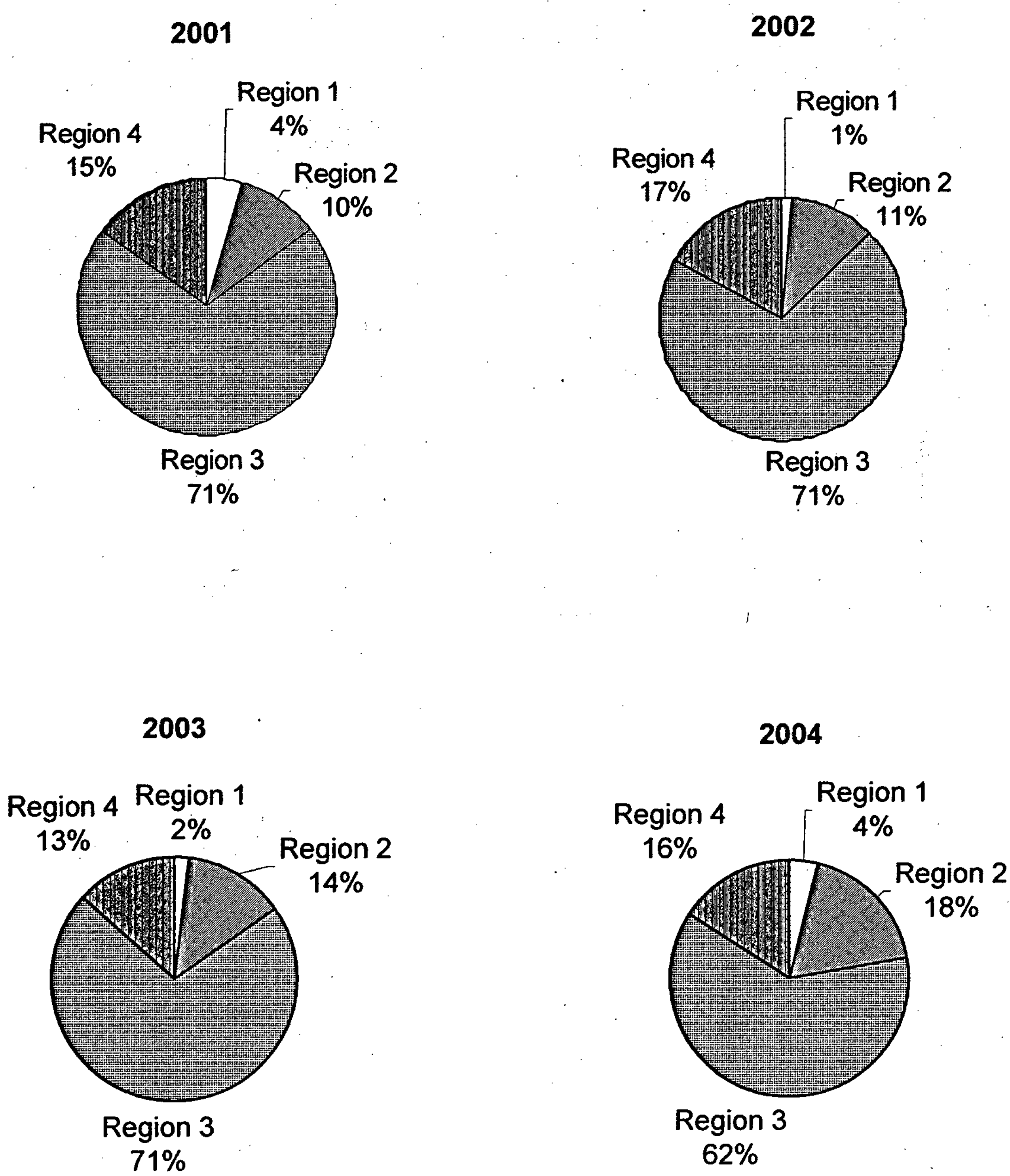

Figure 5. Percent of the state's total watercraft inspection hours spent in each region in 2001, 2002, 2003, and 2004.

transporting zebra mussels to other water bodies. In 2004, 414 inspection hours were spent on the St. Croix River and more than 1,200 watercraft were inspected.

The most recent zebra mussel infestation was discovered in October of 2003 in Lake Ossawinnamakee in the Brainerd area (see Management of Zebra Mussels). Due to Lake Ossawinnamakee's location in a popular recreation area for boaters and anglers and direct connection to the Mississippi River there is a significant potential for spread to other waters by natural or human-caused movement.

In response to this new infestation, the Watercraft Inspection Program increased inspection hours at Lake Ossawinnamakee and in the greater Brainerd Lakes area. Inspection hours on Lake Ossawinnamakee were increased by 29% and the access was visited 59 times, which was an increase of 68% from 2003. The Watercraft Inspection Program increased inspection hours in the Brainerd area by 57% (1,063 hours) and inspections by 53% (2,328 inspections) from 2003.

Increase public awareness
Surveys conducted by watercraft inspectors provide important information on the public's awareness of invasive species laws and help identify high-risk areas (i.e., accesses where many watercraft pick up plant fragments). According to survey information collected by watercraft inspectors, awareness of invasive species laws remains very high among Minnesota boaters. The percent of watercraft users who responded "yes" when asked if they were aware of the invasive species laws for the state was 97%, an increase of 1% from 2003. Boaters from other states using Minnesota water bodies had a slightly lower response at 91%. The range of percentages for each Minnesota county where at least 100 inspections had been done varied from 86% (in Douglas County) to 100% (in Big Stone, Hubbard, Meeker and Sherburne counties). Of those who said they were not familiar with the laws, slightly less than 3% (22 out of 859) had vegetation on their watercraft when they entered the access. In contrast, 1.3% (299 out of 22,151) of the people who said that they were familiar with the laws entered the access with vegetation.

Decals are given to boaters (see Decal Program for Trailered Watercraft) to signify that they have talked with a watercraft inspector. Of those with no decal, 6% said they were not familiar with the invasive species laws. In contrast, of those with a year 2004 decal, 15 out of 15,098 boaters or less than 1/10 of one percent said they were not familiar with the laws. This suggests that the Watercraft Inspection Program is successful at educating boaters about the invasive species laws.

Reduce the percentage of trailered boats carrying invasive species
The Watercraft Inspection Program has been unable to assist with roadchecks due to changes in the law that prevents the Department from conducting them (see Enforcement).

Increase educational efforts with citizen groups
In 2004, the Watercraft Inspection Program participated in many public awareness activities and worked with several citizen groups in order to educate the public about aquatic invasive species. Inspectors answered questions both at the invasive species display at the Minnesota State Fair and at the Minnesota Twins Outdoor Expo event.

The inspectors also educated citizens at the "Spring into Summer with the DNR" day at Cabela's sporting goods store in Owatonna and at Cannon Valley Trail Days in Welch. The Watercraft Inspection Program was also able to work with several citizen groups throughout the season both through awareness events and participation in lake association meetings. Inspectors worked side by side with the members of the Sportsmen's Club of Lake Vermilion during an awareness event at Lake Vermilion in late May.

The Watercraft Inspection Program also worked cooperatively with five lake associations and citizen groups to increase inspection hours in their areas. These citizen groups funded additional hours of inspection at their accesses while the Watercraft Inspection Program provided training, equipment, and supervision. The Lake Minnetonka Conservation District (LMCD) worked with the Watercraft Inspection Program for the third year. Inspectors spent an additional 946 hours on five Lake Minnetonka accesses because of the funding provided by the LMCD. This was also the third year that Kandiyohi County hired cooperatively to increase inspection on lakes within its county. For three lake associations, 2004 was their first year partnering with the Watercraft Inspection Program to increase inspections. Bay Lake Association's cooperative effort with the Watercraft Inspection Program increased inspection hours on its lake by 361 hours. Lake associations for Plantagenet and Pike lakes increased their inspection hours by 48 and 49 hours respectively.

Estimate of Risk from Trailered Boats

The percentage of boats/trailers carrying vegetation as they were trailered out of a lake or river varied widely by county (Figure 6). These variations may be caused by several variables including the amount and type of vegetation in the water body, its proximity to the public water access, and the amount of recreational boating traffic. An average of 14% of the watercraft checked by watercraft inspectors were found with vegetation (3,302 watercraft) as they trailered out of the water. This rate demonstrates a clear risk that boaters will transport aquatic vegetation (and harmful invasive species) from lake to lake if boats are not properly cleaned. The percentage of boats and trailers carrying vegetation as they enter public accesses on infested waters was 1.2%. This is a good indication that the majority of boaters using infested waters are inspecting and cleaning their boats and trailers. Enforcement of invasive species laws continues in an effort to reduce the transportation of vegetation and harmful invasive species (see Enforcement).

Transportation of Other Invasive Species

There were no zebra mussels found on boats being launched into Minnesota waters. Zebra mussels were found on three watercraft exiting Minnesota waters. This demonstrates a clear risk of zebra mussels being moved on boat hulls or on plants caught on trailers if boats are not properly cleaned. Anglers who "catch" zebra mussels off the bottom while angling and discard them in the bottom of their boats can also move them.

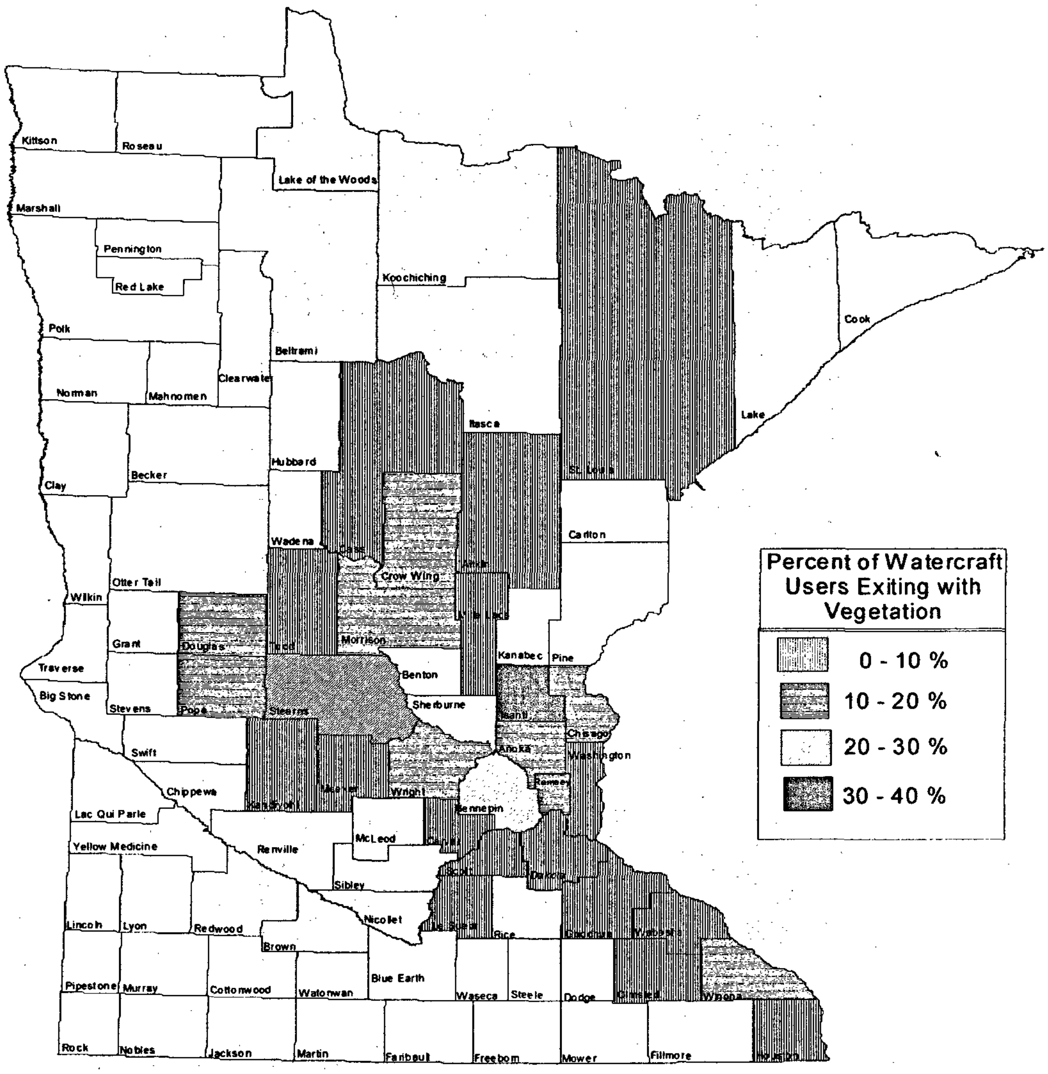

Figure 6. Percentage of exiting watercraft with attached vegetation prior to cleaning (in counties where more than 100 boats were inspected upon leaving an access).

Decal Program for Trailered Watercraft

During the 1994 boating season, several boaters expressed frustration over being approached by inspectors several times each week throughout the summer. To respond to their concerns and to reduce the duplication of education efforts, a decal was developed and distributed to boaters whose watercraft had been inspected for invasive species (Figure 7). Boaters are instructed to voluntarily affix the decal to the winch post of their trailer. This allows inspectors to identify the boaters who have already spoken with inspectors during the summer. Boaters with a decal are given a brief reminder to drain water and remove vegetation from their boats. The decals have been used for eight years now and have been well received by the public. The 34,471 decals distributed during the 2004 boating season also remind boaters to inspect their boats when inspectors are not present.

Figure 7. Decal provided to boaters by DNR watercraft inspectors in 2004.

Future needs and recommendations for watercraft inspections

- Increase cooperation and partnerships with citizen groups that would like to help raise awareness in their areas.
- Expand the number of community events in which we participate in order to educate new audiences about invasive species.

Risk Assessment

2004 Highlights

- A detailed risk assessment of brittle naiad (*Najas minor*) was completed.
- A risk assessment of Internet and catalog sales of aquatic plants funded in part by the DNR was published in 2004 (Maki and Galatowitsch, 2004).
- Invasive Species Program staff revised and widely distributed two publications aimed at slowing the movement of invasive species through the horticultural trade.

Introduction

Many invasive species that cause problems in other parts of the United States or in other countries do not yet occur in Minnesota but could become established here. Keeping these species out of Minnesota is a high priority not only for the environment, but also for the state's economy. Failure to interrupt pathways which bring these species to Minnesota, and to address high-risk species can result in introductions that are costly to manage and may become perpetual problems.

Risk assessments are a way to determine how non-native species move into the state and to identify which species pose the greatest threat to Minnesota. Risk assessments need to be updated regularly as new information becomes available. In addition, continuing to gather information about a non-native species in the state can help determine whether to undertake new steps to manage it.

Risk assessments provide the basis for planning and implementing risk management activities. Risk management activities include, but are not limited to, public education, regulation, and management. The results of a risk assessment can be used to recommend that species be classified as prohibited, regulated, unregulated, or unlisted (M.S. 84D.04-.07). For example, the results of the risk assessment of Eurasian watermilfoil led the DNR Invasive Species Program to propose the species be classified as a *prohibited invasive*, to implement a multi-prong public education effort, to support research on new management methods for milfoil, and to help manage nuisances caused by the milfoil through grants for control work using herbicides and harvesting (See Management of Eurasian watermilfoil).

Goals

The goals of risk assessment, risk management, and related research are to:

- Identify invasive species that may be harmful to Minnesota resources;
- Identify the pathways by which invasive species come to Minnesota;
- Determine the best options to prevent the release and establishment of potentially invasive species and to implement them.

Risk Assessment of Individual Non-native Species

A risk assessment of a potentially invasive, non-native species includes an assessment of how likely it is to be introduced into the state, the likelihood of its naturalization in the state, the possible adverse effects it may have on native species, outdoor recreation, and other uses of natural resources in Minnesota, and the potential for its control.

One of the first risk assessments of individual species of potentially invasive, non-native species in Minnesota was done by the Minnesota Interagency Task Force (1991). The Task Force ranked the relative risk posed by 126 invasive plants and animals found in Minnesota. They also identified 27 species that were not in Minnesota, as potential threats (Minnesota Interagency Task Force, 1991). The scope of their report included both terrestrial and aquatic plants and animals.

Subsequent risk assessments were done by the DNR since the establishment of the Invasive Species Program. Varying approaches to the assessment of individual species have been used depending on need. In 1992, a fact sheet format was introduced for each species that the Invasive Species Program deemed potentially harmful. This format is geared towards the general public and gives basic information about the species, such as what it is, where is occurs, what problems it causes, how it spreads, and what can be done about it.

The DNR has done risk assessments on many species in order to determine if they should be regulated under law. In 1993, the DNR recommended that 26 non-native species be designated as undesirable exotic species via emergency rule. This was the first DNR list of species to be regulated because they were determined to be ecologically harmful. In 1996, state laws intended to minimize the introduction and spread of invasive species of wild animals and aquatic plants were revised, expanded, and consolidated into a new chapter of Minnesota Statutes, 84D. These statutes include a regulatory framework for risk assessment of individual non-native invasive species and for classifying those species. Each classification limits the use of the species based upon its potential to harm Minnesota's natural and economic resources. Species are classified either as prohibited, regulated or unregulated. Species not yet classified are considered unlisted (See Regulations and Proposed Changes).

The criteria used to classify species are: (1) the likelihood of introduction of the species if it is allowed to enter or exist in the state; (2) the likelihood that the species would naturalize in the state were it introduced; (3) the magnitude of potential adverse impacts of the species on native species and on outdoor recreation, commercial fishing, and other uses of natural resources in the state; (4) the ability to eradicate or control the spread of the species once it is introduced in the state, and (5) other criteria the Commissioner of Natural Resources deems appropriate (MS 84D.04).

Recently, two additional risk assessment efforts have started. The Minnesota Invasive Species Advisory Council (MISAC) convened a series of expert panel meetings to screen a large number of organisms potentially invasive in Minnesota. Panel members were brought in from multiple agencies with various regulatory responsibilities, including the Minnesota Department of Agriculture, the DNR, private industry (Invasive Species Program, 2004).

In addition to participating on MISAC panels, DNR staff are preparing detailed risk assessments of individual species. These risk assessments are an extension of past efforts. They contain more information than the MISAC panel risk assessments or the risk assessments done to classify species as prohibited, regulated, or unregulated.

These risk assessments can be used to guide risk management activities and are part of a process for deciding on risk management activities not only for species that are currently being evaluated, but ones that will be reviewed in the future.

Risk assessments of individual species answer the following questions:

1. Can it establish in Minnesota?
2. What are its pathways of spread?
3. What is the probability it can become established in Minnesota: high, medium, or low?
4. Could it be harmful to Minnesota's economy, environment, or society?
5. How can it be controlled?
6. How severe are the consequences of establishment: high, medium, or low?

In 2004, Invasive Species Program staff prepared a detailed risk assessment of brittle naiad (*Najas minor*). The following table shows a summary of the conclusions from the risk assessment for brittle naiad.

Can it establish in Minnesota?	Yes: currently in one lake in Minnesota
Pathways of spread	*Seeds and fragments with seeds attached can* spread on trailered watercraft and by water movement.
Probability of Establishment	**High**
Control methods	Annual control with herbicides or cutting.
Likely to cause problems?	Yes, but only in shallow water.
Consequence of Establishment	**Medium**

The DNR is currently considering which regulatory category to place brittle naiad in, and ways to educate the public about this species. More information about this species can be found in the "Other Invasive Aquatic Plant Species in Minnesota" chapter of this report.

Many less-detailed risk assessments have been completed on species of potentially invasive, non-native aquatic plants and animals that either have spread to or may spread to Minnesota. The following tables list the status of risk assessments of potentially invasive, non-native species. Table 7 lists invasive aquatic plants known to be present in Minnesota. Table 8 lists aquatic plants not known to be present in the state, and Table 9 lists invasive wild animals of concern to Minnesota.

Risk Assessment and Risk Management of Pathways of Invasive, Non-native Species Introduction

Pathway risk assessments are an attempt to predict how invasive, non-native species will enter Minnesota and in what numbers. Table 10 illustrates pathways the Invasive Species Program have identified and what has been accomplished to assess and manage the risks associated with those pathways. New pathways will be added as they become apparent.

Table 7. Non-native aquatic plants known to be established in Minnesota that either have been or may be subjected to risk assessments.

Legal Classification	Species	Distribution in MN	Risk Assessment	Status
Prohibited	Curly-leaf pondweed (*Potamogeton crispus*)	Widespread in MN	Completed	See curly-leaf pondweed chapter
Prohibited	Eurasian watermilfoil (*Myriophyllum spicatum*)	160 water bodies in MN	Completed	See Eurasian watermilfoil chapter
Prohibited	Flowering rush (*Butomus umbellatus*)	Limited number of known locations	Completed	See flowering rush chapter
Prohibited	Purple loosestrife (*Lythrum salicaria*)	Widespread in MN	Completed	See purple loosestrife chapter
Regulated	Yellow iris (*Iris pseudacorus*)	Numerous locations in MN	Completed	
Regulated	Non-native water lilies (*Nymphaea* spp.)	Limited number of known locations in MN	Completed	See other aquatic plants chapter
Unlisted	Brittle naiad (*Najas minor*)	One lake in MN	Completed	See other aquatic plants chapter
Unlisted	Common reed (Non-native genotypes) (*Phragmites australis*)	Widespread in MN	To be assessed by DNR in future	Research on distribution of non-native genotypes
Unlisted	Reed canary-grass (*Phalaris arundinacae*)	Widespread in MN	To be assessed by DNR in future	See other aquatic plants chapter
Unlisted	Hybrid cattail (*Typha x glauca*)	Widespread in MN	To be assessed by MISAC	
Unlisted	Narrow-leaved cattail (*Typha angustifolia*)	Widespread in MN	To be assessed by MISAC	
Unlisted	Salt cedar (*Tamarix ramosissima*)	One location in northern MN	In process by DNR	See other aquatic plants chapter
Unlisted	Watercress species (*Nasturtium* spp.)	Various locations in MN	To be assessed by MISAC	

Table 8. Selected non-native, invasive aquatic plants not known to be established in Minnesota which pose a potential risk to invade the state that either have been or may be subjected to risk assessments.

Legal Classification	Species	Closest occurrence	Risk Assessment
Prohibited	African oxygen weed (*Lagarosiphon major*)	Not found in the United States	Completed
Prohibited	Hydrilla (*Hydrilla verticillata*)	Pennsylvania, Arkansas	Completed
Prohibited	Aquarium watermoss (*Salvinia molesta*)	Found under cultivation in Minnesota; closest wild population in Virginia	Completed
Prohibited	Australian stone crop (*Crassula helmsii*)	Georgia	Completed
Prohibited	European frog-bit (*Hydrocharis morsusranae*)	Michigan	Completed
Prohibited	Water chestnut (*Trapa natans*)	New York, Pennsylvania	Completed
Prohibited	Indian swampweed (*Hygrophila polysperma*)	Texas	Completed
Prohibited	Water aloe (*Stratioites aloides*)	Florida	Completed
Prohibited	Water spinach (*Ipomoea aquatica*)	Found under cultivation in Minnesota; closest wild population in Florida	In process by DNR
Regulated	Carolina fanwort (*Cabomba caroliniana*)	Southeast Michigan	Completed
Regulated	Parrot's feather (*Myriophyllum aquaticum*)	Southern Missouri	Completed
Unlisted	Yellow floating heart (*Nymphoides peltata*)	Northern Illinois	In process by DNR
Unlisted	Brazilian elodea (*Egeria densa*)	Kansas	In process by DNR
Unlisted	Water primrose (*Ludwigia urugruayensis*)	Arkansas	To be done in the future by DNR
Unlisted	Water clover (*Marsilea* spp.)	Iowa	To be done in future by DNR

Table 9. Selected non-native, invasive wild animals that either have been or may be subjected to risk assessments.

Legal Classification	Species	Type of Species	Closest population	Risk Assessment
Prohibited	Bighead carp (*Hypophthalmichthys nobilis*)	fish	In southern Iowa. See Asian carp chapter	Completed
Prohibited	Black carp (*Mylopharyngodon piceus*)	fish	Illinois. See Asian carp chapter	Completed
Prohibited	Grass carp (*Ctenopharyngodon idella*)	fish	Southern MN. See Asian carp chapter	Completed
Prohibited	Round goby (*Neogobius melanostomus*)	fish	Lake Superior, St. Louis River estuary. See other invasive animals chapter	Completed
Prohibited	Rudd (*Scardinius erythrophthalmus*)	fish	Wisconsin, South Dakota	Completed
Prohibited	Ruffe (*Gymnocephalus cernuus*)	fish	Lake Superior, St. Louis River estuary	Completed
Prohibited	Sea lamprey (*Petromyzon marinus*)	fish	Lake Superior	Completed
Prohibited	Silver carp (*Hypophthalmichthys molitrix*)	fish	Mississippi and Des Moines rivers in Iowa. See Asian carp chapter	Completed
Prohibited	White perch (*Morone americana*)	fish	Lake Superior, St. Louis River estuary	Completed
Prohibited	Zander (*Stizostedion lucioperca*)	fish	North Dakota	Completed
Regulated	Alewife (*Alosa pseudoharengus*)	fish	Lake Superior	Completed
Regulated	Common carp, koi (*Cyprinus carpio*)	fish	Widespread in MN. See common carp chapter	Completed
Regulated	Goldfish (*Carassius auratus*)	fish	Naturalized in MN	Completed
Regulated	Rainbow smelt (*Osmerus mordax*)	fish	Northern MN	Completed
Regulated	Tilapia (*Tilapia* sp.)	fish	Texas; farmed in captivity in Minnesota	Completed
Unlisted	Tubenose goby (*Proterorhinus marmoratus*)	fish	Lake Superior, St. Louis River estuary. See other invasive animals chapter	In process by DNR

Table 9. (Continued)

Legal Classification	Species	Type of Species	Closest population	Risk Assessment
Prohibited	Northern snakehead (*Channa argus*)	fish	New England	In process by DNR
Unlisted	Snakehead (*Channa* spp.)	fish	Maryland	To be done in the future by DNR
Regulated	Chinese mystery snail (*Cipangopaludina* spp.)	invertebrate	Naturalized in MN	Completed
Regulated	Rusty crayfish (*Oronectes rusticus*)	invertebrate	Widespread in MN. See other invasive animals chapter	Completed
Regulated	Spiny waterflea (*Bythotrephes cederstroemi*)	invertebrate	Lake Superior, St. Louis River estuary. See other invasive animals chapter	Completed
Prohibited	Zebra mussel (*Dreissena* spp.)	Invertebrate	Mississippi and St. Croix rivers and two inland lakes in MN. See zebra mussel chapter	Completed
Unlisted	New Zealand mud snail (*Potamopyrgus antipodarum*)	invertebrate	Idaho	In process by DNR
Unlisted	(*Daphnia lumholtzi*)	invertebrate	Mississippi River in MN. See other invasive animals chapter	In process by DNR
Prohibited	Finnraccoon (*Nyctereutes procyonoides*)	mammal	Northern Europe	Completed
Prohibited	Eurasian swine (*Sus scrofa scrofa*)	mammal	In captivity in MN	Completed
Prohibited	European rabbit (*Oryctolagus cuniculus*)	mammal	Duluth, MN	Completed
Prohibited	Nutria, any strain (*Mycocastor coypu*)	mammal	Colorado, Ontario	Completed
Regulated	Egyptian goose (*Alopochen aegyptiaus*)	bird	Oregon	Completed
Regulated	Mute swan (*Cygnus olor*)	bird	Some wild in MN. See other invasive animals chapter	Completed
Regulated	Sichuan pheasant (*Phasianus colchicus strachi*)	bird	Michigan	Completed

Table 10. Potential pathways of invasive, non-native species introduction.

Pathway	Risk Assessment Progress	Risk Management Progress
Horticultural Nurseries	MN Sea Grant, MN DNR, in process	Laws passed to make possession and/or release of certain species illegal. MN DNR created and distributed educational documents to buyers and sellers of aquatic plants.
Biological Supply Houses	To be done in the future by DNR	Laws passed to make possession and/or release of certain species illegal.
Mail Order and Internet Catalogs	Perleberg (1998), Maki et al. (2004), completed	Laws passed that make possession and/or release of certain species illegal. MN DNR created and distributed educational documents to buyers of aquatic plants.
Pet Trade	MN DNR, in future	Laws passed that make possession and/or release of certain species illegal. MN Sea Grant and others are preparing educational materials.
Asian Markets	MN DNR, in process	Laws passed that make possession and/or release of certain species illegal.
Trading/Bartering	MN Sea Grant, in process	Laws passed that make possession and/or release of certain species illegal. MN DNR created and distributed educational documents.
Trailered Watercraft/ Recreational Activities	MN DNR, completed	Laws passed that make transporting aquatic plants on public roads, or launching watercraft with certain species attached illegal. DNR inspects boats and educates boaters – see Watercraft Inspections chapter.
Commercial equipment, i.e. aquatic plant harvesters, road construction, etc.	MN DNR, in process	Laws passed that make launching watercraft with certain species attached illegal.

Risk Assessment of Aquatic Plant Sales
Activities such as water gardening, wetland restoration, and shoreline plantings are increasing in popularity. While efforts to restore lakeshores to more natural conditions are recommended, the commercial sale of aquatic plants represents a significant pathway for the introduction of invasive species into Minnesota waters. The risk that invasive species will make their way into natural waters, either by accidental escape of cultivated plants or by deliberate introduction of aquarium or water garden plants, poses a threat to Minnesota lakes, rivers, and wetlands. The Invasive Species Program has been involved in several projects to assess and manage the risks associated with water gardening and related activities. A study of the movement of invasive species by the University of Minnesota, which has been described in previous reports by the Invasive Species Program, was published in 2004 (Maki and Galatowitsch, 2004).

During 2004, Invasive Species Program staff worked with Minnesota Sea Grant on its initiative "Preventing New Introductions of Invasive Aquatic Plants through Water Gardening and Shoreline Restoration." This project examines the potential for the introduction of aquatic nuisance species through the nursery trade, both regionally and nationally, and will develop key messages, and transfer an outreach program to other states. Sea Grant staff are currently in the process of administering a questionnaire for aquatic plant sellers to assess what is moving and how much they know about the risks posed by aquatic invasive plants. They have also put together a survey for water gardeners. This questionnaire can be found at the Web site www.shorelandmanagement.org/survey/.

Risk Management of Aquatic Plant Sales
In 2004, Invasive Species Program staff revised and continued to widely distribute two publications aimed at slowing the movement of invasive species through the horticultural trade: *Harmful Exotic Species: What every water gardener and shoreline restorer should know,* and *Harmful Exotic Species: What every aquatic plant seller should know.* These publications give aquatic plant buyers and sellers the information they need to be able to prevent the introduction of invasive species into Minnesota waters.

Invasive Species Program staff continued to make personal contact with nurseries throughout Minnesota, explaining the risks associated with some non-native aquatic plants, the laws which govern the sale and use of those plants, and how they can help prevent new introductions of invasive species into Minnesota. Nursery managers throughout the state have been extremely cooperative and offered to pass educational material along to their customers and staff.

Future needs for risk assessment, risk management, and related research

Risk Assessment

- Continue to identify non-native species that may be likely to enter Minnesota and evaluate their potential to cause problems if they become established in the wild.
- Continue to identify pathways which could bring non-native species into the state.
- Develop a database and maintain files at the DNR of literature about invasive aquatic plant and wild animal species, and pathways of their introduction to guide risk management activities.

Risk Management

- Determine and carry out appropriate actions to deal with species determined to be harmful to Minnesota. Actions will include education, monitoring and management, and formulation of public policy.

Research

- Encourage, fund, and support research to predict which non-native species are likely to naturalize and be harmful in Minnesota, and to examine the risks associated with particular pathways of introduction of those species.

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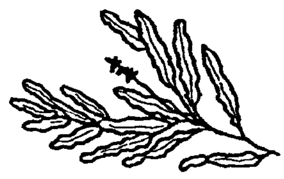
Management of Curly-leaf Pondweed

2004 Highlights



- The DNR has provided funding to the U.S. Army Research and Development Center to determine the lowest rate of fluridone herbicide needed to control curly-leaf pondweed and stop turion production.
- DNR staff assisted with several projects to evaluate management of curly-leaf with endothall herbicide, fluridone herbicide, and winter drawdown. In addition, staff initiated a study to determine the longevity of curly-leaf turions in lake sediments.
- Lake associations in many parts of the state have been successful controlling curly-leaf pondweed with endothall herbicide in cold water.
- DNR staff worked on 15 Lake Vegetation Management Plans for lakes with curly-leaf pondweed.
- Invasive Species Program staff were presenters at three well-attended curly-leaf pondweed symposiums. These workshops were co-sponsored by the Minnesota Lakes Association, the Initiative Foundation, and MInnesota Sea Grant.

Introduction

Issue

Curly-leaf pondweed (*Potamogeton crispus*) is a perennial, rooted, submersed vascular plant that was first noted in Minnesota about 1910 (Moyle and Hotchkiss, 1945). Curly-leaf pondweed is known to occur in 702 Minnesota lakes in 69 of the 87 counties in Minnesota (Figure 8). Unlike most native plants, curly-leaf pondweed plants remain alive, slowly growing even under thick ice and snow cover (Wehrmeister and Stuckey, 1978). Therefore, it is often the first plant to appear after ice-out.

By late spring, curly-leaf pondweed can form dense mats that may interfere with recreation and limit the growth of native aquatic plants (Catling and Dobson, 1985). In mid-summer, curly-leaf plants usually die back, which results in rafts of dying plants piling up on shorelines, and often is followed by an increase in phosphorus (Bolduan et al., 1994) and undesirable algal blooms. A key question underlying management of curly-leaf pondweed is: to what extent do lakes experience algal blooms due to the presence of curly-leaf pondweed, and to what extent do lakes grow large amounts of curly-leaf pondweed due to an abundance of algae and the nutrient regime that supports this condition?

Curly-leaf plants usually die back in early summer in response to increasing water temperatures, but they first form vegetative propagules called turions (hardened stem tips). New plants sprout from turions in the fall (Catling and Dobson, 1985).

Short-term control of dense mats of curly-leaf that interfere with the use of a lake can be obtained using contact herbicides or mechanical harvesting. Over the past few years, there has been an increase in the number of lake residents and lake associations

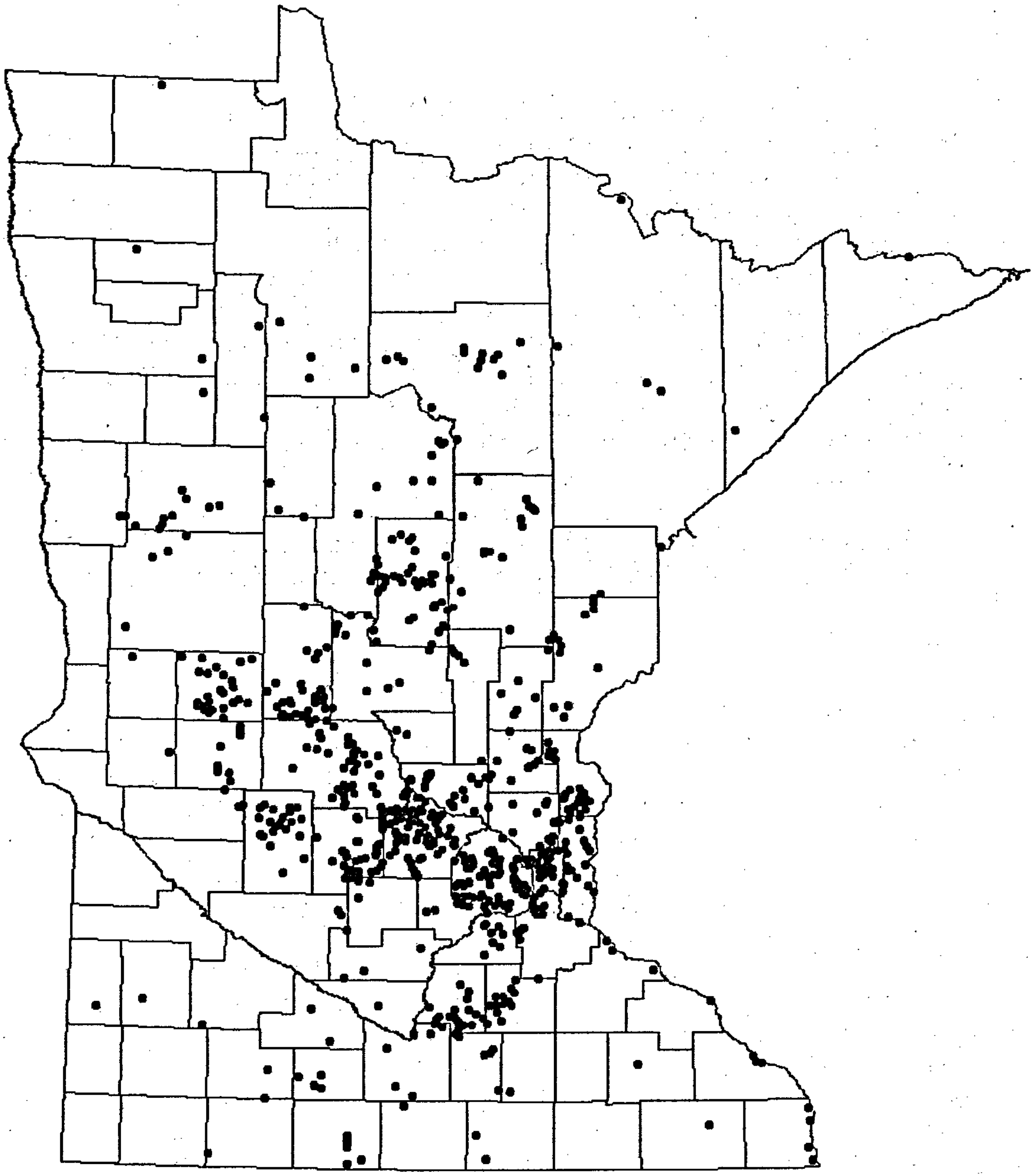


Figure 8. Curly-leaf pondweed locations in Minnesota as of December 2004 (compiled from reports from DNR Fisheries, Wildlife, and Ecological Services staff).

requesting assistance with problems caused by curly-leaf pondweed. More specifically, people want to know whether control can:

1. Reduce the lake-wide abundance of curly-leaf pondweed for long periods of time;
2. Increase the abundance of native submersed aquatic plants, and;
3. Improve water quality by reducing peaks in concentrations of phosphorous, and associated algal blooms.

In response, the DNR has increased its efforts to 1) provide technical assistance to lake residents and 2) evaluate new methods to control curly-leaf pondweed. In order to obtain long-term control of curly-leaf pondweed, the production of turions must be stopped. It is not clear how many years of turion reduction it will take to produce long-term control of curly-leaf

Goals

The DNR has two goals that apply to curly-leaf pondweed management:

- To prevent the spread of curly-leaf pondweed within Minnesota.
- To reduce the impacts caused by curly-leaf pondweed to Minnesota's ecology, society, and economy.

The DNR uses our Watercraft Inspection Program (see Watercraft Inspections and Awareness Events), enforcement (see Enforcement), and general public awareness efforts focused on the boating public (see Education and Public Awareness) to help achieve the first goal. The DNR has two strategies to achieve the second goal. One is to provide technical assistance to people who are managing curly-leaf pondweed. The other is to support and conduct research to improve the management of curly-leaf pondweed, and to communicate research results to the public.

Progress in Management of Curly-leaf Pondweed - 2004

Management of curly-leaf pondweed

DNR staff provided technical assistance to many lake groups working to control curly-leaf pondweed. Technical assistance included inspections and surveys of lake vegetation to determine the distribution and abundance of curly-leaf pondweed and native plants in these lakes. These efforts served as the basis for evaluation by the local residents and the DNR of the extent and severity of the problems caused by curly-leaf pondweed in these lakes. Following these evaluations, DNR staff reviewed options for control with the local residents. These evaluations also provide a basis to evaluate the effects of curly-leaf pondweed management efforts.

On a limited number of lakes, DNR Fisheries staff worked with local residents to produce Lake Vegetation Management Plans (LVMPs). The purpose of an LVMP is to develop agreement on goals for the aquatic plant community, identify issues, and design methods to reach those goals. LVMPs contain a description of the condition of the lake and plans to address any identified problems. DNR Fisheries staff worked on 15 LVMPs for lakes with curly-leaf pondweed in 2004. On eight lakes there were early-season curly-leaf treatments with endothall herbicide. DNR staff conducted lake vegetation surveys to determine the effectiveness of the treatments and the effects on native plant communities.

The DNR also provided technical assistance to people interested in controlling curly-leaf pondweed by providing guidance from CerexAgri, the manufacturer of the endothall based herbicides Aquathol K, Aquathol Super K, and Hydrothol 191. In 2004, CerexAgri provided new recommendations for the use of its products against curly-leaf pondweed. CerexAgri recommends that entire ponds or lakes or large area treatments should be done at 0.75-1.5 ppm, and that lake or pond margin or spot treatments be done at 1.5-2.0 ppm. CerexAgri states that these curly-leaf pondweed treatments may be made when water temperatures reach approximately 50°F. These recommendations were made in part based on the research which has been done in Minnesota on early-season treatments with endothall (see Research section immediately following).

Research to improve management of curly-leaf pondweed

DNR staff have conducted research and provided technical assistance and financial support to researchers working on curly-leaf pondweed. The principal activity in this area has been whole-lake management with herbicides to control the invasive plant. These treatments have four main goals:

1. Reduce the interference with use of the lake caused by curly-leaf pondweed.
2. Reduce the abundance of curly-leaf pondweed for long periods of time.
3. Increase the abundance of native, submersed aquatic plants.
4. Reduce peaks in concentrations of phosphorous and associated algal blooms.

Operational applications of herbicides to whole lakes that are classified as public waters (Minnesota Statutes (M.S.) 103G.005) are not allowed in Minnesota (Minnesota Rules Chapter 6280: Aquatic Plant Management) because this destroys more vegetation than is necessary to give riparian owners access to lakes. Unnecessary destruction of vegetation in Minnesota waters is not permitted because plants provide many benefits to lake ecosystems (M.S. 103G.615). For these reasons, application of herbicides to control submersed vegetation in Minnesota lakes is limited to treatment of no more than 15% of the littoral zone. A variance from this limit may be issued by the DNR. Variances have been issued for studies of control of curly-leaf pondweed by whole-lake management, where there is a well-developed plan and a commitment to monitor and report the effects of the treatment on the lake.

Repeated whole-lake treatments with endothall to control curly-leaf pondweed
Invasive Species Program staff continued to assist U.S. Army Engineer Research and Development Center (USAERDC) staff in their study of repeated whole-lake treatments of endothall herbicide against curly-leaf pondweed at low temperatures. The USAERDC has been treating two small lakes in Minnesota, Schwanz and Blackhawk, every spring since 2000 with endothall, a contact herbicide, to determine whether this approach can provide long-term control of curly-leaf pondweed. USAERDC researchers also monitored two untreated reference lakes as part of this study. It is hypothesized that this approach may deplete the "bank" of turions in the lake sediments and so reduce the growth of the invasive in the following year.

These annual treatments have been successful in controlling curly-leaf pondweed during the year of treatment, encouraging the growth of native plants, and reducing turion production. After whole-lake treatments four years in a row, curly-leaf pondweed was reduced to very low levels in these two lakes. In April 2004, curly-leaf was almost non-existent in Schwanz Lake and in one-half of Blackhawk Lake. In the other half of Blackhawk, curly-leaf was very rare. Enough curly-leaf was present in the one-half of Blackhawk Lake to warrant treatment, so that half of the lake was treated in April 2004.

There were several good-sized patches of curly-leaf pondweed in Schwanz by June 2004, though they were not at nuisance levels. In the untreated half of Blackhawk Lake, curly-leaf was still almost non-existent. It is not clear why curly-leaf came back so quickly in Schwanz and not in Blackhawk.

Based on the USAERDC research so far, the Invasive Species Program recommends that if you wish to use herbicide to control curly-leaf pondweed, you should use an endothall-based herbicide such as Aquathol K when water temperatures are 50 to 60 degrees F in the spring. These treatments should successfully kill curly-leaf pondweed, reduce or eliminate turion production in the treated areas, and will have less of a negative impact on native aquatic plants than treatments done later in the summer. It is not possible to completely eliminate curly-leaf pondweed from a water body using these early-season treatments, but it does appear to be possible to significantly reduce the amount of curly-leaf pondweed present.

Whole-lake management with low rates of endothall combined with 2,4-D for selective control of curly-leaf pondweed and Eurasian watermilfoil
The USAERDC is working in cooperation with Mississippi State University, the DNR, and CerexAgri to test the efficacy of early spring applications of endothall in combination with 2,4-D against curly-leaf pondweed and Eurasian watermilfoil in two Minnesota lakes. Their goal is to determine if selectively removing these invasive plants can result in a more diverse and abundant native plant community and to determine how these changes in the aquatic plant community affects the abundance, size, and species richness of fish communities. Bush Lake in Hennepin County and Zumbra Lake in Carver County were selected as treatment lakes. Piersons and Auburn lakes in Carver County were selected as untreated reference lakes. Pre-treatment plant data were collected during June and August 2003 by determining percent occurrence of aquatic plants and harvesting shoot biomass. Pre-treatment measurement of fish populations was conducted during June and September 2003 using nighttime boat electro fishing, pop-nets, seine nets, and larvae traps in the littoral zone. Plant and fish monitoring continued in 2004, and will continue through a two-year post-treatment period (Skogerboe et al., 2004).

Bush and Zumbra lakes were treated with 2,4-D and endothall herbicides in early May 2004. DNR staff assisted with pre-treatment and post-treatment surveys of Bush and Zumbra lakes. Initial surveys showed good control of curly-leaf pondweed and Eurasian watermilfoil.

Repeated whole-lake management with endothall to control curly-leaf pondweed
The City of Plymouth applied for and received a variance to treat almost the entire littoral zone of Medicine Lake with endothall herbicide in cold water. The City is

planning similar treatments for the next two years. The goals of the treatments are long-term control of nuisance growth of curly-leaf pondweed, establishment of a diverse native plant community, a reduction in the internal loading of phosphorus, an improvement in water quality, and an increase in recreational opportunities (Vlach et al., 2004).

There were two reasons why the DNR approved a variance for this treatment. The first reason is that there was a large body of water quality data from the lake taken over the past several years that indicated that curly-leaf pondweed was contributing to phosphorus loading and algal blooms in the lake. The second is that the City, as a condition of the permit, agreed to do extensive monitoring of the water quality and plant community in the lake. This monitoring will allow a determination of whether or not the goals of the treatment were met.

The City of Plymouth received technical support from the USAERDC, the Three Rivers Park District, and the DNR in planning and implementing the monitoring. The USAERDC did plant frequency sampling with assistance from the DNR, and Blue Water Science did quadrant stem counts and collected biomass samples. Three Rivers Park District monitored the water quality on a bi-weekly basis.

There is evidence from data collected this summer that the treatment led to a decrease in mid-summer phosphorus loading in the lake. In 2002 and 2003, there was a phosphorus pulse in June associated with curly-leaf pondweed dieback, and an associated decline in water clarity. In early May of 2004, almost the entire littoral zone of Medicine Lake was treated with endothall herbicide. In June 2004, there was no increase in phosphorus. There was a phosphorus pulse in May associated with the treatment, but it was smaller than the pulses associated with curly-leaf die back in 2002 and 2003, and there was no associated decline in water clarity (Vlach et al., 2004).

A similar, though somewhat smaller, effort is being undertaken on Spring Lake in Scott County by the Prior Lake-Spring Lake Watershed District. Monitoring was done by Blue Water Science.

Whole-lake treatment with fluridone to control curly-leaf pondweed

<u>Lake Benton, Lincoln County</u>
Lake Benton is a 2,857-acre lake with a maximum depth of nine feet. In August 2003, the Lake Benton Lake Improvement Association (LBLIA) requested permission to treat the lake with a multi-year series of fluridone herbicide treatments to control curly-leaf pondweed and deplete the turion bank in the lake. Recently curly-leaf pondweed has covered the entire lake during its peak biomass season of May-June. The LBLIA proposed to start treatments in 2004.

The DNR suggested to the LBLIA that treatment of up to 1,000 acres with endothall herbicide for at least three consecutive years was a better option because endothall has been shown to effectively control curly-leaf pondweed and encourage the growth of native plants. Lake Benton area groups, including the LBLIA, countered that the suggested endothall treatments would be too expensive, and would not be effective at reducing curly-leaf on a lakewide scale, because so much curly-leaf would remain in the lake to produce turions each year.

After additional discussion, the DNR agreed that an initial fluridone treatment could be scheduled for 2005 but that treatments in future years would be dependent on the success of the initial treatment. Specific criteria to define treatment success were identified, including specific plant community and water quality outcomes. DNR's Invasive Species Program is committed to collecting pre-treatment and post-treatment plant community data and water quality data.

The rate of fluridone used for the initial treatment will depend on the research currently being done by the USAERDC (see Evaluation of low rates of fluridone to control the growth and reproduction of curly-leaf pondweed section below).

Monitoring of the plant community and water quality was initiated in 2004 in anticipation of a 2005 treatment of Lake Benton with fluridone herbicide. DNR Invasive Species Program staff surveyed the plant community in the lake on June 1, 2, and 3, 2004, and on July 15 and 16, 2004. The Redwood-Cottonwood River Control District has been collecting water samples and turion samples from the lake with assistance from the Minnesota Pollution Control Agency. The DNR has arranged for these samples to be analyzed by the Minnesota Department of Agriculture. Lake residents have been collecting water clarity readings on the lake.

One of the goals of the treatment is to increase native plants in Lake Benton. Both the June and July surveys of Lake Benton showed an extremely depauperate community of native plants. Because of this, there has been interest in attempting to plant more native plants in the lake. DNR staff conducted assays on 22 Lake Benton sediment samples to determine whether native plant propagules already occur in the lake, so that replanting efforts could be focused on plants that will not recruit naturally. As expected, there was quite a lot of curly-leaf pondweed sprouting from the sediments. Curly-leaf sprouted from turions in 20 of the samples (91%). In many pots, many curly-leaf plants sprouted, and when they were removed, more sprouted in their place. Two native submersed species emerged from the sediments, leafy pondweed *(Potamogeton foliosus)*, and water stargrass *(Zosterella dubia)*.

<u>Weaver Lake, Hennepin County</u>

Various stakeholders suggested that it would be important to have at least one other lake to test low-dose fluridone. The DNR chose Weaver Lake because it is mesotrophic, it has several species of native submersed aquatic plants which should increase following a fluridone treatment, because there is good pre-treatment water quality and plant community data for the lake, and because there is a willingness from the lake association to fund the treatment and continue the monitoring.

Mesotrophic lakes generally have better water clarity than eutrophic lakes. Lake Benton is a highly eutrophic lake. The DNR felt it was important to test fluridone against curly-leaf in a mesotrophic lake because the outcome of fluridone treatments may vary between mesotrophic and eutrophic lakes. In our study of fluridone to control Eurasian watermilfoil (see Management of Eurasian Watermilfoil), we found that poor water clarity can exacerbate the impacts of fluridone on native plants, and make it difficult for native plants to re-establish.

The DNR has agreed to provide $10,000 each to the Weaver Lake Association and the Lake Benton Improvement District to help fund the fluridone test treatments.

Winter drawdown to control curly-leaf pondweed
Curly-leaf pondweed turions have been shown to be susceptible to freezing and/ or desiccation (Sastroutomo, 1982). Rice Lake (Hennepin County) was drawn down over two consecutive winters to a depth of 5 to 5.5 feet. These drawdowns effectively controlled curly-leaf pondweed for the summers following the drawdowns in the areas where lake sediments were exposed (McComas and Stuckert, 2000a). Although this management strategy may have limited application, the DNR is helping other groups evaluate this management approach. During the winter of 2003-2004, two Minnesota lakes were subjected to winter drawdown in an effort to control curly-leaf pondweed.

Cleary Lake, Scott County
Cleary Lake has been dominated with curly-leaf pondweed and rough fish. In October 2003, Three Rivers Park District and the DNR attempted to drain all of the water out of Cleary Lake in an effort to control curly-leaf pondweed and rough fish. Because of problems digging the channel to drain the lake, they were not able to drain all of the water out of the lake in 2003. There was an area in the center of the lake where the sediments were not exposed; there was ice sitting on top of the sediments. Curly-leaf was not controlled in this area, though it was controlled in the other areas of the lake where the sediments were exposed to drying and freezing (Vlach et al., 2004). They are in the process of drawing the lake down again, and are planning to use a pump to remove most of the water that remains after it drains as much as it can.

Lake Orono, Sherburne County
In November 2003, the City of Elk River in cooperation with the Lake Orono Improvement Association drew Lake Orono down approximately five feet. Lake Orono is an impoundment of the Elk River, and has a dam, which can be used to manipulate lake levels. This drawdown was done to control curly-leaf pondweed, which was growing in several near shore areas of the lake. A survey in December 2003 by DNR and City of Elk River staff found that the sediments, which were exposed to air, were frozen solid. Dead curly-leaf plants were found in this area. Areas, which had a layer of snow and ice over the lake sediments, were not frozen.

DNR staff surveyed Lake Orono in May and June 2004. It appears that the winter drawdown reduced the abundance of curly-leaf pondweed in the lake in the areas where lake sediments were exposed to drying and freezing. Nevertheless, curly-leaf still occurs in the lake. The City of Elk River and the lake association are considering future use of winter drawdown to control curly-leaf pondweed. There was some concern expressed by lake residents about observed turtle mortality caused by the drawdown. In order to prevent turtle mortality in the future, the lake must be drawn down in early October, before turtles have burrowed into the lake sediments for the winter.

Studies of biomass and carbohydrate allocation in curly-leaf pondweed
Researchers at Minnesota State University-Mankato completed studies of biomass and carbohydrate allocation in curly-leaf pondweed to determine the best time of year to control the invasive, non-native plant. This research was funded by the Invasive Species Program, which provided $53,000 of program funds to the researchers over a two and a half year period. The results of this study were published early in 2004 (Woolf and Madsen, 2003).

Evaluation of low rates of fluridone to control the growth and reproduction of curly-leaf pondweed
The DNR is providing $50,000 to the USAERDC to study the effects of fluridone herbicide on curly-leaf pondweed. This study will investigate the effects of fluridone on the growth and reproduction of curly-leaf pondweed. Two small-scale studies are being conducted using low rates of fluridone herbicide in cool water temperatures. The first study will evaluate various concentrations and exposure times of fluridone against curly-leaf pondweed to determine the herbicide doses that suppress or inhibit plant growth and prevent turion formation. The second study will evaluate the ability of fluridone-treated curly-leaf pondweed to withstand varying levels of turbidity. Results from the first study should be available in January 2005. Results from the second study should be available by April 2005.

Study of turion longevity in curly-leaf pondweed
In order to obtain long-term control of curly-leaf pondweed, the production of turions must be stopped. Nevertheless, it is unclear how long the "bank" of turions in lake sediments remains viable. There is very little information available on the longevity of curly-leaf turions in lake sediments. A study by Skogerboe and Poovey (unpublished data 2004) found that lakes, which had been treated with endothall to stop turion production, still had good recruitment from turions in the sediments after three consecutive years of treatment. McComas and Stuckert (2000b) found that after three consecutive years of early cutting aimed at stopping turion production in the cut areas, there was still curly-leaf growing in the cut areas.

During 2004, Invasive Species Program staff and Dr. Ray Newman from the University of Minnesota designed a study to determine the longevity of turions in lake sediments. The basic design is to place turions in "dark" mesh bags at different locations in several different lakes. The bags would be dark to enforce turion dormancy in the lake. At least 10 bags would be placed at each location. Each spring one bag of turions would be retrieved from each location and would be sprouted in the lab. Theoretically, turions will lose viability as they age. Eventually turions pulled from the lake should not sprout. By determining how many years it takes turions to lose viability in lake sediments, it will be possible to estimate how long a "bank" of turions might persist in a lake.

In 2004, DNR staff and Dr. Newman set up a test of these methods. Staff of the Invasive Species Program collected turions from standing plants in Cedar Lake in Rice County. They placed 15 turions each in approximately 40 mesh bags. Dr. Newman placed the bags in Smith's Bay of Lake Minnetonka. Half of the bags were placed in 2.1 meters depth. The other half of the bags were placed in 4.4 meters depth. Dr. Newman will pull one bag from each depth next spring to attempt to sprout the turions. If this method works, this effort will be expanded to include turions from more than one lake, and putting turions in several lakes.

Provide technical assistance

Staff of the Invasive Species Program have continued to provide the public with information on the best management practices for curly-leaf pondweed control through individual contacts and participation in public meetings. In 2004, staff presented talks at three curly-leaf pondweed symposiums organized by the Minnesota Lakes Association, Minnesota Sea Grant, and the Initiative Foundation. Staff also attended many lake association meetings, including meetings with the Lake Benton Lake Improvement Association in Lincoln County, the Weaver Lake Association in Hennepin County, and the Lake Orono Improvement Association in Sherburne County.

In 2003, Invasive Species staff wrote an article for the *Minnesota Lakes Association Reporter* about curly-leaf pondweed and its control (Crowell, 2003). Copies of this article continue to be been given out to many people requesting information on the control of curly-leaf pondweed.

Prevention of spread

Invasive Species Program staff have worked with the general public, lakeshore residents, and researchers to support our goals for curly-leaf pondweed. The Invasive Species Program continued to use watercraft inspections, informational materials, and public speaking engagements to further our efforts to prevent the accidental spread of curly-leaf pondweed. In particular, access inspectors spent time at several lakes, which are heavily infested with curly-leaf pondweed (See Watercraft Inspections and Awareness Events for a description of their activities).

Future needs for management of curly-leaf pondweed

- Review available information on the ecology and management of curly-leaf pondweed to identify possible research projects that might be carried out to improve management of the invasive in Minnesota. Provide funding for identified research needs.
- Continue to support research to determine how the growth and abundance of curly-leaf is affected by the elimination of turion production.
- Continue public awareness efforts focused on containing curly-leaf pondweed to where it is already found. Opportunities include our TV and radio advertising, Watercraft Inspection Program, literature, and public speaking engagements.
- Continue to provide information on the best management practices for curly-leaf pondweed control to the public.
- Continue to provide technical assistance and other support to researchers working on curly-leaf control, and the relationships between curly-leaf populations and lake water quality in Minnesota.

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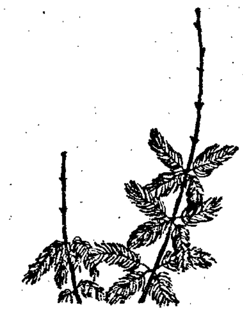
Management of Eurasian Watermilfoil

2004 Highlights

- Eurasian watermilfoil was discovered in eight additional Minnesota water bodies during 2004 including Leech Lake in Cass County. There are now 160 Minnesota lakes, rivers, and streams known to contain the invasive submersed aquatic plant.
- In 2004, the Invasive Species Program increased both the total amount of funding and the amount available to individual lakes for control of Eurasian watermilfoil by cooperators such as lake associations or local units of government. Though there was an increase in the total funds paid out by the DNR to cooperators, there was a decrease in the number of lakes where cooperators were reimbursed by the DNR.



- Results of research completed in 2004 suggest that use of fluridone herbicide, even at low rates, to control Eurasian watermilfoil in lakes with low water clarity, five to seven foot Secchi depth or less, is likely to do more harm than good due to deceases in native plants.

Issue
Eurasian watermilfoil (*Myriophyllum spicatum*) is an invasive submerged aquatic plant that was inadvertently introduced to Minnesota. Eurasian watermilfoil, hereafter called milfoil, was first discovered in Lake Minnetonka during the fall of 1987. Milfoil can limit recreational activities on water bodies and alter aquatic ecosystems by displacing native plants. As a result, Minnesota established the Minnesota Department of Natural Resources' (DNR) Invasive Species Program to manage milfoil, as well as certain other harmful invasive species. Milfoil is classified as a *prohibited invasive species*, which means that it may not be bought, sold, or possessed in Minnesota. In this report, we describe the efforts of the Invasive Species Program to manage milfoil and limit its spread in Minnesota during 2004.

Goals
The Invasive Species Program has two primary goals for management of milfoil in Minnesota. They are listed below along with the principal strategies that are pursued to achieve these goals.

- Prevent spread of milfoil in Minnesota
  - Monitor distribution of milfoil in Minnesota
  - Show boaters how to prevent the spread of milfoil (see Watercraft Inspections and Awareness Events)
- Reduce problems caused by milfoil in Minnesota
- Provide funding for maintenance management by cooperators
  - Conduct high-intensity management and control at public water accesses
  - Provide technical assistance
  - Support or conduct research on the ecology and management of milfoil

Spread of Eurasian Watermilfoil in Minnesota during 2004

Milfoil was discovered in seven new lakes and one new river during 2004 (Tables 11 and 12, plus Figure 9). Three of these lakes are located in the seven-county metropolitan area. In addition, milfoil was found during 2004 in two counties where the invasive had not previously been discovered, Leech Lake in Cass County and Lura Lake in Blue Earth County.

The discovery of milfoil in Leech Lake may signal future problems in a part of Minnesota that has not had to deal with this invasive plant in the past. Only a few other Minnesota lakes are larger than Leech, which covers approximately 112,000 surface acres. Immediately following the confirmation of the identity of the milfoil found in Leech Lake, the DNR sent crews to search for the plant along the entire shoreline. Milfoil was only found in five harbors along the southern shore. The DNR had a contractor apply herbicide to milfoil in all five harbors to reduce the amount of milfoil and thus reduce the likelihood that boaters might accidentally carry the plant from the lake on trailered watercraft.

Leech Lake has nine public water accesses and numerous private harbors and resorts. Consequently, boaters using these accesses may inadvertently transfer milfoil to other lakes in the area if they are not especially careful to clean all vegetation from their boats, trailers, and other equipment before leaving the access.

Though much of Leech Lake does not support growth of submersed aquatic plants, some bays like those in the northern and eastern parts of the lake support stands of cabbage and other native plants. In the future, milfoil may take hold in some parts of the lake where native aquatic plants now grow.

Similarly, the discovery of milfoil in Lura Lake in Blue Earth County means that the invasive plant is now in another part of Minnesota that has not had to deal with this invasive plant in the past. Nevertheless, the clarity of waters in lakes and so potential problems caused by milfoil in this part of Minnesota are, on average, lower than that of lakes in the northern part of the state near Leech Lake.

Milfoil is now known to occur in 160 water bodies in Minnesota. On a statewide basis, milfoil has been found to occur in about 1% of Minnesota's lakes.

The rate of spread of milfoil in Minnesota, as reflected in the annual discovery of new occurrences of the invasive, has changed little over the last three to four years (Table 11). This observation is based on the running three-year average for number of lakes in which milfoil was discovered, which appears to have declined slightly after experiencing an increase that began in 1998 and reaching a peak in 2000.

Discovery of new occurrences of Eurasian watermilfoil in Minnesota

Characteristics of some newly discovered occurrences of milfoil suggest that there likely are other water bodies in Minnesota with the non-native, invasive plant that have not yet been discovered. In some cases, milfoil is discovered years after the time when it became established in a lake. For example, on Leech Lake, a well-developed recreational lake in Cass County, a staff person from the Minnesota Pollution Control Agency while off-duty discovered milfoil on a beach near a public water access.

Subsequent inspection of the lake by the DNR found milfoil, which in one case was matted on the water's surface, in a number of additional areas of the lake. This suggests that milfoil invaded this lake some years ago. Nevertheless, it was not reported to the DNR by local users of the lake, perhaps because they were unfamiliar with the plant.

In other lakes, milfoil appears to have been discovered before the invasive became abundant or widespread when an unusually knowledgeable person noticed the plant (Table 12). For example, a new occurrence of milfoil on Big Marine Lake in Washington County was reported by an individual who is familiar with the invasive plant because he was a summer intern for the DNR's Invasive Species Program. Further, the plant was discovered by the intern while scuba diving and could not be re-located by other DNR staff who subsequently searched the area by boat. This experience suggests that it would be highly unlikely that other users of the lake would discover this milfoil unless they happened to unintentionally catch a plant on a fishing line or anchor.

Many false reports of milfoil result when other species of submersed vegetation, often forming mats, attract the attention of users of Minnesota lakes. These individuals suspect that the abundant vegetation is milfoil and report the occurrence to the Invasive Species Program. During 2004, as in previous years, most of these reports were found to be occurrences of various native aquatic plants. It has been extremely useful for citizens to send the DNR samples of suspected Eurasian watermilfoil so the plants can be quickly identified. The DNR encourages the public to report suspected new occurrences of milfoil to us.

Participation in monitoring the distribution of Eurasian watermilfoil by other state agencies, local units of government, and interested groups

The participation of other divisions of the DNR and outside agencies, citizens, etc., in reporting new occurrences of milfoil remains critical (Table 11). This assistance is very important because people in the Invasive Species Program are only able to visit a limited number of lakes each year. Efforts by others to search for milfoil and report suspected occurrences of the invasive greatly increase the likelihood that new occurrences are discovered. The Program investigates likely reports of new infestations as soon as possible for two reasons. First, it is important to determine whether milfoil actually is present in the lake. Second, if the invasive is present, then it is important to minimize the risk of spread to uninfested waters by notifying the users of the lake. It is hoped that once people who use a lake are aware of the presence of milfoil, they will be especially careful to not transport vegetation from the lake on their boats, trailers, or other equipment.

Table 11. Number of lakes or rivers where Eurasian watermilfoil is known to occur in Minnesota as of December 2004.

Year	Number of lakes in which milfoil was discovered	Running three-year average for number of lakes in which milfoil was discovered	Number of rivers in which milfoil was discovered	Cumulative number of water bodies with milfoil	Cumulative number of counties with milfoil
1987	1	-	0	1	1
1988	8	8	0	9	5
1989	14	11	1	24	8
1990	12	13	1	37	10
1991	14	12	0	51	11
1992	10	10	2	63	13
1993	5	5	0	68	13
1994	2	5	0	70	14
1995	7	5	1	78	14
1996	5	5	0	83	15
1997	5	6	0	88	15
1998	9	7	1	98	17
1999	8	10	0	106	20
2000	14	11	1	121	22
2001	12	11	0	133	23
2002	8	10	0	141	25
2003	11	9	0	152	26
2004	7	-	1	160	28

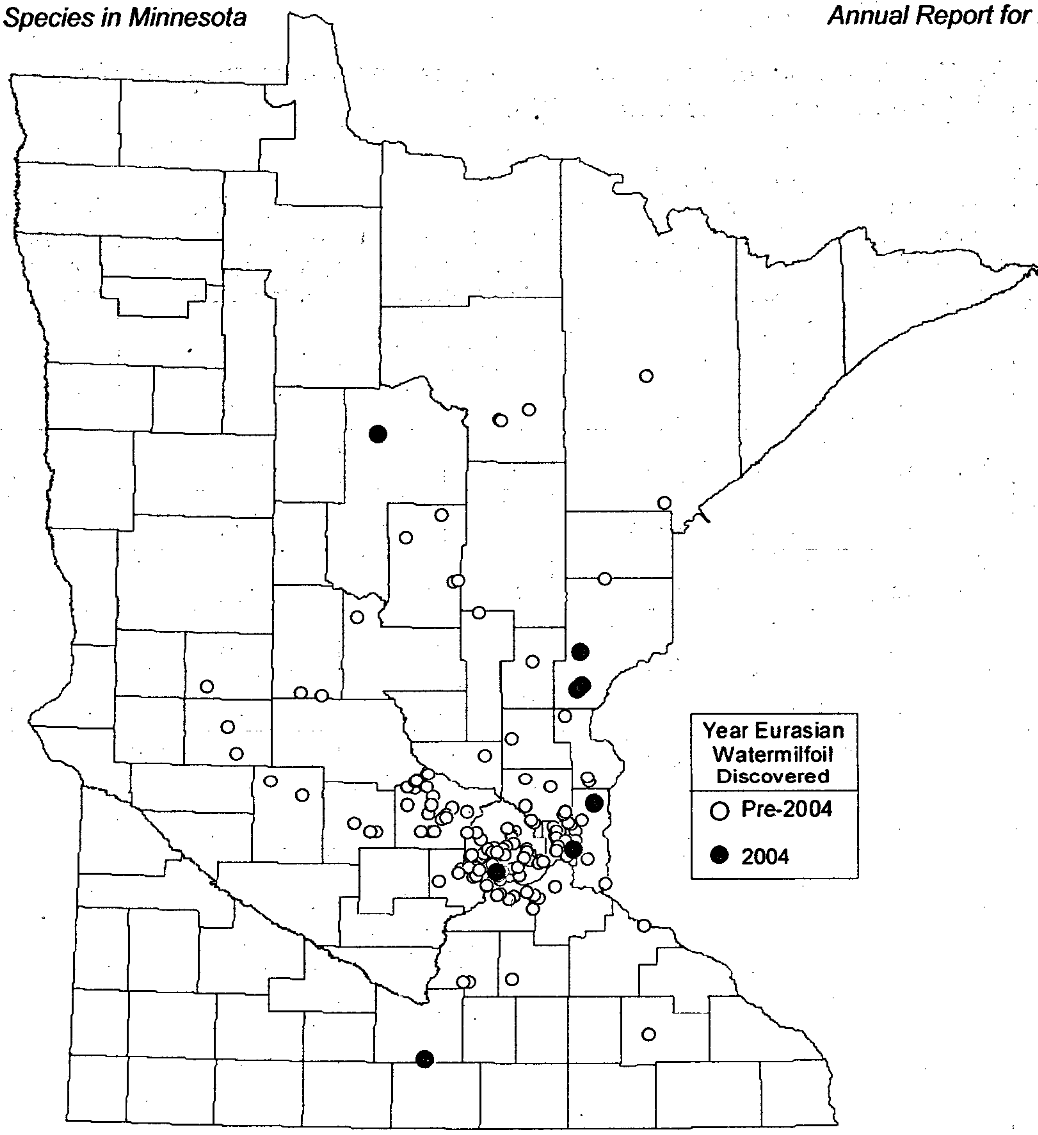


Figure 9. Distribution of water bodies with Eurasian watermilfoil in Minnesota as of November 2004.

Reports of suspected occurrences of milfoil that turn out to be mistaken also have value. In the course of responding to such reports, people in the Invasive Species Program discuss identification of the non-native Eurasian watermilfoil with the observer and so increase the number of people who in the future are likely to be able to distinguish the invasive from native plant species that are similar in appearance.

Table 12. Minnesota lakes and rivers where Eurasian watermilfoil was discovered in 2004.

Number	Date Reported	Lake and County Names	DOW Number	Reporter
1	9 July	Beaver, Ramsey	62.0016	DNR Fisheries
2	14 July	Leech, Cass	11.0203	Pollution Control Agency
3	19 July	Big Marine, Washington	82.0052	DNR Invasive Species Program
4	29 July	Susan, Carver	10.0013	Citizen
5	1 September	Unnamed gravel pit, Pine	58.____	Citizen
6	9 September	Lura, Blue Earth	7.0079	DNR Fisheries
7	14 September	Cross, Pine	58.0119	DNR Invasive Species Program on different assignment
8	14 September	Snake River, Pine	58.____	DNR Invasive Species Program on different assignment

Management of Eurasian Watermilfoil in Minnesota during 2004

Classification of water bodies for management of Eurasian watermilfoil
In the spring of 2004, the Invasive Species Program classified the 152 bodies of water known to have milfoil on the basis of information available in 2003 (Table 13). One hundred thirteen lakes were determined to be eligible for management with state funds because they have public water accesses and are protected waters that are regulated by the state (Minnesota Statute 103G.005, Subd. 15). Lakes eligible for management of milfoil with state funds are divided into two classes: maintenance management and high-intensity management. Most lakes are assigned to the maintenance management class. During 2004, two lakes were assigned to the high-intensity management class (Table 13).

Some lakes were determined to be ineligible for management with state funds because they either do not have public water accesses or are not protected waters. Lastly, flowing waters such as rivers and streams are not usually considered for management of milfoil with state funds because: 1) users of these waters in Minnesota rarely encounter problems caused by milfoil like those found in lakes, and 2) use of herbicides is less reliable in rivers and streams than in lakes.

Five of the eight water bodies that were discovered to have milfoil during 2004 were eligible for management with state funds because they have public water accesses (Table 13). All five were classified for maintenance management. None was placed in the high-intensity management class because all of the newly discovered lakes had more than a limited amount of milfoil or were located in the Twin Cities metro area. Two lakes found to have milfoil in 2004 have no public water access and, consequently, are ineligible for management with state funds.

Maintenance management of Eurasian watermilfoil
During 2004, state funding and technical assistance were available from the Invasive Species Program to potential cooperators for management of milfoil on lakes in the maintenance management class (Table 13). The offer of state funding is described in an announcement that is available to potential local cooperators (DNR 2004) who are expected to take the lead in assessment and control of the milfoil. The offer is briefly summarized here. The most common activity on lakes in the maintenance management class that receive funds from the DNR is application of herbicide, followed by mechanical harvesting and planning. These funds are intended to pay for control during spring or early summer of unavoidable nuisances caused by dense and matted milfoil that will benefit a number of homeowners and the general public who use a lake.

These funds may not be used for control work that would otherwise be done by private individuals. Typically, control undertaken by private individuals is done immediately adjacent to the owner's shoreline or adjacent to structures such as docks. These funds may also be used for control intended to slow the spread of the invasive to other lakes.

During 2002, it was suggested to the DNR that the amount of funding available for control of milfoil on relatively small lakes was too small to encourage potential cooperators to try to obtain this funding. Consequently, the amount of funding available to individual lakes was increased in 2003 and again in 2004 (Table 14).

Table 13. Classification of water bodies in Minnesota with Eurasian watermilfoil during 2004.

Classification	Spring	New in Summer	Fall
Eligible for management with state funds			
Maintenance management	106	5	116
Fluridone evaluation (treated & reference)	5	0	0
High-intensity management	2	0	2
(Subtotal)	(113)	(5)	(118)
Ineligible for management with state funds	26	1	28
Public water but no public access	1	0	0
Fluridone evaluation (treated)	5	1	6
Not public water	(32)	(2)	(34)
(Subtotal)			
Other			
Rivers or streams	7	1	8
Total	152	8	160

Table 14. Basis for offer of state funding to potential local cooperators for management of Eurasian watermilfoil on Minnesota lakes that are public waters and have public water accesses.

Year	Littoral Acres		
	0-50	51-100	> 100
2002	≤ $700	≤ $700	$700 plus $4 for each littoral acre above 100
2003	≤ $700	≤ $1,200	$1,200 plus $5 for each littoral acre above 100
2004	≤ $700	≤ $1,200	$1,200 plus $7 for each littoral acre above 100

The DNR received applications for state funding to control milfoil from potential cooperators on 26 lakes (Table 15). Applications were reviewed by the Invasive Species Program in relation to the standards described in the announcement that is available to potential cooperators (DNR 2004). More than half of the applications were approved as submitted. Questions about the other applications led to inspections of the milfoil in these lakes by staff of the Invasive Species Program. These inspections revealed that some sites proposed to be treated with herbicide either did not have dense and matted milfoil or did not constitute an unavoidable nuisance for users of the lake. The results of these inspections and recommended modifications of proposed control projects were reported to the potential cooperators and staff in the Aquatic Plant Management Program who issue permits for control. On two lakes, proposals were modified by reducing the size of the area to be treated, and subsequently approved. Applications for reimbursement were denied on six lakes. Lastly, in two cases, applications for reimbursement were not pursued because the local cooperator did not actually undertake control.

Table 15. Number of Minnesota lakes in the maintenance management class where management of Eurasian watermilfoil was supported with state funds in 2002-2004.

Status	Number of Lakes		
	2002	2003	2004
Applications received	32	32	26
Applications approved	15	19	16
Applications approved after modification	6	4	2
Applications denied	3	6	6
Applications not pursued	8	3	2
Total approved	21	23	18

As a result, the DNR expects to reimburse 14 cooperators on 18 lakes for costs of milfoil management during 2004. In addition, the Invasive Species Program initiated treatment of milfoil in the immediate vicinity of public water accesses operated by the DNR on five lakes in the maintenance management class. The purpose of this type of control is to reduce the risk that users of the lake inadvertently transport milfoil from the lake to other bodies of water.

During the spring of 2004, the DNR offered funding to local cooperators for assessments of problems caused by milfoil (Table 16). Guidelines for preparation of these assessments were provided by the DNR. These efforts were intended to provide assessments of the potential interference by milfoil with the use of individual lakes (see DNR, 2004). The assessment described here is not a management plan because it is not intended to include descriptions or recommendations of approaches to control milfoil. Nevertheless, an assessment could well become the basis for development of a plan. The DNR will review the assessments completed in 2004 and discuss them with cooperators to determine how to proceed in 2005.

Table 16. Number of Minnesota lakes in the maintenance management class where development of plans for management or assessments of Eurasian watermilfoil was supported with state funds in 2002 and 2004.

	Number of lakes	
Plan or assessments by cooperator	**2002 (Plans)**	**2004 (Assessments)**
Applications received	11	9[1]
Applications approved and projects to be completed during the current calendar year	9	4
Applications approved and projects to be completed during the next calendar year		2
Applications denied	2	1
Applications not pursued		2

[1] Includes three applications received in 2003.

High-intensity management of Eurasian watermilfoil

For lakes assigned to the high-intensity management class, the DNR continued to take the lead in assessment and control of milfoil. The goals of high-intensity management are to: 1) limit the spread of the plant within a lake, 2) reduce the abundance of milfoil within a lake, and 3) slow the spread of the invasive to other lakes. High-intensity management usually involves efforts to find all milfoil in a lake and treat it with herbicide. High-intensity management usually is undertaken by the Invasive Species Program on a very few lakes that either have small, recently discovered populations of milfoil or are located in areas of Minnesota where there are few, if any, other lakes with milfoil. In addition, a small number of lake associations also undertook high-intensity management of milfoil during 2003. During 2004, the Invasive Species Program conducted high-intensity management of milfoil (see description above) on the two lakes in this class (Table 13): McKinney and Ice. High-intensity management began with surveys of the lakes by staff of the Invasive Species Program and was followed by consideration of possible control. In 2004, the DNR decided not to proceed with application of herbicides by commercial applicators under contract to the DNR on either of the two lakes in the high-intensity management class.

Lake McKinney and Ice Lake, which is connected to McKinney, were discovered to have milfoil in 1999. Due to their location in northern Minnesota, in an area with no other known occurrences of milfoil, these two lakes represented a potential source of the invasive that might be spread to many uninfested lakes. To reduce the risk of spread, the DNR subjected these lakes to whole-lake treatment in 1999 with fluridone, the active ingredient in Sonar™ herbicide (see Exotic Species Program, 2000). Inspection of the lakes by the DNR in 2004 found a much larger area with milfoil in Lake McKinney, which was not treated by the DNR. No milfoil was seen in Ice Lake during 2004, as was the case in the four preceding years. Based on past experience in Minnesota with fluridone treatments on other lakes, we expect that milfoil will reappear in Ice Lake in the future.

Technical assistance to cooperators and other citizens
Technical assistance was provided by the Invasive Species Program to cooperators and other citizens and managers. Staff of the Invasive Species Program attended numerous meetings of lake associations and local units of government to make presentations and participate in discussions of approaches to management of milfoil. During the course of a season, staff of the Invasive Species Program have many conversations with people over the telephone. In addition, staff of the Invasive Species Program exchange correspondence by regular mail and e-mail with people who need assistance in dealing with milfoil.

Effectiveness of management of Eurasian watermilfoil in Minnesota lakes
Though the number of Minnesota lakes known to have milfoil increased in 2004, the number of applications received for DNR funding for maintenance management control projects was less than the number in 2003 (Table 15). The number of lakes where cooperators received DNR funding for control of milfoil during 2004 decreased by comparison with the previous year (Table 17). Nevertheless, the cost of control by cooperators that was reimbursed by the DNR in 2004 increased by 40% by comparison with 2003. This is attributed to the increase in funds offered to individual lakes by the DNR.

In 2004, potential cooperators used only 73% of the funds that were budgeted by the DNR for reimbursement for control of milfoil (Table 17). Possible explanations for this outcome include: 1) lack of nuisances caused by milfoil that met the criteria for funding by the DNR, and 2) lack of awareness of the program among potential cooperators.

Table 17. Number of lakes, budgets, and expenditures in different classes of management of Eurasian watermilfoil in Minnesota during 2001-2004.

Year	Number of lakes in class in spring	Funds budgeted in spring	Number of lakes in class where control was done	Funds spent
Maintenance Management Control by Cooperators and Reimbursed by DNR				
2001	74	$149,000	31	$71,000
2002	90	$80,000	21	$43,000
2003	96	$105,000	23	$76,000
2004	105	$145,000	18	$106,000
Assessment by Cooperators and Reimbursed by DNR				
2004		$30,000	4	$11,000
Control by DNR at DNR Public Water Access				
2001	--	--	1	$600
2002	--	--	7	$11,000
2003	--	$15,000	8[1]	$11,000
2004		$15,000	5[2]	$12,000
High-Intensity Management				
2001	16	--	8	$34,000
2002	5	$15,000	2	$9,000
2003	5	$15,000	3	$9,000
2004		$10,000	0	0
Totals				
2001	90	$149,000		$105,000
2002	100	$95,000		$77,000
2003	107	$153,000	31	$96,000
2004	114	$200,000	26	$140,000

[1] Three of these lakes also received funding for maintenance management.
[2] One of these lakes also received funding for maintenance management.

In 2004, the growth of milfoil and also the problems caused by the plant in many lakes seemed to be somewhat less than levels observed in some previous years. In the Minneapolis area, reduced water clarity might have resulted from high levels of precipitation in May followed by levels that appear to be somewhat below average in June (Figure 10). The high levels of precipitation, in turn, would create high levels of overland run-off that would carry nutrients like phosphorous into the lakes. These nutrients can promote the growth of algae, both on plants and in the water column, which can suppress the growth of submerged aquatic plants like milfoil.

It is interesting to note that levels of precipitation in the Minneapolis area during April, May, and June averaged over the four years from 2001 to 2004 are greater than the long-term averages for these months (Figure 10). For comparison, precipitation levels in 1988, a year when we experienced drought in spring, were very low and the growth of milfoil was high.

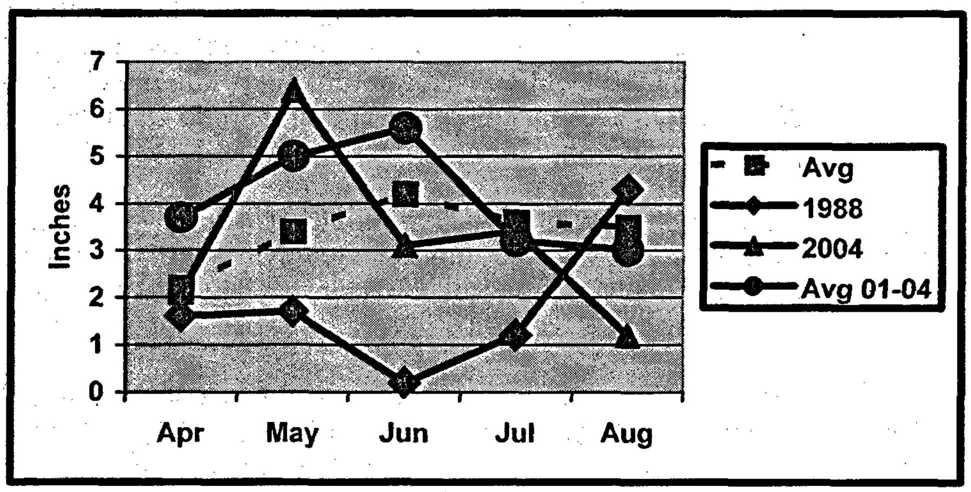


Figure 10. Monthly precipitation in Minneapolis, Minnesota, averaged for the last 112 years; in 1988, which was a drought year; in 2004; and averaged for 2001-2004.

Participation in control efforts by other state agencies, local units of government, and interested groups

Cooperation between the Invasive Species Program and organizations outside the DNR such as lake associations and various local units of government was critical to the success achieved in management of milfoil and the problems it causes in Minnesota. The Invasive Species Program has also received valuable assistance from staff from DNR Fisheries and the DNR's Aquatic Plant Management Program in the Section of Fisheries and the Division of Ecological Services.

Research on Eurasian Watermilfoil and Potential Approaches to Management in Minnesota

The Invasive Species Program has supported or conducted a number of research projects to improve management of milfoil. In this section, we briefly summarize activities or results of recent efforts by researchers.

Potential for biological control of Eurasian watermilfoil
In 2004, researchers at the University of Minnesota concluded efforts to evaluate the potential for biological control of milfoil that have been supported with funding appropriated by the Minnesota Legislature as recommended by the Legislative Commission on Minnesota Resources (LCMR) since 1992. The research was focused on a weevil (*Euhrychiopsis lecontei*) and found that its activities can cause declines in milfoil, but that these declines do not occur in all lakes with the weevil, and that declines may be temporary (Newman, 2004a).

The research described above was supported by funding provided through the DNR with an appropriation of $45,000 for the FY 2002-2004 period made in 2001 by the Legislature as recommended by the LCMR. This appropriation was matched by a commitment of $50,000 from Invasive Species Program funds (see Overview of DNR's Invasive Species Program, Funding Sources).

During 2004, Ray Newman, the principal investigator at the University of Minnesota, published one paper (Newman, 2004b), had one manuscript in review (Ward and Newman), and had two manuscripts in preparation (Newman, Huser, and Brezonik; Newman).

Assessment and modeling of growth and abundance of Eurasian watermilfoil
In February 2004, the Invasive Species Program committed $35,000 to support research by the University of Minnesota on milfoil. Analysis of data collected from previous studies on the biological control of milfoil with herbivorous insects led to development of a model to predict that 38% of Minnesota lakes that are not known to have milfoil are susceptible to invasion (Newman, Herb, and Roley, 2004). The researchers parameterized and calibrated simulation models of milfoil growth and abundance. Subsequent simulations reasonably predicted variation among years in biomass of submersed plants as a function of water temperature, Secchi depth, and solar radiation. Needs for additional work to improve the utility of models were described.

Effects of treatments with alum on Eurasian watermilfoil
Four lakes in Minneapolis dominated by milfoil were treated with alum in attempts to increase water clarity. Overall, these treatments produced little or no increase in the abundance of milfoil, and neither enhanced native plants nor increased species richness (Newman et al., 2004).

Hybrids between the non-native Eurasian and native northern watermilfoil
Late in the summer of 2003, the Invasive Species Program committed an additional $5,000 to support research by the University of Connecticut to determine whether there are differences in growth between Eurasian watermilfoil and the hybrid. This research

determined that rates of growth of the hybrid and Eurasian watermilfoils were similar (Moody and Selsky, 2004).

Potential to use fluridone herbicide to selectively control Eurasian watermilfoil
The potential use of fluridone herbicide, which is formulated as Sonar^{TM} and AVAST! ^{TM}, to control milfoil has been the subject of much discussion in Minnesota because the product is usually applied to whole bays or lakes (see Welling et al., 1997, Exotic Species Program, 2001). Operational treatment of whole bays or lakes with herbicide is not allowed in Minnesota because this destroys more vegetation than is necessary to give users access to the lake.

In 2000, new information was made available from studies in Michigan which suggested that application of fluridone at low rates of 5 to 6 ppb may provide more selective control than had previously been observed in Minnesota (Getsinger et al., 2001; Madsen et al., 2003). To address questions about possible harm to native plants, the DNR is conducting an evaluation of the potential to use fluridone herbicide to selectively control milfoil in Minnesota. As part of this evaluation, three Minnesota lakes were subjected to whole-lake treatments with fluridone in 2002. For the 2002 treatments, the target concentrations were 4.6 to 5 ppb fluridone. The lakes selected for this evaluation were eutrophic lakes, which had average Secchi depths of approximately five to seven feet.

The effect of fluridone on the plant community was evaluated by examination of the distribution and standing-crop biomass of individual species in the lakes. The distribution of individual species was estimated by determining their frequency, which is the percentage of sampling sites at which the plant was present. Sampling by the DNR of the three treated lakes and three untreated reference lakes began in 2001 and continued through 2004.

Results of sampling done from 2001 through 2003 became available during spring, 2004 (Crowell et al., 2004). Crowell et al. (2004) reported that treatment with fluridone reduced the frequency of milfoil to zero. Treatment also reduced the biomass of native submersed plants by an average of 94%. Following treatment with fluridone, the frequency of curly-leaf pondweed increased. Treatment with fluridone did not reduce the distribution or abundance of waterlilies. Following treatment with fluridone and resulting lake-wide reductions in the distribution and abundance of submersed plants, Secchi depth in one of the lakes decreased by half during the year after treatment by comparison with the preceding year.

Preliminary results of sampling done in 2004 indicated that milfoil had not yet been found in any of the three treated lakes. In one of these lakes, Crooked Lake, there was a rebound in the above ground biomass of native submersed aquatic plants during 2004, two years after treatment. This trend was not observed in the other two treated lakes. In addition, the average number of native submersed taxa per sampling site in Crooked Lake rebounded during 2004.

The results of whole-lake treatments of three eutrophic Minnesota lakes made in 2002 suggest that use of fluridone herbicide, even at low rates, to control milfoil in lakes of this type is likely to do more harm than good due to deceases in native plants. Additional information from similar treatments made in mesotrophic lakes, where average Secchi depth would be about 14 feet, suggests that control of milfoil in lakes of this type may be followed by increases in native plants. More research on the effects of fluridone in mesotrophic lakes would appear to be useful.

At this time, the DNR does not intend to allow additional whole-lake treatments with this herbicide to control milfoil before 2006. This means that we would not review any proposal for such a treatment before 2005, when pre-treatment surveys of the vegetation would need to be done.

An exception to this approach would be a situation like McKinney and Ice lakes in Grand Rapids where milfoil was discovered in 1999. These lakes were subjected to whole-lake treatment with fluridone to prevent the spread of milfoil in a part of Minnesota with no other known infestations. If such a situation were to arise, the DNR would consider use of fluridone.

Potential to apply two herbicides at low rates to control both Eurasian watermilfoil and curly-leaf pondweed

In 2004, the U.S. Army Corps of Engineers continued a study in Minnesota to determine whether early spring treatment with low rates of endothall and 2,4-D herbicides will control both milfoil and curly-leaf pondweed. The researchers also want to determine whether reductions in milfoil and curly-leaf will produce a more diverse and abundant native plant community. Lastly, the project is intended to determine whether the expected shift in vegetation will affect the fish community. The study is being conducted in cooperation with Mississippi State University and the DNR. Financial and technical support are being provided by CerexAgri, an herbicide manufacturer. Herbicides were applied in spring and monitoring was done during the open water season of 2004. Preliminary results are expected to be reported to the DNR this winter.

Future plans and needs for management of Eurasian watermilfoil

Priorities for management of milfoil include:

- Keep the public informed about milfoil and the problems it can cause.
- Reduce the plant's spread by targeting watercraft inspection and enforcement efforts in areas of the state where milfoil is present.
- Monitor the distribution of milfoil in the state with emphasis on verification of reports of new occurrences of milfoil.
- Continue to improve our understanding of the ecology and management of milfoil.

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Management of Flowering Rush

Introduction

Issue

Flowering rush (*Butomus umbellatus* L.) is a perennial aquatic plant, native to Europe and Asia. It grows along lake and river shores as an emergent plant with three-angled fleshy leaves and may produce an umbel-shaped cluster of pink flowers (Figure 11). Flowering rush may also grow as a non-flowering submersed plant with limp, ribbon-like leaves.

The plant spreads primarily vegetatively from thick rhizomes (Figure 12) from small tubers that break off the rhizome, and from small bulblets that form in the inflorescence. Water currents, ice movement (Haber, 1997), and muskrats (Gaiser, 1949) can easily move these reproductive structures to new locations within a water body.

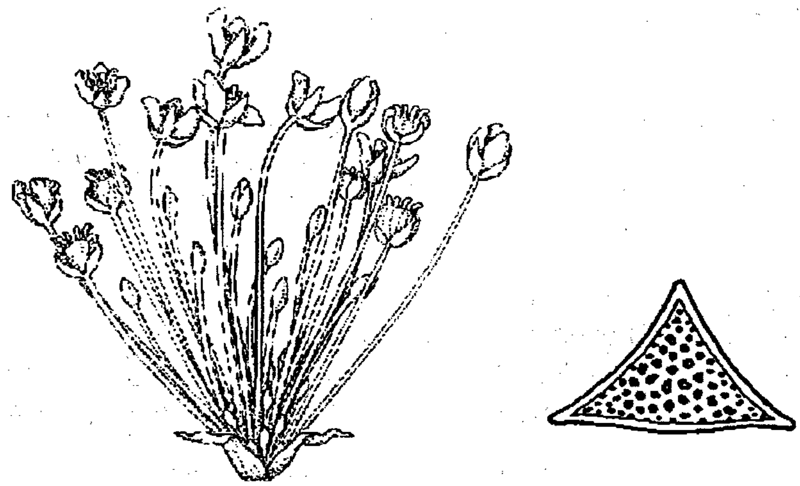

Figure 11. Flowering rush umbel and cross-section of a leaf.

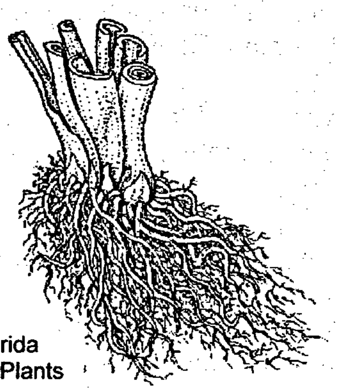

Figure 12. Flowering rush rhizomes

Flowering rush was likely brought to North America in the late 1800s in ship ballast and has also been repeatedly introduced as an ornamental plant. As early as 1973, resource managers and researchers have expressed concern that flowering rush may grow more aggressively in North America than in its native Europe and may become an aggressive competitor with native wetland vegetation (Anderson et al., 1974; Staniforth and Frego, 1980). Given the invasive characteristics of flowering rush, it is classified as a *prohibited* invasive species in Minnesota. A prohibited invasive species is illegal to possess, sell, transport, or release into the wild.

Distribution

Flowering rush was first recorded in Anoka County in 1968 (Moyle, 1968) and has since been located in six other counties. Despite its 30-year presence in the state, the distribution of flowering rush is widely scattered and uncommon (Figure 13). New introductions are likely the result of intentional planting from horticultural sales. More information about the distribution of flowering rush in the state can be found in the 2000 Exotic Species Annual Report (Exotic Species Program, 2001). There were no new discoveries of flowering rush locations in 2004.

Goals

The DNR has two goals that apply to flowering rush management: 1) To prevent the spread of flowering rush within Minnesota; and 2) To reduce the impacts caused by invasive species to Minnesota's ecology, society, and economy. To attain these goals, the following strategies are used:

- Prohibit the sale of flowering rush in Minnesota.
- Monitor current distribution and assess charges.
- Support research to develop and implement better management methods.
- Provide information to those interested in how to best manage flowering rush.

Progress in Management of Flowering Rush - 2004

Prohibit the sale of flowering rush

Flowering rush is a prohibited invasive plant in Minnesota, which means that it is unlawful to possess, purchase, or sell this invasive in Minnesota. Nevertheless, horticultural sales are the most likely means of introducing this plant into a new area. Flowering rush is advertised for sale in catalogs and Internet companies as a hardy, desirable ornamental water garden plant. An effort to inform aquatic plant sellers and buyers about the potential negative impacts of releasing non-native plants into the wild will continue, utilizing various public education materials and personal contacts.

Monitor current distribution and assess changes

Invasive Species Program staff surveyed flowering rush distribution during peak biomass on Detroit Lake (Becker County) and performed a late season survey on Forest Lake (Washington County). The goals of these surveys were to document spread of flowering rush and to monitor the effects of management.

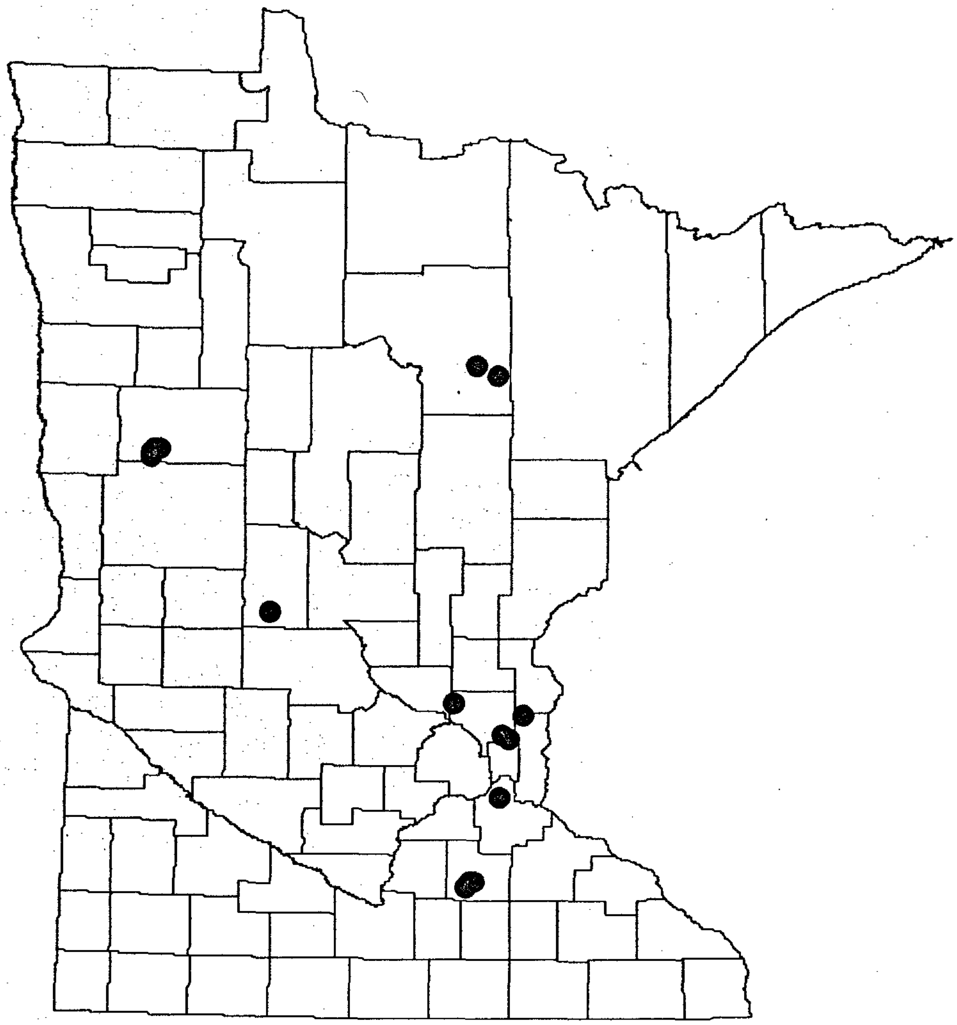

Figure 13. Minnesota flowering rush locations as of December 2004.

Since 2002, a point intercept plant survey has been implemented on Detroit Lake. A point intercept survey is performed by placing sample points equally spaced over the area of interest. In this case, the points were spaced 125 meters apart and within the 10-foot contour line (Figure 14). In 2002, spring and fall surveys were completed, but they did not measure peak biomass of flowering rush. As a result, in 2003, the survey was moved to July. As expected, the results indicate that the spring and fall surveys did not capture the highest frequency of flowering rush (Table 18). During the last two years, the frequency and location of flowering rush have not changed significantly (Figure 15). Given the original intent of these surveys, to monitor the flowering rush population, the scale of these surveys may need to be adjusted in 2005.

Forest Lake (Washington County) was also surveyed to document flowering rush distribution. Informal flowering rush surveys have been performed in Forest Lake for the past four years. During those four years, flowering rush has increased in distribution, but has remained within the "third" or east basin (Figure 16). In 2004, no visible increase in distribution was noted.

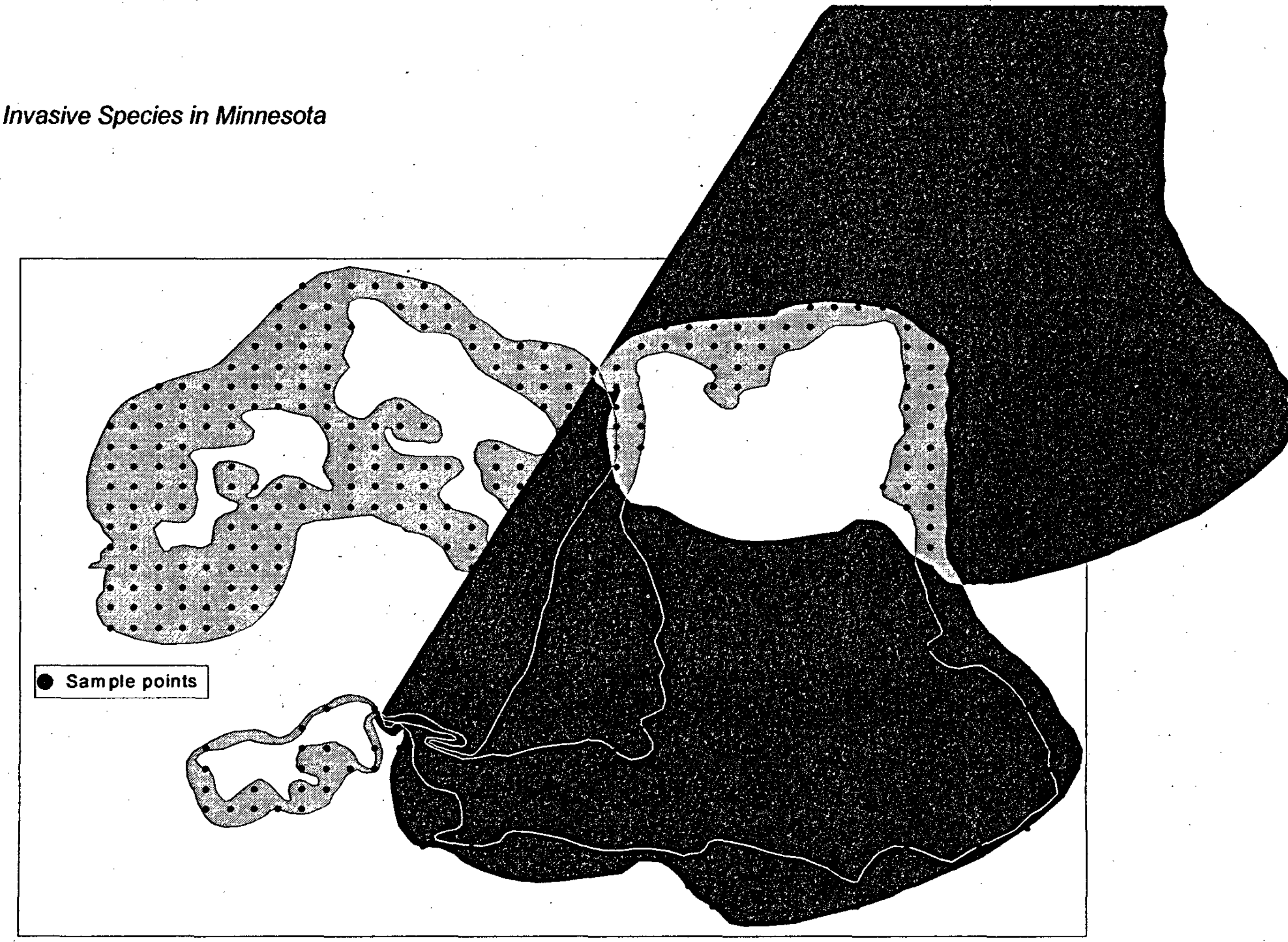

Figure 14. Sample locations on Detroit Lake.

Table 18. Flowering rush frequency on Detroit Lake.

Year of Survey Performed By	Number of Sample Sites	Frequency of Flowering Rush
Spring 2002 – Exotics Program	241	6%
Fall 2002 – Exotics Program	260	7%
Summer 2003 – Invasives Program	190	18%
Summer 2004 – Invasives Program	278	17%

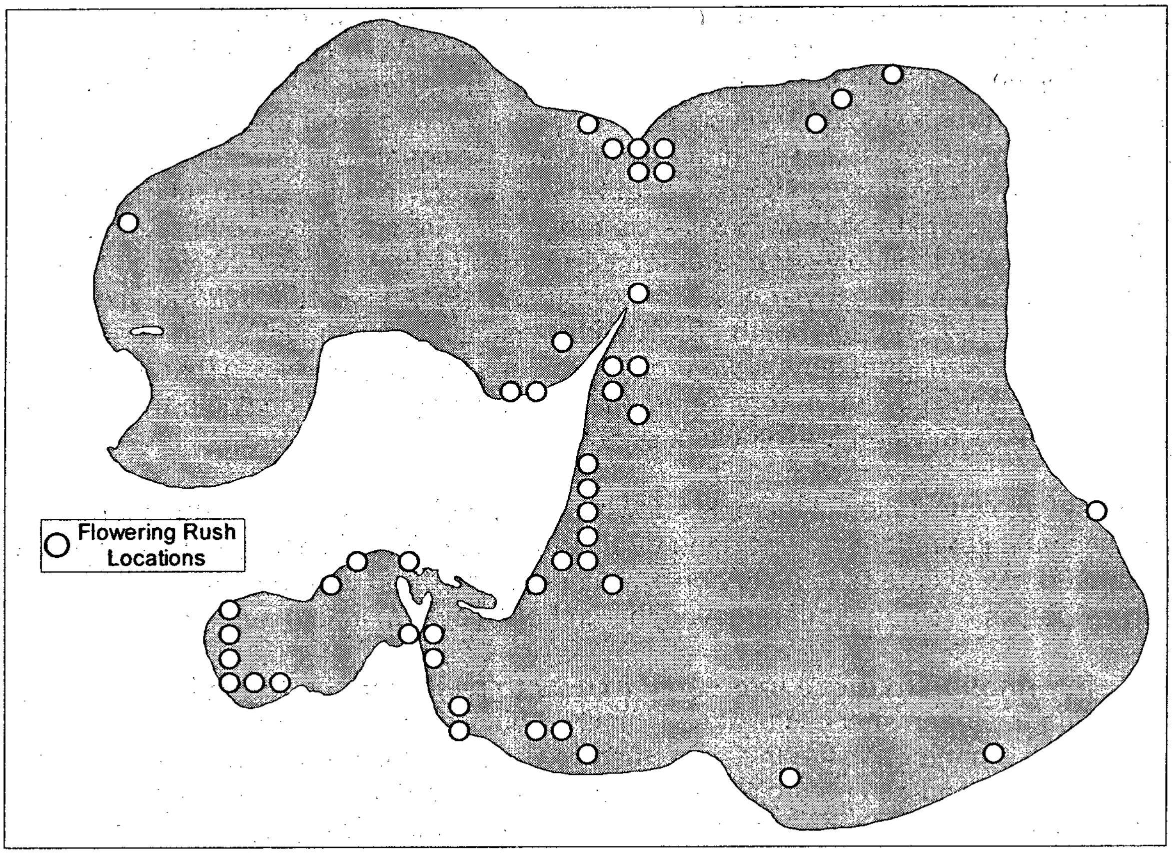

Figure 15. Locations of flowering rush in 2004 in Detroit Lake.

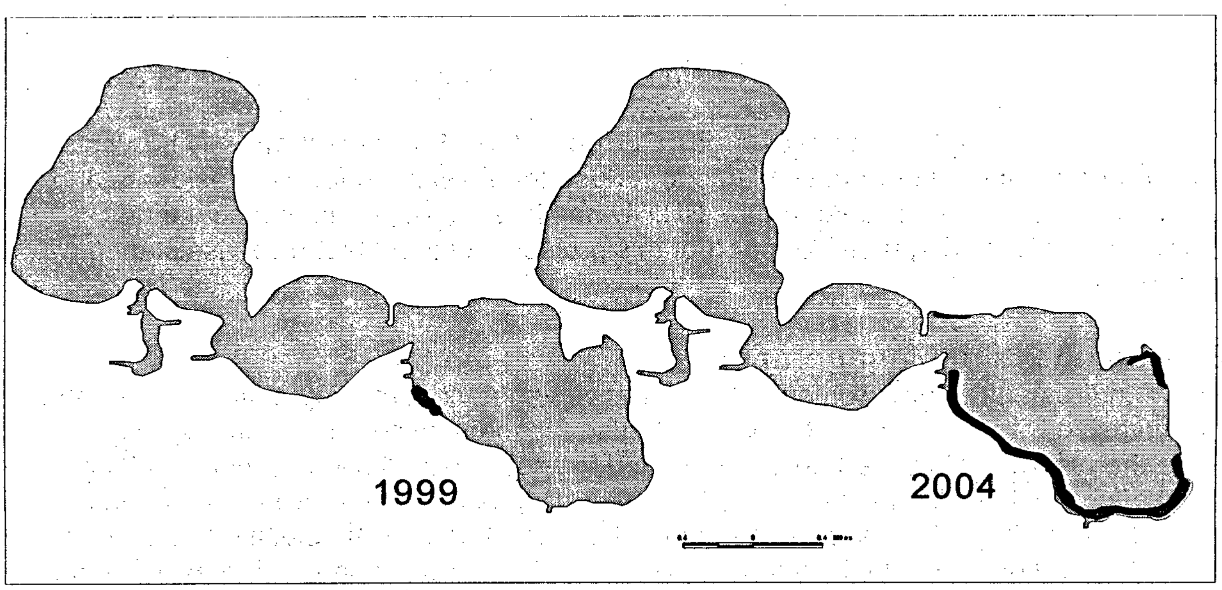

Figure 16. Flowering rush locations in Forest Lake in 1999 and 2004.

Support research to develop and implement better management methods
In 2003 and 2004, the Pelican River Watershed District (PRWD) contracted with a private herbicide applicator to test different aquatically registered herbicides on small plots of flowering rush. In 2003, six sites were sprayed with different herbicides and rates including glyphosate, 2, 4-D (granular and liquid), diquat, and various adjuvants. Two glyphosate sprayed plots showed roughly 50% reduction in flowering rush density. The remaining plots did not show any visible reduction. One potential complicating factor was the unseasonably cool water temperatures in late August 2003, which may have played a part in the early senesce of flowering rush. As a result, in 2004, the treatments were moved up a month. Preliminary results suggest most of the treatments knocked back flowering rush in the year of treatment. The only herbicide that did not reduce flowering rush in the year of treatment was imazypyr. Additional information will be available in 2005, when these plots are looked at again.

The Forest Lake infestation is the only known location in Minnesota to produce fertile seeds, according to recent studies done by Eckert et al. (1999). These seeds may pose an increased risk of spread to neighboring waters. In an effort to reduce this risk, Invasive Species Program staff removed the umbels (flowers) in late summer.

Provide information to those interested in how to best manage flowering rush
Hand-cutting has been successful at seasonally reducing dense stands of emergent flowering rush. In the past, the Invasive Species Program coordinates and assists with a flowering rush hand-cutting project at a public swimming beach in Twin Lakes (Itasca County). Flowering rush impedes fishing and swimming activities at this beach and fishing pier. This beach was cut in spring of 1998,1999, and 2002. It was cut twice in 2000, 2001, and 2003. In an attempt to reduce flowering rush without the labor-intensive cutting, diquat and 2, 4-D were applied in the spring of 2004. The herbicide treatment did not reduce the amount of flowering rush at the beach and public water access area on North Twin Lake.

The PRWD annually meets with DNR staff including representatives from the Invasive Species Program to discuss concerns regarding the expansion of flowering rush within and into lakes in the Detroit Lakes area. Currently, the PRWD mechanically harvests flowering rush and other aquatic plants to reduce the nuisances for lake residents and users. During the past two years, the PRWD has been engaged in testing various herbicides on flowering rush. Support of this project, including technical assistance will continue.

Effectiveness of Management

Flowering rush often grows in stands with native vegetation, making it difficult to control this invasive without harming the native plants. Mechanical control by cutting appears to be the most effective method of reducing dense stands of flowering rush. Cutting is most effective if done early and repeated several times during the growing season (Hroudova, 1989). The disadvantages of cutting are that it lacks selectivity, it is labor intensive, and does it not eliminate the invasive. Digging flowering rush may increase its spread if the entire rhizome is not removed. Recent work contracted by the PRWD, may show some new herbicide combinations that maybe effective on flowering rush. As that information becomes available, the Invasive Species Program staff will evaluate the utility of these treatments.

Participation by Other Groups

Others involved in flowering rush management in Minnesota in 2004 include: DNR's Division of Fish and Wildlife, PRWD, and Greenway Township in Itasca County.

Future needs for management of flowering rush

- Continue efforts to prevent introductions of flowering rush in Minnesota. Inform the public, nursery industry, and other businesses selling flowering rush of the problems associated with this plant and the existing laws against its possession and sale in Minnesota.
- Encourage research on the distribution, reproductive biology, and potential impacts of flowering rush in Minnesota.
- Continue to investigate new methods of controlling flowering rush and to evaluate the results of ongoing flowering rush management within the state.

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Management of Purple Loosestrife

Background

Purple loosestrife (*Lythrum salicaria*, *L. virgatum* and their hybrids) is a wetland plant from Europe and Asia that invades marshes and lakeshores, replacing cattails and other wetland plants. The DNR and other agencies manage purple loosestrife because it harms ecosystems and reduces biodiversity by displacing native plants and habitat for wildlife (Blossey et al., 2001). The Purple Loosestrife Program was established in the DNR in 1987. State statutes direct the DNR to coordinate a control program to curb the growth of purple loosestrife (M.S. 84D.02, Subd. 2) and a significant amount of progress has been made toward the development of a sound approach to manage this invasive.

This management program integrates chemical and biological control approaches and cooperates closely with federal and state agencies, local units of government, and other stakeholder groups involved in purple loosestrife management. The goal of the program is to reduce the impact purple loosestrife is having on our environment. Management efforts include both biological and chemical control methods, monitoring management efforts, and supporting further research.

Statewide Inventory of Purple Loosestrife

In 1987, the DNR began to inventory sites in Minnesota where purple loosestrife was established. DNR area wildlife managers, county agricultural inspectors, local weed inspectors, personnel of the Minnesota Department of Transportation, and the general public report purple loosestrife sites to the DNR. The DNR maintains a computerized list or database of sites that includes the location, type of site, and number of loosestrife plants present (see Figure 17). In 2004, 31 new purple loosestrife infestations were identified in Minnesota. There are now 2,212 purple loosestrife infestations recorded statewide (Table 19). Of those sites, the majority (70%) are lakes, rivers, or wetlands. Inventory totals indicate that Minnesota presently has over 63,000 acres infested with purple loosestrife.

Progress in Management of Purple Loosestrife - 2004

Chemical control of purple loosestrife

Initial attempts by the DNR to control purple loosestrife have relied mainly on the use of herbicides. The most effective herbicide was found to be Rodeo^{TM}, a formulation of glyphosate, which is a broad spectrum herbicide that is also toxic to desirable native plants. To allow maximum survival of native plants, Rodeo^{TM} is applied by backpack sprayer as a "spot-treatment" to individual loosestrife plants.

Beginning in 1991, a prioritization plan was developed for selecting control sites in public waters and wetlands where herbicide would be used for purple loosestrife control. This was done because there are insufficient resources to apply herbicides to all known purple loosestrife sites in Minnesota. In addition, DNR personnel observed that herbicide treatments do not result in long lasting reductions of loosestrife when applied to large populations that have been established for a number of years. This is due in part to the plant's ability to re-establish from an extensive purple loosestrife seed bank.

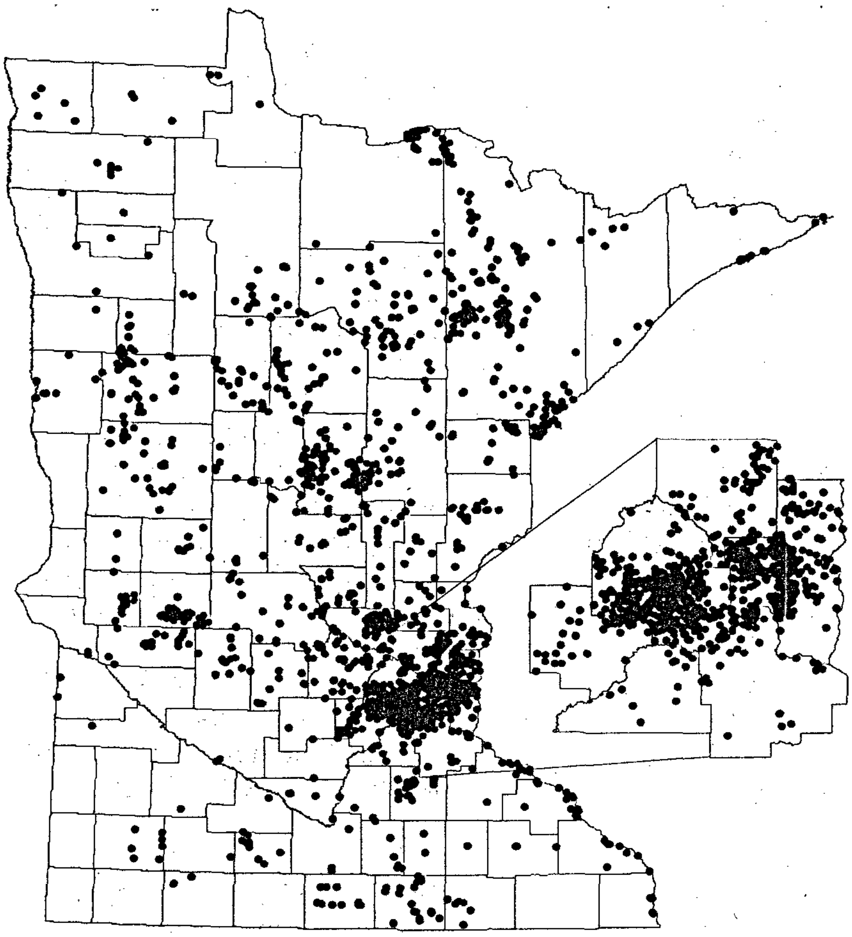

Figure 17. Purple loosestrife infestations in Minnesota as of December 2004.

Table 19. Purple loosestrife infestations in Minnesota recorded by the Minnesota Department of Natural Resources in 2003 and 2004.

Site Type	Total sites 2003	New sites 2004	Total sites 2004
Lake	659	8	667
River	202	1	203
Wetland	687	6	693
Roadsides and ditches	471	16	487
Other[1]	162	0	162
Total	**2,181**	**31**	**2,212**

[1]Includes gardens and other miscellaneous sites.

Research done by the University of Minnesota, under contract to the DNR, demonstrated that long-established stands of loosestrife develop very large and persistent seed banks (Welling and Becker, 1990). Herbicide treatments kill the existing loosestrife population only, creating space for additional seeds to sprout. Consequently, small and recently established populations of loosestrife, which are likely to have small seed banks, are given the highest priority for treatment. In addition, because seeds of this species are dispersed by water movements, the DNR tries to keep loosestrife from infesting downstream lakes. Sites located in the upper reaches of watersheds with small loosestrife infestations are treated before those located in watersheds with large amounts of loosestrife. Implementation of the prioritization scheme in 1991 resulted in fewer large sites (> 1,000 plants) being treated. Only one site that had greater than 1,000 plants was treated in 2004.

Between 1989 and 2004, the number of sites, number of plants, and total cost of treating purple loosestrife with herbicide has decreased (Table 20). This summary includes applications made by DNR personnel, commercial applicators working under contract to DNR, and various cooperators; it is not a complete listing of all herbicide applications made in Minnesota. In 2004, only DNR Staff were used to treat purple loosestrife stands statewide. DNR staff visited 60 purple loosestrife stands for herbicide control work (Figure 18). At 20 sites, workers found no loosestrife plants to treat. A total of 39 sites were treated with herbicides. Most of the sites were very small: 80% had less than 100 plants. At one location, seven purple loosestrife plants were hand-pulled. This work took a total of 370 worker hours, and only 0.58 gallons of Rodeo™ were used to treat the purple loosestrife. Total cost for this effort was $9,400.

Effectiveness of chemical control

Effectiveness of control efforts will be based on short-term and long-term objectives. Control or eradication of small infestations statewide with herbicides is the primary short-term objective. Each year, a small number of purple loosestrife infestations (ten in 2004) are eradicated for at least one year with herbicides. This is critical because these infestations are in watersheds that have very few infestations of loosestrife. This effort helps prevent the spread of purple loosestrife into uninfested wetlands and lakeshores.

Biological control of purple loosestrife

Insects for biological control of purple loosestrife were first released at one site by DNR staff in 1992. This initial release occurred after years of testing to make sure the insects were specific to purple loosestrife and would not damage native plants or agricultural crops and after the insects were approved for release by the United States Department of Agriculture (USDA). To date, four species of insects, two leaf-eating beetles, *Galerucella calmariensis* and *G. pusilla*; a root-boring weevil, *Hylobius transversovittatus*; and a flower-feeding weevil, *Nanophyes marmoratus*, have been released as potential biological controls for loosestrife in Minnesota.

<u>Leaf-Eating Beetles</u>: In 1997, the DNR initiated an insect rearing program by providing county agricultural inspectors, MDA field staff, DNR area wildlife managers, nature centers, lake associations, schools, 4-H and garden clubs with a "starter kit" for rearing their own leaf-eating beetles. A starter kit is composed of pots, potting soil, insect cages, leaf-eating beetles, and other materials necessary to rear 20,000 leaf-eating beetles (*Galerucella* spp.). The insects were then released on high priority areas. All

insect rearing was completed outdoors for ease of production and to produce hardier insects. From 1997 to 2004, this cooperative effort has had a significant effect on total number of insects released (Figure 19).

With success of insect establishment in the field, organized rearing efforts have come to an end in 2004. Resource managers are be able to collect insects from established release sites and redistribute to new infestations. Current research suggests that these insects will move up to five kilometers on their own if purple loosestrife is present (McCornack et al., 2004). The "collect and move" method has reduced the effort needed to further distribute leaf-eating beetles in Minnesota. In 2004, an estimated 140,810 leaf-eating beetles were collected and released on 41 sites. To date, the leaf-eating beetles have been released at more than 771 sites statewide (see Figure 19, Table 21).

Table 20. Historical herbicide applications performed by DNR and applicators contracted by DNR in Minnesota (1989-2004).

Year	Sites visited	Sites with <100 plants treated	Sites with >100 plants treated	No plants located	Total worker hours	Herbicide quantity used	Total treatment costs
1989	166				3,045	471	$102,000
1990	194	74	120	0	3,290	-	$74,900
1991	200	109	58	33	3,420	-	$77,900
1992	227	110	77	40	-	-	-
1993	194	96	79	19	2,300	48	$65,000
1994	188	81	81	26	1,850	30	$52,000
1995	203	102	63	38	2,261	35	$63,000
1996	153	74	56	23	1,396	14	$45,000
1997	132	55	55	22	965	7	$36,000
1998	144	66	51	27	1,193	11	$40,000
1999	131	65	38	28	791	9.5	$26,000
2000	111	38	28	45	518	2.4	$22,800
2001	87	55	17	15	359	1	$19,700
2002	55	32	7	16	305	2.3	$18,800
2003	54	30	7	17	243	0.87	$8,180
2004	60	30	9	20	370	0.58	$9,400

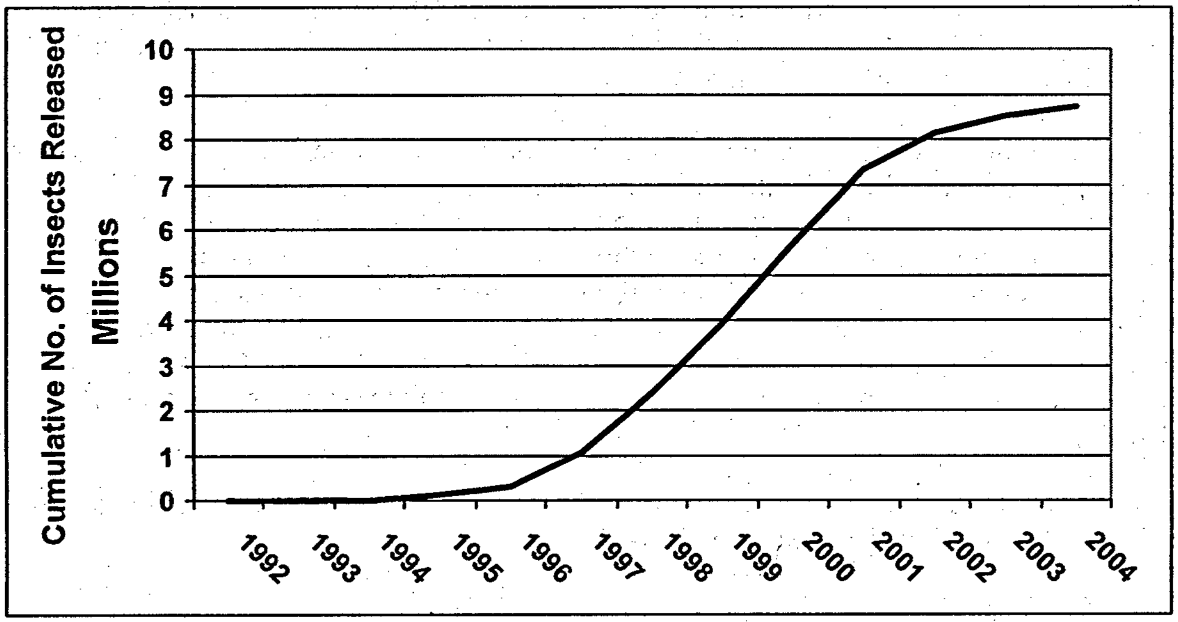

Figure 18. Locations where DNR staff used herbicides to control purple loosestrife in 2004.

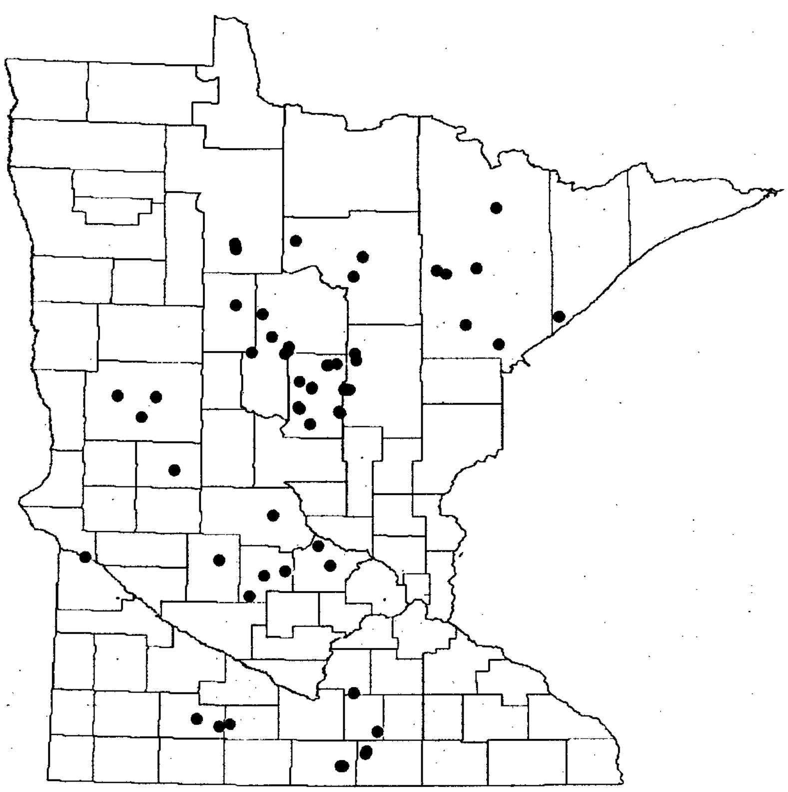

Figure 19. Cumulative number of insects released to control purple loosestrife by year.

Biological control insects released between 1992 and 2004 have established reproducing populations at more than 80% of the sites visited. Insect populations increased significantly at many locations with pronounced damage to loosestrife plants. In the summer of 2004, 178 insect release sites were visited to assess the insect establishment and level of control achieved. At 44% (78 sites) of the sites surveyed, the insect populations are rapidly increasing and causing significant damage to the loosestrife infestations. At 12% of all visited sites, the loosestrife was severely defoliated (90-100%) (Figure 20).

Root-Boring Weevils: Initially, only a small number of root-boring weevils were brought to Minnesota. As of December 2004, there are 12,223 weevils comprising 30 releases, at 23 different sites in Minnesota. In 2004, no weevils were made available for release, but in the future, Minnesota will be receiving additional weevils.

Effectiveness of biological control

A long-term objective is to utilize biological controls to reduce the abundance/impacts of loosestrife in wetland habitats throughout Minnesota. Biological control, if effective, will reduce the impact loosestrife has on wetland flora and fauna. The DNR's goal is to reduce the abundance of loosestrife in wetlands where it is the dominant plant by at least 70% within 15-20 years. Purple loosestrife will not be eradicated from most wetlands where it presently occurs, but its abundance can be significantly reduced so that it is only a small component of the plant community, and not a dominant one. Assessment efforts in 2004 demonstrated that *Galerucella* introductions have caused moderate to severe defoliation of loosestrife populations on 44% of sites visited (Figure 21). The DNR will continue to track these wetlands to assess how loosestrife abundance changes over time and to determine what combinations of biological control agents provided the desired level of control.

Research on Insects as Biological Control Agents

A three-year study to evaluate biological control of purple loosestrife in Minnesota, was completed in 2004. This research was funded by the Minnesota Legislature, as recommended by the LCMR. Evaluation of purple loosestrife biological control found that the leaf-beetles, *Galerucella* spp., can provide long-term control of purple loosestrife. As purple loosestrife populations were reduced, the diversity of other plant species increased. *Galerucella* spp. populations fluctuate over time in response to purple loosestrife abundance (Skinner et al. 2004). At some sites, the leaf beetle populations declined and have not rebounded, suggesting control may vary depending on a number of factors. Evaluations were also made to assess whether *Galerucella* spp. were feeding on non-target species. *Galerucella* spp. did not impact two native Lythrum species. Although *Galerucella* larvae were present and some feeding observed on swamp and winged loosestrife, plant growth or reproductive parameters were not affected (Stamm Katovich et al. 2004). A third study was carried out to monitor movement of *Galerucella* species. *Galerucella* spp. can readily disperse and colonize purple loosestrife infestations within wetlands and across landscapes. *Galerucella* spp. on average, dispersed five kilometers to new purple loosestrife infestations within 3 years. The maximum dispersal distance recorded was 20 kilometers. Beetles were found in 85% non-release sites visited (McCornack et al. 2004). From these data we can advise resource managers who wish to maximize redistribution efforts of *Galerucella* spp. to select wetlands that are greater than five kilometers from any known release.

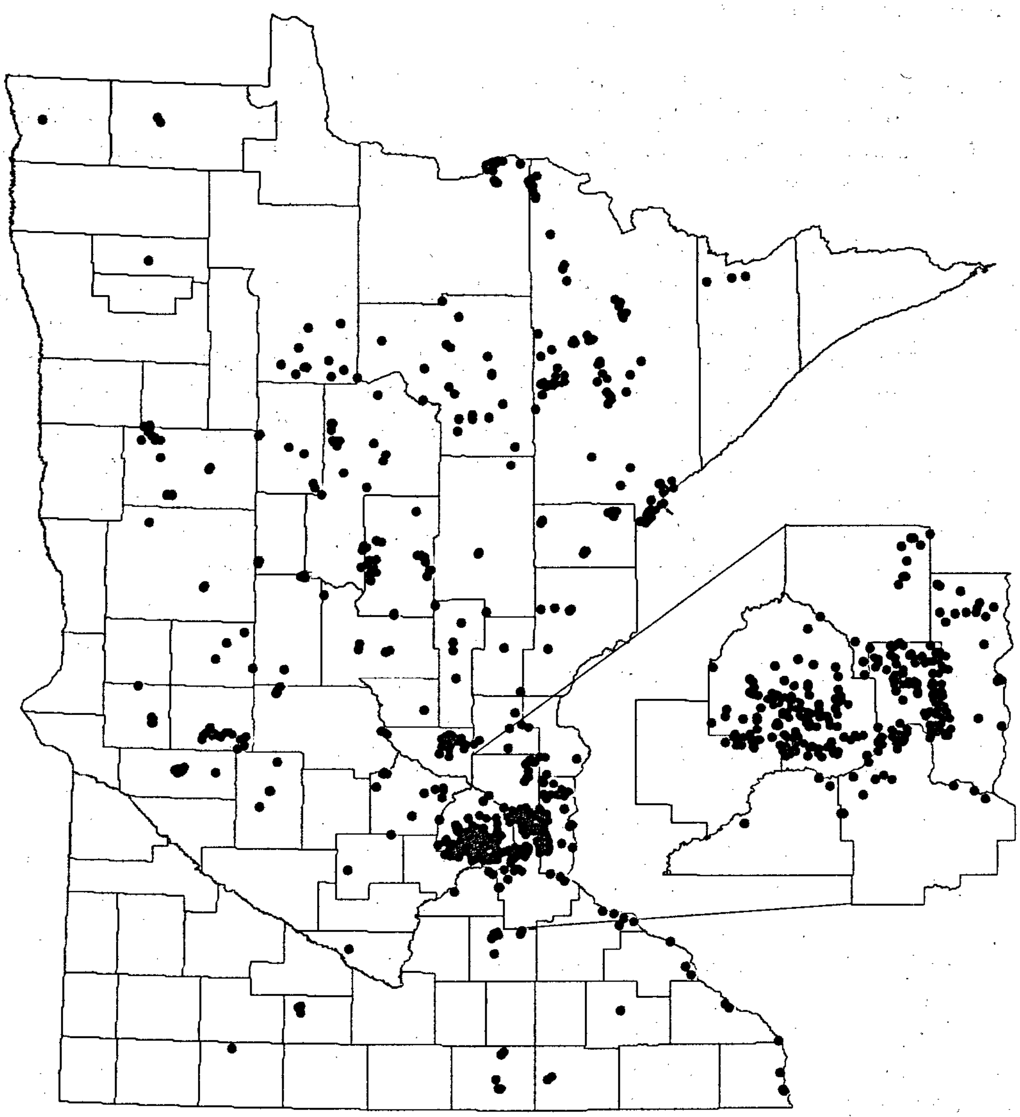

Figure 20. Locations of insects released to control purple loosestrife in Minnesota through 2004.

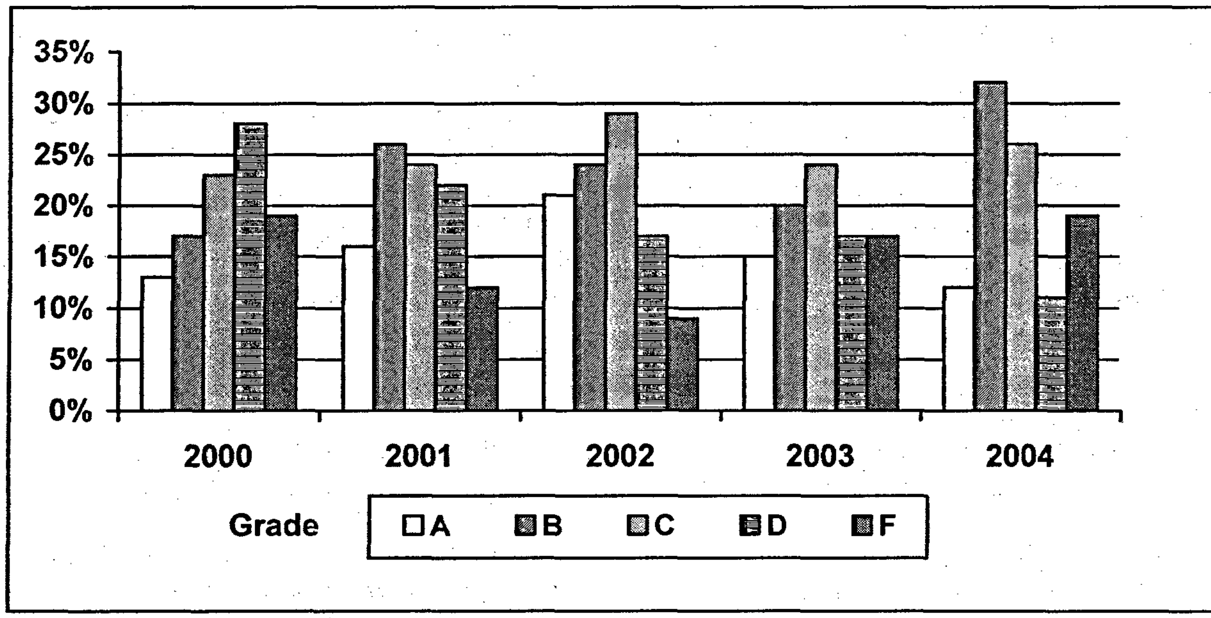

Figure 21. Sites graded for insect establishment and control.

Table 21. Summary of number of insects released in each region to control purple loosestrife (1992-2004).

Minnesota DNR Regions	Number of Release Sites	Number of Insects Released
1 – Northwest	121	1,318,800
2 – Northeast	193	1,602,890
3 – Central	400	5,118,320
4 – South	57	700,800
Totals	**771**	**8,740,810**

A = 90-100% defoliation, B = 50-89% defoliation, C = damage near release point with insects visible, D = no damage, few insects visible, F = no insects or damage present.

Future needs for purple loosestrife management

- Continue Implementation and evaluation of biological control of purple loosestrife.
- Continue DNR funding of herbicide control efforts on small, high-priority infestations.
- Continue to assess effectiveness of overall management strategies.
- Continue to collaborate with county agriculture inspectors, MnDOT, DNR area wildlife managers, nature centers etc., to expand management efforts.

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Other Invasive Aquatic Plant Species in Minnesota

Introduction

Numerous invasive species of aquatic plants exist in the state. The previous chapters described species for which there were ongoing efforts. The species described in this chapter exist in the state, but there are no ongoing efforts by the DNR to manage them in the wild. They are included because they are or have been of interest within the state. In addition to the information presented on brittle naiad, reed canary-grass, hybrid hardy water lilies, and salt cedar in this chapter, Table 22 presents a summary of other invasive aquatic plant species in Minnesota.

Brittle Naiad

In 2004, Invasive Species Program staff confirmed that brittle naiad *(Najas minor)* is in Lac Lavon, a small lake in Dakota County. Brittle naiad resembles the Minnesota rare species spiny naiad *(Najas marina),* but unlike *N. marina* it is not native to Minnesota. Brittle naiad is native to Europe and was first reported in the United States in the Hudson River in 1934 (McFarland et al., 1998).

Brittle naiad spreads by seeds carried on plant fragments. The primary means of reproduction in brittle naiad is by seed, and it is highly fertile (McFarland et al., 1998). During the late summer or early fall, the stems of brittle naiad become brittle, and the top portions of the stem break into small fragments. Seeds remain attached in the leaf axils of these fragments, and the fragments are dispersed by water currents (U.S. Army Corps of Engineers, 2002). In Lac Lavon, brittle naiad has spread from a few scattered plants noted in 2001 to approximately 20% of the littoral zone in 2004 (Wendy Crowell, unpublished data, Nov. 2004).

Brittle naiad can be a severe nuisance in shallow water but does not generally cause problems in deeper water. Brittle naiad grows to about four feet in height, and has stems that are profusely branched toward the top of the plant. In shallow water, brittle naiad can grow so densely it can completely clog the water column, which can result in negative impacts to native aquatic plants and recreation (Vermont Agency of Natural Resources and The Nature Conservancy of Vermont, 1998, U.S. Army Corps of Engineers, 2002). In deeper water, brittle naiad may become abundant but not cause nuisances. In 2003, in Lac Lavon brittle naiad formed dense stands near the bottom of the lake. Because of the water depth these stands did not cause a nuisance (Nick Proulx, personal communication, April 22, 2004). This situation was also noted in Lac Lavon in 2004 (Wendy Crowell, unpublished data, Nov. 2004).

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Hardy Hybrid Water lilies (*Nymphaea* spp.)

Colorful hardy water lilies are popular with water gardeners. Because they are hardy in Minnesota, if planted in natural waters they will survive and spread. Hybrid water lilies may crowd out native lilies and other native aquatic plants that occur in a lake and may hybridize with native *Nymphaea*, making them less suited for Minnesota climate.

Because of this, they have been classified as a *regulated invasive species* (see M.R. 6216). This means that they cannot be placed into a free-living state (into public waters), or into ponds connected to public waters, but they can be sold and used in private water gardens.

A few populations of hybrid water lilies have been found escaped in Minnesota waters. In at least one water, Portage Lake in Park Rapids, the pink water lilies are widespread. In 2004, a small population of pink water lilies was found in Crawford Lake, near Montrose. Because of the small size of the infestation, the DNR treated the lilies with herbicide to control them.

Reed canary-grass

Reed canary-grass (*Phalaris arundinacea*) was first included in the annual report for 2000 as an "emerging issue" (Exotic Species Program, 2001:19). There are several active research groups in the upper Midwest that are investigating the ecology and management of this invasive species. In 2004, a research group at the University of Minnesota-Saint Paul initiated a new study of revegetation of wetlands following control of reed canary-grass. This study is funded by the Minnesota Department of Transportation (MnDOT), which manages reed canary-grass in some of its projects.

The research by the University of Minnesota is directed by a Technical Advisory Panel, which includes a representative from the DNR's Invasive Species Program. In addition to the current study described above, proposals for additional research on the ecology of reed canary-grass are under review by MnDOT and the DNR.

Saltcedar

In 2003, the first recorded wild population of saltcedar (*Tamarix ramosissima)* was found near Hibbing, Minnesota. Saltcedar, a deciduous shrub native to Asia, was introduced to the western U.S. as an ornamental shrub in the early 1800s. Saltcedar has become established on more than a million acres of floodplains, riparian areas, wetlands, and lake margins in the western United States (Figure 22). Saltcedar can crowd out native stands of riparian and wetland vegetation; increase the salinity of surface soil rendering the soil inhospitable to native plant species; degrade wildlife habitat; and can cause springs, wetlands, riparian areas, and small streams to dry up by lowering surface water tables.

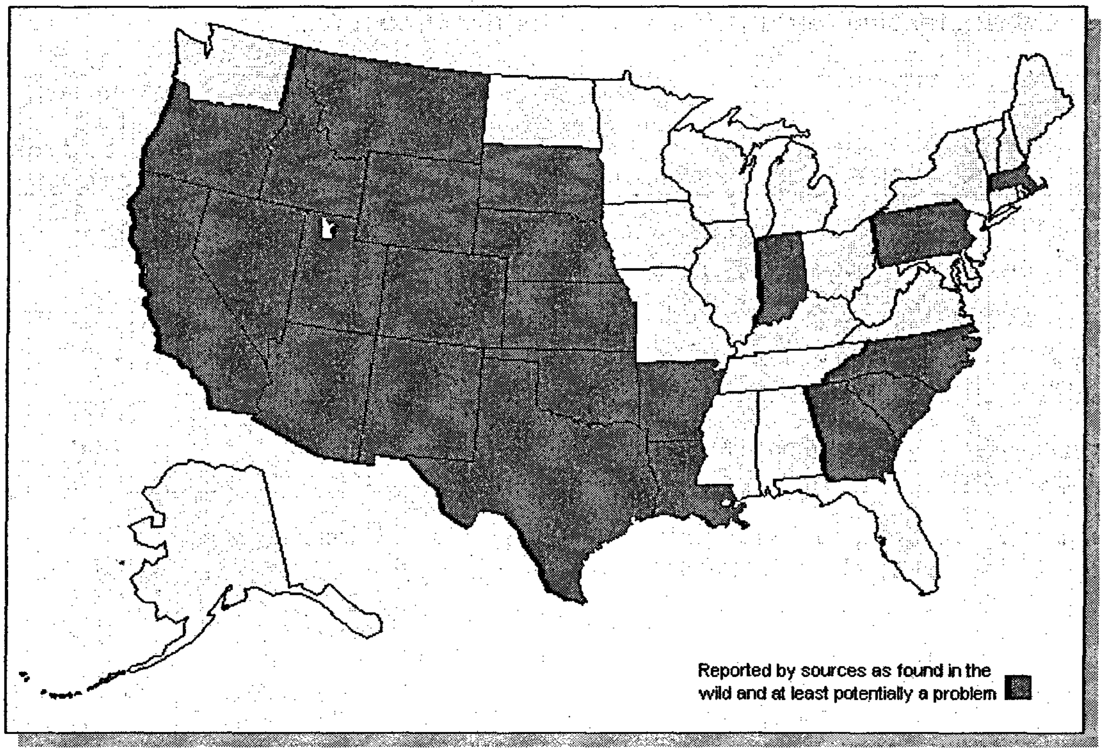

Figure 22. Saltcedar distribution in the United States prior to discovery in Minnesota. (Source: www.nps.gov/plants/alien/map/tama1.htm)

The saltcedar population in Minnesota was discovered by staff of DNR's Lands and Minerals Division in a mining tailings basin west of Hibbing. After confirmation by DNR botanists, a decision was made to attempt to eradicate the saltcedar population. On September 17, 2003, Invasive Species Program and Lands and Minerals Division staff cut and treated with herbicides all the saltcedar plants at the site. Approximately 40 mature plants (4-7 feet tall) were cut and the stumps treated with triclopyr, while the numerous young plants (less than 3 feet tall) were treated with glyphosate.

The site was revisited in September 2004 to evaluate control effectiveness and to control any surviving plants. Overall effectiveness of the 2003 control effort was excellent with only one live saltcedar plant was observed. This remaining plant was pulled and removed from the site.

Table 22. Other Invasive Aquatic Plant Species in Minnesota.

Species	Status	Legal Status	Last annual report to include info on this species
Yellow iris *(Iris pseudacorus)*	Commonly sold, public education has focused on preventing people from planting it in natural water bodies	Regulated	2002
Water lettuce *(Pistia stratiotes)*	No new infestations found since 2001	Unlisted	2001
Reed canary-grass *(Phalaris arundinacea)*	Widespread in Minnesota	Unlisted	2001
Introduced genotypes of common reed *(Phragmites australis)*	Only a few known populations in the state, distribution information is lacking	Unlisted	

Terrestrial Invasive Plant Management

Overview

The Invasive Species Program is playing a key role to improve the management of terrestrial invasive plants in natural areas, including DNR managed lands. A major focus was placed on providing support and technical expertise to DNR land managers statewide and the development of new control methods such as biological control for common buckthorn and garlic mustard. This work is being funded by a combination of sources that includes state funding (LCMR and Heritage Enhancement), and federal funding (U.S. Forest Service, and U.S. Environmental Protection Agency-Great Lakes National Program Office).

Heritage Enhancement Collaborative Projects

The Division of Ecological Services is leading a collaborative effort with the Divisions of Parks and Recreation, Fish and Wildlife, and Trails and Waterways to enhance DNR staffs' ability to effectively manage terrestrial invasive plants. Started in FY04 using Heritage Enhancement Funds, this effort has expanded work in four high priority areas. Those areas are: 1) terrestrial invasive plants inventory, 2) research on control methods, 3) invasive species management, and 4) information/education.

Inventory

Using standardized protocols developed by the DNR and MDA, more than 6,000 locations of invasive plant species on state-managed lands have already been mapped using GPS/GIS technologies. This includes surveys conducted in 20 state parks, 120 wildlife management areas, and along 140 miles of state trails. Managers will now be better able to target and monitor results of control efforts on these populations.

Research

Funds are being provided to support research on biocontrol methods for garlic mustard and buckthorn. Research is also underway to refine methods of controlling Canada thistle in the Talcot area, where Canada thistle dominates many of the wildlife management areas. The goal of the research is to improve control of Canada thistle, reduce herbicide use, and reduce impacts to native plants.

Management

Best management practices are being developed to reduce the movement of invasive plants during DNR management or development projects. Funding is being provided for a demonstration project to manage invasive plants in a public/private effort across ownership boundaries in western Minnesota.

Information/Education

Web pages are being created and updated to provide information to citizens and others on identification and recommended management of invasive plants. A buckthorn web page on the DNR Web site was completed in September 2004. Follow the link below to access the buckthorn and other invasive plant pages:
www.dnr.state.mn.us/invasives/terrestrialplants/index.html

Buckthorn Biological Control Research

Common buckthorn (*Rhamnus cathartica*) and glossy buckthorn (*R. frangula*) are European woody species that invade a number of habitat types in the northeast and north-central regions of the United States and Canada. Both species are very adaptable, forming dense thickets that inhibit the growth of native forbs, shrubs, and tree seedlings. Both species have long been established and are found throughout Minnesota, especially causing problems in the central and southern portions of the state. In Minnesota, common and glossy buckthorn are restricted noxious weeds that are illegal to import, sell, or transport statewide.

Land managers have spent considerable time and money trying to control this invasive shrub using conventional techniques. Their success has been limited and short-term. We believe the best hope for a long-term management strategy may be release of a biological control agent. The DNR has initiated a research project on biological control of European buckthorn, conducted by the Center for Applied Bioscience International in Switzerland (CABI). In 2001, the DNR received a two-year grant from the United States Environmental Protection Agency-Great Lake National Program Office (EPA-GLNPO) and several other contributors to initiate this research. In 2003, the DNR received $109,000 in funding from the Minnesota legislature as recommended by the Legislative Commission on Minnesota Resources, from the Environmental Trust Fund to continue this research. This funding was matched the EPA-GLNPO with an additional $50,000. This funding will allow the research to continue through 2005.

Initial research results suggest that a dozen species of insects show some potential as control agents. Researchers carried out field surveys for potential control agents in 2002 and 2003. Surveys and collection trips were carried out by CABI researchers in Germany, Italy, Switzerland, Austria, and Yugoslavia. In total, over 60 buckthorn sites were discovered and sampled. To date, some 270 arthropod samples have been collected, 184 on *Rhamnus cathartica* and 70 on *R. frangula*.

Several insect species have been selected for detailed host specificity studies based on their food niche, period of attack, potential availability, and likely specificity. Most of these species are targeted for *Rhamnus cathartica*. These are: *Trichochermes walkeri, Philereme vetulata, Synanthedon stomoxiformis,* and as a lower priority, *Triphosa dubitata*. The other priority species, *Sorhagenia janiszewskae* and *Oberea pedemontana*, are targeted for both *R. cathartica* and *Frangula alnus*. Researchers are currently rearing potential control agents and testing whether they feed and/or reproduce on non-target native plants that are closely related to buckthorn. Currently, two North American and three European buckthorn species are being cultivated at the research facility in Switzerland for host specificity testing. More native plant species will be collected and shipped to Switzerland from the United States this summer as the host specificity testing continues.

Preliminary screening tests were carried out with three insect species: *Philereme vetulata*, *Sorhagenia janiszewskae,* and *Trichodermes walkeri*. New emphasis will be put on field surveys of flower and fruit/seed feeding insects as well as on *Oberea pedemontana*, a stem-mining beetle. Flower and fruit/seed feeding insects had not been prioritized in the initial phase of the project because test plants would need to be synchronized at the flowering stage. Now that a smaller subset of potential agents are proposed for further consideration and a few plant species are growing well in the Center's garden, it has been decided to include flower and fruit/seed feeding insects in the study for the next two years. Finally, priority will be given to the biological control of *R. cathartica*, and no detailed work will be planned for biological control of *F. alnus* at this time.

This research is expected to take eight to ten years to complete. If a successful biocontrol agent is discovered, we expect buckthorn populations will be suppressed by: 1) killing buckthorn shrubs outright, 2) stressing or weakening buckthorn plants so that native plant and shrub species can gain a competitive advantage, and/or 3) reducing seed production. In many cases, control or suppression of the pest plant can be long-term.

As part of developing biological controls for buckthorn, it is important to know what insect species are currently utilizing buckthorn in Minnesota. A contract with the University of Minnesota is in place to conduct surveys for insects on buckthorn in Minnesota. Surveys began in late May 2004. Seven locations in Minnesota are being surveyed systematically throughout the growing season to capture insects utilizing buckthorn. To date, more than 350 insects (adult and immature stages) representing eight insect orders have been collected. Immature insects are allowed to complete development prior to preserving and identification. Identifying all the specimens will take place after the field season and collections have ended.

Garlic Mustard Biological Control Research

Garlic mustard, *Alliaria petiolata,* is currently one of the most serious invaders of forested areas in southern Ontario and the northeastern and mid-western United States. This biennial non-native plant can cover large areas where it displaces the native woodland ground flora such as spring ephemerals. Garlic mustard is a prohibited noxious weed in Minnesota, making it illegal to import, sell, and transport, which requires control. Few infested sites were known to exist in the state until recently. In 2001 and 2002, the numbers and sizes of infestations increased significantly. It has become an increasing problem in Minnesota during the past two years. University of Minnesota herbarium records, and reports from citizens and biologists received during 2002, indicate that infestations exist in at least 15 counties: Anoka, Brown, Carver, Cass, Clay, Dakota, Hennepin, Kandiyohi, Nicollet, Otter Tail, Pine, Ramsey, Scott, Washington, and Wright counties. Distribution of garlic mustard is likely more widespread than currently known.

Control of large infestations is difficult and land managers are seeking better control tools. In 1998, a project to search for natural enemies of garlic mustard was initiated at Cornell University. Funding has been provided by the Departments of Natural Resources in Minnesota, Illinois, Indiana, and Kentucky; Hoosier National Forest; Native Plant Societies of Illinois and Indiana; U.S. Department of Defense and others. In 2002, the DNR and the United States Forest Service-Forest Health Technology Enterprise Team, in cooperation with representatives from many of the initial funding agencies organized an informal working group to develop a 3-5 year plan for continuing the project to develop a biological control program for garlic mustard. In 2002-2004, the consortium has cooperatively provided technical and financial assistance to continue the host range testing in Europe, established laboratory colonies of promising agents in a quarantine facility in the U.S., and established permanent evaluation plots in several states. This effort will pave the way for the introduction of garlic mustard biocontrol agents in the near future. To date, several species of insects show promise as control agents against garlic mustard.

To complete host specificity testing of potential control agents, the United States Forest Service-Forest Health Technology Enterprise Team has provided funding to the DNR to help complete testing in quarantine at the University of Minnesota. Testing is currently being carried out to make sure the potential control agents do not feed on native plant species. Working with researchers in Europe (CABI Bioscience, Switzerland) who have completed most of the testing to date, a list of plant species was developed based on their inability to collect or cultivate these species in Europe (Table 23). To date, ten of the 12 species listed in Table 23 have been field-collected and are growing in a greenhouse facility on the University of Minnesota campus. Cooperators in Illinois, Indiana, Michigan, Minnesota, and Wisconsin have helped collect these plant species from the field and shipped them to Minnesota. We will continue to search for the additional two species.

Table 23. Plant species to be used in host specificity testing of garlic mustard biological control agent in quarantine, St. Paul, MN.

Plant Species
Brassicaceae
Arabis Canadensis
Cardamine bulbosa
Cardamine pensylvanica
Dentaria angustata
Dentaria laciniata (cut-leaved toothwort)
Fabaceae
Amphicarpaea bracteata (Hog peanut)
Cyperaceae
Carex laxiflora
Liliaceae
Erythronium americanum (yellow trout lily)
Erythronium albidum (white trout lily)
Ranunculaceae
Ranunculus septentrionalis (swamp buttercup)
Aconitum noveboracense (northern blue monkshood)
Anemone Canadensis (Canada anemone)

Starting in the fall of 2003, two insect species have been brought into the quarantine facility on the St. Paul campus. Three hundred *Ceutorhynchus scrobicollis* adults were received in both 2003 and 2004, and 300 *Ceutorhynchus roberti* adults were received in April 2004 from the CABI facility in Delemont, Switzerland. The weevils arrived in excellent shape and were placed under quarantine conditions in the High Containment Security Facility on the University of Minnesota campus. To date, sequential host range studies were conducted with mating pairs of *C. scrobicollis* on the plant species.

Results of host specificity completed to date are found in Table 24. No *C. scrobicollis* feeding was noted for any of the test plant species (Table 24). However, several eggs were found on three of the test plant species. In each case, eggs were laid directly on the leaf or stem surface. This is not considered normal oviposition behavior by *C. scrobicollis* which normally inserts eggs into the stem or underneath the leaf mesophyll.

Because the eggs were left exposed, they all desiccated and did not hatch. Eggs that were found on a leaf or stem of the test plant were held and the eggs were checked periodically. All eggs either desiccated on the leaf surface, or rolled off of the leaf and were not found. Also, when an egg was found on a test plant, the mating pair was offered a leaf of the same test plant species for a second time. No eggs were laid on the test plant leaf in the second test.

Table 24. Results of current *Ceutorhynchus scrobicollis* host specificity testing in quarantine at the University of Minnesota, St. Paul, MN. 2003-2004.

Species	Number of valid Replications	Feeding	Oviposition
Canada anemone (*Anemone canadensis*)			
Sequential no-choice test	12	No	No
Single choice test	12	No	No
Sedge spp.(*Carex laxiflora*)			
Sequential no-choice test	12	No	No
Single choice test	12	No	No
Hog peanut (*Amphicarpaea bracteata*)			
Sequential no-choice test	8	No	1 egg *
Single choice test	9	No	No
Swamp buttercup (*Ranunculus hispidus*)			
Sequential no-choice test	8	No	3 eggs *
Single choice test	8	No	No
Northern blue monkshood (*Aconitum noveboracense*)			
Sequential no-choice test	8	No	4 eggs *
Single choice test	10	No	1 egg *

* Eggs desiccated and never hatched

These results are encouraging, but more testing needs to be carried out. Once all the testing is completed, the results will be evaluated and a decision will be made whether to petition the federal government for permission to release the control agents into the United States.

Management of Asian Carp

Introduction

Four non-native species of carp, collectively known as Asian carp, have been imported for commercial aquaculture use in the Mississippi River basin and appear to have significant potential to harm aquatic ecosystems in Minnesota. The species are: Bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and black carp (*Mylopharyngodon piceus*). All four species have escaped from captivity and all but the black carp are known to have established populations in the Upper Mississippi River Basin (UMRB). Monitoring has documented that these populations are expanding their geographic range and are moving up the Mississippi River towards Minnesota (a single bighead carp was caught in Lake Pepin in 2003). There is also concern that these fish could enter the Great Lakes through the Illinois waterways that connect the Mississippi River basin with the Great Lakes and potentially reach the Minnesota waters of Lake Superior.

Resource managers throughout the UMRB are concerned about Asian carp and their associated impacts on natural resources and human safety. The distribution of these fish species in Asia and risk assessments suggest that they will thrive in the UMRB. Asian carp are already the most abundant large fish in parts of the Missouri River and are present in large numbers in parts of the Mississippi River and its tributaries. Each of these species has unique characteristics and poses different threats to fish and other aquatic species. Taken together they appear capable of having profound effects on aquatic resources and recreational opportunities.

At present, no populations of Asian carp are known to have established in Minnesota. No Asian carp were reported caught in the state in 2004. The closest known populations are in Iowa waters of the Mississippi River and its tributaries. Monitoring has documented that these populations continue to move upstream. Asian carp can move up to seven miles a day (Anderson, 2004) and 150 miles in a season (Chapman, 2004), so there appears to be a short window of opportunity to limit the spread of these species throughout the UMRB. Without deliberate actions to slow their spread, populations of bighead and silver carp are likely to move into state waters of the Mississippi River in one to two years.

Bighead Carp

The bighead carp are a planktivorous fish (they eat microscopic organisms) and are native to China. They prefer zooplankton (microscopic animals), but will supplement their diet with phytoplankton (microscopic plants) and detritus. They can get quite large, with individuals reaching over 30 inches in length and weighing over 60 pounds. A unique feature that distinguishes the bighead carp from our native fishes is the placement of the eyes, which are located below the mouth. Bighead carp feed on the same food items as many of our native species and they will directly compete with the commercially-harvested bigmouth buffalo, the threatened paddlefish, young-of-the-year of many fish species, and freshwater mussels.

Bighead carp were imported to the U.S. by the aquaculture industry as a specialty food item, as well as to improve water quality in fish rearing ponds. Since the bighead carp were first discovered in the Mississippi and Ohio rivers, they have expanded their distribution into nearby states such as Illinois, Iowa, South Dakota, and Missouri. Two bighead carp have been caught in Minnesota border waters by commercial fishermen. In 2003, one fish was caught near the south end of Lake Pepin — a widening of the Mississippi River near Lake City. Another specimen was captured in the southern half of the St. Croix River in 1996, but not identified as a bighead carp until 2003.

In 1998, a fish farmer illegally brought "breeder" bighead carp from Missouri to a fish farm in Iowa with the intention of raising the species in ponds. These carp subsequently spawned, creating about one million bighead "fry" that were later returned to ponds at the Missouri farm.

Silver carp

Silver carp are native to eastern Asia. They were imported into the U.S. and stocked in private waters in other states to control algae/phytoplankton. The fish was first found in natural waters in Arkansas around 1980, likely the result of escapes from private aquaculture facilities. This fish has the potential to cause considerable damage to native species because it feeds on plankton required by larval fish, gizzard shad and other plankton eating fish, and native mussels. The silver carp has also attracted attention because of its habit of jumping out of the water in response to passing boats (Figure 23). Because of their size and the height the fish reach, this behavior creates a serious hazard to boaters. Silver carp have not yet been documented in Minnesota waters.

Figure 23. A silver carp jumping in response to a powerboat.

Grass carp

Grass carp are native to eastern Asia. Wild populations are now present in many natural waters in the United States. These fish have been and continue to be widely stocked to control aquatic vegetation. A proposal to allow the introduction and use of triploid grass carp in isolated waters licensed for private aquaculture was introduced during Minnesota's 2003 legislative session, but did not pass. According to fisheries biologists in Midwest states, reproducing populations of grass carp are found in tributaries of the Mississippi River south of Minnesota. Grass carp have not become established in Minnesota waters, but individual fish have been caught in state border waters (Mississippi River below the Twin Cities and Okamanpeedan Lake on the Minnesota-Iowa border). They have been sampled periodically in the Mississippi River with the northern-most record at Wabasha, Minnesota, in 1994, and the earliest record in Lake Winona in 1977.

Black carp

Black carp are native to eastern Asia. This species was first brought into the United States in the early 1970s as a "contaminant" in imported grass carp stocks for a private fish farm in Arkansas. In the early 1980s, black carp were imported as a food fish and to control the spread of yellow grub *Clinostomum margaritum* in aquaculture ponds (Source: http://nas.er.usgs.gov/queries/SpSimpleSearch.asp). Their establishment in the wild would pose a significant risk to the mollusk and fisheries resources throughout the Mississippi River and its tributaries.

Black carp are already present in, or are proposed for use in, aquaculture ponds in at least three southern states. Black carp were also illegally imported into aquaculture ponds in Iowa in 1998. If these practices continue, it is likely that black carp will escape or be inadvertently released and become established in the wild. According to a U.S. Geological Survey fact sheet (http://nas.er.usgs.gov/queries/SpSimpleSearch.asp), a number of escapes have already been documented. In 1994, about 30 black carp escaped from a fish farm in Missouri into the Osage River, Missouri River basin. The first specimen reported from the wild was captured in March 2003 from Horseshoe Lake, Illinois. In April 2004, two black carp were captured from the wild in the lower Red River, Louisiana. In June 2004, a single black carp was collected in the Mississippi River near Lock and Dam 24 across the river from Clarksville, Missouri. Black carp have not yet been found in Minnesota.

Management Goals and Options

There are three general options to manage wild populations of Asian carp:

1) do nothing;
2) attempt to prevent further geographical spread; and
3) attempt population control after colonization.

Based on results in areas where Asian carp have already become established, it is clear that, if no actions are taken, Asian carp will eventually jeopardize aquatic resources and use of those resources in much of the Mississippi River Basin. Currently there are no effective measures that would selectively control these species. The Minnesota DNR's goal is to prevent or slow the introduction of Asian carp into state waters and continue to support research efforts to develop new control techniques. To accomplish this goal, states, federal agencies, and Congress will need to act promptly, ideally during 2005 and 2006, to limit the northern spread of Asian carp in the UMRB.

Progress in Management of Asian Carp

Actions

Because of the potential for significant impacts, the DNR has worked with several partners to identify and implement steps to keep Asian carp from entering the state.

1998 - the DNR designated black, bighead, grass, and silver carp as a *prohibited invasive species* in Minnesota. Prohibited invasive species are illegal to possess, transport, import, propagate, and release in the state.

2003 - the DNR was one of the groups opposing a bill introduced in the state legislature to allow use of triploid grass carp in the state. The bill did not pass.

The DNR investigated the use of electrical barriers to deter Asian carp species from moving up the Mississippi River and invited other agencies to help evaluate the Asian carp problem and recommend next actions (see Annual Report for 2003).

2004 -

- A feasibility study, funded by DNR, the U.S. Fish and Wildlife Service (USFWS), and Wisconsin DNR was completed by the FishPro consulting firm (FishPro, 2004). The study focused on technology that could deter the spread of Asian carp and their costs.
- Public awareness materials about Asian carp were prepared and distributed to the public.
- An interagency team of experts from the Minnesota DNR, Wisconsin DNR, Iowa DNR, U.S. Army Corps of Engineers, USFWS, and the National Park Service reviewed the FishPro feasibility study and recommended steps to implement the study's recommendations (the recommendations of that interagency team are listed below).
- DNR staff continued to conduct surveys and contact commercial fishing operators in the Mississippi River to help determine the northernmost extent of the Asian carp species.
- DNR's Deputy Commissioner met with congressional staff to discuss potential federal funding for two dispersal barriers.
- DNR funded and USFWS provided fish for studies of the response of fish to various sound frequencies (audiograms) by Fish Guidance Systems Ltd. on paddlefish and lake sturgeon to help determine their potential response to proposed acoustic barriers. Fish Guidance Systems Ltd. reported (Nedwell, Lovell, and Pegg, 2005) that a significant difference between the hearing of paddlefish and lake sturgeon versus bighead and silver carp raises the possibility of building a selective acoustic fish barrier to allow paddlefish and sturgeon to pass while deterring the passage of bighead and silver carp species.

The results indicate that a differential acoustic fish deterrent barrier that would be greater than 95% effective on Asian carp and less than 20% effective on paddlefish and lake sturgeon might be achievable, but additional work is needed before such a system could be designed and built.

- Minnesota and the other Great Lakes states recognize the critical need to keep aquatic invasive species, such as Asian carp, out of the Great Lakes and worked actively with the Council of Great Lakes Governors, the Great Lakes Fishery Commission, and other groups to fund and install a new dispersal barrier in the Illinois waterways. The Department of the Army will contribute $6,825,000 of federal funds, the Illinois Department of Natural Resources will contribute $1.8 million, and the states of Minnesota, Indiana, Michigan, Ohio, New York, Wisconsin, and Pennsylvania contributed $67,857 each toward the non-federal cost share. DNR's Invasive Species Program provided the funds for Minnesota.

Interagency Team Recommendations

- Install barriers in conjunction with two Mississippi River locks and dams (L&D) such as L&D11 and L&D 14 or 15 by spring 2006 (Figure 24).
- Use a combination of barrier technologies and an integrated pest management approach (e.g., harvest, education, and regulations) to maximize the probability of success of limiting the upstream movement of Asian carp in the UMRB.
- Seek federal leadership from USFWS for technical assistance, and USACE for barrier design, installation, and operation and maintenance.
- Obtain funding and initiate work on environmental documents and barrier design.

Concerns/Issues

- Restricting migration of native fishes is a concern, because the current goal for states within the UMRB and their federal management partners is to make fish passage improvements at dams, and to remove small dams to restore native fish migrations. Therefore, when barriers are used, their potential benefits to deter upriver passage of Asian carp at key sites should outweigh the limitation of upriver passage of native fish. Some currently proposed technologies could be somewhat selective given differences in the responses of fish species. Future solutions to limit the spread of Asian carp and other invasive species should include development of more selective approaches that would allow the migration of native species.
- Flooding and technological limitations pose challenges for preventing upstream spread of Asian carp past potential fish barriers.
- The costs will be significant. According to the feasibility study (FishPro, 2004), the costs to build two fish barriers will depend on the sites and types of technologies:
  - Sound and bubble diversions (Bio Acoustic Fish Fence) placed at the lock chambers are estimated to cost approximately $1.2 - $1.6 million each.
  - Costs of $.5 - $3 million are estimated for creating a harvesting area for carp that congregate below each lock.

The need and feasibility of adding additional barrier technology along the spillway of the dam that will not compromise other river management concerns is still being examined and, if pursued, could cost an additional $8 to $10 million per dam.

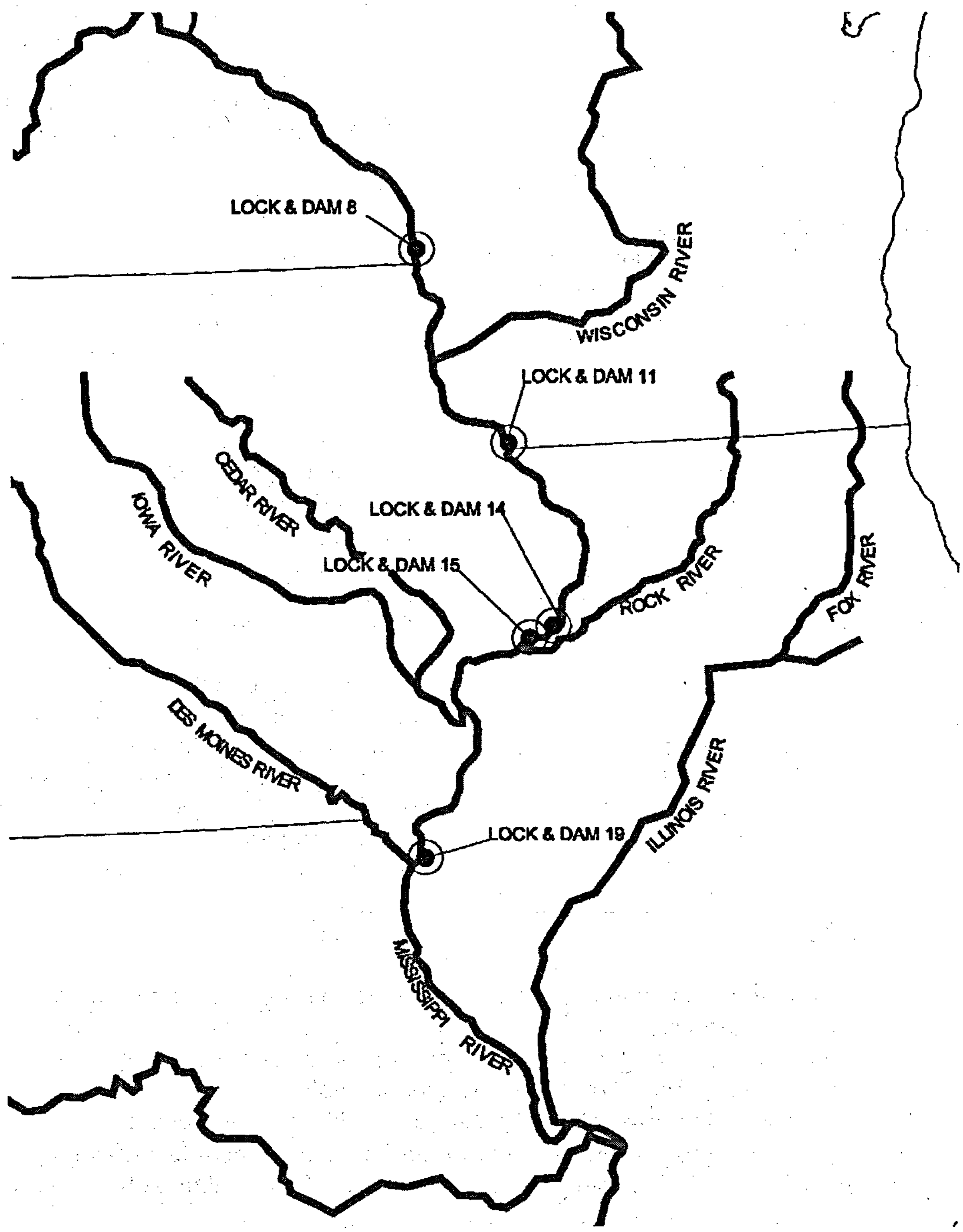

Figure 24. Locations of selected locks and dams on the Mississippi River.

Participation of Others

Federal Regulations

The USFWS began a process in 2002 to determine if it will list black carp as an injurious wildlife species. A similar process was initiated in 2003 to determine if bighead and silver carp should be listed as injurious wildlife species (see Regulations and Proposed Changes). If listed, it would be illegal to import these species into the country or to ship them between states. As of December 2004, the USFWS has not designated any of the three species as injurious wildlife.

National Asian Carp Management Plan

The USFWS has formed an Asian Carp Work Group to develop an Asian carp management plan that will cover bighead, silver, and black carp. Jay Rendall, Minnesota's Invasive Species Program Coordinator, is a member of that group. The Work Group's goal is to provide the draft of the plan to the federal ANS Task Force in 2005.

Illinois Barriers I and II

The original demonstration barrier (Barrier I), which became operational in 2002, continues to function though one of its electrodes is corroding. The Corps conducted safety testing in December 2004 to define safe operation guidelines for barges.

Construction of the second barrier (Barrier II) began in October 2004. The construction timetable anticipates the barrier will be turned on for its trial run in February 2005.

The USFWS (Pam Thiel, personal communication) reported that in 2004 no Asian carps were collected in the Chicago Sanitary and Ship Canal (the waters that connect the Mississippi River basin with the Great Lakes basin), nor in the Des Plaines River where a bighead carp was captured near Channohan in 2002. Therefore, Asian carps still appear to be about 21 miles below Barrier I and 50 miles from Lake Michigan. However, bighead carp, silver carp, and grass carp were frequently caught by crews in the Illinois River near La Salle and Peru, about 100 miles from Lake Michigan.

Future Needs

- Support efforts to maintain two effective barriers to prevent Asian carp passage in the Illinois Waterways.
- Seek funding for one or more dispersal barriers in the Mississippi River to prevent Asian carp from moving into Minnesota waters.
- Evaluate potential to re-establish St. Anthony Falls as a natural barrier.
- Evaluate potential to prevent spread of Asian carp in Minnesota's major tributaries to the Mississippi River including the St. Croix, Minnesota, Zumbro, Cannon, and Root rivers.

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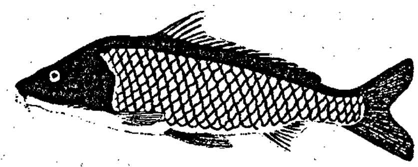
Management of Common Carp

Introduction

Issue



Common carp (*Cyprinus carpio*) were intentionally introduced into Minnesota waters before 1900. They remained relatively unnoticed as a threat to environmental quality until after the drought of the 1930s. The drought caused many wetlands and wetland areas around lakes to dry up and set the stage for an explosion of aquatic vegetation and invertebrates. The early wetland drainage efforts also provided connections into many wetlands and shallow lakes previously inaccessible to fish. With the recovery of precipitation and subsequent increase in water levels in wetlands, lakes, and streams, the common carp found an abundance of food and spawning habitat. As early as the 1940s, carp had noticeably damaged aquatic habitat in famous waterfowl lakes such as Heron Lake in southwestern Minnesota. By the 1960s, common carp were recognized as a major factor in the deterioration of aquatic habitat across southern Minnesota.

The role of common carp in causing habitat deterioration is primarily related to their search for invertebrates in aquatic vegetation and bottom sediments. Their feeding activity disrupts shallowly rooted plants and suspends bottom sediments in the water column. The sediments release phosphorus that increases the growth of phytoplankton. As water clarity is reduced, remaining aquatic plants find it difficult to survive. As the rooted plants disappear, more bottom soils are exposed to wave action and further suspension. The cycle continues until the water body is devoid of rooted aquatic plants and phytoplankton thrives in the suspended nutrients. Habitat for most native game fish and aquatic wildlife such as waterfowl is devastated. Since carp do not require clear water to feed and reproduce, they eliminate competition from fish that do, including those that would prey on young carp.

Common carp are a carrier of a new disease in the state, spring viremia of carp. All C*yprinids* (minnows) and northern pike are susceptible to the disease.

Goals

The DNR has two goals related to management of common carp:

- Prevent the spread of carp into waters within Minnesota where they do not currently exist or have been successfully removed.
- Remove common carp from high-priority waterfowl waters, such as shallow lakes and wetlands where they are present.

Distribution

Carp currently occur in the majority of waters across the southern half of Minnesota (see Figure 25).

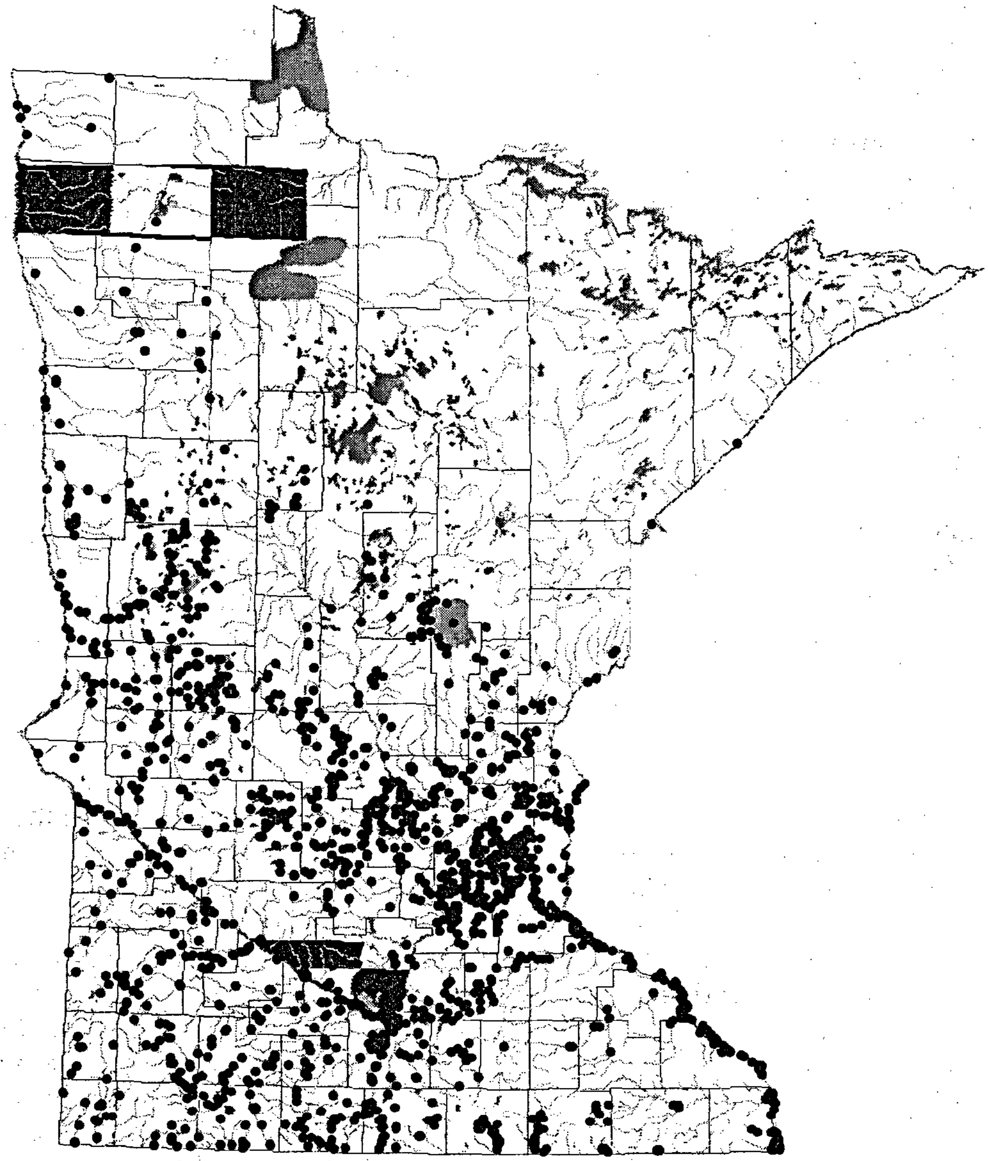


Figure 25. Distribution of common carp in Minnesota as of December 2004.

Progress in Management of Common Carp - 2004

Several activities occur to inventory common carp infested waters, limit their spread, and remove carp from waters where they exist. Those activities (described below) are primarily conducted by staff of the Division of Fish and Wildlife.

Evaluation of habitat conditions on shallow lakes

Habitat evaluation surveys were conducted on 60 shallow lakes by DNR Wildlife staff in 2004. These surveys evaluate water clarity, chemistry, and depth along with occurrence and density of rooted aquatic plants.

Evaluation of fish populations
Fish population surveys were proposed at 600 managed fishing lakes by DNR Fisheries. The results of those surveys will be available in June 2005.

Establish and maintain fish barriers
Fish barriers are used to limit the movement of common carp between connected waters. Fish barriers continued to be constructed, repaired, and maintained by DNR Wildlife in 2004.

Remove carp from priority lakes
A large project was conducted by DNR Wildlife at Howard and Mud lakes, shallow lakes near Carlos Avery Wildlife Management Area, to remove common carp, bullheads, and other zooplankton-eating fish. The lake was treated with Rotenone in October 2004 to kill the fish in the lake.

A similar treatment was conducted in Lake Christina in 2003. One year following application of the fish-killing agent, researchers from the Department of Natural Resources, North Dakota State University, and the University of St. Thomas are noting some positive trends in water quality and habitat conditions on the lake.
Water level drawdowns were conducted by DNR Wildlife on more than 20 shallow lakes to eliminate carp and restore aquatic vegetation.

Research

Research to identify pheromones to attract or repel carp is being conducted at the University of Minnesota, with Dr. Peter Sorenson as the project leader, in cooperation with DNR Wildlife. A report on his initial common carp research was submitted to DNR this year (Sorenson and Sherman, 2004). The report states that both visual and pheromonal cues could be employed to enhance trapping success during carp control efforts and that when employed together they have great potential. Using a large square tank with small traps, Dr. Sorenson found that male goldfish were attracted by a F-prostaglandin pheromone, that the sight of other fish was also attractive, and that when the pheromone was introduced in the presence of spawning fish, especially strong attraction was noted. His preliminary experiments using a laminar flow tank also found mature male carp to be attracted to the prostaglandin pheromone. Sorenson suggests further research to identify spawning requirements of common carp in the laboratory and field are needed, however, to guide how to incorporate these findings into a control program.

A project entitled "Developing Pheromones for Use in Carp Control" that was recommended by the Legislative Commission on Minnesota Resources (LCMR) and was subsequently funded by the Legislature continued this research at the University of Minnesota in FY 04-05. In addition to the $100,000 of state funds, the U.S. Fish and Wildlife Service (USFWS) contributed $75,000. It is hoped that the findings from the pheromone research will allow development of an integrated approach to carp management.

In 2004, the LCMR recommended additional funding of $500,000 to continue Dr. Sorenson's research on common carp management during FY 06-09. The DNR is a partner on the proposed project and will contribute staff and equipment from DNR

Fisheries and $60,000 from the Invasive Species Program. The aim of this proposal is to develop a basic understanding of two aspects of carp biology which can be meaningfully targeted (pheromonally-mediated aggregation and spawning), and a statistical model to explore how to best target different life histories of carp, thereby establishing the foundations of an integrated control program (Sorenson, 2004).

Effectiveness

Common carp management has been only moderately effective in all types of waters within Minnesota. Nevertheless, in shallow waters where removal of carp has been successful, the aquatic habitat has responded immediately the next spring with improved water clarity and abundant native rooted aquatic plants.

Participation of Others

Participation of others varies depending on the individual management project for common carp. During 2004, participation on common carp management projects included Ducks Unlimited, Minnesota Waterfowl Association, USFWS, DNR Fisheries, and local lake associations.

Future needs for management of common carp

- Continue support for funding of research related to the application of pheromones, induce winterkill to remove carp, develop and evaluate new fish barrier designs, and make additional refinements of chemical applications to remove common carp.
- Continue to seek and provide funding for management to accelerate the removal of common carp from high-priority affected waters and/or the construction of barriers to limit natural dispersal.
- Monitor the new disease, spring viremia of carp, to determine how widespread it is in Minnesota and consider new limitations on live carp shipments.

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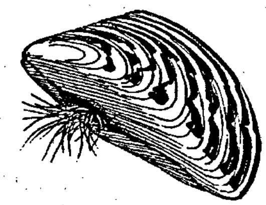
Management of Zebra Mussels

Introduction

Issue



The zebra mussel (*Dreissena polymorpha*) is a small striped invasive mussel that was brought to North America in the ballast waters of trans-Atlantic freighters in the late 1980s. Unlike our native mussels, zebra mussels secrete sticky threads that are used to firmly attach to any hard surface in the water. The ability of these mussels to attach in large clumps can create numerous problems, such as clogging intake pipes for industry or killing native mussels. Attachment of the adults to recreational boats or aquatic vegetation (which may be transported by boaters) can serve to move zebra mussels to other waters.

Zebra mussels have a microscopic free-living larval stage (veliger), which may float in the water for two to three weeks. This larval stage ensures widespread distribution in lakes, and downstream of any established zebra mussel populations in rivers. Additionally, this microscopic life stage may also be moved to other water bodies in any water (such as bait buckets) transported over land. The high reproductive capacity and free-living veligers of the zebra mussel allows for rapid dispersal within a water body.

Zebra mussels feed by filtering algae and other small particles out of the water. These same small food particles are the food base for zooplankton and larval fish in our lakes and rivers. Hundreds of thousands of zebra mussels may filter so much of this food that it could interfere in the aquatic food chain, reducing the food availability for larval fish and impacting fish populations.

Goal

- Prevent the spread of zebra mussels to uninfested waters within Minnesota.

Distribution

Zebra mussels occur in the Mississippi River from St. Paul to the Iowa border, the lower 25 miles of the St. Croix River, the Duluth Harbor, Lake Zumbro, the Zumbro River downstream of Lake Zumbro, Lake Ossawinnamakee, and Pelican Brook immediately downstream of Lake Ossawinnamakee (Figure 26).

Progress in Management of Zebra Mussels - 2004

Monitoring

Scuba divers in Lake Zumbro found significant settlement of zebra mussels again this year, occurring later in the season than previous years. Populations of zebra mussels in the lake are well established and continued reproduction and recruitment can be expected. Veliger sampling in Lake Ossawinnamakee showed increasing numbers of veligers in the lake, suggesting successful reproduction in this new population. Divers on one location in the lake found numerous zebra mussels of different size classes attached to rocks and wood on the lake bottom. Diving and sampling in Kimball Lake,

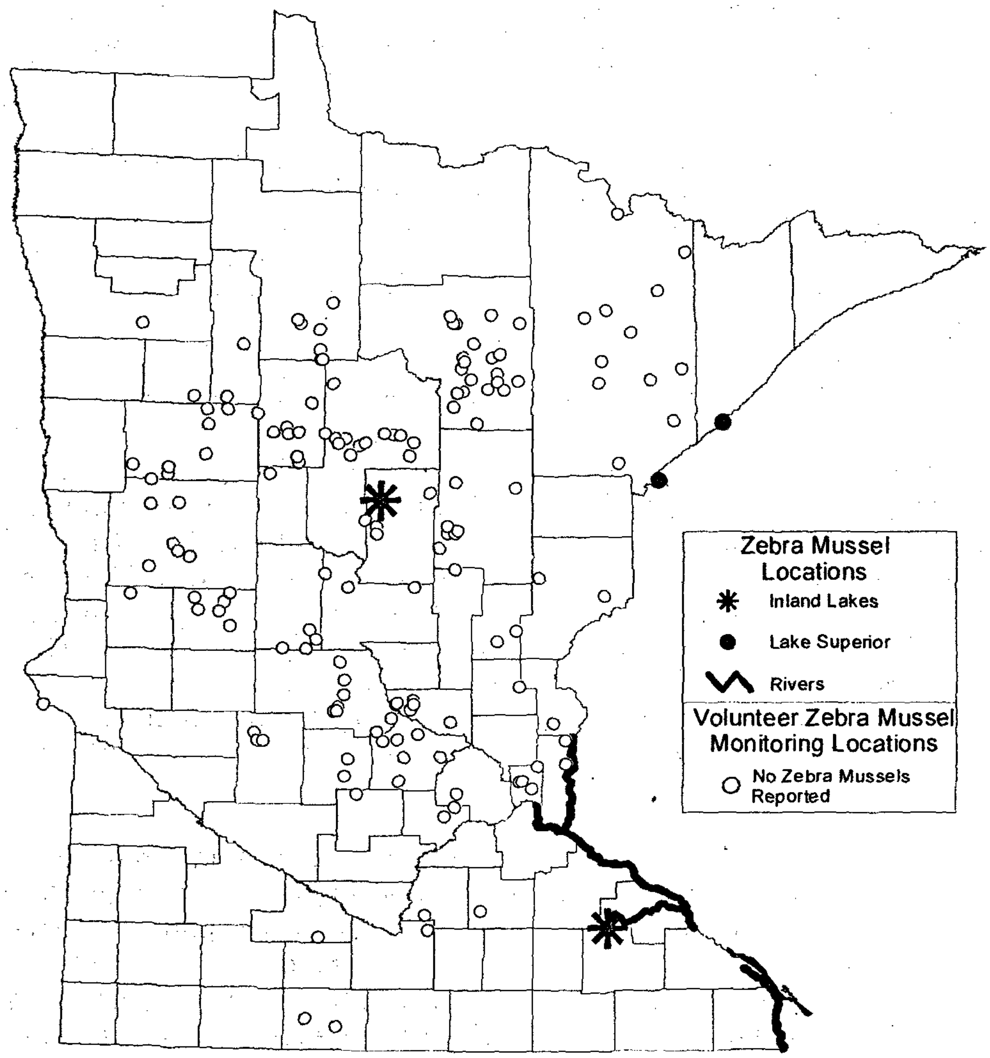


Figure 26. Zebra mussel and volunteer zebra mussel monitoring locations in Minnesota as of November 2004.

upstream of and connected to Lake Ossawinnamakee by a small creek, found no evidence of zebra mussels.

The Volunteer Zebra Mussel Monitoring Program continued with mailing of report forms and results from the previous year to all lakeshore residents who had participated. Reports to date from volunteers monitoring their lakeshore areas have not found any zebra mussels in any other waters of the state.

The National Park Service monitors for zebra mussels using slides on settling plate samplers in the federal zone of the St. Croix River, above the infested section of the river. Samples taken by the National Park Service were analyzed in the aquatic invertebrate office by DNR biologists. No zebra mussels were found on the slides examined for 2004, suggesting that this invasive has not been moved upstream within these waters and continues to be confined to the lower 25 miles of the St. Croix.

Prevention of spread

Lake Ossawinnamakee is located approximately 120 miles from the nearest zebra mussel location and presents a risk of movement to other waters in this area by boaters who may not have previously boated in zebra mussel infested waters. Watercraft inspection efforts were increased on the lake and the Brainerd area (see Watercraft Inspections and Awareness Events). Public awareness efforts were increased substantially in this area.

Zebra mussels in Lake Ossawinnamakee present two significant challenges for preventing spread. First, a small creek connects the lake with Kimball Lake, the next lake upstream from Ossawinnamakee (Figure 27). Boat traffic moving between the lakes could spread zebra mussels, particularly boats which may be moored during the summer in Lake Ossawinnamakee. To address this possible pathway, the DNR installed six large boulders in the upstream end of the creek. These rocks, while not preventing the flow of water through the channel, prevent boat movement into or out of Kimball Lake. Additionally, the DNR Brainerd Area Fisheries manager worked with the Crow Wing County Board of Commissioners, who unanimously passed an ordinance prohibiting boat traffic through the creek. While preventing boat traffic through the creek, these actions do not prevent boating on Kimball Lake, which has a public access site.

A second and more difficult challenge is that Lake Ossawinnamakee has an outlet stream (Pelican Brook), which is connected to the Mississippi River via the Pine River (Figure 27). This natural water movement pathway could permit transport of veligers from the lake eventually to the Mississippi River north of Brainerd. In an attempt to prevent downstream spread of the veligers, the DNR contracted to have copper sulfate applied weekly during the summer to the bay (Muskie Bay) feeding the outlet stream. Sampling of veligers in this treatment area and the main lake basin suggested that the copper had eliminated or significantly reduced veliger numbers in the bay. Additionally, fall sampling in Pelican Brook failed to collect any attached zebra mussels in the outlet area, despite their scattered presence in this area in the spring. While this treatment was effective as a short-term control measure, toxicity to other aquatic life and metal accumulation in sediments would prevent this from being used as an annual operational control option. The DNR is seeking technical assistance to assess viable long-term control options for this pathway.

Research

The DNR contracted with the U. S. Army Corps of Engineers Experimental Waterways Research Station to conduct laboratory studies to determine copper toxicity to veligers. Results from this study suggest that the levels of copper used in the treatments should have been highly toxic to veligers, and dosage may even be able to be reduced slightly.

While copper is effective, toxicity issues make this a short-term measure. The DNR is seeking an outside contractor to assess potential long-term control measures that could be implemented on the stream to prevent movement of veligers and other life stages.

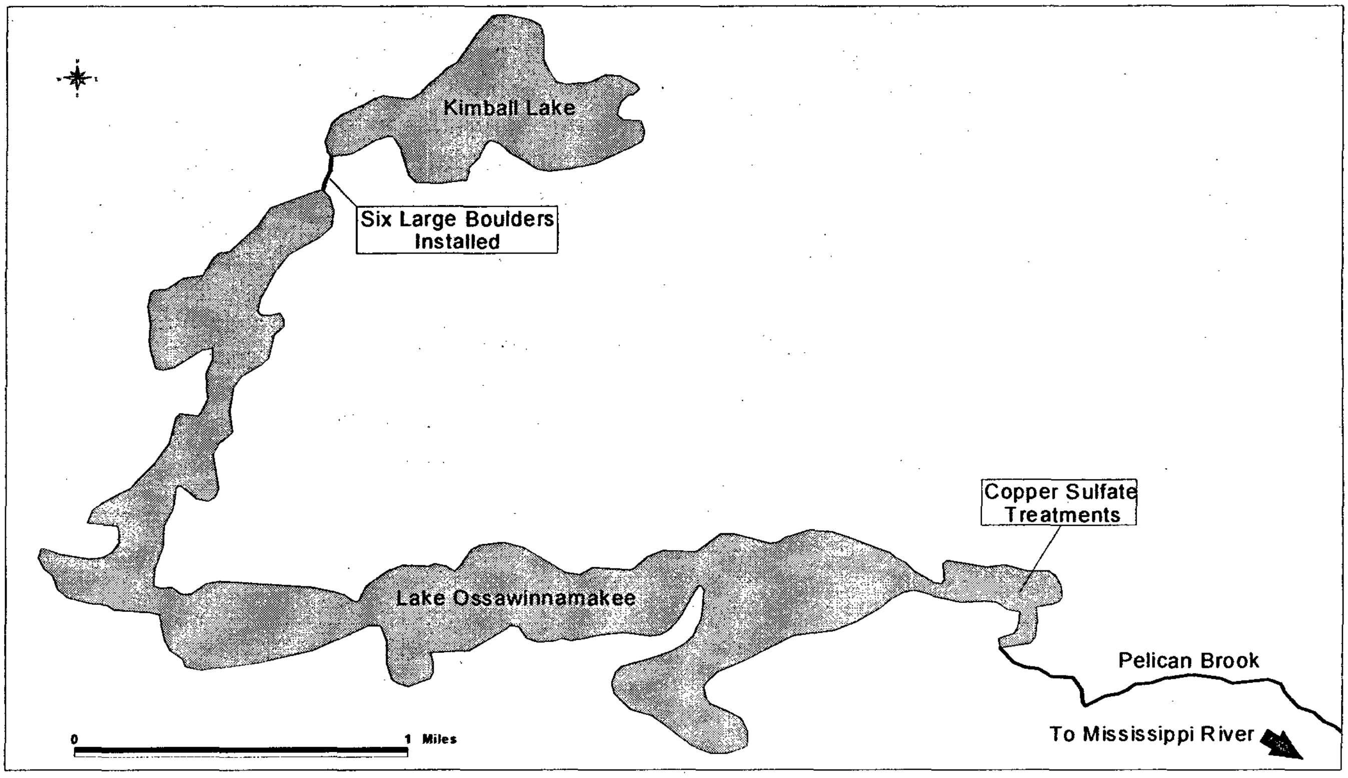


Figure 27. Lake Ossawinnamakee, Kimball Lake, and Pelican Brook.

Effectiveness of Management

Minnesota still only has two inland lakes that contain this invasive. Movement to inland waters in Minnesota has been much slower than in other Midwest states. However, the infestation in the Brainerd lakes area puts this invasive in a heavily used vacation and recreation area. Public awareness efforts were intensified in 2004 and will continue in an effort to prevent movement to other lakes in this area. In comparison to Minnesota, Wisconsin has more than 40 inland water bodies with zebra mussels, while Michigan has approximately 200 infested inland waters. Unlike Minnesota, these states do not have statutes that prevent movement of aquatic plants, which research has suggested is the primary avenue for overland transport leading to new infestations. The prohibition on moving aquatic plants is extremely important as surveys in Lake Ossawinnamakee found substantial settlement of zebra mussels on aquatic vegetation in many areas of the lake.

Participation of Others

Funding for an interstate management plan for coordinated actions against the zebra mussel for the St. Croix River was continued by U.S. Fish and Wildlife Service. The Minnesota DNR, Wisconsin DNR, and the Great Lakes Indian Fish and Wildlife Commission received funding assistance for zebra mussel activities on the St. Croix River outlined in the management plan.

Monitoring efforts for zebra mussels continued by lakeshore residents throughout Minnesota. Over the past two years, approximately 225 people annually have participated in the Volunteer Zebra Mussel Monitoring Program, checking lakes across the state for zebra mussels. These efforts provide a much more extensive examination of Minnesota waters for this invasive than could be conducted by the Invasive Species Program alone. Inland lake infestations in Minnesota (Zumbro and Ossawinnamakee) were both reported by members of the public indicating the importance and value of this volunteer effort.

Future needs for management of zebra mussels

- Continue monitoring zebra mussel populations in various Minnesota waters.
- Continue the Volunteer Zebra Mussel Monitoring Program.

Other Invasive Animal Species in Minnesota

Introduction

Numerous invasive wild animals exist in the state. The previous chapters described species for which there were ongoing efforts. The species described in this chapter exist in the state, but there are no ongoing efforts by the DNR to manage them in the wild. They are included because they are or have been of interest within the state. In addition to the information presented on rusty crayfish, spiny waterflea, *Daphnia lumholtzi,* round and tubenose goby, Eurasian collard-dove, and mute swan in this chapter, Table 27 presents a summary of other invasive animal species in Minnesota.

Rusty Crayfish

The rusty crayfish (*Orconectes rusticus*) is an invasive species in our state that is native to the eastern and mid-eastern United States. It has been spread across the Midwest through human activities, likely through release from bait by anglers. This invasive can out-compete native crayfish and may interbreed with our native species. It can displace native crayfish, reduce or eliminate aquatic vegetation, and may interfere with some fish populations in certain lakes. There are currently no selective and effective control methods once the rusty crayfish become established in lakes or rivers. Researchers in Wisconsin are examining management of crayfish predators (specific fish species) to attempt to manage numbers of this invasive in natural lakes; however, this research is still preliminary. A recent report on crayfish control (*Investigation of Crayfish Control Technology)*, M. W. Hyatt, Arizona Game and Fish Department) looked at varying methods of control and came to the conclusion that non-specific biocides might work in very limited circumstances, but no other control method (manual removal, trapping, predator management) would eliminate crayfish. With the lack of any selective or even effective control methods, the Invasive Species Program does not conduct any active management of rusty crayfish.

These crayfish have been reported from over 40 lakes and eight rivers in the state, scattered from northeast to south-central Minnesota. Fisheries staff encounter rusty crayfish in their lake sampling gear and report findings to the Division of Ecological Services. Many lakes in St. Louis and Lake counties are connected, and it has been shown that the rusty crayfish will move between interconnected water bodies. Judging from the widespread reported distribution, it is highly likely that rusty crayfish are present, but unrecorded in more waters in the state.

Spiny Waterflea

The spiny waterflea (*Bythotrephes longimanus*) is an invasive cladoceran zooplankter native to Europe. It was brought over to North America in ballast water in the late 1980s and first appeared in the Great Lakes. This zooplankter is a predaceous cladoceran, feeding on other smaller zooplankton. The long, barbed tail spine on this invasive can prevent predation by small larval fish as well as other aquatic animals. Some species of larger fish have been shown to feed heavily on the spiny waterflea. This invasive may interfere with lake food webs by preying heavily on and reducing the number of other zooplankton. Some research suggests that the most significant impacts will occur in larger, oligotrophic (lacking plant nutrients) lakes with simpler fish communities. The spiny waterflea produces resting eggs similar to those of native Cladocera, which can resist desiccation and freezing, providing a long-range dispersal method for overland spread. Adults may become entangled in fishing gear and moved to other water bodies.

The spiny waterflea was discovered in Lake Superior in the late 1980s, and shortly after that was found in two nearby lakes (Fish and Island lakes, near Duluth). Monitoring by area Fisheries staff reported that it disappeared from Fish Lake, while remaining in Island Lake. Researchers at the University of Minnesota-Duluth sampled selected lakes in the northeastern area of the state, and confirmed spiny waterflea in four lakes: Flour, Greenwood, McFarland and Pine lakes, all in Cook County. With the connections among many lakes in this area, it is very likely that the spread to other lakes may occur (or have already occurred) through natural movement. The resting eggs or viable adults can be carried through connections into other water bodies.

Fisheries staff in the Duluth area are currently working on completing a research study examining *B. longimanus* populations in Island Lake. The Aquatic Invertebrate Biology staff is assisting in laboratory work for this study.

Daphnia lumholtzi

Daphnia lumholtzi is an invasive cladoceran native to the subtropical regions of Africa, Asia, and Australia. This species was first reported in North America in 1990 from a small reservoir in eastern Texas and shortly thereafter from a reservoir in southwest Missouri. Since its first sightings, it has spread rapidly throughout the southern and mid-western states. It was most likely brought to North America with African fish imported for the aquarium trade or to stock reservoirs. *D. lumholtzi* can be easily distinguished from native daphnia by its large pointed helmet, long tail spine, and numerous smaller spines along its carapace. Because of its armored body, *D. lumholtzi* may be less susceptible to predation than native daphnia and could compete with native daphnia, which are very important in the diet of juvenile fishes.

D. lumholtzi were first found in reproductive densities in Lake Pepin in 2003. However, none were collected in standardized set sampling in 2004. Zooplankton samples have been collected from Lake Pepin since the early 1990s as part of the Long Term River Monitoring Program. Similar to native cladocerans, *D. lumholtzi* survives the winter by producing resting eggs that can resist freezing and desiccation, and hatch the following summer when optimum temperatures return (25-31° C). These resting eggs can also be a means of dispersal for the species as they can be transported across land by migrating birds, wind, and human activities. Because *D. lumholtzi* is a subtropical species requiring warmer water temperatures than native daphnia, it generally does not appear until late summer and is often restricted to warmer shallow water. Lake Pepin is the furthest north *D. lumholtzi* has been found so far. Water temperature may present a major physical constraint on its long-term success in northern latitudes, but this has yet to be determined. Cooler temperatures, increased flow from heavy precipitation, and other climatic conditions may have contributed to the lack of this invasive in Lake Pepin in 2004. Future sampling may help determine if this species will ever become a major component in the zooplankton community or sporadically occur under ideal conditions.

Round and Tubenose Goby

The round (*Neogobius melanostomus*) and tubenose (*Proterochinus marmoratus*) gobies (Figure 28) are bottom dwelling fish from Europe and native to the Black and

Caspian seas. The gobies were discovered in Michigan waters in 1990, likely the result of ballast water exchange from transoceanic vessels.

Figure 28. The round and tubenose goby.

In 1995, the round goby was discovered in the Duluth/Superior Harbor. Since then, the population has steadily increased according to bottom trawl data from U.S. Geological Survey (USGS) (Lori Evrard, November 23, 2004). Wisconsin DNR surveys have shown a decrease in population within the St. Louis estuary, possibly due to the late spring and relatively cool summer, coupled with a slow expansion of submersed aquatic vegetation beds in which the tubenose goby seem to prefer and could have a seasonal advantage over the round goby (Dennis Pratt, November 10, 2004). The round goby has documented negative impacts on mottled sculpin reproduction (Janssen and Jude, 2001) and suspected impacts on other native bottom dwelling fish, such as darters and sturgeon. The round goby has expanded its range throughout the Great Lakes, Detroit River, Lake Superior watershed, and the Illinois waterway.

The tubenose goby was first discovered in the St. Louis River estuary in 2001. It was originally thought to be less invasive than the round goby and recent surveys by the Wisconsin DNR and USGS actually show an increase in tubenose goby population, especially within the last couple of years (Table 25) (Lori Evrard, U.S. Geological Survey, November 23, 2004). It should be noted that the trawling data from USGS suggests that the tubenose goby population is still significantly lower than the round goby.

Table 25. Number of round and tubenose gobies captured using a seine at nine sites (Dennis Pratt, Wisconsin DNR, November 10, 2004).

	1998	1999	2000	2001	2002	2003	2004
Round Goby	14	25	316	18	148	1,836	487
Tubenose Goby	0	0	0	1	10	175	589

References Cited

Janssen, J and Jude, D.J. 2001. Recruitment Failure of Mottled Sculpin *Cottus bairdi* in Calumet Harbor, Southern Lake Michigan, Induced by the Newly Introduced Round Goby *Neogobius melanostomus*. J. Great Lakes Res. 27(3):319-328.

Eurasian Collared-dove

The Eurasian collared-dove (*Streptopelia decaocto*), a bird native to the Indian subcontinent and Turkey, was first described as a new, non-native bird species in the state in the annual report for 1999. The bird has been observed in 18 Minnesota counties from 1999 to 2003: Big Stone, Blue Earth, Brown, Carver, Chippewa, Dakota, Freeborn, Houston, Lyon, Kandiyohi, Martin, Pennington, Pipestone, Renville, Rock, Roseau, Stearns, and Yellow Medicine.

In 2004, Eurasian collared-doves were reported for the first time in the town of Marietta in Lac qui Parle County and Appleton in Swift County. They were reported again in Chippewa, Houston, Lyon, and Renville counties. Mating and nesting birds were reported in two counties. In December 2004, a flock containing 15 collared-doves was reported in downtown Benson in Swift County. The birds are likely in other Minnesota counties and will continue spreading throughout the state.

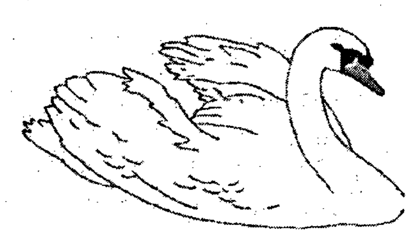
The DNR is not attempting to eliminate or control the population of Eurasian collared-doves in Minnesota. There are several reasons: it would be difficult to prevent their continued introduction from adjoining states; the birds look similar to mourning doves; and there is not a regional or national effort to stop their spread.

Mute Swans

Mute swans (*Cygnus olor*) are native to Europe and Asia and were brought to the United States from the mid-1800s through the early 1900s. Populations of mute swans have established in numerous states. These populations have originated from release or escape of individuals from captive flocks.

Mute swans are currently regulated in part by the Minnesota game farm statutes in Minnesota Statutes 97A.105 and they are designated as a *regulated invasive species* in Minnesota Rules 6216.0260. It is illegal to release mute swans into the wild under the game farm and regulated invasive species statutes.

Unconfined mute swans were reported in Minnesota in 2004 and in previous years. Monitoring mute swans in the wild is a strategy necessary to help DNR respond to birds that may establish naturalized populations. During 2004, the DNR recorded six reports of wild or escaped mute swans in the state. A total of 11 birds were reported in the wild in three counties (Table 26). Sources of the reports include: conservation officers, birders, calls from the public, and other DNR staff who observed unconfined birds. In 2004, of concern was a pair of mute swans that successfully nested at Big Carnelian Lake.



The DNR's goal for mute swan management is to avoid the establishment of naturalized populations of mute swans in Minnesota. Recent federal court decisions that required the United States Fish and Wildlife Service (USFWS) to protect non-native, invasive, and injurious birds under the Migratory Bird Treaty Act (MBTA) prevented the DNR from controlling mute swans for the past two years. This limitation may be removed in 2005. In mid-November 2004,

Table 26. Unconfined mute swans reported in Minnesota counties during 2004.

County	Number of swans	Month Reported
Olmstead	1	December
Rice	3	April
Washington	7	June
Total for all counties	**11**	

Congress passed an omnibus spending bill that included language to remedy the problem. The legislative remedy defines native species, which means that only those migratory birds that are native or otherwise listed by USFWS will be covered under the MBTA. This will exclude non-native species, such as mute swans. The Secretary of Interior is directed to publish, within 90 days of the bill, a list of all non-native human introduced species to which the MBTA does not apply.

In the future, the DNR has the following needs for management of mute swans:

- Verify occurrences of mute swans in the state and take appropriate actions to have the birds confined under game farm licenses or remove the birds from the wild.
- Develop and distribute informational materials about mute swans and related state and federal laws.
- Obtain a depredation permit from the USFWS to control unconfined mute swans.

Table 27. Other invasive and non-native species which have been found wild in Minnesota.

Species	Status	Legal Status	Last report to include info on this species
Earthworms (various genera)	Continued public education has focused on preventing the release of earthworms.	Unlisted	2003
Eurasian swine (*Sus scrofa*)	No new reports of escaped Eurasian swine in 2004.	Prohibited	2002
Three spine and four spine stickleback (*Gasterosteus aculeatus* and *Apeltes quadracus*)	In Lake Superior.	Unlisted	2000
Red deer (*Cervus elaphus*)	No new escapes since 1999.	Unlisted	1999
Sika deer (*Cervus nippon*)	Several escapes in past years. No reports in 2004.	Unlisted	2001
Fallow deer (*Dama dama*)	Several escapes in past years. No reports in 2004.	Unlisted	2001
Ruffe (*Gymnocephalus cernua*)	No new water bodies since 1988.	Prohibited	2002

Appendix A - Invasive Species Program Staff

Title / Area of Responsibility	Name	Phone	E-mail
Invasive Species Program Coordinator - rulemaking, legislation, state representative on regional aquatic invasive species committees or panels and federal invasive species issues, education and public awareness	Jay Rendall	651-297-1464	jay.rendall@dnr.state.mn.us
Purple Loosestrife Coordinator - technical assistance for management of purple loosestrife, and biocontrol of other invasive species	Luke Skinner	651-297-3763	luke.skinner@dnr.state.mn.us
Eurasian Watermilfoil Coordinator - technical and financial assistance for management of milfoil, and technical assistance for other invasive aquatic plants	Chip Welling	651-297-8021	chip.welling@dnr.state.mn.us
Invasive Species Biologist - technical assistance for management of milfoil, curly-leaf pondweed, and other invasive aquatic plants	Wendy Crowell	651-282-2508	wendy.crowell@dnr.state.mn.us
Invasive Species Biologist - technical assistance for management of milfoil, flowering rush, and other invasive aquatic plants	Nick Proulx	651-284-3589	nick.proulx@dnr.state.mn.us
Invasive Species Biologist - invasive species issues in northern portions of the state	Dan Swanson	218-833-8645	dan.swanson@dnr.state.mn.us
Invasive Species Ecologist - invasive species issues in northern portions of the state; purple loosestrife database management	Rich Rezanka	218-833-8646	richard.rezanka@dnr.state.mn.us
Watercraft Inspection Program Coordinator - supervises watercraft inspection interns; awareness events at water accesses	Heidi Wolf	651-297-4891	heidi.wolf@dnr.state.mn.us
Watercraft Inspection Program Assistant - awareness events at water accesses	Vacant	651-284-3586	
Aquatic Invertebrate Biologist - zebra mussels, rusty crayfish, and other invasive aquatic invertebrates	Gary Montz	651-297-4888	gary.montz@dnr.state.mn.us
Conservation Officer - statewide enforcement of invasive species regulations for aquatic plants and wild animals	Cathy Hamm	651-772-7906	cathy.hamm@dnr.state.mn.us
General Information		651-296-2835	

Appendix B - Other State Contacts for Invasive Species Prevention and Control Programs and Interagency Groups

Department of Natural Resources - Forest Pest Program

DNR's Division of Forestry, working in cooperation with the MDA, is charged with surveying and controlling forest pests, including invasive organisms such as gypsy moth and several bark beetles (an annual report is prepared by the DNR Forest Health Protection Team on those issues).

Forestry Division Contacts

Metro Forest Health Specialist	Susan Burks	651-772-7927
Southern Forest Health Specialist	Ed Hayes	507-285-7431
Northeast Forest Health Specialist	Mike Albers	218-327-4115
Northwest Forest Health Specialist	Jana Albers	218-327-4234
Forest Development Health and Use Supervisor	Al Jones	651-296-4482

U of Minnesota Sea Grant - Aquatic Invasive Species Information Center

The Aquatic Invasive Species Information Center at the University of Minnesota Sea Grant Program provides research, outreach, and education in collaboration with the DNR's Invasive Species Program. The Center has served as an important resource on aquatic nuisance species (ANS) and provides information to the public to prevent and slow their spread.

Center Coordinator - Duluth	Doug Jensen	218-726-8712

Minnesota Department of Agriculture - Invasive Species Programs

The MDA is responsible for the state's noxious weeds, plant pests, and invasive species of terrestrial plants and insects. MDA's Invasive Species Program addresses species such as Japanese beetle, gypsy moth, long-horned beetle, Grecian foxglove, and Eurasian buckthorn. MDA prepares an annual report for these programs.

Agronomy and Plant Protection Division Contacts

Invasive Species Unit	Teresa McDill	651-296-8448
Terrestrial Invasive Species Program	Peter Dziuk	651-296-3343

Agricultural Development Division Contacts

Weed Biological Control	Tony Cortilet	651-282-6808
Integrated Pest Management Coordinator	Jeanne Ciborowski	651-297-3217

Interagency Invasive Species Groups

There are several invasive species committees or work groups that facilitate coordination between the involved agencies.

Minnesota Noxious Weed Potential Evaluation Committee - Peter Dziuk, Chair, MDA - Weed and Seed Unit, Agronomy and Plant Protection Division, 651-296-3343.

Weed Integrated Pest Management Committee - JeanneCiborowski, MDA - Integrated Pest Management Coordinator, Ag Development Division, 651-297-3217.

Gypsy Moth Program Advisory Committee - Kimberly Thielen-Cremers, MDA - Invasive Species Unit, Agronomy and Plant Protection Division, 651-297-2428.

St. Croix River Zebra Mussel Task Force - Includes these primary members and other less active members: Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Great Lakes Indian Fish and Wildlife Commission, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the National Park Service.

Minnesota Invasive Species Advisory Council - Co-chairs: Teresa McDill, MDA - Invasive Species Unit, Agronomy and Plant Protection Division, 651-296-8448 and Jay Rendall, DNR Invasive Species Program, Ecological Services Division, 651-297-1464.

Development of a Macroinvertebrate Index of Biological Integrity (MIBI) for Rivers and Streams of the Upper Mississippi River Basin

By John Genet and Joel Chirhart

Minnesota Pollution Control Agency
Biological Monitoring Program

St Paul, Minnesota
2004

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Development of a Macroinvertebrate Index of Biotic Integrity (M-IBI) for Rivers and Streams of the Upper Mississippi River Basin

I. INTRODUCTION

Rivers and streams serve many functions in today's society including serving as a source of food and water, a mode of transportation for much of our crops and material goods and as a recreational and aesthetically pleasing resource for many people. The innumerable functional and aesthetic qualities of rivers and streams create pressures on the resource that are exacerbated by an expanding human population. Watersheds that were once mainly forested have been altered for the social and economic benefit of today's society. The degradation of Minnesota's rivers comes from numerous sources including chemical pollutants from municipal and industrial point source discharges; agricultural runoff of pesticides, nutrients, and sediment; hydrologic alteration from stream channelization, dams, and artificial drainage; and habitat alteration from agriculture and urban encroachment. To ensure the integrity of our rivers and streams we must understand the relationship between human induced disturbances and their affect on aquatic resources.

For many years we have managed human impact on stream systems by restricting the amount and kinds of chemicals that enter them. Federal and state government agencies have developed and enforced water quality standards to ensure that chemical concentrations in our streams do not exceed certain limits. But while we have been largely successful in limiting chemical pollution sources we have, in many respects, failed to recognize the effects that landscape alteration and non-point pollution have on river and stream quality. Watershed disturbances from urban, residential, and agricultural development contribute to an overall decrease in the biological integrity of our rivers and streams (e.g., road building, stream channelization, alteration of the stream's riparian zone, and many others). It is increasingly apparent that monitoring activities cannot focus on chemical indicators alone, but must instead focus on indicators that integrate the effects of both physical and chemical stressors. Proper management of river and stream systems must be predicated upon a comprehensive monitoring strategy that is able to detect degradation in streams due to human disturbance.

In recent years, scientists have developed methods to quantify and interpret the results of biological surveys, allowing water-quality managers and policy makers to make informed decisions concerning rivers and streams. The Index of Biotic Integrity (IBI) was first developed in the early 1980's using attributes of the fish community in midwestern streams (Karr 1981). This method has subsequently been adapted for use throughout the country for multiple assemblages (e.g., aquatic macroinvertebrates, periphyton) in various aquatic systems (e.g., streams, wetlands). The Minnesota Pollution Control Agency (MPCA), Biological Monitoring Unit has begun development of statewide biological criteria for Minnesota's rivers and streams utilizing fish and macroinvertebrate IBIs. There are numerous advantages to using macroinvertebrates and fish in a water quality monitoring program (Barbour et al. 1999).

OBJECTIVES OF BIOLOGICAL MONITORING PROGRAM

The MPCA's Biological Monitoring Program has several objectives, including:

- to define and document statewide baseline conditions of instream macroinvertebrate and fish communities
- to measure spatial and temporal variability of population and community attributes
- to develop regional indices of biological integrity based on community similarity, beginning with each of Minnesota's ten major river basins with the intent of developing statewide biological criteria in the future

- to assess the condition of Minnesota's rivers and streams

It is paramount to the development of biological criteria in Minnesota that we obtain macroinvertebrate and fish community information statewide. There is currently a paucity of macroinvertebrate and fish community data for streams in Minnesota, particularly those streams that have little potential to contain game fish. In fact, macroinvertebrate and fish community information had not previously been obtained for most of the small streams sampled during the course of this study.

PURPOSE AND SCOPE

This report is the result of an effort to develop a macroinvertebrate index of biotic integrity (M-IBI) for all permanent coolwater rivers and streams within the Upper Mississippi River Basin (UMRB). The report is intended to provide guidance for those interested in conducting an M-IBI assessment. Readers interested in the theoretical underpinnings of multimetric indices in general should refer to Karr and Chu (1999).

II. THE UPPER MISSISSIPPI RIVER BASIN

An overview of the Upper Mississippi River Basin as well as water quality issues in the basin is provided in Niemela and Feist (2002). For a more thorough description of the basin the reader is referred to the UMRB Information Document (MPCA 2000). Only the macroinvertebrate assemblage of the basin will be discussed here.

THE MACROINVERTEBRATE ASSEMBLAGE

The macroinvertebrate assemblage of rivers and streams in the UMRB has received relatively little attention considering the global significance of the river which originates in this basin. Moyle (1940) conducted an extensive biological survey of rivers and streams in the UMRB that included macroinvertebrate sampling. He collected a total of 111 taxa; however, this figure may represent an underestimate of the actual number of species collected as most identifications were to genus and some groups (e.g., Trichoptera, Chironomidae) were only resolved to family. A relatively sparse bivalve assemblage was also noted for the basin with only 9 species collected.

The UMRB harbors a critically imperiled (globally and nationally) caddisfly, *Chilostigma itascae*, which has only been collected in Itasca State Park (Wiggins 1975). In addition, a number of caddisfly species listed as Special Concern by the MNDNR (1996) have been collected from rivers and streams within the basin (Monson and Holzenthal 1993, Houghton et al. 2001). Moyle (1940) collected a state-listed threatened bivalve (*Tritogonia verrucosa*) and two special concern bivalves (*Lasmigona compressa* and *Ligumia recta)* during his survey of the UMRB.

III. M-IBI SAMPLING METHOD

Sampling occurred in late summer/fall of 1999 and 2000, primarily during the month of September. Flood and drought events can have strong effects on macroinvertebrate community structure; therefore streams were sampled under stable, base flow conditions. Sampling was delayed in streams following high flow events until stable conditions returned. If a stream was known to have been dry at an earlier date in the sample year, it was not sampled.

SAMPLE REACH DETERMINATION

It is important to collect a sample representative of the stream reach selected. The reach established during site reconnaissance was walked in its entirety to determine the presence and abundance of productive macroinvertebrate habitats. The reach length is based on what is necessary to collect an adequate fish sample, 35 times the average stream width (Lyons 1992a). However, some constraints were applied to this rule with the minimum reach length set at 150 m and the maximum set at 500 m. However, it was often not necessary to sample the entire reach for invertebrates as long as all major habitat types were sampled in the length traversed. Collecting an adequate sample normally required walking 75 to 100 m of stream length, although sometimes much longer distances were required.

BENTHIC SAMPLING TECHNIQUE

A qualitative multi-habitat (QMH) sample was collected at each site to characterize the overall macroinvertebrate diversity of the sample reach. A D-frame dip net and sieve bucket (both 500 μm mesh) were the only equipment required for this sampling method. A total of 20 sampling efforts were collected at each site, sampling each of the major habitat types present within the reach in equal proportion. Determination of major habitat types was made prior to sampling by qualitatively evaluating the sample reach. During this evaluation only five habitats were considered: 1) riffles or shallow, fast flowing runs, 2) undercut banks and overhanging vegetation, 3) submerged or emergent aquatic macrophytes, 4) snags and woody debris, and 5) leaf packs. Fine sediment substrates were not considered productive habitat in this study. Deciding whether or not a habitat type was predominant enough to sample was contingent upon the total number of productive habitats. For example, if four habitat types were present within the sample reach, a habitat would only be sampled if a total of five (total # of sample efforts/ # habitats present) sample efforts could be reasonably obtained. If only two habitat types were present, there would need to be enough habitat to get at least half of the 20 sample efforts from each habitat type, otherwise all 20 sample efforts would be collected from the predominant habitat type.

Each sampling effort consisted of placing the dip net on the substrate and disturbing the area directly upstream of the net opening equal to the square of the net width, ca. 1 ft^2. When flow in the sample reach was negligible, the net was swept repeatedly in the upstream direction or water was flushed through the net by hand. These techniques were used to ensure that as many invertebrates as possible were collected for each area sampled. All debris collected by the 20 sampling efforts was composited in a sieve bucket, transferred to 1 L plastic sample jars, and preserved in 100% denatured ethanol. Sample jars were labeled internally and externally with site ID, site name, date, collector(s), and sample type.

Estimating the amount of area (ca. 1 ft^2) to sample for each dip net sample becomes complicated when dealing with multi-dimensional substrates like weed beds and woody debris. Following is a description of each habitat and how it was sampled:

Riffles - This category is intended to cover rocky substrates with fast flowing water. Runs and wadeable pools often have suitable rocky substrates, and were not excluded from sampling. Riffles were sampled by placing the dip net firmly and squarely on the substrate downstream of the area to be sampled. If the water was shallow enough, the area directly in front of the net was disturbed with the hands, taking care to wash large rocks off directly into the net. If the water was too deep for this, kicking the substrate in front of the net was adequate.

Aquatic Macrophytes - Any vegetation found at or below the water surface was included in this category. Emergent vegetation was included because all emergent plants have stems that extend below the water surface, serving as suitable substrate for macroinvertebrates. The emergent portion of these plants was not sampled. Submerged plants were sampled with an upward sweep of the net. If the net became filled with weeds, they were hand washed vigorously or jostled in the net for a few moments and then discarded. Emergent plants were sampled with horizontal and vertical sweeps of the net until it was felt that the area being swept had been adequately sampled.

Undercut Banks - This category is meant to cover shaded, in-bank or near-bank habitats, away from the main channel that typically are buffered from high water velocities. Undercut banks often appeared to extend further under the bank than they actually did. For this reason, undercut banks were thoroughly prodded to determine if there was enough habitat to warrant sampling. Overhanging vegetation was treated in the same manner. Sampling consisted of upward thrusts of the net, beating the undercut portion of the bank or overhanging vegetation so as to dislodge any clinging organisms.

Woody Debris - Woody debris (snags) can include any piece of wood found in the stream channel, including logs, tree trunks, entire trees, tree branches, large pieces of bark, and dense accumulations of twigs. Rootwads or masses of roots extending from the stream bank are also considered woody debris. Best professional judgment was used to determine the extent of each sampling effort in this habitat type. Approximating the amount of sampleable surface area is a sensible method with larger tree trunks or branches, whereas masses of smaller branches and twigs must be given a best estimate. Given their variable nature, there is not one best method for sampling snags. Using something akin to a toilet brush works well for large pieces of wood, whereas kicking and beating with the net works best for masses of smaller branches.

Leaf Packs - Leaf packs are dense accumulations of leaves typically present in the early spring and late fall. They are found in depositional zones, generally near stream banks, around log jams, or in current breaks behind large boulders. A leaf pack sample was taken near the surface of the leaf pack. Sweeping to the bottom of every leaf-pack could create a disproportionately large amount of sample volume being collected for a given area. Due to the sample index period, leaf packs were generally not dominant enough to be included in a sample.

LABORATORY SAMPLE PROCESSING

Due to the large volume of sample material, the QMH sample was subsampled using a 24 inch by 24 inch gridded screen tray divided into 144 two inch squares. The sample material was spread evenly across this grid and organisms were picked from randomly selected grid squares until a minimum of 300 organisms were collected. Following this, any large and/or rare organisms were removed from the remaining sample material on the grid. The two subsample components were not combined until the data was analyzed.

Ten percent of each sample was checked by another biologist for picking efficiency. If more than ten percent of organisms previously picked were found, the sample was reprocessed. For new staff, entire samples were checked until picking efficiency exceeded 95%.

All organisms were identified to the generic level if possible, using various taxonomic keys (e.g., Hilsenhoff 1995, Merritt and Cummins 1996). Five percent of all samples identified were checked for proper taxonomic characterization by another biologist. An independent taxonomist resolved any taxonomic discrepancies. A reference collection is maintained for taxonomic comparisons.

IV. SITE CHARACTERIZATION

QUANTIFYING HUMAN DISTURBANCE

The amount of human disturbance impacting each site was characterized by evaluating the extent of human development within the drainage area of the sample reach and the alteration to the instream habitat and riparian corridor. Niemela and Feist (2002) provide technical details that describe how each of these factors was quantified. For this study, disturbance was characterized using a watershed rating, a habitat rating, or a standardized composite of both.

STREAM CLASSIFICATION

Proper stream classification is an important component in M-IBI development. With too few classes it may be difficult to distinguish between natural stream variability and human induced variability (Karr and Chu 1999). Alternatively, the limited resources available to conduct biological monitoring may be wasted with too many stream classes. We considered stream size, morphological type (riffle/run or glide/pool), and ecoregion (Omernik 1987: Northern Lakes and Forests, NLF or North Central Hardwood Forest, NCHF) as possible stream classification variables.

Streams were categorized as either riffle/run or glide/pool based on observational data and habitat information collected using Wisconsin's habitat assessment guidance (Simonson et. al. 1994). However, the primary determinant of whether a site was classified as either glide/pool or riffle/run was the presence of riffle habitat within the sample reach. In general, if there was sufficient riffle habitat in a reach to be considered a major habitat type and therefore sampled, the site was designated as riffle/run. Glide/pool sites are not necessarily devoid of rocky areas but they differ from riffle/run sites in that they lack the flow to create the turbulent, well oxygenated habitat that riffle dwelling organisms prefer.

Stream temperature greatly influences the structure of the fish community and consequently, the metrics in a fish IBI. Temperature has less effect on the invertebrate community, but since the goal of this study was to develop fish and invertebrate IBIs concurrently, we did not include stream reaches considered to be cold water. Data from a stream that contained a significant population of trout or, based on water temperature data, was considered cold water was omitted from the data set.

EVALUATING ALTERNATIVE CLASSIFICATION SCHEMES

Classification schemes for environmental monitoring of aquatic resources have been a prominent topic in the recent literature (e.g., Van Sickle 1997, Van Sickle and Hughes 2000, Marchant et al. 2000, Hawkins and Vinson 2000). In order to facilitate comparisons with previous work by other researchers addressing this question, the methodology of Van Sickle (1997) and Van Sickle and Hughes (2000) was used here. These methods focus on the use of similarity/dissimilarity coefficients to compare the faunal assemblages of all pairwise combinations of sites. These coefficients can then be grouped according to a priori classifications as either within-class or between-class. The classification strength (CS) of each scheme can be measured by the difference between mean within-class (W) and mean between-class (B) similarity. The classification scheme with the largest difference has the most potential for a framework which can be used to partition the aquatic resource (e.g., streams).

The first step in this type of analysis was the construction of a *site x taxa* matrix for all of the least-impaired or reference sites (composite disturbance rating > 1.5). In determining the best classification scheme one is only interested in whether the expectations of the assemblage differ by class (e.g., ecoregion, stream morphology, etc.), therefore, we only included reference sites in the analysis in an attempt to limit the possible confounding influence of human disturbance. The *site x taxa* matrix was created using the relative abundances of each taxon collected in the subsample portion of the QMH. In addition, a *site x metric* matrix was constructed for 50 commonly used macroinvertebrate metrics.

Bray-Curtis dissimilarity coefficients were calculated for each pairwise combination of sites in the matrix using SYSTAT® Version 10.2. Dissimilarity coefficients range from zero to one, with zero indicating that a pair of sites has exactly the same community composition and structure and one indicating that a pair of sites has no taxa in common. Mean similarity analysis was performed using MEANSIM6 software, available on the EPA, Western Ecology Division web site (http://www.epa.gov/wed/pages/models.htm). This program computes mean between-class dissimilarity (B), mean within-class dissimilarity (W), and the mean dissimilarity within individual classes (W_i). This methodology was used to test the relative strength of two classification schemes: ecoregion and stream morphology.

Table 1. Strength of two classification schemes for macroinvertebrate assemblages from 29 least-impaired sites in the UMRB. Classification strength (CS) = [B - W]. For tests of no class structure all resulting P-values were < 0.05 unless noted otherwise.

		Taxa Matrix			Metric Matrix		
Classification	# of classes	between class (B)	within class (W)	classification strength (CS)	between class (B)	within class (W)	classification strength (CS)
Ecoregion	2	0.780	0.755	0.025	0.407	0.389	0.018*
Stream Morphology	2	0.779	0.749	0.030	0.408	0.375	0.033

* P = 0.08 for no class structure test.

In addition to determining the strength of a classification system, MEANSIM6 also uses a permutation test to determine whether the overall strength of a specific a priori classification scheme is significant in the sense of being greater than would be expected in a random set of sites. The statistic CS was calculated for each of 10,000 randomly chosen reassignments of sites to groups of the same size as used in the tested classification. The resulting P-value gives evidence against the null hypothesis of *no class structure* and was estimated as the proportion of the 10,000 trials having CS at least as large as the observed CS value for the tested classification.

The mean similarity analysis comparing the two classification schemes indicated that stream morphology provided a slightly better framework than did ecoregion (Table 1). Since these results were inconclusive, we decided to evaluate the macroinvertebrate community attributes (Appendix A) to determine how many differed significantly among the least-impaired sites based on either ecoregion or stream morphology. A Mann-Whitney U non-parametric test was used to test for significant differences between riffle/run and glide/pool reference sites as well as NLF and NCHF reference sites. The results of these tests would help determine whether expectations for the macroinvertebrate community differ according to either ecoregion of stream morphology.

A total of 74 macroinvertebrate community attributes were tested for significant differences among the reference sites. Stream morphology resulted in 33 (44.6%) significant differences, while the ecoregion comparison only resulted in 7 (9.5%) significant differences. Therefore, we decided to develop an M-IBI that accounted for metric expectations due to morphological characteristics by developing scoring criteria for two stream morphological classes: riffle/run and glide/pool.

Stream size could not be evaluated in the manner above since it is not a categorical variable. Therefore, the influence of stream size on metric expectations was determined by examining the relationship between drainage area (see CALCULATION OF THE WATERSHED DRAINAGE AREA in Niemela and Feist 2002) and selected richness metrics (Total and Ephemeroptera+Plecoptera+Trichoptera, EPT) for glide/pool and riffle/run sites separately. If either relationship was significant, a scatter plot of watershed drainage area ($\log_{10}$) vs the richness measures was examined to determine size classification break points (Niemela and Feist 2002). Size classes were chosen to minimize differences in maximum species richness within each size class. However, the number of size classes that could be partitioned was limited by the resulting number of sites within each class. For example, a break point may be evident at a drainage area of < 5 mi^2 but only 10 sites may fall into this category, making it very difficult to develop a robust IBI with so few sites.

For the glide/pool streams, both total taxa richness (R^2=0.093, P=0.025) and EPT (R^2=0.225, P<0.001) exhibited a significant relationship with drainage area ($\log_{10}$). Since the relationship with EPT was the stronger of the two, we used the scatter plot of EPT vs drainage area ($\log_{10}$) to determine size classes (Figure 1). Given the number of glide/pool sites (N = 54), we decided that only two size classes could be delineated while allowing for an adequate number of sites in each class for developing an IBI. Therefore, the size classification break point that was closest to bisecting the number of sites was selected. The glide/pool M-IBI accounts for differences in species richness due to stream size by developing separate scoring criteria for two stream size classes: < 40 mi^2 and > 40 mi^2.

In riffle/run streams there was no significant relationship between either total taxa richness or EPT and drainage area ($P > 0.05$). Therefore, it was not necessary at this time to develop separate scoring criteria based on stream size for this morphological class of streams. However, the relationship between total richness and drainage area was marginally significant ($P = 0.052$), perhaps indicating the future need for a riffle/run size classification system as more data becomes available.

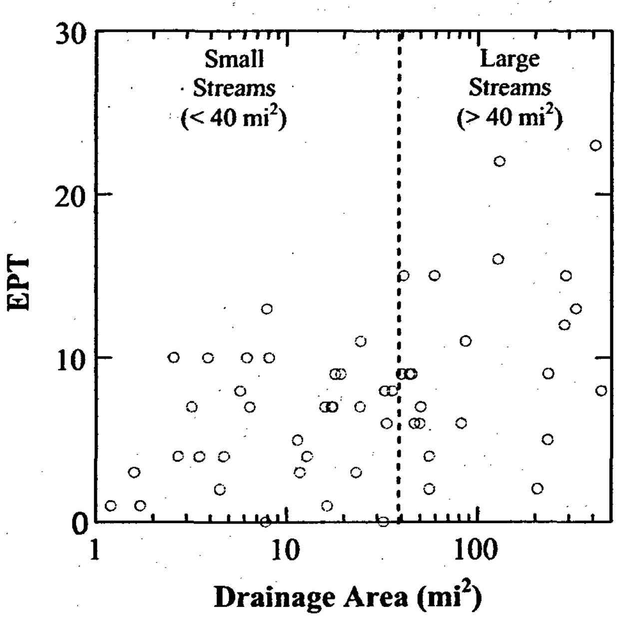

Figure 1. Number of Ephemeroptera, Trichoptera, and Plecoptera taxa (EPT) versus drainage area (mi^2) in glide/pool streams. Vertical line represents size classification break point.

A total of 75 stream sites were used in the development of the UMRB M-IBI (Appendix B). Classification of these sites based on stream morphology resulted in 21 riffle/run and 54 glide/pool sites. Thirty two of the glide/pool sites were below the 40 mi^2 drainage area breakpoint and 22 were above.

V. THE METRICS

METRIC SELECTION

A total of 95 invertebrate community attributes were evaluated for their ability to perform as metrics (Appendix A). The list of attributes was comprised of metrics that have proven useful in the NLF and NCHF ecoregions (Stroom and Richards 2000, Butcher et al. 2003, Chirhart 2003) as well as metrics that have been used in stream M-IBIs in other regions (Kerans and Karr 1994, Barbour et al. 1996, Barbour et al. 1999). In addition to these field-tested metrics, a number of other attributes were evaluated in this study. For example, a number of richness attributes were evaluated with either chironomids identified to genera or tribe/subfamily in order to determine which level of taxonomic resolution was more effective at detecting impairment. Also, combinations of Ephemeroptera, Plecoptera, Trichoptera, and Odonata taxa richness were evaluated as alternatives to the traditional EPT metric.

Invertebrate community attributes were selected as metrics based on: 1) their ability to distinguish between least- and most-impaired sites; 2) a significant relationship with human disturbance; and 3) their contribution of non-redundant information to the final M-IBI. For each stream (riffle/run or glide/pool) and size class (e.g., drainage area < 40 mi^2), a Mann-Whitney U test was used to test for significant ($P < 0.05$) differences in the value of each community attribute between the most and least disturbed sites. Spearman Rank correlation was used to determine if an attribute exhibited a significant ($P < 0.05$) relationship with any of the three measures of human disturbance (watershed, habitat, composite). Attributes that met both of these criteria were considered candidate metrics.

Table 2. Mean and standard error of metric values for each of the three M-IBIs, including results of Mann-Whitney U tests. Spearman Rank correlation coefficients (r_s) represent relationship between metric value and composite disturbance score (watershed + habitat). All correlation coefficients are significant at $\alpha = 0.05$ level.

	Least-Impaired		Impacted		Mann-Whitney U	Correlation with
Metric	Mean	*SE*	Mean	*SE*	P value	Human Disturbance (r_s)
<u>Riffle/Run, < 500 mi²</u>						
# Trichoptera	10.4	*1.3*	3.0	*0.0*	0.005	0.730
# Ephemeroptera + Plecoptera	6.6	*0.8*	3.2	*0.9*	0.027	0.633
# DipteraCH	17.6	*0.6*	12.2	*0.7*	0.008	0.633
# Orthocladiinae + Tanytarsini	8.8	*0.7*	4.4	*0.8*	0.011	0.713
# IntolerantCH	7.8	*1.8*	0.6	*0.4*	0.008	0.787
# ScraperCH	9.0	*1.3*	4.0	*0.8*	0.015	0.661
# Collector-GathererCH	15.8	*1.2*	10.2	*1.1*	0.012	0.735
% Trichoptera (excluding Hydropsychidae)	10.27	*3.32*	0.03	*0.03*	0.007	0.737
% Non-Insect	13.8	*4.3*	37.7	*9.8*	0.016	-0.606
Hilsenhoff Biotic Index (HBI)	5.17	*0.23*	6.68	*0.46*	0.028	-0.666
N =	5		5			21
<u>Glide/Pool, <40 mi²</u>						
POET (# Plecoptera+Odonata +Ephemeroptera+Trichoptera)	11	*0.9*	5.9	*1.2*	0.008	0.493
# ClingerCH	6.1	*0.7*	3.3	*1.0*	0.036	0.370
# Collector-FiltererCH	4.8	*0.6*	3.1	*0.5*	0.023	0.457
# IntolerantCH	3.1	*0.3*	1.3	*0.4*	0.004	0.555
% Dominant One CH	22.8	*3.8*	43.9	*4.9*	0.004	-0.507
% Ephemeroptera	16.5	*4.3*	7.2	*4.2*	0.028	0.396
% Intolerant	9.4	*3.2*	1.2	*0.8*	0.003	0.598
% Tolerant	48.3	*3.8*	75.4	*4.6*	0.002	-0.460
% Trichoptera (excluding Hydropsychidae)	2.9	*1.0*	0.7	*0.5*	0.024	0.437
Hilsenhoff Biotic Index (HBI)	5.95	*0.29*	7.37	*0.31*	0.007	-0.527
N =	10		10			32
<u>Glide/Pool, > 40 mi²</u>						
% Coleoptera + Hemiptera	3.6	*1.4*	13.4	*3.4*	0.007	-0.639
# Gastropoda	3.5	*0.4*	2.0	*0.3*	0.004	0.539
# Non-Insect	7.4	*0.5*	5.5	*0.3*	0.007	0.516
% Caenidae	1.7	*0.8*	9.8	*4.6*	0.100	-0.455
% Oligochaeta	1.0	*0.4*	3.7	*1.2*	0.034	-0.477
% Crustacea + Mollusca	43.6	*9.5*	20.4	*6.0*	0.049	0.479
# Odonata + Trichoptera	9.9	*1.5*	5.9	*1.1*	0.036	0.607
N =	10		10			22

To evaluate the redundancy in information provided by the metrics, a correlation analysis of all pairwise combinations of candidate metrics within each stream class was performed. Metrics that are highly correlated with each other and show a graphically linear relationship, contribute approximately the same information. Those with scatter in the correlation can still contribute useful information despite a strong correlation (Barbour et al. 1996). A metric was retained if there was a non-linear or curvilinear relationship. If the Pearson correlation coefficient (r) was 0.85 or greater, and the relationship was linear, the metrics were compared in order to determine which one was more robust. To do this, box-and-whisker plots were examined to determine which metric had better separation of the most and least disturbed sites and lower variability among the least disturbed sites. Other considerations for determining which metric was better included the strength of the relationship with human disturbance, the number of other metrics each was highly correlated with, and its frequency of use in other M-IBIs.

UPPER MISSISSIPPI M-IBI METRICS

As a result of the metric selection process a total of ten metrics each were used to create a M-IBI for the riffle/run and glide/pool (< 40 mi^2) streams of the UMRB (Table 2). For glide/pool sites with a drainage area > 40 mi^2, only seven attributes met all three criteria (Table 2). The final set of metrics selected for the riffle/run and glide/pool (< 40 mi^2) M-IBI included metrics from each of the four categories outlined in Appendix A: Taxa Richness, Composition, Tolerance, and Feeding Group. The glide/pool, > 40 mi^2 M-IBI contained metrics from only two of the four categories: Taxa Richness and Composition. For definitions of each of the metrics used in the M-IBIs see Appendix A.

The metrics used to develop the M-IBIs were largely unique to each stream type/drainage area category. However, the following metrics were used in two of the M-IBIs: # Intolerant Taxa(CH), % Trichoptera (excluding Hydropsychidae), and Hilsenhoff Biotic Index. Due to differences in the range and/or distribution of metric values, scoring criteria were different for metrics that were used in multiple M-IBIs (Table 3).

SCORING METRICS

Cumulative distribution functions (CDF) were used to score each metric. A CDF indicates what percent of the total observations in the data are of a particular value or lower. Depending on the shape of CDF, different scoring techniques were used. If natural breaks were apparent in the CDF, vertical lines were drawn at the breaks (Figure 2a) dividing the graph into three sections. If no natural breaks were apparent and there was a linear progression throughout the entire plot, the range of metric values was trisected (Figure 2b). If there were no natural breaks and a linear progression was not present throughout the entire plot, the 95th percentile rather than the range of metric values was trisected (Figure 2c). This adjustment helped to limit the influence of outliers in the scoring process.

VI. CALCULATION AND INTERPRETATION OF M-IBI SCORES

Calculation of an M-IBI score first requires the designation of a stream class, riffle/run or glide/pool. It also requires a determination of the drainage area at the sample reach for glide/pool streams. Once this information has been obtained, an M-IBI score can be calculated by summing all the metric scores for the appropriate stream class/size combination (Table 3). Scores of 0, 2, or 4 have been assigned for each metric. Low metric scores indicate that the macroinvertebrate community deviates significantly from a least-impaired stream. Conversely, a high metric score indicates that the macroinvertebrate community attribute approximates that of a least-impaired site.

The M-IBI score ranges from 0 (lowest biological integrity) to 40 (highest biological integrity) for the riffle/run and glide/pool, < 40 mi^2 sites. The M-IBI score for the glide/pool, > 40 mi^2 sites ranges from 0 to 28 because it contains only 7 metrics. Therefore, in order to make the scores from the three different M-IBIs

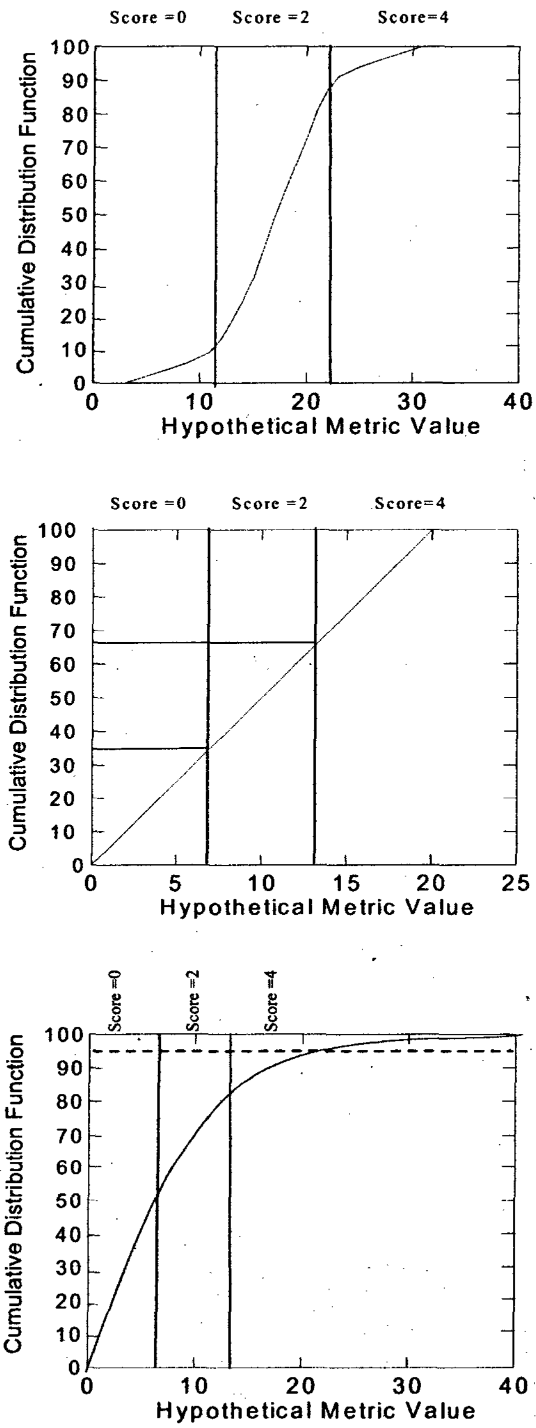

Figure 2. Hypothetical CDFs illustrating the three methods used for scoring metrics: a) natural breaks, b) trisection of range, and c) trisection of 95th percentile.

comparable, they were normalized to a 0 to 100 point scale. This was accomplished by dividing the actual IBI score for each site by the maximum IBI score possible and then multiplying by 100. A list of all the sites used in the development of this M-IBI including their scores is in Appendix B.

Three factors may contribute to the variability of M-IBI scores: sampling error, natural variability, and human disturbance. The first two sources of variability must be limited in order to detect the third. Sampling error results from a failure to characterize the invertebrate community with accuracy and precision. Natural variability occurs because of climatic fluctuations, biological interactions, or any other factor that cannot be attributed to human disturbance (Lyons, 1992b). Proper study design and rigorous adherence to sampling protocols can limit the effects of sampling error and natural variation on the M-IBI score.

The M-IBI methodology described in this report will allow the user to detect changes in environmental condition due to human disturbance with a reasonable level of certainty. The M-IBI score was significantly correlated with all three measures of human disturbance as well as the amount of disturbed land use in the drainage area (Table 4).

This M-IBI is intended to be used in streams with drainage areas less than 500 mi^2. Streams with drainage area > 500 mi^2 are classified as large streams or rivers. With our current methods, such streams are typically too large to sample effectively and are difficult to accurately characterize.

VII. DISCUSSION

Given the geographic distribution of the stream sites used in this report, the metrics and IBI presented here are tailored specifically for the UMRB. Currently, the MPCA Biological Monitoring Program is in the process of obtaining a statewide data set for fish and macroinvertebrate assemblages of Minnesota's rivers and streams. Once all ten of Minnesota's major river basins have been sampled, various classification frameworks (e.g., ecoregion, basin) for the state will be evaluated using methods

Table 3. Scoring criteria for the three separate M-IBIs developed for the Upper Mississippi River Basin.

Metric	range	response to disturbance	Score 0	2	4
<u>Riffle/Run, < 500 mi^2</u>					
# Trichoptera Taxa	1-15	decrease	0-4	5-8	>8
# Ephemeroptera + Plecoptera Taxa	1-9	decrease	0-4	5-6	>6
# Diptera Taxa	4-24	decrease	0-10	11-16	>16
# Orthocladiinae + Tanytarsini Taxa	1-11	decrease	0-4	5-7	>7
# Intolerant Taxa	0-14	decrease	0	1-4	>4
# Scraper Taxa	0-13	decrease	0-4	5-7	>7
# Collector-Gatherer Taxa	3-19	decrease	0-10	11-14	>14
% Trichoptera (excluding Hydropsychidae)	0-22.2	decrease	0	>0-3.3	>3.3
% Non-Insect	2.8-76.2	increase	>42.6	>22.7-42.6	0-22.7
HBI	4.77-7.67	increase	>6.70	>5.74-6.70	<5.74
<u>Glide/Pool, < 40 mi^2</u>					
POET	1-16	decrease	0-6	7-11	>11
# Clinger Taxa	0-11	decrease	0-4	5-7	>7
# Collector-Filterer Taxa	1-8	decrease	0-3	4-6	>6
# Intolerant Taxa	0-5	decrease	0-2	3	>3
% Dominant Taxon	12.8-65.4	increase	>47.8	>30.3-47.8	<30.3
% Ephemeroptera	0-50.3	decrease	0-5.9	>5.9-22.8	>22.8
% Intolerant	0-32.1	decrease	0-1	>1-3.3	>3.3
% Tolerant	28.2-95.1	increase	>72.8	>50.5-72.8	0-50.5
% Trichoptera (excluding Hydropsychidae)	0-8.4	decrease	0	>0-1	>1
HBI	4.85-8.65	increase	>7.38	>6.11-7.38	<6.11
<u>Glide/Pool, > 40 mi^2</u>					
% Coleoptera + Hemiptera	0-38.4	increase	>16.5	>8.2-16.5	0-8.2
# Gastropoda Taxa	1-6	decrease	0-2	3-4	>4
# Non-Insect Taxa	4-10	decrease	0-6	7-8	>8
% Caenidae	0-43.2	increase	>7	>0-7	0
% Oligochaeta	0-10.6	increase	>2.3	>1.1-2.3	0-1.1
% Crustacea + Mollusca	0.6-94.6	decrease	0-26.2	>26.2-51.7	>51.7
# Odonata + Trichoptera Taxa	2-17	decrease	0-7	8-12	>12

Table 4. Spearman Rank correlation coefficients (r_s) for the relationship between M-IBI score and various measures of disturbance. All P values < 0.001 unless noted otherwise.

Disturbance Rating	Riffle/Run (< 500 mi^2)	Glide/Pool (< 40 mi^2)	Glide/Pool (40-500 mi^2)
Watershed	0.828	0.663	0.860
Habitat	0.432*	0.548**	0.766
Watershed+ Habitat	0.816	0.695	0.860
% Disturbed Land Use	-0.647**	-0.554**	-0.833
N =	21	32	22

* P < 0.10
** P < 0.01

similar to those used in this report (e.g., Van Sickle 1997, Van Sickle and Hughes 2000). Therefore, if a framework other than major river basins (e.g., the framework that is currently being used) is adopted, the metrics used to assess rivers and streams in the UMRB may change slightly or require adjustments to their scoring criteria.

Comparison of the M-IBI presented here to a previously developed M-IBI for Minnesota's portion of the St. Croix River Basin (SCRB; Chirhart 2003) may provide some insight on the effectiveness of expanding the geographic coverage of the M-IBI. These basins are adjacent and similarly oriented with respect to ecoregions (Omernik 1987); both have their northern half in the NLF ecoregion, southern half in the NCHF ecoregion, and a small portion in the Western Cornbelt Plains ecoregion. Therefore, it is reasonable to expect that the metric selection process and stream classification analysis conducted for these two basins would result in similar M-IBIs.

Stream morphology was determined to be a stronger classification scheme than ecoregion in both basins. This was supported by the large number of potential metrics that differed significantly between reference riffle/run and glide/pool sites in both basins. Both basins also required a size classification system due to significant relationships between richness measures and drainage area. However, neither basin required size breakpoints for both stream morphological classes. Only the riffle/run sites in the SCRB and the glide/pool sites in the UMRB required size breakpoints. Size classifications may be required for all stream type/basin combinations once a larger data set is obtained and analyzed.

The M-IBIs developed for riffle/run sites in the two basins shared a number of their metrics. Richness measures such as Ephemeroptera, Trichoptera, Plecoptera, Intolerant, Collector-Gatherer, and Tanytarsini taxa richness were important components of both the UMRB and SCRB M-IBIs. However, the two M-IBIs did not have any of the proportional metrics (e.g., % Trichoptera) in common. Similarly, glide/pool M-IBIs for the two basins had a number of metrics in common. Taxa richness metrics such as the number of Plecoptera+Odonata+ Ephemeroptera+Trichoptera (POET), Clinger, and Intolerant taxa worked well in both basins. In addition, % Tolerant taxa was selected as a metric for glide/pool streams in both basins.

While analyses for the SCRB and UMRB didn't converge on identical M-IBIs, the similarities in classification schemes and metrics are promising for the geographic expansion of M-IBIs if a classification framework other than major river basins is adopted in the future. In fact, even greater similarity may exist in the data when inter-basin comparisons are made within the same classification type (e.g., ecoregion).

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APPENDIX A – MACROINVERTEBRATE COMMUNITY ATTRIBUTES

Metric	Description[1]	Predicted response to disturbance
Taxa Richness		
# Amphipoda	Number of Amphipoda taxa (ss, lr)	Decrease
# Chironomidae	Number of Chironomidae taxa (ss, lr)	Decrease
# Coleoptera	Number of Coleoptera taxa (ss, lr)	Decrease
# Diptera	Number of Diptera taxa, chironomids identified to tribe/subfamily (ss, lr)	Decrease
# DipteraCH	Number of Diptera taxa, chironomids identified to genera (ss, lr)	Decrease
# Ephemeroptera (E)	Number of Ephemeroptera taxa (ss, lr)	Decrease
EOT	Number of Ephemeroptera, Odonata, and Trichoptera taxa (ss, lr)	Decrease
EO	Number of Ephemeroptera and Odonata taxa (ss, lr)	Decrease
EP	Number of Ephemeroptera and Plecoptera taxa (ss, lr)	Decrease
EPT	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa (ss, lr)	Decrease
ET	Number of Ephemeroptera and Trichoptera taxa (ss, lr)	Decrease
# Gastropoda	Number of Gastropoda taxa (ss, lr)	Decrease
# Legless	Number of taxa without well-developed legs (ss, lr)	Decrease
# LongLived	Number of taxa with life cycles of one or more years (ss, lr)	Decrease
# Non-Insect	Number of non-insect taxa (ss, lr)	Decrease
# Odonata (O)	Number of Odonata taxa (ss, lr)	Decrease
# Orthocladiinae	Number of Orthocladiinae taxa (ss, lr)	Decrease
# Orthocladiinae + Tanytarsini	Number of Orthocladiinae and Tanytarsini taxa (ss, lr)	Decrease
# Plecoptera (P)	Number of Plecoptera taxa (ss, lr)	Decrease
POET	Number of Plecoptera, Odonata, Ephemeroptera, and Plecoptera taxa (ss, lr)	Decrease
PT	Number of Plecoptera and Trichoptera taxa (ss, lr)	Decrease
# Tanytarsini	Number of Tanytarsini taxa (ss, lr)	Decrease
# Trichoptera (T)	Number of Trichoptera taxa (ss, lr)	Decrease
TO	Number of Trichoptera and Odonata taxa (ss, lr)	Decrease
Total Richness	Total number of taxa, chironomids identified to tribe/subfamily (ss, lr)	Decrease
Total RichnessCH	Total number of taxa, chironomids identified to genera (ss, lr)	Decrease
Composition		
% Amphipoda	Percent Amphipoda abundance (ss)	Increase
% Baetidae	Percent Baetidae abundance (ss)	Increase
% Caenidae	Percent Caenidae abundance (ss)	Increase
% Chironomidae	Percent Chironomidae abundance (ss)	Increase
% Coleoptera	Percent Coleoptera abundance (ss)	Decrease
% Coleoptera+Hemiptera	Percent Coleoptera and Hemiptera abundance (ss)	Variable
% Crustacea	Percent Crustacea abundance (ss)	Decrease
% Crustacea+Mollusca	Percent Crustacea and Mollusca abundance (ss)	Decrease
% Diptera	Percent Diptera abundance (ss)	Increase
% non-chironomid Diptera	Percent Diptera abundance, excluding chironomids (ss)	Increase
% Dominant 1 taxa ChAs1	Percent dominant taxon with chironomids grouped at the family level (ss)	Increase
% Dominant 1 taxa CH	Percent dominant taxon with chironomids treated as individual genera (ss)	Increase
% Dominant 1 taxa woCH	Percent dominant taxon excluding chironomids (ss)	Increase

APPENDIX A. (continued)

Metric	Description[1]	Predicted response to disturbance
% Dominant 2 taxa ChAs1	Percent dominant 2 taxa with chironomids grouped at the family level (ss)	Increase
% Dominant 2 taxa CH	Percent dominant 2 taxa with chironomids treated as individual genera (ss)	Increase
% Dominant 2 taxa woCH	Percent dominant 2 taxa excluding chironomids (ss)	Increase
% Ephemeroptera	Percent Ephemeroptera abundance (ss)	Decrease
% Ephemeroptera (exc. Baetidae)	Percent of Ephemeroptera, excluding Baetidae (ss)	Decrease
% EOT	Percent Ephemeroptera, Odonata, and Trichoptera abundance (ss)	Decrease
% EP	Percent Ephemeroptera and Plecoptera abundance (ss)	Decrease
% EPT	Percent Ephemeroptera, Plecoptera, and Trichoptera abundance (ss)	Decrease
% ET	Percent Ephemeroptera and Trichoptera abundance (ss)	Decrease
% Gastropoda	Percent Gastropoda abundance (ss)	Decrease
% Hemiptera	Percent Hemiptera abundance (ss)	Increase
% Hydropyschidae	Percent Hydropsychidae abundance (ss)	Increase
% Legless	Percent of individuals without well-developed legs (ss)	Variable
% LongLived	Percent of individuals with life cycles of one or more years (ss)	Decrease
% Isopoda	Percent Isopoda abundance (ss)	Increase
% Isopoda+Amphipoda	Percent Isopoda and Amphipoda abundance (ss)	Increase
% Mollusca	Percent Mollusca abundance (ss)	Decrease
% Non-Insect	Percent Crustacea, Mollusca, and Oligochaeta abundance (ss)	Variable
% Odonata	Percent Odonata abundance (ss)	Decrease
% Oligochaeta	Percent Oligochaeta abundance (ss)	Variable
% Orthocladiinae	Percent of chironomids in the subfamily Orthocladiinae (ss)	Increase
% Orthocladiinae+Tanytarsini	Percent Orthocladiinae and Tanytarsini abundance (ss)	Decrease
% Pelecypoda	Percent Pelecypoda abundance (ss)	Decrease
% Plecoptera	Percent Plecoptera abundance (ss)	Decrease
% PT	Percent Plecoptera and Trichoptera abundance (ss)	Decrease
% Tanytarsini	Percent of chironomids in the tribe Tanytarsini (ss)	Decrease
% Trichoptera	Percent Trichoptera abundance (ss)	Decrease
% Trichoptera (exc. Hydropyschidae)	Percent of Trichoptera, excluding Hydropsychidae (ss)	Decrease
% TO	Percent Trichoptera and Odonata abundance (ss)	Decrease
Tolerance[2]		
# Intolerant	Number of taxa with tolerance values less than three, chironomids identified to tribe/subfamily (ss, lr)	Decrease
# IntolerantCH	Number of taxa with tolerance values less than three, chironomids identified to genera (ss, lr)	Decrease
# Intolerant Chironomidae	Number of chironomid taxa with tolerance values less than three(ss, lr)	Decrease
# Tolerant	Number of taxa with tolerance values greater than five, chironomids identified to tribe/subfamily (ss, lr)	Increase
# TolerantCH	Number of taxa with tolerance values greater than five, chironomids identified to genera (ss, lr)	Increase
# Very Tolerant	Number of taxa with tolerance values greater than seven, chironomids identified to tribe/subfamily (ss, lr)	Increase
# Very TolerantCH	Number of taxa with tolerance values greater than seven, chironomids identified to genera (ss, lr)	Increase
% Intolerant	Percent of individuals with tolerance values less than three (ss)	Decrease
% Tolerant	Percent of individuals with tolerance values greater than five (ss)	Increase
% Very Tolerant	Percent of individuals with tolerance values greater than seven (ss)	Increase
HBI	Hilsenhoff's Biotic Index (ss)	Increase

APPENDIX A. (continued)

Metric	Description[1]	Predicted response to disturbance
Feeding and other habits		
# Clinger	Number of clinger taxa, not including chironomid genera (ss, lr)	Decrease
# ClingerCH	Number of clinger taxa, including chironomid genera (ss, lr)	Decrease
# Collector-Filterer	Number of Collector-Filterer taxa, not including chironomid genera (ss, lr)	Decrease
# Collector-FiltererCH	Number of Collector-Filterer taxa, including chironomid genera (ss, lr)	Decrease
# Collector-Gatherer	Number of Collector-Gatherer taxa, not including chironomid genera (ss, lr)	Variable
# Collector-GathererCH	Number of Collector-Gatherer taxa, including chironomid genera(ss, lr)	Variable
# Predator	Number of Predator taxa, not including chironomid genera (ss, lr)	Variable
# PredatorCH	Number of Predator taxa, including chironomid genera (ss, lr)	Variable
# Scraper	Number of Scraper taxa, not including chironomid genera (ss, lr)	Decrease
# ScraperCH	Number of Scraper taxa, including chironomid genera (ss, lr)	Decrease
% Clinger	Percent Clinger abundance (ss)	Decrease
% Collector-Filterer	Percent Collector-Filterer abundance (ss)	Variable
% Collector-Gatherer	Percent Collector-Gatherer abundance (ss)	Variable
% Predator	Percent Predaor abundance (ss)	Variable
% Scraper	Percent Scraper abundance (ss)	Decrease
Scraper:Filterer ratio	Ratio of Scraper to Collector-Filterer taxa (ss, lr)	Variable

[1] Data was used from the subsample (ss) and/or large/rare (lr) portion of the QMH sample in the calculation of metric values.

[2] Tolerance values from Hilsenhoff 1987 and Barbour et al. 1999

APPENDIX B – UPPER MISSISSIPPI RIVER BASIN SAMPLING SITES

Stream Name	Sample Date	Drainage Area (mi^2)	Field Number[1]	County	Location	Latitude[2]	Longitude	MIBI	std. MIBI[3]	land rate[4]	Habitat rate[5]	Total rate[6]	Land Use%[7]
					Riffle/Run Streams (< 500mi^2)								
trib. to Bassett Creek	10/12/00	3.08	00UM094	Hennepin	@ 32nd Avenue in Crystal	45.02089	93.36128	8	20	0.38	0.67	1.04	92.12
trib. to Willow River	9/14/00	6.01	00UM014	Cass	10 mi. E of Remer	46.98470	93.79281	32	80	0.98	0.67	1.64	0.30
trib. to Sauk River	9/9/99	6.10	99UM064	Stearns	0.5 W of Farming	45.51736	94.60620	14	35	0.50	0.92	1.42	95.47
trib. to Medicine Lake	10/2/00	7.29	00UM068	Hennepin	downstream of 26th Ave. N.	45.00664	93.44457	6	15	0.43	0.75	1.18	80.32
Little Rock Creek	9/8/99	11.20	99UM058	Morrison	~3 mi. SW of Buckman	45.87263	94.14609	22	55	0.55	0.83	1.38	86.78
Sand Creek	10/5/00	15.04	00UM065	Anoka	upstream of Olive St.	45.18856	93.28525	14	35	0.55	0.33	0.88	78.41
County Ditch # 4	9/20/00	15.19	00UM050	Renville	downstream of 490th St.	44.81192	94.69040	12	30	0.25	0.83	1.08	98.73
West Savanna River	9/25/00	25.29	00UM021	Aitkin	@ Savanna Portage State Park	46.82736	93.18047	38	95	1.00	0.92	1.92	1.56
trib. to N Fork Crow River	9/13/99	27.10	99UM055	Meeker	~ 5 mi. N of Litchfield	45.20036	94.52970	24	60	0.53	0.75	1.28	88.10
Shingle Creek	10/2/00	27.41	00UM069	Hennepin	upstream of Queen Ave. bridge	45.05065	93.31174	4	10	0.50	0.50	1.00	82.34
Clearwater Creek	9/21/00	39.31	00UM084	Anoka	upstream of Peltier Lake Rd.	45.16425	93.05321	12	30	0.43	0.33	0.76	51.37
Hillman Creek	9/2/99	40.10	99UM023	Morrison	1 mi. W of Center Valley	45.97096	94.00360	34	85	0.80	0.75	1.55	40.21
Birch Creek	9/13/00	43.24	00UM011	Hubbard	on C.R. 4 in Yola	47.23312	95.01148	30	75	0.98	0.83	1.81	11.41
Blueberry River	9/12/00	43.43	00UM025	Wadena	upstream of C.R. 16	46.78451	95.14922	38	95	0.78	1.00	1.78	44.94
Twelvemile Creek	9/14/99	45.70	99UM060	Wright	~3.0 mi. E. of Howard Lake	45.06199	94.01757	2	5	0.40	0.92	1.32	84.53
Bradbury Brook	9/19/00	47.92	00UM033	Mille Lacs	5 mi. S of Onamia	45.99742	93.66522	36	90	0.90	0.67	1.57	10.88
Little Pine River	9/14/00	80.71	00UM017	Crow Wing	7 mi. S of Emily	46.65651	93.97946	36	90	0.95	1.00	1.95	4.00
Judicial Ditch # 15	9/20/00	99.20	00UM051	Renville	downstream of 550th St.	44.76638	94.55767	8	20	0.13	0.17	0.29	98.54
Coon Creek	10/3/00	103.98	00UM064	Anoka	in Erlanson Nature Center	45.17204	93.30096	24	60	0.55	0.83	1.38	54.12
Rice Creek	10/3/00	151.65	00UM083	Ramsey	upstream C.R. 10 @ Moundsview	45.09450	93.18966	6	15	0.45	0.58	1.03	53.64
Rice River	9/25/00	181.64	00UM019	Aitkin	2 mi. E of Kimberly	46.55010	93.42095	18	45	0.90	0.48	1.38	10.67
					Glide/Pool Small Streams (<40 mi^2)								
unnamed ditch	8/30/99	1.20	99UM015	Aitkin	~3.0 mi. SW of Palisade	46.67194	93.50546	6	15	0.45	0.33	0.78	69.84
County Ditch # 23	9/12/00	1.60	99UM040	Meeker	~3 mi. NW of Cosmos	44.97896	94.71129	8	20	0.35	0.17	0.52	99.32
unnamed creek	9/8/99	1.71	99UM007	Wadena	2 mi. SW of Sebeka	46.59606	95.11773	2	5	0.58	0.25	0.83	71.45
trib. to Bluebill Lake	9/26/00	2.57	00UM005	Itasca	downstream of C.R. 52	47.62830	93.39102	32	80	1.00	0.67	1.67	2.51
trib. to Sauk River	9/13/99	2.70	99UM029	Stearns	~2 mi. W of St. Martin	45.49670	94.70513	6	15	0.50	0.58	1.08	97.65
Pigeon River	9/13/00	3.19	00UM008	Itasca	downstream of culvert off F.R. 2382	47.58834	94.18702	26	65	1.00	0.83	1.83	0.71
unnamed creek	9/9/99	3.50	99UM002	Ottertail	9 mi. E of Henning	46.35046	95.26268	18	45	0.48	0.67	1.14	68.46
Nicollet Creek	9/13/00	3.88	00UM002	Clearwater	Itasca State Park	47.19315	95.23087	30	75	1.00	1.00	2.00	0.00

APPENDIX B. (continued)

Stream Name	Sample Date	Drainage Area (mi²)	Field Number[1]	County	Location	Latitude[2]	Longitude	MIBI	std. MIBI[3]	land rate[4]	Habitat rate[5]	Total rate[6]	Land Use%[7]
trib. to N Fork Crow River	9/14/99	4.50	99UM025	Wright	1 mi. W. of Rassat	45.15452	94.01093	14	35	0.63	0.75	1.38	92.20
County Ditch # 4	9/2/99	4.70	99UM013	Mille Lacs	2 mi. SE of Pease	45.67909	93.60691	22	55	0.33	0.42	0.74	97.32
Moose Creek	**8/31/99**	**5.70**	**99UM001**	**Itasca**	**4.5 mi. NW of Alvwood**	**47.71539**	**94.37396**	**26**	**65**	**0.85**	**0.75**	**1.60**	**15.49**
trib. to Shell River	**9/1/99**	**6.20**	**99UM047**	**Becker**	**Smoky Hills State Forest**	**46.91605**	**95.36395**	**22**	**55**	**0.85**	**0.83**	**1.68**	**21.80**
trib. to Swan River	**8/31/99**	**6.40**	**99UM056**	**Itasca**	**~1.5 mi. NE of Warba**	**47.15004**	**93.25504**	**28**	**70**	**0.98**	**0.75**	**1.73**	**5.33**
trib. to Bear Creek	9/9/99	7.80	99UM012	Todd	2.0 mi. SE of Hewitt	46.30526	95.05619	0	0	0.25	0.67	0.92	86.75
Briggs Creek	9/19/00	7.87	00UM043	Sherburne	upstream of C.R. 48	45.51623	93.92420	18	45	0.78	0.67	1.44	60.02
Island Lake Creek	8/31/99	8.10	99UM036	Itasca	~6.0 mi. NE of Deer River	47.41456	93.72482	24	60	0.83	0.50	1.33	5.42
Mike Drew Brook	**9/19/00**	**11.40**	**00UM031**	**Mille Lacs**	**5 mi. N of Milaca**	**45.83505**	**93.61943**	**18**	**45**	**0.83**	**0.83**	**1.66**	**41.21**
unnamed creek	8/31/99	11.80	99UM041	Aitkin	~ 2.5 mi. SW of Jacobson	46.98552	93.32008	8	20	0.75	0.58	1.33	7.86
Skunk River	**9/2/99**	**12.80**	**99UM067**	**Morrison**	**2 mi. SE of Sullvan**	**46.09853**	**93.89825**	**20**	**50**	**0.88**	**0.83**	**1.71**	**33.13**
Arvig Creek	9/1/99	15.90	99UM042	Cass	~2 mi. SE of Pine River	46.70560	94.36294	20	50	0.70	0.42	1.12	28.40
unnamed ditch	8/30/00	16.40	99UM030	Aitkin	~1.5 mi. NW of Tamarack	46.65219	93.15917	0	0	0.70	0.33	1.03	25.69
unnamed ditch	9/1/99	17.20	99UM035	Aitkin	~1.5 mi. N of Pine Knoll	46.59765	93.76502	14	35	0.63	0.17	0.79	14.41
Union Creek	9/13/00	17.50	00UM095	Wadena	downstream Wadena treatment plant	46.44409	95.12494	20	50	0.35	0.75	1.10	75.26
Hoboken Creek	9/19/00	17.97	00UM037	Stearns	south of Hwy 28	45.71507	95.00683	22	55	0.25	0.58	0.83	98.49
Fish Creek	**9/1/99**	**19.30**	**99UM011**	**Becker**	**2 mi. W of Pine Point**	**46.97780**	**95.40983**	**28**	**70**	**0.80**	**0.75**	**1.55**	**43.75**
County Ditch # 6	9/19/00	23.31	00UM073	Pope	11 mi. W of Sauk Centre	45.70177	95.18167	4	10	0.35	0.33	0.68	91.05
Daggett Brook	**9/12/00**	**24.24**	**00UM016**	**Crow Wing**	**12 mi. SW of Garrison**	**46.19203**	**94.04243**	**24**	**60**	**0.90**	**0.67**	**1.57**	**29.70**
Hay Creek	**9/21/99**	**24.50**	**99UM061**	**Itasca**	**E of Swan Lake, 0.2 mi. E of Hwy 12**	**47.28496**	**93.14543**	**38**	**95**	**0.80**	**0.83**	**1.63**	**31.39**
Jewitts Creek	9/17/00	32.33	00UM097	Meeker	1.5 mi. N.E. of Litchfield	45.16097	94.50340	8	20	0.38	0.83	1.21	82.56
Battle Brook	9/7/99	32.60	99UM028	Sherburne	~4 mi. N of Zimmerman	45.50148	93.61526	8	20	0.68	0.28	0.96	67.82
Kettle Creek	**9/2/00**	**33.42**	**00UM009**	**Becker**	**upstream of C.R. 119**	**46.76514**	**95.20550**	**22**	**55**	**0.80**	**0.83**	**1.63**	**52.15**
Moran Creek	**9/13/00**	**35.70**	**00UM077**	**Todd**	**5 mi SW of Staples**	**46.28296**	**94.85652**	**20**	**50**	**0.68**	**0.92**	**1.59**	**56.32**
					Glide/Pool Large Streams (> 40 mi²)								
Turtle Creek	9/13/00	40.01	00UM078	Todd	3 mi E of Browerville	46.07755	94.80560	16	57	0.55	0.83	1.38	70.93
Day Brook	**9/26/00**	**41.15**	**00UM006**	**Itasca**	**14 miles N of Nashwauk**	**47.56683**	**93.19076**	**16**	**57**	**0.90**	**1.00**	**1.90**	**23.81**
Trott Brook	9/21/00	43.90	00UM067	Anoka	upstream of C.R. 5 in Ramsey	45.28201	93.44155	14	50	0.53	0.83	1.36	61.89
Grove Creek	9/13/99	45.00	99UM045	Meeker	3 mi. NE of Grove City	45.19823	94.62782	8	29	0.33	0.42	0.74	87.74
Mayhew Creek	9/11/00	46.53	00UM042	Benton	5 mi. E of Sauk Rapids	45.61270	94.10610	8	29	0.35	0.67	1.02	86.21
Wing River	**9/13/00**	**49.72**	**00UM023**	**Otter Tail**	**upstream of C.R. 42**	**46.22554**	**95.21056**	**20**	**71**	**0.75**	**0.92**	**1.67**	**61.32**

APPENDIX B. (continued)

Stream Name	Sample Date	Drainage Area (mi^2)	Field Number[1]	County	Location	Latitude[2]	Longitude	MIBI	std. MIBI[3]	land rate[4]	Habitat rate[5]	Total rate[6]	Land Use%[7]
Coon Creek	9/21/00	50.21	00UM059	Anoka	downstream of Hwy 65	45.23314	93.23592	8	29	0.48	0.17	0.64	37.76
Crooked Lake Ditch	9/14/00	55.61	00UM072	Douglas	4 mi. N of Osakis	45.92931	95.13734	8	29	0.38	0.50	0.88	86.91
Buffalo Creek	9/20/00	55.93	00UM049	Renville	upstream of 440th St.	44.78795	94.79429	2	7	0.25	0.25	0.50	98.73
Eagle Creek	9/13/00	59.31	00UM075	Todd	in Browerville on Cr 89	46.11954	94.91873	8	29	0.55	0.67	1.22	80.29
Third River	**9/13/00**	**81.86**	**00UM007**	**Itasca**	**upstream of F.R. 2171**	**47.54456**	**94.26144**	**24**	**86**	**0.98**	**0.83**	**1.81**	**4.18**
Elm Creek	10/3/00	86.17	00UM085	Hennepin	upstream of bridge on Elm Creek Rd.	45.16235	93.43614	16	57	0.65	0.75	1.40	68.31
Little Elk River	**9/8/99**	**127.90**	**99UM003**	**Morrison**	**1 mi. NE of Randall**	**46.08569**	**94.48830**	**14**	**50**	**0.73**	**0.92**	**1.64**	**48.83**
SchoolCraft River	**8/31/99**	**130.30**	**99UM026**	**Hubbard**	**5.5 mi. SE of Becida**	**47.31294**	**94.94684**	**16**	**57**	**0.88**	**0.92**	**1.79**	**8.78**
South Fork Crow River	9/20/00	206.67	00UM048	Kandiyohi	along 210th Ave. SE	44.92114	94.80447	6	21	0.20	0.33	0.53	87.13
Long Prairie River	9/14/00	232.61	00UM076	Douglas	1/2 mile west of Carlos	45.98158	95.30352	20	71	0.55	0.75	1.30	59.77
Buffalo Creek	9/30/00	233.76	00UM052	Renville	2 miles N of Stewart on 580th St.	44.74244	94.50008	4	14	0.25	0.25	0.50	97.34
Elk River	9/7/99	284.70	99UM038	Sherburne	~ 3.5 mi. N.W. of Big Lake	45.37844	93.76982	12	43	0.50	0.50	0.75	78.33
Boy River	**9/14/00**	**289.30**	**00UM012**	**Cass**	**9 mi. NW Remer**	**47.07895**	**94.10055**	**22**	**79**	**0.90**	**0.92**	**1.82**	**6.42**
North Fork Crow River	9/19/00	326.10	00UM056	Meeker	11.5 mi. N of Grove City on Hwy 4	45.27840	94.66102	4	14	0.30	0.33	0.63	86.71
Long Prairie River	9/14/00	413.64	00UM074	Todd	Long Prairie @ public access	45.97383	94.86837	16	57	0.48	0.33	0.81	67.24
Sauk River	9/13/00	442.08	00UM038	Stearns	C.R. 168, in Melrose	45.68155	94.77174	10	36	0.58	0.50	1.08	82.64

[1] Field number assigned to each station to designate a unique sampling location.
[2] Latitude and longitude are formatted in WGS 84 decimal degrees.
[3] Standardized MIBI score assigned to each site. Calculated by dividing the raw IBI score by the maximum IBI score, then multiplying this value by 100 (range 0 to 100).
[4] Normalized (maximum value = 1) watershed rating based on GIS coverages for land use, point sources, feedlots, and channelization.
[5] Normalized (maximum value = 1) habitat rating based on the quantitative habitat assessment or QHEI.
[6] Sum of watershed and habitat rating.
[7] Land use expressed as a percent of the watershed that has been altered by human development. It includes disturbance from agriculture residential, urban, and mining land uses.
* Sites in bold text were selected as reference sites based on watershed and habitat ratings.

Fremling + Drazkowski 2000

Ecological, Institutional, and Economic History of the Upper Mississippi River

Dr. Calvin Fremling and Mr. Barry Drazkowski
Resource Studies Center
St. Mary's University of Minnesota
July 17, 2000

The **Ecological, Institutional, and Economic History of the Upper Mississippi River** was prepared by Dr. Calvin Fremling and Mr. Barry Drazkowski of the Resource Studies Center St. Mary's University of Minnesota under a grant from the Environmental Protection Agency. The grant code number is CP995037-01-0.

Contents

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INTRODUCTION

The Mississippi is not just any river; it is the "Mighty Mississippi," a busy, vital, intracontinental water highway that connects North America's "breadbasket" with the rest of the world. The Mississippi River drainage basin includes the agricultural heartland of the United States, supermarket to the world. Its fertile soils, some of the world's richest, feeds one in every 12 of the world's people.

Today, most of the Mississippi River south of St. Paul, Minnesota, is a "working river," a water highway to the sea dominated by powerful, ponderous towboats. On their way downstream, the big ones may wrestle six acres of grain-laden barges toward the deep-water ports of Baton Rouge and New Orleans where the corn and soybeans will be transferred to ocean-going freighters for worldwide distribution. On their return trip, the towboats may push barges of fertilizer for the farmers that grew the grain, or fuel for cars, trucks, and farm machinery. Coal is shuttled upstream, as well as downstream, to supply power plants that furnish most of the electrical energy for cities, industries, and farms.

Commercially, the Mississippi is one of the world's most important and severely regulated rivers. "Regulated river" is a recent euphemism describing rivers that are dammed and constrained. By definition, the Upper Mississippi River is the reach from St. Anthony Falls in Minnesota to the mouth of the Ohio River at Cairo, Illinois. The Mississippi was modified to improve navigation as early as 1829 when snag removal was begun on the Lower Mississippi. Canals, cut through the Keokuk Rapids and Rock Islands Rapids, were completed in 1839 and 1854, and the river was intensively channelized with wing dams, closing dams, and shoreline protection during the 1878 - 1912 period. With minor exceptions (St. Anthony Falls, Rock Island Rapids, Keokuk Rapids, and Chain of Rocks at St. Louis), most rocks larger than volleyballs - from Minneapolis to Cairo - were placed there by the U.S. Army Corps of Engineers or the Corps' contractors as part of early channelization projects. In the past decade, additional rockwork has been done for habitat enhancement.

Broad, shallow impoundments were created on the Upper Mississippi when 29 navigation dams were constructed, mainly during the 1930's, to create a slack-water navigation channel 9 feet deep between St. Louis and Minneapolis. River travelers are usually surprised at the width of the Upper Mississippi in its impounded reaches where it is much wider (but much shallower) than it is at St. Louis or New Orleans where the river is undammed. The Upper Mississippi River contains some of the planet's most productive ecosystems, and most of the river above St. Louis supports intensive recreational use.

Because the impoundments alone are insufficient to maintain the 9-foot commercial channel, the river's main channel is routinely dredged in some reaches. Almost all sand islands along the main channel have been placed there as result of dredging. In recent years, attempts have been made to minimize the adverse environmental impacts of this practice.

Dams and levees, which aid navigation and floodplain agriculture, have reduced the river's natural ability to create habitat for fish and wildlife during periods of high flow. Yet, floods have increased in frequency and severity. Navigation impoundments, side channels, and sloughs are filling with sediment - and the rate of filling may be exacerbated by proposed increases in commercial traffic. Some river reaches are severely polluted. Exotic plants and animals are competing with native species, and whole ecosystems seem to be unraveling. Yet, we are exponentially increasing our demands on this diminishing resource. While the myriad manmade problems affecting the Mississippi are of recent origin, they have their foundation in the natural forces that shaped the river and its enormous watershed. A basic understanding of that geological history is necessary to appreciate today's river and its ills.

EARLY GEOLOGIC HISTORY OF THE UPPER MISSISSIPPI RIVER BASIN

Lakes are temporary features, but rivers are virtually immortal, and they are relentless shapers of the land. Mountains may rise up and detour them, but they continue to flow.

At the beginning of the Cambrian period, about 570 million years before present (B.P.), the North American continent was smaller than it is now and was mainly above sea level. At about that time, the earth's crust began to subside throughout much of the interior of the continent, causing oceans to advance over the low-lying, bleak, barren, land surface of the area now drained by the Mississippi River and its tributaries.

As the sea advanced, its pounding surf attacked the uplands and stripped off rock debris from the severely weathered land areas where a cover of protective plants had not yet evolved. Beach zones were high-energy environments where wave action and currents continued the disintegration of the rock debris, winnowing it, and depositing the coarsest particles in the surf areas as clean, well-sorted beds of sand that ultimately formed sandstones. Silt and clay were wafted out into quiet, deeper waters where they settled and were compressed to form shales. Abundant lime-secreting organisms produced deposits that formed limestones and dolomites in warm shallow water, with little input of sand, silt or clay. During the ensuing 500 million years the shallow Epicontinental Sea served as a collection basin for sediments that eroded and washed outward from primordial uplands and mountain ranges.

The oceans did not advance at a uniform rate. Forces deep within the earth caused mild subsidence or downwarping in some areas and uplifts in adjacent areas, causing shorelines to advance and retreat. This caused distinctive cyclic patterns in the sediment deposits, and ultimately in the sedimentary rocks that were formed from them. A sandstone stratum, for example, may be bounded above and below by shale or limestone. The layers of sedimentary rocks are now hundreds of feet thick in southern Minnesota and thousands of feet thick in the far west and deep south.

It is generally accepted that during this interval of inundation North America straddled the equator and subsequently became part of the supercontinent "Pangaea." Nearly all of the marine fossils found in central North America are of animals that flourished in warm, tropical seas.

Geologic forces during the westward drift of the North American plate caused the general uplifting of the North American continent from the Mississippi River to the Pacific Ocean. To the east of the Rocky Mountains, a great sedimentary rock plateau rose from the sea constructing a stable platform of sedimentary strata, bounded on the west by the youthful Rocky Mountains and on the east by the much older southern Appalachian Mountains.
The strata along the Upper Mississippi River are very stable. They were originally laid flat, and for the most part remain that way, but they do bulge upward, reaching their highest elevations near La Crosse, Wisconsin. They then tilt downward to the north, west and south, buried beneath younger strata.

It is within the easily erodible sedimentary platform that most of the Mississippi River and most of its tributaries now flow. Eastern tributaries drain heavily vegetated uplands. Their clear waters run through well-defined valleys. Western rivers drain the Rockies through semi-arid, sparsely vegetated, highly erodible areas. Although dams presently intercept much of their sediment load, western tributaries still provide the most silt to the Mississippi.

HOW PLEISTOCENE GLACIATION DETERMINED THE MODERN UPPER MISSISSIPPI RIVER DRAINAGE SYSTEM

Changing river courses

Soon after discovery of continental glaciation in the last century, geologists learned that there were at least four major glacial periods during the Pleistocene epoch that began about 1.8 million years B.P. The progressively younger Nebraskan, Kansan, Illinoian, and Wisconsin glaciations are each named for the state where their maximum development is evidenced. Most evidence for continental glaciation came from studies of the continents themselves, but oceanographers have recently amassed a detailed glacial chronology from cores of deep-sea sediments. Each glaciation was followed by an interglacial interval in which the climate became similar to today's.

During preglacial time (late Tertiary), the Central Lowlands of the northern United States had been drained principally by streams flowing northward into Canada. The northern tributaries of the Missouri River drained into the Arctic Ocean via Hudson Bay. The northern tributaries of the present Ohio River flowed northward across Pennsylvania, Ohio, and Indiana into the St. Lawrence River system that flows into the North Atlantic Ocean.

Nebraskan, Kansan, and Illinoian glaciers sequentially advanced as far south as the approximate present position of the Missouri and Ohio Rivers. The modern courses of these rivers were determined as vast quantities of meltwater collected along the leading edge of the glaciers. Because northward flow was restricted by ice, the rivers of meltwater flowed in a general southerly direction and became tributaries of the Mississippi River.

The "Wisconsin" glacial, that began about 100,000 years B.P. and ended about 10,000 years B.P., was the last major glaciation in North America, and is the best understood because its deposits are widely exposed and have not been disturbed by subsequent glaciers.

Worldwide, about 20 million square miles of the earth's surface were covered during Pleistocene glacial maximums. As much as 30 percent of Earth's land surface was ice-covered, compared with about 10 percent today. The average thickness of the ice sheets was about one mile, causing sea levels to be lowered about 450 feet. Expansive tracts of the continental shelves of North America were then dry land. Today, commercial fishermen trawling along the eastern seaboard often snag tree stumps from forests that grew there.

Continental glaciation and commensurate changes in ocean levels greatly accelerated erosional processes in the Northern Hemisphere. Worldwide, falling ocean levels caused river gradients to become steeper. Consequently, the rivers ran faster and were able to "degrade" or downcut through previously deposited sediments. Rising ocean levels, on the other hand, reduced the gradient of rivers, decreased their sediment carrying capacity, and caused valley floors to rise or "aggrade" as they became choked with sediment. This complex interplay of glaciation and fluctuating ocean levels alternately caused master valleys and tributary valleys to flush and to fill. In the case of the Mississippi River, the story is more complex because the rapid draining of glacial lakes, impounded by retreating glaciers late in the Wisconsin glacial, caused torrents of sediment-free water to entrench the Upper Mississippi valley while the Lower Mississippi valley was aggrading.

Evolution of the modern Upper Mississippi River downstream from Minneapolis is generally believed to have begun about 1,500,000 years ago when Nebraskan glacial ice, that had approached from the west and northwest, displaced the Mississippi River eastward from its northwest-southeast course through central Iowa to its present location. As it flowed along the eastern edge of the Nebraskan glacier as an "ice-border stream", it incised a new channel through sedimentary rock strata, and establishing the present general course of the Mississippi River from near the Twin Cities southward to the Mississippi Embayment. The general course of the Lower Mississippi is much older - probably as old as the Atlantic Ocean. It has probably flowed through the Mississippi Embayment - the sediment-filled troughlike structure that reaches north from the Gulf of Mexico to Cairo, Illinois - since the late Paleozoic Period over 250 million years ago.

As the Wisconsin ice sheet retreated northward, it stood across the valley of the Mississippi at St. Paul and discharged great quantities of water, gravel, sand, silt, and clay down the valley. As the valley floor of the main stem rose, the gradients of tributaries decreased commensurately, causing them to drop their sediment loads. This, in turn, additionally elevated the floors of tributary valleys, causing them to be flat and continuous with the valley floor of the mainstem.

The greatest of all Upper Mississippi floods began about 12,700 years ago when Glacial Lake Agassiz, North America's largest glacial lake, spilled over its southern rim, forming the torrential Glacial River Warren that carved the immense valley now occupied by the Minnesota River. Lake Agassiz served as the source of the Mississippi River for about the next 2,700 years, and was the hub of migration for cold-water fishes and many other species of aquatic life that now live in the interior of Canada, the northern United States, and much of Alaska.

With the Great Lakes' outlet to the North Atlantic Ocean via the St. Lawrence River blocked by ice during Wisconsin glaciation, the water level of Glacial Lake Superior rose until it was four or five hundred feet higher than today's Lake Superior. It spilled over its southern rim, forming the Glacial St. Croix River that supplemented the flows of the River Warren.

During the time when the St. Lawrence outlet of the Great Lakes was blocked by ice, the Mississippi River also received overflow of meltwater from Glacial Lake Michigan via the Illinois River, and from Glacial Lake Erie via the Ohio River. Flowing waters tend to transport as much sediment as they can carry. Sediment-poor water is called "hungry water" due to its great erosive capacity. Because Glacial Lake Agassiz and the Great Lakes served as settling basins for glacial sediments, their overflows ran comparatively clear, and their hungry waters greatly increased the erosive capacity of the Upper Mississippi River, enabling it to export sediments faster than they could be supplied by tributaries. This resulted in the entrenching of the Mississippi channel over 200 feet in some reaches.

As ice retreated northward, Glacial Lake Agassiz drained to the north and east, and the Great Lakes resumed their drainage via the St. Lawrence River into the Atlantic Ocean. Relieved of their massive burdens of ice, the glacial outlet channels of both Lake Agassiz and the Great Lakes began to rebound, completing the beheading of the River Warren, and the Glacial St. Croix, Illinois and Ohio Rivers. With the cessation of flows from its glacial tributaries, the Mississippi lost most of its ability to transport sediments from steep-sloped tributaries, causing its valley to fill to its present level as an overloaded braided stream.

Terraces

The Mississippi tended to entrench itself during the floods caused by the draining of glacial lakes, but between floods the valley floor aggraded as tributaries brought in more glacial drift than the Mississippi could carry away. The result was a succession of prominent, bench-like terraces (remnants of the former flood plain) flanking the river from St. Anthony Falls to the mouth of the Ohio River.

The highest terraces are evidence that the valley had aggraded to over 50 feet above its present level prior to scouring by flows from the glacial rivers, which entrenched the Mississippi valley, and secondarily caused the entrenchment of flat tributary valley floors. Because the terraces are nearly level, and less subject to flooding, they have been used as locations for communities. They are also used for agriculture, roads, railroads, and as home building sites. Native Americans used them for summer encampments, especially if they occurred where a navigable tributary joined the Mississippi.

The remarkable Unglaciated Area

Near Red Wing, Minnesota, the Mississippi enters the distinctive "Unglaciated Area," a rugged landscape of stream-dissected rock strata of Paleozoic Age. It includes parts of northeastern Iowa, southeast Minnesota, northwest Illinois, and southwest Wisconsin. Glacier after glacier approached this remarkable area, but left it virtually unscathed. If the area had been recently scoured by ice, its topography would not be nearly so rugged. The beautiful cliffs would have been erased.

Most of the bluffland within the unglaciated area and along both sides of the river from the Twin Cities all the way downriver to Cairo, Illinois, are marked by karst landscape - characterized by sinkholes, caves, springs and disappearing streams. The groundwater of the karst region are extremely susceptible to pollution from farm fields, feedlot runoff, failed sewage lagoons, and residential development.

POSTGLACIAL CLIMATE AND ITS ECOLOGICAL IMPACTS

As glacial ice retreated northward, climatic zones and vegetation also shifted to the north. Deciduous forests, for example, replaced Iowa's coniferous forests,, and they, in turn, gave way to prairie grasslands.

The climate of immediately postglacial midwestern America has no modern analog. The present interglacial period, called the "Holocene or Recent", was triggered by a gradual increase in the earth's mean annual temperature for the first 4,000 or 5,000 years, culminating in a period of temperatures higher than today called the "Altithermal." The warmest time interval in our interglacial, called the hypsithermal interval, was warmer than now, and has no modern analog. It began about 8,500 years B.P., lasted until about 5,000 years B.P., and was followed by cooler temperatures that favored several episodes of advance and retreat of mountain glaciers. Cold returned about 1350 AD, causing the "Little Ice Age" that lasted until about 1870 AD. It caused the temporary expansions of glaciers and ice caps, and southward shifts of vegetative zones - and it must have severely impacted native Americans. It is interesting to note that much of the exploration and early exploitation of the Upper Mississippi River Basin took place during the last years of the Little Ice Age.

PREHISTORIC PEOPLES

The Mississippi River and its tributaries may have been utilized by prehistoric peoples for 11,000 years or more - first as hunter gatherers and more recently as agriculturists who supplemented their cultivated produce with fish, game, and wild plants from the river, its valley, and the uplands.

The Mississippi and its tributaries became transportation routes, facilitating the trading of copper from Michigan, lead ore from Illinois and Iowa, obsidian from the Yellowstone, and shells from the sea. There were extensive trade networks in place on the Mississippi River long before the American-European invasion. The rivers were also avenues for the diffusion of cultural influences long distances from their points of origin.

On the Illinois side of the Mississippi River within sight of the soaring Gateway Arch at St. Louis, lie the archaeological remains of the central section of an ancient Indian city that today is known as Cahokia. Cahokia was the center of the most sophisticated pre-historic Indian civilization north of the Rio Grande, and it acted as an intense cultural reactor that profoundly touched and influenced aboriginal groups throughout the Mississippi Basin. The city was first inhabited about 700 AD by prehistoric Indians of the Late Woodland culture. Between 800 AD to 1,000 the Mississippian culture emerged, and developed an extensive agricultural system with corn, squash, beans, and several other seed bearing plants as principal crops. This stable food base, supplemented by hunting, fishing, and gathering wild food plants, enabled Cahokians to develop a highly specialized social, political, and religious organization. At its peak, from AD 1100 to 1200, the city covered six square miles and had a population of about 20,000.

A gradual decline in Cahokia's population began sometime after AD 1200, and by the 1400s the site had been abandoned. Depletion of resources probably contributed to the city's decline. Climate change after AD 1200 may have adversely affected crops and wild plants and animals needed to sustain a large population. Agriculturists were probably more sensitive to minor climatic changes than were hunters. Other factors such as war, disease, social unrest, and declining political and economic power may have taken their toll.

By 1,000 AD, American Indians were cultivating localized portions of the Mississippi River valley below the Twin Cities for maize or corn, beans, squash, sunflowers, and tobacco. Timbered areas in the rich river bottoms were cleared for garden plots. Hunting and fishing remained important, however. Farther north, in the Headwaters area, wild rice was substituted for corn as the staple vegetative food.

During the past 1,000 years the climate has changed several times alternating from warm/moist (1000-1250 AD), to warm/dry (1250-1450 AD). Warm/moist conditions recurred for about 100 years, and were followed by the much cooler/moist conditions of the Little Ice Age that lasted from 1350 to 1870 AD.

THE MYTH OF THE ECOLOGICALLY BENIGN NATIVE AMERICAN

A popular misconception is that American Indians were ecologically invisible, living in perfect harmony with the environment. On the contrary, many Indians were farmers. By 1500 AD they had cleared large areas to produce corn, beans, squash, tobacco, and other crops. Today, 60 percent of the dollar value of U.S. crops comes from crops first cultivated by American Indians.

Vast areas of the Mississippi Basin were cultural landscapes where Indians regularly set fires to improve game habitat, facilitate travel, reduce insect pests, remove cover for potential enemies, enhance conditions for berries, and drive game. Frequent, low intensity fires shaped the famous oak savannas of the Midwest. They existed as components of the landscape prior to Indian intervention, but Indians' actions greatly expanded the extent of such habitats.

For native Americans, fire was a prime horticultural tool. It was easily and quickly employed, and it could be used to work large areas. Applied periodically for centuries, fire was a force as profound as weather in its ecological impact. Most Indian fires were set in spring and fall when soil moisture was high and conditions were favorable for low-intensity burning of the forest. This tended to create plant communities adapted to low-intensity fires and to reduce the number of high-intensity fires caused by lightning.

The European perception that indigenous people had small ecological impact was influenced by the devastating effect of Old World diseases on native populations. Smallpox, introduced in the early 1500s, was especially lethal. It has been estimated that North America's Indian population collapsed from perhaps 18 million in 1500 to less than 1 million by the late 1700s, when the first waves of American-European settlers poured westward over the Appalachians. Thus, many Indian agricultural lands had two to three centuries to reforest before the first permanent European-American settlers arrived. The landscape looked more "pristine" than it had in more than 1,000 years.

VEGETATION AND WILDLIFE AT THE TIME OF AMERICAN-EUROPEAN SETTLEMENT

The Headwaters pineries extended southward to about Brainerd, Minnesota. There the Mississippi River entered an area characterized by a mosaic of prairie, savanna (grassland interspersed with fire-resistant trees), and extensive stands of "big woods." Although the prairie was mainly a product of climate, much of it owed its existence to grazing and prairie fires that kept invading forests in check. Trees standing in prairies were prime targets for lightning that often ignited them and/or the dry grasslands. Fires also set by native Americans, either accidentally or purposely for a variety of reasons including making the grasslands more attractive to grazers like elk and bison.

Indian use of fire as a game management tool in the Winona, Minnesota, area was documented by Lafayette Bunnel (1897, p225). "After a very cold spell until late in the fall, that had closed Lake Pepin, there came several days of mild, dry weather, and then a sudden change and a strong westerly wind. In a few hours time it was almost as dark as night. All of the men folks were away but myself, and I had just returned, when Matilda told me that she did not know what to do with Mrs. Kennedy, for the coming darkness and smoke had led her to believe that the world was coming to an end sure enough. Just then an old squaw with some of her people came up to the house, and asked what was the matter, and Mrs. Kennedy told her. Indians do not swear, but they have strong expressions of contempt, and the Sioux woman withheld none of her language, and ended her harangue by saying: 'Thou foolish white woman, canst thou not smell the burning grass of our buffalo prairies? Thinkest thou that our people are fools not to prepare early food for them?'"

Along the river corridor south of St. Paul, easily burned areas tended to be grassland or savanna. These included bluff tops, broad terraces, broad valley floors, and large islands. Most steep southwest-facing slopes existed as "goat prairies." Hardwood forests were most prevalent in areas protected from fire. These included deep valleys, north-facing slopes, and smaller islands.

In mid-September, 1805, after journeying upstream through the Unglaciated Area below Lake Pepin, Zebulon Pike penned this vivid, concise description of karst topography, savanna, and a braided river. (Being braided is characteristic of rivers that are overloaded with sediment.) "In this division of the Mississippi the shores are more than three-fourths prairie on both sides, or, more properly speaking, bald hills which, instead of running parallel with the river, form a continual succession of high perpendicular cliffs and low valleys; they appear to head on the river, and traverse the country in an angular direction. Those hills and valleys give rise to some of the most sublime and romantic views I ever saw. But this irregular scenery is sometimes interrupted by a wide and extended plain which brings to mind the verdant lawn of civilized life, and would almost induce the traveler to imagine himself in the center of a highly cultivated plantation. The timber in this division is generally birch, elm, and cottonwood; all the cliffs being bordered by cedar. The navigation unto Iowa River [Upper Iowa River] is good, but thence to the Sauteaux River [Chippewa River] is very much obstructed by islands; in some places the Mississippi is uncommonly wide, and divided into many small channels which from the cliffs appear like so many distinct rivers, winding in a parallel course through the the same immense valley. But there are few sand-bars in those narrow channels; the soil being rich, the water cuts through it with facility" (Coues, 1965, p 306).

George Catlin also described the unspoiled Mississippi River blufflands in 1824. "The whole face of the country is covered with a luxuriant growth of grass, whether there is timber or not; and the magnificent bluffs, studding the sides of the river, and rising in the forms of immense cones, domes, and ramparts, give peculiar pleasure, from the deep and soft green in which they are clad up their broad sides, and to their extreme tops, with a carpet of grass, with spots and clusters of timber of a deeper green; and apparently in many places, arranged in orchards and pleasure-grounds by the hands of art."

Stephen Long, in his journals of 1817 and 1823, also described the prairies, savannas, and forests along the Mississippi River between St. Louis and the Falls of St. Anthony. His descriptions corroborate those of Pike and Catlin.

Today, the prairie heritage of the Upper Mississippi Basin is reflected in the names of its cities and towns - Mound Prairie, Long Prairie, Belle Prairie, Belle Plain, Plainview, Eden Prairie, Prairie de la Crosse (La Crosse), Prairie du Chien, and Blooming Prairie to name a few. If not named for the prairies, towns were often named for groves of trees that provided shelter, fuel, and building material for pioneers - Walnut Grove, Soldier's Grove, Maple Grove, Cedar Grove, Cherry Grove, Inver Grove, and Spring Grove.

SETTING THE STAGE FOR THE CAUCASIAN INVASION

Hernando De Soto, searching for riches with 600 Spanish conquistadors, is credited with the "discovery" of the Mississippi near Memphis in 1541. Most likely, the river came as no surprise to him because it had appeared on a Spanish map in 1513, probably as a result of intelligence gained from Indians. After De Soto, 132 years passed before Caucasians again visited the Mississippi.

By the seventeenth century, three "superpowers"- England, France, and Spain- were competing to establish colonies and control the New World. They also hoped to discover a river that flowed into the Pacific Ocean, so they could establish a lucrative trade route to the Orient. The French were first to penetrate the Upper Mississippi Valley, when, in 1673, the fur trader Louis Joliet and his party, which included Father James Marquette, canoed from the Green Bay of Lake Michigan up the Fox River, portaged over the low continental divide into the headwaters of the Wisconsin River, and continued downstream into the Mississippi. After floating southward to the mouth of the Arkansas River Joliet concluded that the Mississippi flowed into the Gulf of Mexico and not the Pacific Ocean. They returned by going up the Illinois River, over the low continental divide, and down the Chicago River into Lake Michigan.

Although they had not found a short cut to the Orient, the exploration of Joliet and Marquette helped establish France's claim to the interior of the continent. Soon France was sending colonists to populate the vast new
territory it called "Louisiana." Other French explorers ascended the Mississippi from its mouth; some reached its headwaters by traveling overland from Lake Superior. A trade route became firmly established from Lake Superior up the St. Louis River, and then overland to the headwaters of the Mississippi. A route from the Mississippi to the far north was established by ascending the Minnesota River to its source on the western border of Minnesota, through Big Stone Lake and Lake Traverse into the headwaters of the Red River of the North, which flows northward toward Hudson Bay.

La Salle was the first European to travel the length of the Mississippi River from the Great Lakes to the Gulf of Mexico. He claimed the entire drainage area for France and named it Louisiana.

The French established trading posts at many locations along the Mississippi and demonstrated that it was navigable along its entire course. By the middle of the 18th century, France had established trading posts throughout the mid-continent, providing further support for ownership. St. Genevieve, Missouri, the first permanent settlement west of the Mississippi, was founded in 1735. St. Louis, located strategically at the confluence of the Mississippi and Missouri Rivers, was founded in 1764. The names of other towns along the Upper Mississippi are further testament to the far-reaching influence of the French: Cape Girardeau, Prairie du Chien, La Crescent, La Crosse, Trempealeau, Lamoille, and Belle Prairie to name a few.

In 1763, following its defeat by the British in the French and Indian War, France ceded its holdings west of the Mississippi to Spain and its lands east of the river to England. At the end of the American Revolution, just 20 years later, Great Britain ceded all land from the Appalachian Mountains to the Mississippi River to her former colony - and American settlers poured over the Allegheny Mountains into the eastern part of the Mississippi basin.

Subsequently, the Spanish returned ownership of the territory of Louisiana to the French, who, in turn, sold it to the United States in 1803. Except for a very small portion of what is now southern Alberta and Saskatchewan, Americans now controlled all of the land drained by the Mississippi River and its tributaries.

Three centuries passed between the discovery of the mouth of the Mississippi in the Gulf of Mexico and the location of its source in the wilds of northern Minnesota. Many explorers searched for the river's source. Zebulon Pike made the first unsuccessful attempt in 1805. Henry Rowe Schoolcraft, guided by an Ojibwe Indian, finally "discovered" that Lake Itasca was the true source of the Mississippi in 1832.

With Lieutenant Zebulon Pike's exploratory voyage up the Mississippi from St. Louis in 1805, the U.S. Army Corps of Engineers began extensive surveys of the Upper Mississippi. From 1817 to 1823, Major Stephen H. Long explored the UMR, looking for ways to improve it for settlement and commerce. As a result of his report recommending, among other things, that canals be constructed around the rapids, Congress assigned responsibility to the Corps for managing the Mississippi and improving it for steamboats. The authority has rested there ever since (Madison 1985).

PRESETTLEMENT PLANT COMMUNITIES

An interesting mix of modern technologies has corroborated the vivid descriptions of presettlement landscapes by explorers Like Pike, Catlin, and Long. In 1785, the U. S. General Land Office (GLO) initiated the Rectangular Survey System to dispense land to settlers in western territories. It divided the landscape into townships containing 36 sections, each of which was one square mile in size. At each section corner and midway between section corners, GLO surveyors pounded a steel post into the ground. In timbered areas they referenced the post's location by selecting two nearby trees, and recording the direction and distance to them, the trees' common names, and their diameter breast high. If no trees were present, the post was set into an earthen mound and prairie was recorded in the field notes. After each surveyed mile, the surveyors recorded type of terrain, soil, plants composing the undergrowth, and tree species. Early surveyors and explorers often used the term "oak opening" for savanna.

As part of the U. S. Geological Survey's Upper Mississippi River Long Term Resource Monitoring Program, survey records of the GLO have been used to reconstruct the structure and distribution patterns of plant communities that existed over 150 years ago along the UMR. Using digitized GLO data, computer-generated maps plot the former forests, savannas, prairies, marshes, and areas of open water.

These reconstructions reveal that prairies once dominated the floodplain. Forests were generally restricted to islands, banks of the Mississippi and its tributaries, valley slopes and ravines. Flooding has long been considered the principal factor influencing plant community types on the floodplain, but it is now known that fire, either natural or human-caused, played an important role in maintaining floodplain prairies, savannas, and open woodlands.

In the Pool 4 area, for example, GLO surveyors reported that island forests were dominated by flood tolerant species like elm, silver maple, willow, bur oak, birch, and ash. Because the GLO surveyors did most of their work along the Mississippi during the winter when trees were leafless, they may not have always distinguished bur oak from swamp white oak. The barks of the two species are similar. Uplands were predominantly covered with savanna communities of fire-tolerant white oak, bur oak, and black oak. Some of the savannas had a park-like distribution of trees with a grassy understory. In others, oak groves were interspersed with open prairies and dense thickets of fire-stunted oak and hazel brush. Fire-sensitive sugar maple - basswood forests were restricted to steep mesic ravines and north facing slopes protected from fire. The floodplain had communities similar to both islands and the surrounding uplands. Bur oak, tolerant of both fires and floods, was the dominant tree species on both floodplains and uplands in 1848. Presently, silver maple is the dominant flood plain species in Pool 4.

Farther south, using GLO survey records from 1815-1817, reconstructions were made of the presettlement landscape at the confluence of the Illinois and Mississippi Rivers. About 56% of the floodplain consisted of forest and savanna dominated by hackberry, pecan, elm, willow, and cottonwood. Prairies covered about 41% of the presettlement floodplain.
Between 1817 and 1903, all of the higher elevation mesic prairies were converted to agriculture. Species diversity has decreased in floodplain forest communities since impoundment in the 1930s, and silver maple is now the dominant species.

After 1830, steamboat traffic increased rapidly, creating an enormous demand for the fuelwood that lined the river banks. Woodyards became "big business" and many farmers supplemented their incomes by harvesting and selling cordwood from bottomland forests. Hardwoods with the highest fuel value were selectively harvested. These included oak, ash, maple, elm, pecan, and hackberry. Willow and cottonwood were less desirable, just as they are now for woodstoves and fireplaces.

EARLY EXPLOITATION OF WILDLIFE RESOURCES

By 1900, elk and bison had been eliminated from most of the Mississippi River Basin. Beaver seemed doomed to extinction because of over a century of exploitation by trappers, and a closed season was declared in 1910.

The extinction of the passenger pigeon was especially shocking to Americans, many of whom could remember flocks that darkened the sky hour after hour. In 1813, John James Audubon had mathematically calculated that a single flock in the Ohio River Valley contained more than 1,115,000,000 birds. A century later the world population of passenger pigeons had been reduced to a single captive bird in the Cincinnati Zoo. Named "Martha", she died on September 1, 1914, at age 29 (Department of the Interior 1976). Commemorating the passing of the passenger pigeon, Aldo Leopold wrote:

The pigeon was a biological storm. He was the lightning that played between two opposing potentials of intolerable intensity: the fat of the land and the oxygen of the air. Yearly the feathered tempest roared up, down, and across the continent, sucking up the laden fruits of forest and prairie, burning them in a traveling blast of life. Like any other chain reaction, the pigeon could survive no dimunition of his own furious intensity. When pigeoners subtracted from his numbers, and the pioneers chopped gaps in the continuity of his fuel, his flame guttered out with hardly a sputter or even a wisp of smoke.

The effects of man on the aquatic resources of the Mississippi River had been recognized as early as 1870, when it was observed that the fishery resources in the river system were rapidly declining. In 1871, the Congress established the Office of the United States Commissioner of Fish and Fisheries. Within four years, the states of Iowa, Minnesota, Wisconsin, and Missouri had established their own Fish Commissions. The activities of these groups basically fell into two categories, fish stocking and fish-rescue.

Prior to the formation of the 9-foot channel impoundments in the 1930s, water levels fluctuated greatly throughout the year. Spring floods submerged lowland areas and as the floodwaters receded, pools and lakes cut off from the main channel of the river were formed. Conditions were favorable for the growth of newly hatched fish in such flood plain lakes, but the stranded fish usually died as water levels receded and the lakes dried up. Freeze outs usually killed those land locked fish, which survived the summer, during the winter.

The U.S. Fish Commission began rescue operations in 1889, and 35 fish rescue stations had been established on the Mississippi River in Minnesota, Wisconsin, Iowa, and Illinois by 1923. Fish rescue operations declined substantially after 1925, but were continued until the 1950s at a few locations.

MISMANAGEMENT OF THE LAND

Impacts of agriculture

The exploitation of the Upper Mississippi River drainage basin, beginning in the 1840s, by immigrants and their descendants profoundly affected landforms. Their farming and forestry practices bared the land, creating the equivalent of a great climatic change. Pioneer farmers cultivated the Mississippi Valley floor, terraces, and the top of the plateau. Erosion rates increased so much that the floor of the modern Upper Mississippi Valley was blanketed by soil that washed into the river and its valley as a result of steep-land agriculture. Hay and small grains such as wheat, oats, and barley were the main crops.

Below the Twin Cities, the bluffland is very rugged - especially in the Unglaciated Area; and most agricultural land in the area is not level. Early settlers usually cultivated every part of their land, which was not too steep for horse-drawn machinery. Conservation to the early farmers usually meant letting no portion of their land lie unproductive.

With horse-drawn machinery and the moldboard plow that had been introduced in 1837, they opened land that should not have been cultivated. Bluff tops were plowed to the extreme edges of the bluffs - and often over the edges. Sure-footed horses traversed areas that today's tractors cannot. Hillsides that were too steep to be plowed were logged, burned, and grazed. Bluffland fires were so common that steamboats could sometimes travel at night because their routes were fire lighted. White settlers carried on the Indian tradition of burning to discourage tree growth and to stimulate the production of additional grasses for grazing.

Dairy cattle and horses were the principal grazers, but sheep and goats also helped denude the hillsides. Soil conservation measures such as contour tillage, strip cropping and terracing were unheard of. Soil conservation practices improved after the 1930s, but wetland drainage and stream channelization increased. Adding insult to injury, the gullies that developed on steep land were often filled with topsoil so that cultivation could continue.

Because the land lost so much of its protective cover and its water retention capacity, floods in tributary valleys were common at all seasons of the year, and alluvium washing down from the uplands caused the aggradation of most valley floors. Entire valley communities were slowly inundated, in some instances, by sand and silt from the uplands. The lower reaches of tributaries and their deltas still store most of the eroded soil.

The settlers that migrated to the Upper Mississippi River Basin to farm the rich prairie soils also drained the wetlands that had filtered nutrients and helped regulate runoff rates. An estimated 34-85% of wetlands in Wisconsin and Minnesota have been lost, and 85 to 95% in Iowa, Illinois, and Missouri. Because of wetland destruction, stream channelization, agricultural drainage, and urbanization, floodwaters presently reach the river faster. Today, Mississippi River flood stages are higher and last longer, but low water stages are lower.

European settlers transformed the native tall-grass prairie into one of the most productive agricultural regions in history, first with horse-drawn machinery, and more recently with heavy machinery and an ever-expanding arsenal of fertilizers and insecticides. The Great Plains has become an inland ocean of corn and soybeans.

Contour farming and strip cropping were introduced in the area in the late 1930's. Row crop agriculture, mainly for corn and soybeans, was limited before World War II, but it expanded greatly after the war.

In Wisconsin, upland erosion and tributary sediment yields to the Mississippi were highest during the 1850s through the 1920s, with rates declining since then because of improved land management practices.

Tillage that does not use the moldboard plow and leaves at least 30% of the plant residue on the ground is considered conservation tillage. Moving away from the moldboard plow toward conservation tillage and no-tillage has reduced soil erosion while increasing soil fertility. Soybean acres rotated to corn lend itself to no-tillage because there are fewer weeds and a lighter blanket of crop residue. Conservation practices such as minimum till or no till provide more vegetative cover and reduce runoff; this increases base flow and reduces storm flow.

In the silt-loam soils of the rugged unglaciated areas of Winona County, Minnesota, for example, conservation tillage and no-tillage have been practiced by some farmers since the 1950s, but the practices have become very popular since about 1985. Conservation tillage is now practiced by at least 80% of area farmers.

Increasing numbers of farmers have discontinued grazing woodlands and steep slopes since the 1950s, recognizing that it is poor business and poor conservation. Large scale burning is no longer permitted, except as a prairie restoration tool in some state and federal preserves. The impact of no grazing or burning is most evident on steep, south-facing slopes that are characterized by dryness and temperature extremes. In these "goat prairies," prairie vegetation is rapidly being replaced by dense stands of red cedar (juniper). Most of the red cedar stands are virgin forests, having invaded areas that were treeless for thousands of years due to climate, grazing, and burning.

We cut the top off Minnesota and Wisconsin and sent it down the river

Removal of pine forests by clearcutting in the St. Croix, Chippewa, Black, and Wisconsin watersheds disrupted the stability of soils and sediments that had been held in place only by dense vegetative cover. As settlers poured into the treeless prairies of the mid-continent in the 1840s and 1850s, the need for lumber for houses, barns and sheds became acute. Fortuitously, the upper watersheds of the Mississippi Headwaters, St. Croix, Chippewa, Black, and Wisconsin Rivers were forested with mature stands of white pine and Norway pine. What's more, the immense forests were laced with big rivers that seemed to be designed for the sole purpose of floating logs. At the peak of the ensuing logging that peaked in the 1880s there were over 100,000 lumberjacks, armed with double-bitted axes and two-man crosscut saws, in the winter forests of Minnesota and Wisconsin. White pine, a light and strong wood, was exploited first. It took only 40 years to log off the world's finest stand of white pine.

With the depletion of the white pine, loggers turned to the less valuable Norway pine. Sixteen-foot logs were hauled by sleigh over iced roads or by railroad to riverside landings where they were stacked to wait for the spring floods that would transport them to saw mills or downstream to the Mississippi. Logs and rough-sawn lumber were made into rafts for their trip downstream to saw mills in Winona, Minnesota; La Crosse, Wisconsin; Clinton, Iowa; and Rock Island, Illinois, and other cities. During the peak of the lumbering period in the late 1800s, there were more than 80 sawmills located on the Upper Mississippi River and about 120 located on tributary streams.

The short-lived logging boom which began in 1875 hit its peak in 1892, and in 1915 the steamboat Ottumwa Belle snaked the last remnants of Wisconsin lumber down the Mississippi River. By early in the twentieth century most of the pine forests of Minnesota and Wisconsin had been cut, and the logging companies moved westward.

The pearl button industry

Commercial fishing for clams began on the Mississippi River in 1889, when the first button factory was started in Muscatine, Iowa. The fishery rapidly expanded northward and southward to supply pearl button factories at several cities along the river. The clam beds were depleted, however, in a few years in most areas. For example, beds near New Boston, Illinois, produced more than 10,000 tons of shells between 1894 and 1897, but were then abandoned. It became apparent that the mussel fishery was doomed unless methods of artificial propagation could be developed. Accordingly, the U.S. Bureau of Fisheries established the Fairport Biological Station in Iowa in 1908. Although artificial propagation was successfully employed on a large scale, depletion of the beds continued. Water pollution and siltation accelerated the process, and by 1950 the few remaining button factories were making buttons cut from shells collected from streams in Tennessee and Arkansas. The development of synthetic buttons in the early 1950s was responsible for the demise of the industry.

IMPROVING THE RIVER

Ockerson gave one of the most complete physical descriptions of the Upper Mississippi River while it could still be considered in a relatively natural state in his 1898 paper, "Dredges and Dredging on the Mississippi River". He noted that between St. Anthony Falls and the mouth of the Missouri the "banks are low, and the oscillation between high and low water rarely exceeds 25 ft. In the upper half of this reach the river is divided into a great many sloughs, which serve as high water channels, but are often nearly or quite dry at low water. The water carries but little sediment; bank erosion is comparatively slight; for 21 miles it flows through a lake of slack water 30 ft deep (Lake Pepin); the flow in two places is interrupted by rapids where the bed of the stream is solid rock (Rock Island and Keokuk); in the upper portion, the navigable depth at low water sometimes gets down to 2 1/2 ft, and navigation is usually suspended during the winter season for a period of four months or more in consequence of the river being frozen. The low-water slope averages about 0.5 ft per mile. The low water discharge is about 25,000 cu. ft per second. High water generally comes in May and June, and the low water season begins about the first of September and lasts until navigation is closed by ice. Sandbars are numerous and crossings are consequently frequent, and their locations are constantly shifting.

In 1823, the steamboat Virginia reached St. Paul, Minnesota, and marked the beginning of a new era for the Upper Mississippi. Steamboats made it possible for people to travel to the frontier without bearing the hardships that early explorers had experienced. The Corps of Engineers began to improve navigation on the river in 1829 by removing snags and sandbars, by excavating rock to eliminate rapids, and by closing off sloughs to confine flows to the main channel. These alterations enabled shallow-draft steamboats to use the river and its tributaries as water highways. Concurrently, erosional processes in the watershed were accelerated as settlers logged the forests, grazed and plowed the prairies, and practiced steepland agriculture.

Early canal construction, dredging, and snag clearing

The Upper Mississippi had long stretches of rocky rapids largely missing downstream from St. Louis. The lower rapids (Des Moines Rapids) stretched for about nine miles from Keokuk, Iowa, to Montrose, Iowa. The upper rapids were more extensive and dangerous; they ran for about 15 miles from Le Claire, Iowa, to Rock Island, Illinois. Rocks weren't the only threat to steamboats. For thousands of years sunken trees, logs, and stumps had accumulated in the river, lying in wait to tear out the hulls of keelboats and steamboats. Powerful, twin- hulled snag boats, known as "Uncle Sam's tooth pullers," began removing snags on the Lower Mississippi River in 1829.

The Upper River's rapids were an even greater problem than the snags. In 1837, surveys were made of the Rock Island rapids at Rock Island, Illinois, and the Des Moines rapids at Keokuk, Iowa. In 1838 and 1839, the USACE was authorized to blast a channel 5 feet deep and 200 feet wide through the Des Moines Rapids. In 1854 the Corps was further authorized to cut a channel through the Rock Island Rapids and to clear snags and other hazards from the Upper Mississippi River. The snag clearing was completed in 1867. Even though the larger rocks were removed from its channel, the Rock Island rapids remained a major obstacle until the Moline Lock, completed in 1907, enabled boats to bypass the worst of it. Six years later the Keokuk Lock was completed as part of a power dam built to generate electricity.

The 4 1/2-ft and 6-ft channel projects

The completion of the first transcontinental railway in 1869 was followed by a growing railway network that threatened river commerce. Not only did the railroads provide greater access to markets in the east and west, but they could run when the river was frozen or impassable due to extreme low flow. Railroads running westward needed bridges, and the first Mississippi bridge, completed in 1856 at Rock Island had already claimed 64 steamboats.

In1878, Congress authorized the creation and maintenance of a navigational channel 4-1/2 feet deep on the Upper Mississippi River between St. Paul, Minnesota, and the mouth of the Ohio River. Among the reasons for this authorization were the beliefs that effective waterways would force the railroads to charge competitive prices and that, if river routes did not improve soon, the railroads would become so dominant that future river improvement would be impossible. The 4-1/2-foot channel was to be obtained by the construction of wing dams, closing dams, and shore protection, and by dredging. Although it was funded yearly by Congress, the 4 1/2-foot channel project was not substantially finished until 30 years later, in 1907.

The purpose of wing dams and closing dams was to constrict the area through which the river flowed. Using closing dams to cut off alternate channels and wing dams to direct the river's flow down a single narrow channel, a swift current was created to prevent deposition of sediments in the main channel. The main areas of deposition were on the downstream side of the wing dams where the sand gradually filled in the area between the dams and the shore. When successful, the wing dams forced the current toward the opposite bank at a greatly increased velocity. As a result, that bank was in danger of eroding away and had to be protected. Rock and brush were again the materials used.

Wing dams were constructed of readily available materials - willows cut from the river bottoms and limestone and dolomite quarried from nearby bluffs. The willows, which were tied in bundles 20 feet long and 12 inches in diameter, and rocks were barged to dam site. There the bundles were loaded aboard a building barge and woven into mattresses. The mattresses were skidded into the river and held in place by ropes until sufficient rock could be loaded on the mattresses to sink them, layer after layer, into the depths. The dams were built in from 5 to 40 feet of water and were constructed so that they projected as much as 6 feet above the water. Usually, on the opposite side of the river from the wing dams, the shore was fortified with rock so that water, which rushed around the ends of the wing dams, did not erode away the opposite shore. Durable, erosion-resistant dolomite and limestone rock was quarried from the bluffs and brought down to the river by horsecart originally, but some quarrymen developed tram systems that brought rock to the river's edge much more efficiently.

Wing dams were usually constructed in the summer, but sometimes they were built during the winter, and the materials were hauled onto the ice on sleighs. Once the rock and brush had been laid, workers sawed through the ice around the dam and let the dam fall into place.

Wing dams were usually built in a series with the shorter ones on the up-river end. The action of the current around the ends of the wing dams scoured a channel and deposited the sand in eddies behind the dams. The spaces between the wing dams rapidly filled with sand as high as the dams, and willows soon sprouted on these sandbars, creating new islands in a few years.

Meanwhile, larger, more powerful riverboats had evolved and they needed a deep channel to carry greater payloads. Congress appropriated additional funds in 1907 to deepen the navigable channel to 6 feet. This was to be accomplished by constructing additional wing dams and shore protection and by additional dredging. The project was only half completed in 1925 when the Corps determined that the 6-foot depth would not be possible the entire length of the river using present methods. In any case, the River and Harbors Act of 1927 abandoned the 6-foot proposal and authorized an eventual 9-foot channel.

The magnitude of the early channelization projects is mind boggling. In constructing the 4-1/2-foot and 6-foot channels, the Corps of Engineers built over 2,000 wing dams and closing dams between St. Louis and Minneapolis. In addition, many miles of shoreline were protected with riprap. Most limestone and dolomite bluffs that abut the river have quarries in them where rock was excavated for constructing the channelization structures. A typical quarry still has a pillbox-shaped mound of solid rock within it where the capstan of the derrick stood.

Riprap and wing dams prevented lateral movement of the river. In effect, they "hardened" the river or "fixed" it in position. They also had a dilatory effect on the river because they collected sewage and garbage.

Connecting the Mississippi with the Great Lakes

During the era of channelization of the Mississippi, a fateful connection was made linking the Mississippi with the Great Lakes. Completed in 1900, the Chicago Sanitary and Ship Canal connected Lake Michigan with the Illinois River. Lake Michigan had long been degraded by domestic and industrial sewage in the Chicago area, and the canal enabled the city to use Lake Michigan water to flush its wastes down the Illinois River into the Mississippi. In addition to being an ecological tragedy that caused severe degradation of the Illinois River, the canal also provided an avenue for exotic biota (e.g. the zebra mussel) to enter the rivers of the Mississippi watershed from the Great Lakes.

Headwaters reservoirs

Nine in-channel glacial lakes are found in the Mississippi Headwaters, including Lake Winnibigoshish and Lake Pokegama, both of which were dammed in the late 1800s as part of a U.S. Army Corps of Engineers navigation and flood-control system that includes four other lakes in the Headwaters watershed. The original purpose was to store spring runoff in order to augment low summer flows for commercial navigation between St. Paul and Prairie du Chien, but the nine-foot channel project made that function unnecessary. The reservoir dams are now mainly used for flood control, recreation, residential amenities, and conservation.

Taming the Des Moines Rapids

Although steamboats had operated on the Lower Mississippi River since 1811, it wasn't until 1820 that Major Stephen H. Long arrived at Keokuk on an exploratory trip for the U.S. Army in his strange sternwheeler the "Western Engineer." At Keokuk he encountered the first of two major obstacles to steam navigation of the Upper Mississippi River, the formidable Des Moines Rapids. They extended from Keokuk at the mouth of the Des Moines River 11 1/4 miles up the Mississippi to Montrose. The prevailing feature of the rapids was the flatness of the river bed, formed by almost horizontal ledges of limestone that followed the slope of the river. At low water the rapids were no more than 24 inches deep, a severe obstacle even for shallow draft steamboats. The rapids had limited traffic on the Mississippi as far back as the 18th century when fur traders had to have their boats unloaded and their cargo carried across the rapids in smaller craft called "lighters." Indian villages had sprung up at Keokuk and Montrose in response to the need for labor. Lieutenant Zebulon Pike used lighters in his exploratory voyage up the Mississippi in 1805.

In 1820 most rivermen assumed that no steamboat would ever conquer the rapids, although the small steamboat "Virginia" crossed them twice in 1823 on two trips to Fort Snelling, Minnesota. George Catlin, the famous artist, was a passenger on one of the trips. Few other steamboats dared go through the rapids.

In 1824 Congress passed the General Survey Act that gave the President authority to use officers of the U.S. Army Corps of Engineers to make surveys of navigation routes. This action has been of profound importance for the Mississippi River and the nation.

The first reconnaissance surveys of the Des Moines and Rock Island Rapids was made in 1829, and recommendations were made to excavate the Des Moines Rapids channel to a depth of 5 feet, but no further work was done until 1837 when Lieutenant Robert E. Lee resurveyed the rapids and endorsed excavating the channel. Work was done sporadically until1866 when it was apparent that excavation was not working. To improve the rapids the way suggested by Lee and others would have required an 11-mile cut, two hundred feet wide through solid rock, resulting in a narrow sluice with an extremely strong current, making navigation difficult and dangerous.

Keokuk was a busy place at the end of the Civil War, and there was a growing need for improving the rapids. Over 300 steamboats were engaged in commerce on the Upper Mississippi, yet they still had to transfer cargo to lighters or to the new railroad that ran between Keokuk and Montrose. The five state bordering the Mississippi north of the Des Moines Rapids were growing more than a third of the produce in the United States, and they wanted to ship it downriver. Most important, the young lumber industry was booming, with more than 400,000,000 board feet of lumber being rafted downriver to sawmills each year.

Anxious to heal the wounds of the Civil War and aware of the need to improve the Mississippi for trade between North and South, Congress authorized a four-foot channel north of St. Louis. As part of the River and Harbor Act, money was provided for improvement of the Des Moines Rapids and the Rock Island Rapids.

About a thousand men were employed at the peak of construction of the Des Moines Rapids Canal that opened to traffic in 1877. The lateral canal ran along the Iowa shore and was 7.6 miles long, 300 feet wide, and five feet deep. Its three locks provided a total lift of 18.75 feet. The locks were constructed of limestone quarried from the adjacent bluff.

The Hydroelectric Facility and Lock and Dam 19, Keokuk, IA

The Des Moines Rapids Canal performed well for many years, but it had limitations. During high water about 15% of downbound steamers chose to bypass the canal, thus saving over an hour of travel time. Almost all boats going up river used the canal rather than fight the current. The massive log rafts that floated downstream wouldn't fit in the canal and had to be broken up and reassembled, a procedure that could take 40 to 50 hours.

The beginning of the end for the Des Moines Rapids Canal came when the River and Harbor Act of 1902 authorized a survey at Keokuk to determine if a dam constructed at the foot of the rapids would benefit navigation. The report was favorable for a dam that would flood the entire rapids. A single lock would cut travel time and operating expense. Raft traffic would suffer, but it was already dying. Only one sawmill remained on the Mississippi south of Keokuk.

In 1905, the Keokuk and Hamilton Water Power Company (now the Union Electric Power Company) was authorized to construct a dam with a hydroelectric plant, a lock, and a dry-dock at Keokuk. These structures, with the exception of the dam and powerhouse, were turned over to the United States upon their completion in 1913. At the time of construction, the hydroelectric plant was one of the world's largest. Because it generated more electricity than could be sold, drainage districts were formed. They de-watered the floodplain land for agriculture using electric pumps, thus eliminating large expanses of floodplain forest. In 1913, the Keokuk dam was the only dam on the Mississippi below the Falls of St. Anthony. It profoundly impacted the ecology of the Mississippi River. Water that does not go through the dam's turbines, goes over the top of the 40-foot high dam which is consequently a barrier to migrating fish. The impoundment is an effective sediment trap.

The original 358-foot lock was an impediment to river traffic in the 9-foot channel project. It was replaced by lock 1,200 feet long and 110 feet wide, completed in 1957. Filling time for the lock is about 10 minutes and emptying time is about 9 minutes. A 15-barge tow can pass through the lock in one-half hour if the lockage goes smoothly.

The 9-ft channel

Channelization projects prior to 1930 had employed wing and closing dams, shore protection, and auxiliary dredging over other methods of maintaining the navigation channel. These methods were not only less costly, but they also permitted open-channel navigation, which was preferred by those who ran log rafts and packet boats. The short-lived logging boom began in 1878, hit its peak in 1892, and was over in 1915, when the last remnants of Wisconsin lumber were rafted down the Mississippi. Traffic by 6-foot draft steamboats also decreased rapidly because these obsolete craft could not compete with the rapidly expanding railroads. For these reasons and to provide work for the unemployed during the great economic depression of the 1930s, the Rivers and Harbors Act of July 3, 1930, authorized a 9-foot navigation channel with a minimum width of 400 feet to accommodate long-haul, multiple-barge tows. This was to be achieved by the construction of a system of locks and dams, supplemented by dredging.

In 1930, when it was first authorized, there were early concerns about the biological impacts of the 9-foot channel project. In numerous pronouncements, the Isaac Walton League condemned the 9-foot channel plan as detrimental to the environment. The league was especially concerned that soil erosion and pollution be controlled before the project began.

Writers of outdoor columns in newspapers were also vocal in condemning the 9-foot channel project. For example, the Voice of the Outdoors (Winona Republican Herald, July 26, 1930) stated,

> ".......we are still against the alleged nine-foot channel under the dam form of construction. We are now more convinced than ever that it will be a gigantic commercial failure and will be impossible to maintain without spending millions of dollars each year in dredging operations. It will completely destroy bass fishing on the river and will look like a lot of link sausages on a map and smell worse than said sausage if they were left exposed to the present heat for a week. The scenic attraction of the river will be completely wiped out."

Many observers expressed concern that soil erosion would constitute a severe problem in the proposed navigation pools. C. G. Bates, a forestry engineer, was quoted by the Voice of the Outdoors (Winona Republican Herald, July 23, 1930) as predicting that the proposed pools would be completely filled with sand in a period of 20 years.

The U. S. Bureau of Fisheries viewed the 9-foot channel project with serious misgivings. The following are direct quotes from the Bureau's written testimony presented at a hearing in Wabasha (Culler, 1931).

> "The Bureau of Fisheries views with much concern the establishment of a series of slack water pools along the Upper Mississippi River until the problem of pollution and erosion as they affect this upper section of the Mississippi River are solved. If the lake formed by the Keokuk Dam may be taken as a criterion, the creation of similar pools may mean the eventual elimination of all fish life inasmuch as the production of fish in Lake Cooper, which is formed by the Keokuk Dam, has declined according to the official statistics of the Bureau of Fisheries from 701,181 pounds in 1922 to 350,750 pounds in 1929.

The construction of slack water pools such as the one that is contemplated at this time and in this particular section north of Winona, will mean the eventual elimination of the smallmouth black bass for which this section is so widely known."

The U.S. Bureau of Biological Survey (Henderson, 1931) reported on the other hand, that the 9-foot channel project could be beneficial to waterfowl and muskrats if water levels were stabilized. The Bureau's conclusions were based on a comprehensive study of the biological effects of Lock and Dam 19 on the Mississippi River. The following is a direct quote from Henderson's report:

It is very probable that considerable portions of the Upper Mississippi River Wildlife and Fish Refuge would be benefited by the construction level above a maximum of five feet in depth over the newly flooded bottomlands, provided that stable water levels are maintained throughout the year. The construction of these dams will undoubtedly make an entirely different type of Refuge, for most of the bottomland timber will be destroyed and the percentage of land unaffected by the flooding will be relatively small. Immediately following the construction of any system of dams flooding the lowlands, an adverse period must be anticipated, but following the re-adjustment and re-establishment of the aquatic and marsh vegetation, the Refuge should be an improved place for waterfowl and probably also for muskrats.

Although authorization for the project came in 1930, it received minimal funding during the early years of the Great Depression and the last years of the Hoover administration. With the Roosevelt administration in 1933 and its New Deal, the 9-foot channel project was resurrected to put people back to work. It authorized the Corps to build and operate one of the largest public works projects in the history of the U.S., and ultimately led to the construction of 29 locks and dams on the Upper Mississippi River. The system enabled modern towboats to traverse the 400-foot elevation gradient and 670 miles of river between St. Louis and Minneapolis.

By the end of the 1930's, the 9-foot channel and the lock and dam system had formed a series of lake-like river pools. This inundation altered the function of the rock channel-training structures. Their ability to direct flow to a narrow channel and their sediment-holding function were greatly reduced. In fact, rather than holding large volumes of sediment, some wing dams developed large scour areas. If not for the 9-foot channel, accretion behind the emergent wing dams would probably have created a river like much of the Missouri River, with a narrower, faster channel.

The establishment of the 9-foot channel project facilities raised water levels in most reaches of the river, but was not sufficient to provide the depth needed throughout its length. Thus, in areas where there is less depth than programmed for, it is necessary to dredge. Most channel deepening is accomplished by using a hydraulic suction dredge and discharging to channel-side higher ground through pipes floated on pontoons. The Corps of Engineers' dredge "William A. Thompson" performs most of this function on the Upper Mississippi.

Most of the resultant 29 locks and dams were constructed during the 1930s. An exception is Lock and Dam 19 at Keokuk, Iowa, which was constructed as part of of a hydroelectric facility in 1914. An 1100-foot lock was added at Keokuk in 1958. The southernmost lock on the Mississippi is the Chain-of-Rocks facility at St. Louis, Missouri.

The movable section of the dams consists of tainter gates, roller gates or a combination of both. Earth dikes and overflow spillways, where required, complete the dams. The dams are designed for navigation purposes only, except for some power generation at Upper St. Anthony Falls and Dam No. 1. The dams serve no flood control function.
The river reach between two dams is called a "pool," but the pools are not stagnant, they remain riverine in form and function. Water flows have been slowed, but remain strong in in the main channel and less so in labyrinths of side channels in upper pools. The effects of impoundment are increasingly less apparent in downstream pools where the main channel is fairly straight, less of the floodplain is impounded, and there are fewer side channel and backwaters.

CONVERSION OF THE FLOODPLAIN TO AGRICULTURE

Owners of flood plain land between LaCrosse and Prairie du Chien, Wisconsin, proposed during the early 1920's, that their land be drained so that it would be suitable for agriculture. The proposed reclamation project was to include timber clearing, construction of dikes to protect the land from high water and the digging of internal ditches to drain the land toward pumping stations where the drainage water would be pumped over the dike. The land owners proposed that drainage districts be created under state law and that drainage costs be charged against the land to be benefited. Opponents of such reclamation insisted that the flood plain areas should be preserved for recreation and for the conservation of plant and animal life. The Izaak Walton League of America, which strongly supported the parties opposing drainage, requested the Department of Agriculture to investigate the practicability of reclaiming floodplain land between St. Paul, Minnesota and Rock Island, Illinois. As a result, a reconnaissance survey was made to determine the use and potential value of the flood plain land.

The survey revealed that there were about 343,000 acres of flood plain land between St. Paul and Rock Island and that the principal agricultural use of the land was for pasturage for cattle in dry seasons. Less than a fourth of the land was mowed for hay and only a very small part was cultivated. Reclamation of about 10,000 acres of the land had already been accomplished by 1924. Most of this early land reclamation was done in Wisconsin where 6,600 acres of bottom land in Buffalo and Trempealeau counties had been drained by 1912. Because of a break in a dike in 1913, most of the area was flooded and no pumping was done between 1913 and 1924. The land reclamation program was abandoned and most of this land ultimately became the Delta Fish and Fur Farm (now part of the Trempealeau National Wildlife Refuge). A second drainage district of 3,600 acres was completed just below Savanna, Illinois in 1925. The survey reported that another 86,000 acres could be reclaimed at an average ditching and diking cost of $45 to $75 per acre. Operation and maintenance of the drainage pumping plants were to be provided by an additional annual assessment. Farm land thus created was to be utilized for growing corn, the report continued, because dairy farmers on the hills bordering the Mississippi were reported to have insufficient land suited to the growing of corn and were forced therefore, to import cattle feed from other states.

Agricultural development of the UMR floodplain is heavily weighted to the river below Rock Island where the floodplain width averages 4-6 miles but may exceed 10 miles in some areas. Floodplain agriculture depends upon levees, and they too are unevenly distributed. From Minneapolis to Rock Island the floodplain is narrow, and about 3% has been leveed (about 15,000 acres). Between Rock Island and St. Louis, the floodplain is wider, and about 53% (about 530,000 acres) has been leveed. From St. Louis to Cairo, about 82% (about 543,000 acres) has been leveed.

POLLUTION

Early explorers were impressed with the quality of the Mississippi's waters. Both Pike and Long described the waters of the Mississippi below the St. Croix as reddish in color in the shallows. In deep water, Pike said it was as "black as ink." Long incorrectly interpreted the reddish color as being due to the color of sand on the bottom. Above the St. Croix, Long noted that Mississippi water was "entirely colorless and free from everything that would render it impure, either to the sight or taste." We now know that the waters of the St. Croix were naturally tannin-stained, reflecting their origin in northern bogs. They colored the waters of the Mississippi at their confluence. In its virgin state the Upper Mississippi was seldom muddy.

The first pollution complaints on the UMR concerned sawmill refuse, not because of aesthetics but because it constituted a navigation hazard. By the late 1870s, steamboat pilots reported that bars composed of sawdust were obstructing navigation above Lake Pepin and as far south as Winona. Also, river water permeated with sawdust retained resins that caused foaming in steamboat boilers.

By the late 1880s, Minneapolis was dumping about 500 ton of garbage into the Mississippi River below St. Anthony Falls each day in addition to raw domestic sewage and industrial wastes. St. Paul added an even greater amount of garbage and slaughterhouse wastes.

At the dawn of the 20th century, the River and Harbors Act of 1899 was the most broad and effective water pollution legislation in existence. It outlawed casting refuse into navigable waters and also stipulated that refuse could not be dumped on the banks of tributaries if it was liable to wash into navigable waters. The sawmill waste problem solved itself when the lumbering era petered out early in the century, but the problem of solid urban wastes continued to plague the river. Many citizens thought that treating these wastes was unnecessary, theorizing that the river would purify any material dumped into it. Many felt that rivers must forever be the common sewers and dumping grounds for everybody. By the end of the 19th century, the river was more important as a sewer than it was a navigation channel.

Today, the Upper Mississippi receives a complex mixture of agricultural chemicals, primarily herbicides and their degradation products, from the surrounding rich agricultural land that is intensively cultivated for corn and soybeans. The Minnesota and Des Moines Rivers, for example, are the primary contributors of alachlor, cyanazine, and metachlor.

To most observers, water quality in the Upper Mississippi River, has improved in recent decades. Gross pollution by domestic sewage has been reduced since passage of the Federal Water Pollution Control Act of 1972 that mandated secondary treatment of sewage effluent. But the river still receives an array of contaminants from agricultural, industrial, municipal, and residential sources. The impacts of these contaminants on river biota are still largely unknown.

Lake Pepin has been severely impacted by pollutants from the Twin Cities and from the Minnesota River. Lying in Pool 4, the lake begins about 75 kilometers below Minneapolis-St. Paul and extends 35 kilometers downstream. Ranging from 1.5 to 4 kilometers wide, Lake Pepin has a mean depth of about 5 meters and a mean water-retention time of 19 days. The hydrological effect of Lake Pepin has greatly enhanced the quality of the reach of river farther downstream. The lake traps sediment and associated contaminants, greatly reducing the transport of pollutants from the Minneapolis-St. Paul metropolitan area, the Minnesota River basin, and other sources to the riverine ecosystem downstream. Recent sedimentation rates in Lake Pepin range from 3 centimeters per year or greater in upstream reaches to about 0.5 centimeters per year in downstream reaches; 21 % of the lake's volume was lost between 1897 and 1986. The sediment-trapping ability of Lake Pepin substantially reduces contamination of burrowing mayflies and sediment downstream from toxic substances such as polychlorinated biphenyls (PCBs) and cadmium. The lake's sediment-trapping ability, however, will diminish as it fills with sediment and its volume declines.

The presence of PCBs in the river is attributed mainly to industrial sources. In sediments sampled during 1991-92 and in emergent Hexagenia mayflies sampled in 1988, concentrations were highest from the Twin Cities through Lake Pepin. Downstream from Lake Pepin, concentrations were much less. Greatest concentrations were in pools with cities, especially in the Quad Cities area (Rock Island, Moline, Davenport, and Bettendorf).

Improved waste treatment facilities in the Twin Cities area have caused marked improvement in general water quality during the past decade, resulting in recurrence of Hexagenia mayflies, increased fish diversity, and a more normalized comparative abundance of game and non game fishes.

The Mississippi changes character at St. Louis where the Missouri River enters the Mississippi, increasing the Mississippi's flow by nearly 50%. Historically, the Missouri contributed vast quantities of sand and silt from the Rocky Mountains and Great Plains. As evidenced by meander scars, flows of water and sediment, especially during floods, contributed to channel migration within the broad floodplain below St. Louis.

In the Upper Mississippi River Basin, more than 60% of the land area is devoted to cropland or pasture, and the major sources of nitrogen to most river waters are commercial fertilizers, manure, organic soils, and plant debris. The basin, excluding the Missouri River watershed, accounted for 31% of the total nitrogen delivered from the Mississippi River to the Gulf of Mexico between 1985 and 1988. Resulting high rates of nutrient loading downstream have contributed to the development of a 7,000 sqare-mile zone (about size of New Jersey) of reduced dissolved oxygen in the Gulf of Mexico.

INTRODUCTIONS OF EXOTICS

Fish stocking on the Upper Mississippi River began in 1872 with unsuccessful introductions of American shad and Atlantic salmon. Carp, deliberately imported from Europe, were caught in 1880 at Hannibal, Missouri; they were common as far north as Minneapolis by 1890.

Grass carp first appeared in the Upper Mississippi River commercial fishery in 1975. Natural reproduction in the Upper Mississippi has not been reported, but evidence of reproduction has been reported in the Lower Mississippi and some of its tributaries. Other exotics such as salmonids, rainbow smelt, and goldfish appear as strays in the Mississippi fishery, but none occur in significant numbers.

Purple loosestrife, a nonindigenous wetland plant introduced to North America from Europe in the early 1800's, was probably introduced into the Upper Mississippi River basin as an ornamental in the early 1900's. This beautiful, perennial plant forms dense monotypic stands in wetlands, replacing many native wetland plants. Purple loosestrife has no food value for wildlife, and its replacement of native emergent plants such as cattail makes wetlands less suitable as wildlife habitat. By 1985, purple loosestrife had become established throughout much of the Upper Mississippi River Basin. In the early 1980's, it had become notably abundant on the Upper Mississippi River National Wildlife and Fish Refuge, and it had infested wetlands of Pools 4 through 14 by the late 1980's.
Traditional control methods have met with little success, probably because the plant's seed reservoir is so extensive. Biological-control methods through the release of natural enemies such as root-boring and leaf-eating insects appear to be succeeding. Eradication of purple loosestrife is probably not feasible, but it may be possible to

achieve modest control.

Exotic submerged aquatic plants include Eurasian milfoil and curlyleafed, which have caused nuisance problems throughout the river system.

By 1991, the zebra mussel, a nonindigenous species from Eastern Europe, had entered the Upper Mississippi River via the tributary Illinois River. Zebra mussel populations expanded rapidly, and by mid-1993 zebra mussels were found throughout most of the Upper and Lower Mississippi River. By mid-August 1993, average densities of zebra mussels in the lower Illinois River had increased to more than 50,000 per square meter of river bottom. Subsequent high mortality reduced densities there to about 4,000 per square meter by August 1994.

Zebra mussels can directly harm certain native benthic invertebrates, particularly clams. Zebra mussels attach to hard surfaces, including the shells of clams, by means of byssal threads. Zebra mussel infestation on clams may interfere with the clams' feeding, reproduction, and movement.

Thus, the native clam fauna in the river could rapidly and severely decline unless methods for protecting clams from zebra mussels can be developed. Perhaps no other group of freshwater organisms is more seriously threatened with extinction than our native clams.

Zebra mussels could also alter the invertebrate communities inhabiting, the rock substrates of wing dams and other structures. Colonization by zebra mussels will probably affect some invertebrate species more than others. Zebra mussels do not prefer habitats with high water velocity. They are more likely, therefore, to displace Cheumatopsyche caddisfly larvae than Hydropsyche caddisfly larvae.

URBAN SPRAWL

The highest human population densities in the Upper Mississippi River watershed are in cities along its rivers. Urban development has increased the rate of water delivery to the river because of the conversion of permeable soils to concrete, asphalt, and rooftops. Storm runoff is contaminated with automobile wastes, industrial contaminants, residential fertilizers and pesticides, yard wastes, and trash. While municipal and industrial pollution have been controlled to a great extent in most municipalities, most urban runoff enters the river untreated.

IMPACTS OF RECREATIONAL USE

Recreation is a major use of the Upper Mississippi River. Activities include fishing, hunting, trapping, boating, camping, swimming, birding, and tourism. However, these activities are not evenly distributed along the river. Recreational use and expenditures are highest from Minneapolis to Rock Island where the river provides a rich mosaic of braided channel, islands, floodplain vegetation, and vegetated backwaters - mostly on public land. Recreational use and expenditures are low from Rock Island to Cairo where most of the broad, fertile floodplain has been separated from the river by levees and converted to agriculture, and where there are few backwaters and little public land.

In upper pools, especially from Lake Pepin to Prairie du Chien, recreational use is high. Swimmers and campers flock to the beautiful public sand beaches that flank the main channel, unmindful that virtually all of them are composed of dredge spoil that was pumped there by the Corps of Engineers as part of their routine channel maintenance practices prior to the 1973 ban on indiscriminant placement of spoil. Most of the islands are no longer being nourished by new spoil and they are being eroded by currents during floodtime, wind-driven waves, and especially by waves generated by boats. The effects of boat wakes are obvious along the main channel where the shores are subject not only to wakes of towboats, but also to the intense wakes of large, fast pleasure boats that far outnumber towboats on upper pools. The sediments that wash into the main channel are carried along by the current, inexorably moving downstream unless they are swept out into the backwaters where they will probably remain forever.

While impacts of boat-generated waves are obvious along the main channel, less obvious is the insidious damage done by hunters, fishermen, and trappers in the backwaters. Most of their impacts go unseen because their boating activity often occurs in early morning or late evening when observers are not usually active. Duck hunters who penetrate the most remote locations in pre-dawn darkness do the most serious damage. Competition for good hunting spots is fierce, and as hunters roar through narrow side channels with boats encumbered with bags of decoys and other heavy gear, their wakes wash sediment away from the shallow roots of the floodplain trees that line the channel banks. Because the trees are still anchored by their roots on the landside, the wind usually topples them inland, throwing up massive walls of roots about one foot thick. Thus, the shoreline retreats, islands become smaller, and the side channels becomes wider, usually shallower, and more monotonous.

ECOLOGICAL IMPACTS OF CHANNELIZATION

The Caucasian invasion of the Mississippi River Basin caused environmental changes that were analogous to a great climatic change. The pioneers came into a river environment where aggradation had been underway for over 10,000 years. By barring the land and increasing sediment input, they accelerated the rate of aggradation. Their engineering works also accelerated the aggradation. The free-flowing river was "hardened" with rock structures that collected sediment and prevented the river from meandering. Finally, the river was converted into a series of man-made lakes that serve as sediment traps and are subject to problems, such as eutrophication, that are typical of lakes receiving nutrient-rich effluent and runoff. It is important to remember that while rivers are virtually immortal, lakes are mortal. Lakes are born, and then pass through the stages of youth, middle age, old age, senescence and death as they inexorably fill with sediments or the products of enrichment. Lakes within agricultural and other fertile watersheds tend to age faster. This enhanced aging process is known as eutrophication.

Because the river has been channelized and dammed, it can no longer function as the large floodplain river that it once was - one that wandered within its floodplain, cutting new channels, creating new backwaters, and rejuvenating itself by alternately flooding and drying out. Presently, the river's productive wetlands are rapidly being transformed to relatively unproductive floodplain forest. Left unchecked, most of the transformation will apparently be completed in less than 50 years.

Impacts of nine-foot channel

Impacts resulting from the project are due to: 1) construction of wing dams, closing dams and shoreline protection associated with the 4 1/2-foot, 6-foot and 9-foot channel projects; 2) construction of locks, dams and earthen dikes; 3) impoundment of the river and the subsequent stabilization of water levels; 4) operation of the locks and dams; 5) construction and maintenance of navigation assistance structures such as channel markers; 6) dredging and the consequent creation of dredge spoil deposits; and 7) operation of commercial craft, pleasure boats and U.S. Coast Guard vessels.

Prior to the 1930's the river bottoms were primarily wooded islands separated by deep sloughs. Hundreds of lakes and ponds were scattered through the wooded bottoms. Bay meadows and small farming areas occupied some areas on larger islands. Marshes were limited to the shores of lakes and guts leading off the sloughs. Marsh flora was also limited, with river bulrush making up the dominant habitat. Most marshes, lakes and ponds generally dried up completely by the end of the summer. Thus, the uncontrolled river was subject to wide fluctuations of water levels, ranging from flooding in the spring to drying out of the river bottom land in the summer. Fluctuating water levels allowed marshes to dry prior to stabilization of water levels by the 9-foot channel project. During dry years the entire refuge throughout its 284 mile length became almost at once a virtual tinder box. Wild fire was a constant threat.

Early channelization projects, which were initiated in 1878, have been overshadowed by the 9-foot channel project of the 1930s. The navigation dams have transformed the Mississippi River, which was formerly a braided stream, into a series of large, well-fertilized, silted impoundments through which an appreciable current still flows. Navigation markers punctuate the main stream of the river and it is flanked in many areas by extensive deposits of dredge spoil. Railroad beds, highways, land fills and municipal flood dikes have constricted the flood plain in many areas and intercepted historic channels.

To accomplish the objectives of the project, the moveable section of the dams consists of tainter gates or roller gates or a combination of both, and earth dikes and fixed-elevation overflow spillways where required. The low dam elevations and small pool capacities relative to flood volume precludes operation of the dams for flood control. All the gates in each dam are removed from the water long before flood stage is reached so that natural open river conditions exist during the flood period.

Whenever flooding threatens in the Mississippi River valley because of high water content of the winter's accumulation of snow, some people believe that the navigation pools should be drawn down to provide storage capacity for the coming floodwaters. In earlier years, pools were drawn down in winter to increase capacity for spring floods; the result was devastating losses to fish and wildlife populations. However, there are two reasons why this drawdown cannot be performed, one legal and one technical. The legal reason is the 1934 "Anti Drawdown Law". It directs the Corps of Engineers to operate and maintain pool levels as though navigation was carried on throughout the year in recognition of the needs of fish and other wildlife resources and their habitats.

The technical reason for not drawing the pools down is the fact that the storage capacity of the navigation pools is so small in comparison with the magnitude of the flood flows that a drawdown would be refilled in a matter of hours and would not appreciably lower the stages reached by the flood.

The navigation dams of the Upper Mississippi have transformed the river into a series of impoundments, which occupy most of the floodplain of the river. Consequently, the river is much wider, and much shallower, above most dams than it is at New Orleans where the river is undammed. Each impoundment consists of three distinct ecological areas. The tailwater areas just downstream from the dams show the river in relatively unmodified form. The areas are typified by deep sloughs and wooded islands. The middle portions of most pools contain large open areas with few large trees, because stands of timber were usually cut prior to impoundment. The inundated floodplain prairies and hay meadows of the mid-pool areas now provide the best marsh habitat and are among the most productive ecosystems of the earth. The middle portions of the pools are principally flooded hay meadows. They now provide the best marsh habitat. The downstream reaches of the pools are deeper, however. They consist mainly of open water and their bottoms are heavily silted. Marsh vegetation is presently creeping downstream as the pools silt in. Marsh vegetation in the middle pool areas is being replaced, in turn, by trees and other terrestrial vegetation. The pool areas contain expansive fields of submerged or partially submerged stumps. Like wing dams, they too may lurk about propeller depth, depending on pool level.

Rising pool levels of the 9-ft channel project submerged most of the rock wing dams, closing dams, and shoreline protection that were constructed during the 1878-1907 period. Still partially functional, now lie beneath the water. The wing dams provide rocky corrugations on the river floor, so that they, in effect, have increased the total surface area of the river bottom - thus increasing its carrying capacity for invertebrates such as hydropsychid caddisflies and periphyton. When first constructed they provided excellent fish habitat, especially for smallmouth bass. Impoundment has also increased the surface area of the river, thereby increasing the area of the trophogenic zone. Below St. Louis, where the river is not impounded, wing dams still rise above the water during normal flow.

From St. Louis southward the river is flanked by agricultural levee districts within which parcels of fertile, often waterlogged, bottomland have been "reclaimed" by ringing them with flood levees. The wettest parcels are usually ditched to conduct excess water to sumps where it is collected and pumped over the levees and into the river.

For the recreational boater and fisherman, the rock structures used in the channelization of the river are of profound importance. They usually lurk, unmarked, about propeller depth. Most serious boaters have accidentally hit them - usually with dire consequences such as a mangled propeller, or a damaged lower unit.

The creation of slack-water areas and marshes improved the river corridor for furbearers and waterfowl. Significant portions of the world populations of canvasback ducks and tundra swans utilize the river for resting and feeding during fall migrations. A large portion of the river resource is presently contained within the Upper Mississippi River National Wildlife and Fish Refuge and the Mark Twain National Refuge. The U.S. Department of Interior in cooperation with adjacent state governments is responsible for its management.

Unfortunately, the ecological changes that occurred immediately after impoundment were not well documented. The concern for environmental quality, as perceived today, was not foremost in the minds of most early scientists and laymen. In addition, water quality investigations in the United States had concentrated on closed lake systems. Rivers tended to be ignored. The passage of the National Environmental Policy Act of 1969 required that governmental agencies address the environmental impacts of the operations and maintenance of all water-related projects. In response to this, the U.S. Army Corps of Engineers conducted environmental impact studies on the Upper Mississippi. These studies elucidated at least some of the problems associated with the closure of the dams 30 yr. earlier. Most investigators now perceive the river's major resource quality problems as being associated with shallow reservoir dynamics.

The Mississippi River is generally considered to be a clearwater stream with regard to sediment transport. Most of the sediment load at St. Louis is derived from the Missouri River. The closure of the navigation locks and dams and the conversion of the open river into a series of shallow pools have changed the sedimentation patterns in the river, but most of the reservoirs accumulate sediments at high rates due to the lack of current in non-channel areas during periods of normal flow. The significance of these sediment depositions in non-channel areas lies in the relationship between loss of depth and eutrophication processes. Loss of depth has facilitated the encroachment of rooted aquatic plants into open water areas. In turn, they have accelerated sedimentation rates by retarding water flow. The net result has been an increase in sedimentation rates, particularly in many of the highly valued, biologically productive areas. Furthermore, a decrease in biotic diversity has occurred in many of these areas due to the introduction of unstable substrata. Finally, increased sedimentation rates have contributed significantly to eutrophication processes that also appear to be occurring at increasing rates.

Many of the wetlands created by the 9-Foot Channel Project are located great distances from the main channel, and water circulation through them is usually poor during low-flow conditions. Entrapment and accumulation of allochthonous materials occur in these areas mainly during periods of high river discharge when surrounding landforms are overtopped with water. This results in the accumulation of sediments and associated nutrients and in the stimulation of the growth of aquatic plants. Collectively, these processes lead to increased inputs of nutrients and in accelerated rates of eutrophication. It is clear that nutrient recycling plays a dominant role in the eutrophication processes. The growth and distribution of aquatic plants have changed significantly during the past 30 yr as a result of wind and/or loss of depth. Furthermore, the progression toward hypereutrophy as a result of impoundment has resulted in the reduction in diversity of benthic invertebrate communities.

The locks and dams have produced many beneficial effects. By impounding the river, they have increased the water surface per linear mile of river, thus increasing the total photosynthetic area of the river. As a consequence, the river now produces more pounds of fish per linear mile than it did before the impoundment. Moreover, the tailwaters of the dams are virtual feed lots for fish. The fish, which congregate in the tailwaters of a dam, receive food produced in the huge expanse of the impoundment above. Not only have the dams provided more fish, they have also concentrated the fish so that they may be harvested more efficiently. Because the river is so productive, sport fishermen are able to fish year around, with two lines, for most river fish. Catch limits are more liberal in most instances than they are in inland waters.

By dedicating almost 100% of the lands in the river bottoms to public ownership and control, the 9-foot project brought to fruition a long-sought dream of conservationists from all walks of life for the preservation of the bottom lands as a haven for wildlife and fishes. It also made the lands available for all times to lawful and legitimate public use, the foremost of which has been for general recreation.

The project removed farming operations from a high-risk area. Crop production, haying and grazing were always subject to flooding, and access was often difficult or impossible in high water. Consequently, flood plain farming operations were submarginal at best.

Prior to the project, a large-scale program of fish rescue was carried out each year. The rescue work was made necessary by fluctuating water levels, which caused fish to be stranded in flood plain pools. Stabilization of water levels made this work unnecessary.

Complete federal ownership of bottomlands permits efficient designation of sanctuaries and open hunting areas to the welfare of migratory waterfowl populations during the hunting season.

The navigation dams have increased waterfowl habitat and made pleasure boating possible. In some pools, the sand from dredging has made beaches that are intensively used by swimmers, campers, and boaters.

Complete federal ownership of the bottomlands assures the continued free use of the area by the public. In an era when 1!no trespassing" signs are becoming increasingly prevalent, it is refreshing to know that such signs will not appear in the Mississippi River Refuge, and 9-foot navigation project lands and waters.

The existence of the pools has led to greater cooperation between state natural resource departments, enabling the states to manage fish and wildlife resources more efficiently. The present impoundments usually extend, to the railroad tracks, which flank the river on either side. The tracks serve as easily recognized boundaries to the area of fishing reciprocity, which lies between states.

The locks and dams are impressive structures and most people enjoy viewing them. Many people also enjoy watching tows pass through the locks. The play of spotlights and the sound of amplified radio messages are dramatic and exciting. Visitors from most of the 50 states and many foreign countries heavily patronize the viewing stands at the locks. The sight of a modern towboat with a full complement of barges lends beauty and contrast to the naturalness of the river setting.

The project has enhanced the opportunities for boating on the river. It is unlikely that water skiing and the use of personal watercraft, for example, would be as popular under natural river conditions. The inundated bottom lands presently offer a labyrinth of channels and back water lakes which are available to pleasure boaters, fishermen and hunters.

Increased water areas have caused populations of valuable fur bearers, such as muskrat and beaver, to increase. In addition to being valuable monetarily, the animals provide a distinct recreational resource for trappers.

Unfortunately, the extent or abundance of many key native biotic communities and organisms has decreased along substantial reaches of the river in recent years or decades; these communities include floodplain forests, submersed plants, clams, fingernail clams and other bottom-dwelling invertebrates, certain fishes, migratory waterfowl, colonial waterbirds, songbirds, and mink. Abundance of certain nonindigenous plants and animals have increased recently.

Prior to 1973, dredge-spoil deposits were often placed by the dredge at the nearest available point to reduce costs. This was detrimental to marsh areas that have become covered with sand. The sand flowed directly into the marsh from the discharge pipe, or it was carried there by normal currents, floods, or by the wind. Slough openings were closed and spawning beds and food producing areas were covered with sterile sand. Many acres of forest were killed or stunted by the deposits. The above changes were continual, accumulative and, in most cases, irreversible.

Many channels of the river have been intercepted by flood levees, railroads, highways, and barrier islands of dredge spoil. Such channels stagnate in the summer and the deeper ones stratify thermally. The rich organic ooze, which collects on the bottom, consumes oxygen from the lower stratum of water until it becomes a death zone. Most forms of life, clams included, fail to live in such areas. Because of the lack of circulation in such areas, organic matter accumulates rapidly on the bottom under anaerobic conditions. The isolated channels, which have become extremely rich eutrophic lakes, now have bottoms consisting of deep deposits of unproductive organic ooze.

Towboats scour the channel with their propellers, increase turbidity, erode shorelines, and entrain and impinge fish. Their barges pose the threat of toxic spills and may damage riparian and littoral habitats at fleeting areas.

Floodplain forests

As it relates to forest communities, the floodplain is defined as that area of a river valley covered with materials deposited by floods. Floodplain forests benefit the riverine ecosystem in many ways. They serve as rich habitats for fish and wildlife during floods. They reduce soil erosion, improve water quality, and beautify and diversify the landscape. Fallen leaves that arise from the floodplain or wash in from the tributaries are an important energy source that fuels complex food webs that culminate in organisms as diverse as mayflies, walleyes, and eagles.

Floodplain forests in the Upper Mississippi River valley are now confined to a riparian zone a few kilometers wide at most. By 1989 the proportion of the Upper Mississippi River valley covered by forest had decreased spatially from upstream to downstream as follows: 18.9% between Minneapolis, Minnesota, and Bellevue, Iowa; 13.5% between Bellevue and Alton, Illinois; and 7.3% downstream from Alton. In many reaches, especially downstream from Bettendorf, Iowa, most of the remaining floodplain forest occurs on islands. The floodplain forest of today represent only a small portion of presettlement forests. Floodplain forests decreased rapidly in the 1800s because of the conversion to agricultural land and the harvesting of trees for fuel and lumber.

In northern reaches, floodplain tree species include silver maple, willow, cottonwood, elms, green ash, and river birch. Pin oak, bur oak, and swamp white oak may dominate well-drained higher grounds and terraces. Common associates include shagbark hickory, bitternut hickory, box elder, and mulberry. The complex understory includes small tree species, shrubs, and poison ivy. Frost grape and poison ivy may climb 30 feet into the trees. Wood nettles are the most conspicuous herbaceous plants.

In southwestern Illinois, the floodplain forests include swamp cypress communities dominated by bald cypress. The ground cover of the floodplain forest includes tree seedlings and herbaceous plants - especially wood nettles.

Recently, large floodplain forest areas are recovering from the great Midwest flood of 1993. While most floodplain trees can survive inundation for a week or two, prolonged flooding can be deadly for species like pin oak and hackberry that require well-drained soils.

Changing species composition of floodplain forests

The composition of dominant tree species in floodplain forests of the Upper Mississippi River has changed considerably in the last 200 years. American elm declined markedly after 1960 because of Dutch elm disease. Eastern cottonwood, green ash, and oaks (mainly pin, swamp white, and bur oaks) have become less abundant, compared with silver maple. During early European settlement, the floodplain forests at the tristate border of Iowa, Minnesota, and Wisconsin were codominated by green ash and silver maple. Floodplain forests at the confluence of the Mississippi and Illinois rivers, codominated by hackberry, elm, pecan, willows, and eastern cottonwood during early European settlement, are now dominated by silver maple. Similarly, eastern cottonwood and sycamore dominated floodplain forests just upstream from the mouth of the Ohio River during early settlement times but are now dominated by silver maple and willow. The amount of floodplain forest in pioneering and transitional successional stages has decreased greatly, and much of the present floodplain forest in the Upper Mississippi River valley is mature.

Many species, such as hackberry, pecan, elm, willow, and cottonwood have decreased in abundance since presettlement. This indicates that reproduction and/or establishment of these species is poor. This is probably due to a lack of suitable site conditions due to effects of impoundment, as well as to a lack of an abundant seed source due to past logging activities. These species probably will continue to decline in importance in the floodplain forests. Floodplain forests through the entire Upper Mississippi River are increasingly lacking in diversity, trending toward forests dominated by silver maple.

The silver maple, a fast-growing swamp species that may attain a height of 120 feet, is well adapted to dominate the floodplain forest. Its shallow root system enables it to flourish in moist soils, but it also does well on drier sites. It has a wide tolerance to temperature extremes and is abundant throughout the entire Upper Mississippi River all the way north to the river's source in northern Minnesota. It is relatively shade tolerant and can withstand prolonged submersion during floods. If cut by loggers or beavers, it clones readily from the stump, creating multiple trunks. If partially buried by sediment, it develops adventitious roots. It blooms early in the spring, long before leaves appear, sometimes while there is still ice on the river. Winged seeds mature in late spring and are spread by the wind, but also by river currents during the usual "June rise." As river levels drop, the seeds may be stranded on fresh sediment deposits where they germinate at once and, like a ring in the bathtub, show how high the water was. They also germinate on the forest floor, where they may persist for years in dense stands of stunted seedlings, waiting in reserve for a sunlit opening to be created by the demise of a tree of the overstory. Once an opening is created, they grow rapidly. The loss of elms due to Dutch elm disease opened new habitat for silver maples during the last 40 years. Unlike the silver maple, willow and cottonwood are not shade tolerant and require new sediment deposits and sunlight to flourish.

Extreme flooding during a single growing season can severely disturb floodplain forests. Such disturbance through flooding was illustrated by the effects of the Flood of 1993, a year when unusually heavy, persistent rainfall caused extreme flooding that lasted from early spring through much of the growing season along a significant portion of the Upper Mississippi River. The Flood of 1993 caused substantial tree mortality in the floodplain forests, particularly in the lower reaches of the Upper Mississippi River. In general, young trees were more vulnerable to flooding than older trees. For older trees, the longer the flood the greater the mortality.

The mortality of trees and saplings due to flooding also varied greatly among species. The least flood-tolerant trees were hackberry, Kentucky coffeetree, sugarberry, river birch, and white mulberry. Pin oak, silver maple, American elm, and slippery elm were moderately tolerant. Sycamore, hawthorn, green ash, black willow, swamp white oak, and eastern cottonwood were most tolerant. The effects of the Flood of 1993 on floodplain forests along the Upper Mississippi River are expected to persist for decades.

Aquatic vegetation

The following is excerpted from a paper written by William Green on ecological changes within the Upper Mississippi River Fish and Wildlife Refuge since inception of the 9-foot channel.

The Upper Mississippi River valley is unique in its flora and fauna. It enjoys conditions not generally associated with its geographic location. What has been referred to as a "pseudo-Carolinian zone" extends north along the Mississippi into the Alleghanian Zone. Thus, refuge flora and fauna, although primarily Alleghanian, have representatives of Carolinian species as well as occasional Canadian forms. A feature making the refuge even more interesting is the overlapping of eastern and western *species and subspecies. There are also several high "sand prairie" areas scattered along the length of the refuge, offering habitat conditions normally found much farther west. These sand areas reach elevations high enough to protect them from severe floods, and consequently have developed a flora very distinct from that of the true flood plain, with plants of dry upland prairie predominating.*

River bulrush, which was the most common marsh species prior to impoundment, has continued to be an important marsh plant. Coming in dense, solid stands for several years following impoundment, this species deliquesced for a few years, but has since made a comeback and is at present an important marsh species, especially for muskrats. Although this species seldom sets seed to any extent on the river, there have been years when it seeded heavily, and then it was of considerable value to waterfowl also.

Emergent and submersed aquatic plants were present but not abundant in the Upper Mississippi River before the locks and dams constructed during the 1930's flooded thousands of hectares of former agricultural areas, lowland hardwood forests, and shallow marshes. The creation of navigation pools abruptly altered the hydrology of the river; similarly, the diversity, abundance, and distribution of aquatic plant species changed markedly in the decades after impoundment. The downstream reaches of the newly created pools provided stable habitat for aquatic plant species. In midpool regions, conditions after impoundment were also favorable to marsh vegetation. Upstream reaches, in contrast, remained similar to their preimpoundment conditions.

Extensive, dense beds of water smartweed developed in the year after impoundment, often in such dense beds that the bottoms took on the reddish tinge of the blooms. The smartweed remained productive for about 5 years. Thereafter, remnant stands were sterile and reproduced only vegetatively. Eventually, water smartweed was replaced by various species of pondweeds, mostly longleaf pondweed and sago pondweed.

The abundance of submersed plants changed notably after drawdowns of water in several pools during the winters of the early 1940's. Pool 8, for example, was drained from 1 January to 15 February 1944 and from 10 January to 15 March 1945. Although Congress ended this practice by the passage of an Anti-Drawdown Law in 1948, the lower water levels apparently stimulated the germination of seeds. The most common submersed plants to become established during this period were long-leaf pondweed, sago pondweed, narrow-leaf pondweed, flatstemmed pondweed, curly leaf pondweed, coontail, elodea, water star grass, and wildcelery. Of these, long-leaf pondweed was most abundant and most widely distributed, occurring in habitats ranging from shallow water to deep, flowing channels.

Wildcelery, which produces a vegetative tuber important as food for migratory waterfowl, became the dominant submersed plant around 1960 in much of the river between Pools 4 and 19. No stands of water smartweed were identified, indicating a marked change in species composition since the 1940's. In lower Pool 8, wildcelery contributed nearly 50% of the relative biomass of submersed plant species in 1975. Most of the remaining 50% of biomass was collectively contributed by coontail, long-leaf pondweed, water star-grass, sago pondweed, and elodea.

Until the late 1980's, a submersed plant community dominated by wildcelery covered large areas of lower Pool 8 and Lake Onalaska (Pool 7). The wildcelery beds were maintained by production of overwintering buds that emerged each spring. By early summer, wildcelery beds were well established and so dense that they significantly affected the hydrology and water quality of the lake. The perimeters of the beds functioned as a sediment screen, making the water inside the beds normally quite clear. Submersed plants grew in all areas of the lake where water was less than 2 meters deep. Several other submersed plants were common in these beds, including water star-grass, sago pondweed, Richardson pondweed, narrowleaf pondweed, flatstemmed pondweed, curlyleaf pondweed, and Eurasian watermilfoil.

The abundance of many submersed plants, including wildcelery, declined markedly in much of the Upper Mississippi River in the late 1980's and continued to decline through 1994. This decline coincided with the severe midwestern drought of 1987-1989, which affected water quality in the Upper Mississippi River.

In Lake Onalaska (Pool 7), the abundance of wildcelery changed little during 1980-1984 but declined greatly after the extremely dry, hot summer of 1988. Most of the submersed vegetation, mainly wildcelery, disappeared in Lake Onalaska during 1988 and 1989 after the plants failed to produce winter buds during the late summer and fall of 1988.

The declines of submerged aquatic plants were observed throughout the Upper Mississippi River. Large beds of submersed vegetation also disappeared in the lower half of Pool 19, where plant beds dominated by wildcelery, water star grass, sago pondweed, and coontail had generally been expanding since the 1960's. In early September

1990, small patches of Eurasian watermilfoil were the only submersed vegetation found in the lower half of Pool 19.

Today, much of the area formerly occupied by wildcelery remains unvegetated, although Eurasian watermilfoil, a nuisance nonindigenous species, now occupies some of the shallower sites. The abundance of Eurasian watermilfoil has seemingly increased since the mid 1980's. In Pools 8 and 13, monotypic beds of Eurasian watermilfoil have been found near areas where wildcelery had occurred. In Pools 4-8, 13, and 26, Eurasian watermilfoil is occasionally found near or with other submersed plants, including sago pondweed, wildcelery, and coontail.

The recent decline in submersed plants in the Upper Mississippi River coincided with the severe drought of 1987-1989. Although information on drought-related conditions in the river is limited, a number of potential causes have been identified. Blooms of planktonic or attached algae during the drought, particularly in the summer of 1988, may have severely limited the depth to which sufficient light penetrated the water column to support the growth of rooted aquatic plants. High concentrations of dissolved nutrients in water, retained in backwaters because of extremely low flows, and abnormally high solar radiation during the drought may have stimulated the production of epiphytes or planktonic algae, thereby reducing light penetration in the water column. Concentrations of orthophosphorus at several main-channel sites were high during the summer of 1988, possibly contributing to the prolific bloom of the blue-green alga Aphanizomenon. The bloom extended from Lake Pepin (Pool 4) to Pool 11.

Conversely, there is evidence that submersed aquatic plants may benefit from conditions caused by moderate drought. During summer 1985, for example, water clarity markedly increased in Pool 8 in apparent response to reduced runoff caused by a summer drought, and the mean depth of the light zone during that growing season increased to 1.3 meters. That summer, the distribution of submersed plants, including wildcelery and Eurasian watermilfoil, increased in Pool 8 in apparent response to the increased availability of light. Similar increases in submersed aquatic plants occurred in 1977 in Pool 19, coincident with a period of increased water clarity, low flow, and stable water levels during spring and summer.

The availability of sediment nutrients may have been reduced by low flows during the drought. The possible depletion of sediment nutrients, particularly nitrogen, during the low flows of 1987, 1988, and 1989, in combination with above-normal water temperatures, may have reduced plant growth and reproduction in some areas of the river.

The reestablishment of submersed aquatic plants in the river may be inhibited by grazing fish, particularly common carp that often forage in beds of submersed plants where they resuspend bottom sediments, increase turbidity, and uproot some submersed plants, particularly species with shallow root systems. Feeding waterfowl, especially tundra swans, uproot vegetation and cause turbidity. Many observers have noted expansive plumes of silt downstream from large flocks of swans that probe deeply with their long muscular necks for duck potatoes buried in the sediments.

The Flood of 1993 also affected the river's submersed aquatic plant communities. During the 1993 growing season, most species of submersed plants decreased in frequency of occurrence at monitoring sites in Pools 4, 8, 13, and 26. The decreases were greatest in Pools 13 and 26, which had more severe flooding than Pools 4 and 8. In 1994 submersed aquatic plants had recovered to pre-flood frequencies in Pools 8 and 13, but not in Pool 26, where the duration and magnitude of the flood were greatest. Interestingly, the distribution and abundance of wildcelery in Pools 8 and 13 were greater after the flood year than before the flood.

The environmental factors that regulate submerged aquatic plants are complex, interconnected, and poorly understood. Of necessity, most conclusions have been based on anecdotal evidence because Upper Mississippi River aquatic habitats are so vast. Happily, many areas have shown a resurgence of submerged aquatic plants, especially wildcelery, in 1998 and 1999.

Bottom-dwelling macroinvertebrates

Macroinvertebrates include a wide range of invertebrate fauna including adult and immature insects, crustaceans, mollusks, and worms. They inhabit all riverine habitats, including the water column, sand, mud, and the surfaces of rocks, plants, and debris. They occupy the submerged surfaces of manmade structures like locks and dams, bridges, navigation buoys and their anchoring chains, barges, towboats, and pleasure craft. Towboats and their barges are especially important because their rough, rusted hulls are excellent substrate for many species. They transport sedentary species upstream, enabling them to colonize new areas throughout the entire commercial waterway. Modern cruisers and houseboats with smooth fiberglass hulls provide less surface for attachment, but the roughened metal of their propulsion units suffices as substrate for many species. Because they travel long distances, they too can disseminate species throughout the river system.

Adult insects are also transported by watercraft. For example, hordes of Hexagenia mayflies emerging at one locality may be transported over 100 miles on barges before they lay their eggs on the evening following emergence.

Bottom-dwelling macroinvertebrates are called benthos. Because: 1) they are widely distributed, 2) are important as food for fish and wildlife, and 3) can exhibit dramatic community changes when exposed to water and sediment pollution, they are commonly used as indicators of environmental quality. Fingernail clams and burrowing mayflies (e.g. Hexagenia) have been target organisms for most studies. They are important food for migrating diving ducks and coots, as well as many fish species. Unfortunately, macroinvertebrates are laborious to sample, identify, count, and weigh.

Macroinvertebrate communities that live on submerged hard surfaces such as rocks are called epilithic. In the unmodified river they would have been found on the rocks below falls and in rapids, and on cobble sediments in fast-water areas. Rock substrates in the untamed river were scarce. They occurred mainly at the Falls of St. Anthony, and in the rapids at Rock Island and Keokuk. Submerged fallen trees and woody debris were abundant, and provided additional substrate. Before the river's immense clam populations were devastated by commercial exploitation and pollution, the shells of living mussels and dead shells furnished hard substrate for epilithic fauna in a mud and sand environment.

Epilithic communities were enhanced by early channelization projects in the 1878-1912 period that provided immense quantities of rock in the form of wing dams, closing dams, and shoreline protection. Lock and Dam 19 at Keokuk, completed in 1913, and the 9-foot channel dams, completed in the 1930s, provided great expanses of submerged concrete. Their tailwaters created a fastwater rapids-like environment, usually full of huge stones placed there to prevent scouring. Navigation buoys and their anchoring chains, located at regular intervals along the edge of the navigation channel, serve as excellent substrate in the relatively fast current of the tailwaters and in the moderate current of impounded areas. They are especially important for hydropsychid caddisflies, indicators of good water quality. Since about 1995, zebra mussels have increasingly displaced most ipilitheic fauna on most of the aforementioned structures

The construction of Lock and Dam 19 at Keokuk, Iowa, created an interesting combination of habitats for aquatic insects. Prior to impoundment, hydropsychid caddisflies (filter feeders that require swift water and hard substrate) must have thrived in the rocky Des Moines Rapids. Hexagenia mayflies (detritivores that require a muddy substrate for construction of their burrows) were probably not very abundant. When the dam was finished in 1913, creating Lake Cooper and its rich, muddy bottom, Hexagenia mayflies flourished. The rocky tailwaters of the dam, as well as the concrete and steel structure of the dam and powerhouse, provided habitat for hydropsychid caddisflies. Although other river cities have nuisance problems with mayflies, only Keokuk has problems with both mayflies and caddisflies.

For decades, benthic invertebrates were absent or scarce in reaches where water quality was degraded by sewage. The river downstream from the Twin Cities all the way into Lake Pepin, for example, suffered severe oxygen depletion caused by sewage, and pollution-sensitive organisms, such as burrowing Hexagenia mayflies, were absent or scarce. Burrowing mayflies began recolonizing riverine reaches downstream from the Twin Cities in the early 1980's when dissolved oxygen concentrations increased in response to improved wastewater treatment.

In Pool 19, where fingernail clam and burrowing mayfly populations have been tracked for over 20 years, population biomass has been cyclical. Declines in the mid-1970s were followed by recovery in the mid-1980s. Severe declines in the late 1980s were followed by recovery after the 1993 flood.

Native freshwater mussels (clams)

The Upper Mississippi River is one of a few large rivers that still has a substantial freshwater mussel fauna. Their abundance and species richness in the Upper Mississippi exceeds that of many other midsize to large North American rivers. Historically, about 50-60 species of freshwater mussels have been documented in the Upper Mississippi River-Illinois River System, but only about 30 species have been found recently. Because they are sedentary, long-lived and pollution sensitive, their decline reflects past abuse of the river.

Commercial exploitation of freshwater mussels was greatest in the late 1800s and early 1900s. The pearl button industry began in 1889 when the German button maker John Boepple pioneered the use of the Mississippi's freshwater mussel shells. By 1898, 49 button-making plants in 13 river cities employed thousands of people and processed thousands of tons of mussels. First centered around Muscatine, the industry spread to Keokuk, Prairie du Chien, La Crosse, Lake Pepin, and other areas. Harvests declined as pressure on the resource increased, and the industry failed rapidly after 1930. The advent of plastic buttons hastened its demise.

The decline of clam species richness in the Upper Mississippi River mirrors a broader continental pattern. Almost half of the 292 pearlymussel species in North America are either extinct or at serious risk of extinction. Factors contributing to these declines include habitat modification and degradation, pollution, over-harvest, commercial and recreational navigation, and the recent invasion of exotic zebra mussels.

Fingernail clams

Populations of fingernail clams have declined in certain reaches during recent decades. Significant declines were evident in five of eight pools examined along the reach of river from Hastings, Minnesota, to Keokuk, Iowa. Densities in Pool 19, which had the longest historical record on fingernail clams, averaged 30,000 per square meter in 1985 and decreased to zero in 1990. The declines of fingernail clams occurred chiefly during low-flow periods associated with drought.

Fingernail clam population declines do not seem to be directly linked to the periodic depletion of dissolved oxygen that occurs in backwater areas. Although fingernail clams are much more tolerant of low dissolved oxygen concentrations than are burrowing Hexagenia mayflies, they have not readily recolonized the reaches recolonized by Hexagenia mayflies. Their subsequent slow rate of recolonization was seemingly caused by the uninhabitability of bottom sediments-perhaps due to the presence of one or more toxic substances. Fingernail clams are sensitive to many toxicants, including un-ionized ammonia.

Recent studies by the U.S. Geological Survey have shown that surficial sediments add considerable amounts of nitrogen to the reach of the Upper Mississippi where populations of fingernail clams have declined. The production of ammonia by microbial decomposition in the sediments would presumably be increased by the conditions of high temperature and nutrient enrichment associated with low-flow, drought periods. High microbial activity (decomposition), stimulated by high temperature and an abundant supply of organic matter, would greatly increase the concentration of toxic ammonia in the sediments, possibly causing episodic toxicity in fine-grained sediments during periods of drought and low flow..

Hexagenia mayflies

Impoundments have provided habitat for Hexagenia mayflies that thrive in areas where there is a silt bottom and well-oxygenated water. There is no doubt that Hexagenia mayfly populations have increased because of Lock and Dam 19 and the dams of the 9-foot channel project. The insects are a nuisance to most people, but are excellent fish food organisms, as reflected in fish abundance. However, as pool areas and backwaters are lost to sedimentation, Hexagenia populations will decrease.

Fishes

The fossil record shows that the Mississippi River has long provided suitable habitat for many fishes, some of ancient lineage. Although major changes in climate, including the Pleistocene glaciations, have occurred, there have been few fish extinctions. Most fishes probably retreated ahead of southward-moving glaciers and repopulated northern reaches of the basin as the glaciers receded. An estimated 67 fish species inhabit the Headwaters, and an estimated 132 species inhabit the Upper Mississippi River.

The Upper Mississippi River provides many aquatic habitats, including main channel, tailwater, main-channel border, side channel, navigation pool, floodplain lake or pond, slough, and tributary mouth. These habitats can differ markedly in current velocity, depth, temperature, water quality, bottom substrate, vegetative structure, food resources, and other characteristics. The main channel has a swift current, coarse-sand or gravel substrate, and deep water. Tailwaters, which extend about 0.8 kilometers below each dam, have well-oxygenated water, rapid currents, and coarse substrates. Walleye, sauger, white bass, freshwater drum, and catfishes concentrate in these tailwaters. Dike fields (wing dams) along the main-channel border provide rocky substrates where walleye, sauger, channel catfish, smallmouth bass, white bass, black crappie, bluegill, redhorse, freshwater drum, and smallmouth buffalo concentrate. Main-channel borders have multiple substrates, including silt, sand, wing dikes, snags, and riprap. Abundance of fishes in main-channel borders varies with season and river stage. The flow of side channels links them to other habitats during most of the year, and these channels are used by many species. Nearshore zones in main-channel borders, side channels, and pools provide important nursery areas for many fish species, especially including bluegill, crappie, and largemouth bass.

Most fishes require several different habitats to complete a life cycle. The quantity and quality of certain habitats, however, have diminished in many reaches. Overwintering habitats for fish have declined as sedimentation reduces water depth. Recent die-offs of aquatic vegetation have reduced the suitability of many areas as nursery habitats for fishes. In many places, declines of invertebrate prey organisms associated with soft bottom sediments and aquatic vegetation have diminished food resources for fishes.

Lack of suitable winter habitat is a threat to bluegills, crappies, and largemouth bass in ice-covered northern reaches of the Upper Mississippi. Bluegills and crappies require off-channel areas where water temperatures exceed 34 degrees F (1 degree C), current velocities below 0.4 inches per second (1 cm per second), and dissolved oxygen above 2 ppm (mg/L).

Ice fishermen are experts at exploiting sunfish, crappie, and largemouth bass populations in overwintering habitats, some of which may be smaller than one-fourth acre. An army of prospectors sets out to find these sanctuaries in early winter when the ice is barely thick enough to support their weight. Most of them hike to get there, but some use outboard motor boats, airboats, picker boats, and hover craft. When the ice gets a little thicker they employ snowmobiles and all-terrain vehicles. Like seagulls, fishermen converge on the overwintering areas. Armed with sophisticated gear including sonar, ultra-light graphite rods, thin monofilament line, and tiny lures enhanced with insect larvae, they exploit the fish that bite aggressively in early winter. In their portable darkened shelters, they can watch the fish bite if the water is shallow and clear enough. It is unlikely that many overwintering panfish habitats remain unknown to these fishermen.

At first ice, some of the habitats may be less than three feet deep. Water temperatures at the mud surface may be as high as 39 degrees F. because water is densest at 39 degrees F. However, the water temperature right under the ice is 32 degrees because water is least dense at that temperature. By March, the ice may have thickened to three feet in northern pools, especially in winters with little insulating snow. The habitats seldom freeze to the bottom, but the space under the ice may be scarcely deeper than the fish are tall. Light penetration decreases as the ice thickens, especially if heavy snows cover it. Lessened photosynthetic activity results in decreased levels of dissolved oxygen. To make matters worse, heavy snows may depress the ice, causing water to ooze upward through cracks, creating translucent slush that further decreases light penetration and dissolved oxygen concentrations. The fish become lethargic and refuse to bite, but they may still be curious enough to scrutinize lures. Sometimes the fish succumb on site, but they most often vacate their sanctuaries, often entering areas where increased current further stresses them.

In most fish, the production of disease-fighting antibodies falls off at winter temperatures, and after a prolonged winter, stressed fish are doubly susceptible to bacterial infections. Their deaths usually go unnoticed because the spring ice has become too rotten for most observers. The crows, eagles, ospreys, and gulls quickly clean up the mess.

Below St. Louis, levees have isolated the river and its fisheries from its floodplain in most areas. Levees have encouraged development, and, as a result, fisheries habitat behind levees has been drained and filled. Flood control works have greatly decreased the amount of floodplain available as nursery, spawning, and feeding habitat. Further, many floodplain lakes have been isolated from river overflow and no longer serve as habitat for river fishes.

Mississippi River dams are hindrances to fish migration, and none of them have engineering works designed to allow fish passage. Lock and Dam 19, the oldest navigation dam on the Upper Mississippi River, also has a hydroelectric power Plant. It creates a formidable obstruction for migrating fish because it has a head of about 40 feet, and water must flow either through the dam via turbines or over the top of the regulatory gates. The first documentation of the dam's impact on river ecology was the blocked migration of the skipjack herring, the only known host of the larvae of the ebony shell mussel which has consequently been nearly eradicated above Lock and Dam 19. Some fish may pass through the dam during lockage.

Recent evidence establishes that some species do migrate through other navigation dams, most of which have roller gates that cause water to flow under the gates rather than over the top. Dams may have blocked lake sturgeon spawning movements, but the length of the sturgeon's immature life (18-20 yr.) and its susceptibility to nets and boat propellers have also been important to its decline. The same may be true for paddlefish, which frequently swim near the surface and therefore seem especially vulnerable to propellers.

Completion of the locks at St. Anthony Falls in 1963 provided access for all species previously excluded from the Headwaters, and the dam at Coon Rapids, Minnesota, completed in 1906, is now the principal migration barrier and serves to maintain distinct fish communities in the Upper Mississippi and Headwaters.

Anoxic zones have also served as barriers to fish movement. Lock and Dam 1, completed in 1917, collected most of the raw sewage of Minneapolis and St. Paul. Lock and Dam 2, completed in 1930 at Hastings, accumulated the remainder of the Metro sewage and that of the suburbs, packinghouses, and stockyards. The Bureau of Fisheries reported that during August of 1927, 73 km of the river below St. Paul lacked sufficient oxygen to sustain fish life of any kind. Although navigation dams did not cause the pollution problem, they exacerbated the situation and focused attention on the deteriorating quality of the water. A sewage treatment system built in 1938 improved water quality, and most fish species could again live in the reach below St. Paul.

Flooding

Flood stages have increased along the Middle Mississippi River due mainly to contraction of the high water channel by dikes and loss of floodplain capacity due to leveeing and development. Ironically, present day river elevations during low flows are lower than they were in the pre-modification days, mainly due to scouring of the low-water channel by wing dikes. River stage fluctuates as much as 50 feet annually, effectively dewatering some secondary channels during low flow.

Man's physical impact on the Upper and Middle Mississippi River was dramatically and tragically illustrated in the great flood of 1993, reported in the media as a 500-year flood. Actually, the greatest flood in history at St. Louis was in 1844 when the river's flow was about 1,300, 000 cfs and the crest (stage) was 41.3 ft. In 1993, the peak flow was only about 1,000,000 cfs, but the crest was 48.58 ft.

Sedimentation

Today, many tributaries (especially the Chippewa) flow through extensive deposits of glacial alluvium that stand poised and ready to wash into the Mississippi. With the notable exception of the Illinois River, most tributaries of the Mississippi have steeper gradients than the master stream, and they deliver sediments faster than the Mississippi can remove them, causing the valley to aggrade. The agricultural activities of man in the watershed and construction projects on the river floodplain have accelerated the process.

When the 9-foot channel impoundment were created in the 1930s, they also impounded the lower reaches of tributaries that entered in the downstream portions of pools. This hydraulic damming action reduced tributary gradients, causing their beds to be raised. Reduced current velocity resulted in deposition of sediments, causing formation of deltas and new wetlands in the lower reaches of tributaries.

The construction of Lock and Dam 19 in 1913 exacerbated natural sedimentation rates. Sediment accumulations in Pool 19 have been extreme, with about 36 feet of sediment deposition occurring in one area since 1891 (1 1/2 miles upstream from Lock and Dam19 near the Illinois shore. This high rate is not representative of the entire river, and the rate of accumulation has decreased with time.

Sedimentation is among the most critical ecological problems in the UMR. Various studies have predicted that the ecologically productive backwaters will fill and disappear within 50-100 years. Sedimentation studies are complex, expensive, and are usually limited to relatively small sample areas. Anecdotally, I have seen many of my prime fishing and hunting areas of Pools 5, 5A, and 6 degrade and disappear in 40 years. Numerous channels that accommodated houseboats in the 1960s can now scarcely handle fishing boats. The loss of channels and marshes is seldom, compensated by the natural creation of new ones. Increasingly we see airboats being employed, as well as Louisiana-style "digger boats" that can not only handle extremely shallow water, but can tear open new channels through soft sediments and semi-terrestrial habitats, creating new problems.

In general, waves and currents redistribute sediments, eroding shallow areas and filling deeper areas, thus simplifying bottom topography. As islands erode and disappear, the wind has a longer fetch that causes allowing waves to build, resuspending soft sediments, increasing turbidity, and limiting aquatic plant growth. When redeposited, flocculent bottom sediments provide an unstable substrate for rooted aquatic plants that may be torn up by wave action or ripped out by ice in the spring. In most pools, the general trend in the rich mosaic of habitats is toward monotony.

A classic example of this is the Weaver Bottoms twelve miles upstream from Winona, where the Whitewater River, a notorious sediment contributor, created a huge delta and expansive wetlands in historic time.

The pools differ in their ability to transport sediment, depending on sediment input of tributaries and land use. In LTRMP studies of Pool 13 in 1995, for example, 97% of flow and 67% of sediment came from mainstem sources. Pool 13 exported nearly all the sediment that came from upstream sources.

The Missouri River, which drains the Great Plains Region, is the Mississippi's largest tributary, and it greatly alters the unimpounded Mississippi River below St. Louis. It drains 74% of the Upper Mississippi River Basin and supplies about 40% of the long-term discharge below St. Louis. Its drainage area is more than twice that of the Upper Mississippi River above St. Louis, and its suspended load is more than double that of the Upper Mississippi River.

At St. Louis, the sediment load of the Mississippi has declined 66% from pre-1935 levels, mainly due to sediment entrapment in Missouri River impoundments. Today, the Middle Mississippi receives about 80% of its average suspended sediment load from the Missouri and about 20% from the Upper Mississippi. Suspended sediment load of the Mississippi at St. Louis averages 47% clay, 38% silt, and 15% sand. Bed material is approximately 70% medium-to-coarse sand.

REFUGES

Primarily because of the enthusiastic sponsorship of the Izaak Walton League, the United States Congress on June 7, 1924 authorized appropriations aggregating $1,500,000 for purchase of Mississippi bottom lands on a willing seller basis to be administered as the Upper Mississippi River Wildlife and Fish Refuge. The refuge, which was originally intended primarily as a refuge primarily for protection of smallmouth bass, extended from the foot of Lake Pepin to Rock Island, Illinois.

By 1930, the Upper Mississippi River Wildlife and Fish Refuge encompassed about 87,000 acres of flood plain land. The 9-foot channel project enabled the U. S. Army Corps of Engineers to condemn land to obtain flowage rights and it became obvious that it was needless for federal wildlife interests and federal navigation interests to compete for land. Consequently, the Bureau of Sport Fisheries and Wildlife gave the U.S. Army Corps of Engineers flowage rights on refuge land in return for wildlife management rights on land owned by the Corps. By this means, the Upper Mississippi River Wildlife and Fish Refuge was increased to about 195,093 acres.

Today, the UMR contains three National Wildlife Refuges: UMRWFR - 78 975 ha (1924); Trempealeau National Wildlife Refuge - 4 415 ha (1943); and Mark Twain National Wildlife Refuge - 13 090 ha (1958). Today, their major emphasis is migratory waterfowl management rather than fish management as envisioned by the Isaak Walton League.

HABITAT MANAGEMENT AND MITIGATION

Beaver, which had been trapped to near extinction before the turn of the century, were experimentally introduced at various points in the Upper Mississippi River Wildlife and Fish Refuge during the late 1920's. One small colony established in 1929 had increased to about 100 individuals four years later. Beavers are now abundant throughout the refuge.

An interesting beaver-managed area lies on the Minnesota-Iowa border where Winnebago Creek enters Pool 9 from the west. Because Pool 9 is 31 miles long, this upper reach does not lie within the permanently impounded portion of the pool, and water levels fluctuate wildly, sometimes within 24 hours, depending on how many gates on L&D 8 are open. The delta of Winnebago Creek is laced with tributaries that are dammed by beavers. Some of the interconnected low-head dams are over one-half mile long. Together they create about a square mile of rich, heavily vegetated, shallow ponds that are prime habitat for wood ducks, teal, mallards, widgeon, herons, great egrets, mink, muskrats, and raccoons. When the gates of Lock and Dam 8 restrict river flow, and most of the tailwaters reach below the dam has been reduced to a mudflat, the ponds remain brimming with water like oases in a sea of mud. The beaver are, without doubt, the most cost effective habitat managers on the UMR. They work the night shift, industriously and unobtrusively cutting trees for food and building materials, as they build and maintain their dams and lodges. In the process they manage the marsh and the floodplain forest. They are on call 24 hours per day, but receive no wages, vacations, fringe benefits, sick leaves, or coffee breaks. Thankfully, they aren't required to attend meetings, write grant proposals and progress reports, or plead to state and federal governments for funding. I doubt if they worry about reciprocity between states.

Prior to environmental legislation of the late 1960s (National Environmental Policy Act), only minor attempts were made to manage MR habitats. Public Law 697, passed in 1948 and known as the Anti-Drawdown Law, was probably the most significant habitat management completed during that period. It ordered the Corps of Engineers to maintain Upper Mississippi River navigation pools "as though navigation was carried on throughout the year. " In earlier years, pools were drawn down in winter to increase capacity for spring floods; the result was devastating losses to fish and wildlife populations.

The Mississippi is the only river in the United States that has been designated for two major federal purposes - commercial navigation and wildlife refuges. Conflicts between these two authorizations and project purposes peaked in the 1970s when growing public support for environmental protection and management led to lawsuits over operation, maintenance (dredging), and expansion of the $2.7 m navigation project. The lawsuits, in turn, led to major interagency studies (GREAT 1, 1980; GREAT 11, 1980; GREAT III, 1982; and UMRBC, 1982). Habitat management and rehabilitation became a major thrust of these studies as biologists proposed new techniques such as opening and rehabilitating backwaters, altering wing dikes and closing dams, using larger rock for revetments, creating islands, protecting shorelines, and evaluating their effectiveness.

THE GREAT STUDIES

GREAT I, II, and III

The Great River Environmental Action Team (GREAT) formed in 1974 through the efforts of the Corps of Engineers, Fish and Wildlife Service, and the Upper Mississippi River Basin Commission. They created a partnership to work out a long term management strategy for the River's multi purposes. The Team was composed of representatives for the five river basin States and the five resource-oriented Federal Agencies. They operated under the authority of the Upper Mississippi Basin Commission. The Team established in 1974 studied the river from Minneapolis to lock and Dam 10. It was called GREAT I. GREAT II was organized in 1976 and studied the river from lock and dam 10 to Saverton, Missouri. GREAT III was organized in 1977 and studied the area from Saverton to the mouth of the Ohio River. The studies focused on several objectives:

- Develop ways to significantly reduce the volume of dredged material removed for the navigation project.
- Open backwaters that have been isolated from freshwater flow as a result of navigation maintenance.
- Ensure the capability to maintain the total river resources on the Upper Mississippi River.
- Contain or stabilize all floodplain dredged material placement sites to benefit river resources
- Assure that all navigation project authorizations include fish, wildlife, and recreation as project purposes.
- Develop physical and biological base-line data to identify factors controlling the river system.
- Identify sites that can be developed to provide for fish and wildlife habitat irretrievably lost to water development projects.
- Identify and develop ways to use dredged material as a valuable resource for productive uses.
- Implement programs to provide for present and projected recreation demands on the river system.
- Strive to comply with Federal and State water quality standards.
- Strive to comply with Federal and State floodplain management standards.
- Develop procedures for ensuring an appropriate level of public participation.

The GREAT organizational structure was typical of intergovernmental river institutions, it was large, complicated and had diverse representation. It had representatives from the States of Iowa, Minnesota, Illinois, Wisconsin, and Missouri, the Fish and Wildlife Service, Corps of Engineers, Environmental Protection Agency, Department of Transportation, Soil Conservation Service, the Minnesota-Wisconsin Boundary Area Commission, and the Upper Mississippi River Conservation Committee. Its organizational structure was bilateral. On one side the Chief of Engineers was over the North Central Division, who oversaw the District Corps of Engineers offices. On the other side, the Water Resources Council, was over the Upper Mississippi River Basin Commission, which oversaw the Great River Study Committee. Both chain of commands oversaw the specific GREAT study teams. Each study team also had and Internal Overview Committee. The Study Team then sat over a Plan Formulation Work Group, which oversaw the Functional Work Groups. The Functional Work Groups consisted of, Commercial Dredging Requirements, Dredged Material Uses, Fish and Wildlife Management, Floodplain Management, Material and Equipment Needs, Public Participation and Information, Recreation, Sediment and Erosion, Side Channel, and Water Quality.

The GREAT studies resulted in volumes of results and recommendations. It resulting in a major change in the management of dredged material, its placement and beneficial use. Today river communities utilize dredge material as a principle source of sand for road construction, road maintenance, and building construction. In some areas secondary uses of dredged material exceed its availability. The studies elevated and focused both public and governmental concern over the river and the management of its ecological components. It highlighted the problems of sedimentation resulting from watershed and agricultural practices, and the resulting habitat losses within the floodplain. It systematically laid out the problems, their causes, and management needs. In all, it was a successful government partnership both in its management and informational outcomes. It was the foundation for the next major partnership effort, the Master Plan.

The Master Plan

In 1968, the District Engineer of the St. Louis District, Corps of Engineers office recommended replacement of the locks at Dam 26. It recommended construction of a new dam and 1200 foot locks at Alton Illinois. This project was approved the Corps of Engineers and it received several appropriations through 1975. On August 6, 1975, the Izaak Walton League, the Sierra Club, and 21 western railroads filed lawsuits to prevent the Corps from beginning construction of the locks and dam 26. The suit contended that the Corps did not receive due Congressional authorization, the environmental impact statement did not consider system effects, and that the Corps had ignored the objectives of the national economic development and environmental quality requirements, improperly and inadequately assessed project costs and benefits, and failed to consider feasible alternatives. Major national and congressional debate followed these actions. On October 21, 1978, President Carter signed into law the Inland Waterways Authorization Act, which authorized the construction of locks and dam 26, established an inland waterway user tax, and directed the Upper Mississippi River Basin Commission (UMRBC) to prepare a Comprehensive Master Plan for the Management of the Upper Mississippi River.

The Master Plan was to include:

- Identify the economic, recreational, and environmental objectives of the Upper Mississippi River System.
- Recommend guidelines to achieve such objectives.
- Propose methods to assure compliance with such guidelines and coordination of future management decision.
- Include any legislative proposal which may be necessary to carry out such recommendation and achieve such objectives.
- Define the navigation carrying capacity of the Upper Mississippi River Systems.
- Define the relationship of capacity expansion to national transportation policy.
- Define the effect of expansion of navigation capacity on the railroads.
- Define the transportation costs and benefits to the nation from expanded navigation capacity.
- Define the economic need for a second lock at Alton.
- Define the systemic ecological impacts of present and expanded navigation capacity on fish and wildlife, water quality, wilderness, and recreational opportunities.
- Defined the means and measures to prevent such impacts.
- Define the immediate environmental effects of a second lock at Alton.
- Define the benefits and costs of disposing of dredged material in areas outside of the floodplain.
- Develop a computerized analytical inventory and analysis system.

The UMRBC responded by creating a management framework and Action Plan. The framework had the Commission overseeing its implementation by the Great River Study Committee. The Committee formed work teams for specific study responsibilities. They included the Environmental Studies, Navigation/Transportation, Dredged Material, Computer Inventory and Analysis, and Public Participation and Information Work Teams. The resulting plans and recommendations were published in the

Comprehensive Master Plan for the Upper Mississippi River System on January 1, 1982. The Master Plan recommended:

- authorization of the 600 foot second lock at Lock and Dam 26;
- Congress exclude the second lock from further action under the National Environmental Policy Act of 1969;
- immediate action to reduce erosion rates to tolerable levels; a habitat restoration program;
- a long term resource program;
- immediately implement a computerized river information center,
- implement a program of recreation projects and assess the economic benefits of recreation to the UMRS;
- increase the capacity of the navigation sysem through implementation of non-structural and minor structural measures;
- update traffic projections,
- verify lock capacities, and refine justifications for future expansion;
- continue implementation of current GREAT I disposal recommendations;
- develop a State and Corps of Engineers coordination program to develop economically feasible and productive uses of dredge material;
- finally, the States should develop a coordinative arrangement to maintain coordination and management activities for water and related land resources within the UMRS.

The five UMR States, Minnesota, Wisconsin, Illinois, Iowa, and Missouri formed the Upper Mississippi River Basin Association following the end of the UMRBC. The UMRBA provides a forum for its members to discuss issues related to river management and advocate consensus positions to Congress. The UMRBA also invites Federal Agencies to participate as non voting members. The UMRBA also plays an important role in coordinating the Environmental Management Program.

THE ENVIRONMENTAL MANAGEMENT PROGRAM

Public Law 99-662 (1986) designated the Upper Mississippi River System as a nationally significant ecosystem and a nationally significant commercial navigation system. It also authorized a $124.6-M, 10-yr habitat rehabilitation and enhancement program for the Upper Mississippi River as part of a larger $190-M Environmental Management Program for the Upper Mississippi and selected navigable tributaries. The program is being implemented through an interagency (state and federal) effort. General program oversight is governed by the Environmental Management Program Coordinating Committee (EMPCC), made up of many UMRBA members, the Corps of Engineers, the Fish and Wildlife Service, U.S. Geological Service, Department of Transportation, Department of Agriculture, and Coast Guard. This group meets quarterly, usually in conjunction with the UMRBA meetings, due to the broadly shared membership. The EMPCC oversees the program, its adherence to its operating plan and annual work plans, and provides management priority recommendations to the Corps of Engineers. An EMPCC subgroup is the Analysis Team (A-Team). The A-Team is the field, biologists level advisory group that provides informational needs definitions to the Long Term Resource Monitoring Program.. They advise the Program manager on program priorities, which are subsequently integrated into the Program's annual work plan.

The Program covers the Upper Mississippi River system, which is defined as the commercially navigable portions of the Mississippi River north of Cairo, Illinois: the Minnesota, Black, St. Croix, and Kaskaskia Rivers, plus the Illinois River and Waterway. St. Paul District projects are located along the Mississippi River from Guttenberg, Iowa, to Minneapolis-St. Paul, Minnesota (about 250 river miles). Projects have included backwater dredging, dike and levee construction, island creation, bank stabilization, side channel openings and closures, wing and closing dam modifications, aeration and water control systems, waterfowl nesting cover, acquisition of wildlife lands, and forest management.

Habitat Rehabilitation and Enhancement Program

The Habitat Rehabilitation and Enhancement Program (HREP) builds habitat projects within the EMP boundaries, based on the State and Federally defined resource management priorities. The Program is managed and construction implemented by the Corps of Engineers, Mississippi River Division in Vicksburg, Mississippi. The St. Paul, Rock Island, and St. Louis Districts are each very involved in the management and project development within their respective river reaches. Since 1987 24 habitat projects have been built affecting approximately 28,000 acres. Projects are varied in size, objective, and distribution. Projects are designed to address four main areas of habitat loss or degradation. They are: tributary effects related to increased flood flows and sediment/nutrient transport; decreased floodplain structural diversity, including

Island erosion, sediment deposition, hydraulic training structure effects, and effects of levees; altered hydrology including, flood zone reduction, water level alterations, and river-floodplain connectivity; and water/sediment quality as defined by increased suspended sediment, nutrients, and toxics. The types of project features designed to address these concerns included: backwater dredging; water level management, including dikes and water control structures; Island construction to restore physical conditions necessary for the re-establishment of aquatic vegetation and reduction in wind and wave energy; shoreline stabilization to prevent erosion and to create fish habitat; secondary channel modifications to preserve habitat through reducing sedimentation in backwater areas; aeration to restore aquatic habitat through improved water quality; and physical modifications like potholes, wing dams, and land acquisition. Once project design is completed a monitoring plan is developed and implemented to ensure both pre and post project assessment is completed.

Project monitoring contains several components. The physical responses to the project are assessed to measure effectiveness in meeting the physical project objectives. The monitoring typically includes flow velocity and distribution, water levels, water quality, and sediment transport. Biological response monitoring includes the projects effects on plants, fish, and wildlife. Monitoring responses are evaluated and summarized in the Performance Evaluation Reports. These would include the natural resource managers reports on the project's success.

In general, the HREP has been very successful. Both the public and resource management community believes it is meeting or exceeding its intended objectives. The Program has fostered an environment of cooperation, partnership, and shared vision amongst the resource management community previously only dreamed of. The effectiveness of project features, designs and objectives is also growing as a result of experience, lessons learned, improvement in techniques, and refinement of management processes. The HREP portions of the EMP are truly one of the river's great success stories and "good buys" for both the Government and the people of this Country.

Long Term Resource Monitoring Program

The Long Term Resource Monitoring Program was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. Original authorization provided for a 10-year Program starting in 1987; Section 405 of the Water Resources Development Act of 1990 (Public Law 101-640) extended the Program an additional 5 years.

The Long Term Resource Monitoring Program is being implemented by the U.S. Geological Survey (USGS) in cooperation with the five Upper Mississippi River System states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), with guidance and overall Program responsibility provided by the U.S. Army Corps of Engineers. A directive outlining the mode of operation and the respective roles of the agencies is embodied in a 1988 Memorandum of Agreement.

The U.S. Geological Survey's Upper Midwest Environmental Sciences Center administers both the Long Term Resource Monitoring Program and the Computerized River Information Center components of the Environmental Management Program. Six remote state-operated field stations have been established for data collection. Water levels and quality, sedimentation, fish, vegetation, and invertebrates are being monitored, as well as land cover/use. To document system-wide ecological trends, resource monitoring data are being collected in five separate 25- to 30-mile reaches of the Mississippi River and in one reach of the Illinois River. Scientific guidance is being provided by an international committee of scientists.

Significant resource problems are being investigated, including navigation impacts, sedimentation, water level fluctuation, lack of aquatic vegetation, and reduced fisheries populations.

THE GREAT COORDINATION NETWORK

We have discussed the UMRBC, the UMRBA, the EMPCC, the COE (Division, St. Paul, St. Louis, and Rock Island Districts), LTRMP, HREP, and GREAT I, II, and III. However, there are still a host of other coordinating groups that must be considered when trying to understand UMR management. The State resource management agencies have an organization called the Upper Mississippi River Conservation Committee (UMRCC), a forum for discussing and sharing issues, management efforts, lessons, and needs. It has subsections for fisheries, wildlife, recreation, water quality, and law enforcement. The UMRCC independently comments on River management efforts and issues and is not considered a representative of any participating State or Federal agency. The UMRCC is actively involved in navigation and resource management issues. It also maintains a library of agency and managers reports prepared on a great variety of river related subjects.

Each River State maintains staffs of resource management personnel responsible for the States fish, wildlife, water quality, and environmental management within their respective portions of the River floodplain in their States. The States maintain primary management authority over these resources within their boundaries. The exceptions are for migratory birds which are the management responsibility of the U.S. Fish and Wildlife Service and the forest resources on lands owned by the Corps of Engineers and by the Fish and Wildlife Service. Generally, the States maintain responsibility for water quality management, regulation of public drinking water supplies, floodplain management, regulation of water withdrawal and uses, management of state lands, fish and wildlife management, coordination with commercial and federal agencies on issues affecting navigation, participation in the EMP, boating safety programs, wetland protection and regulation, programs promoting soil conservation, emergency response for floods and other natural disasters, and response to oil and hazardous materials spills.

The major Federal authorities on the Upper Mississippi River include the following:

- Army Corps of Engineers. The Corps is responsible for construction, operation, and maintenance of the commercial navigation system, flood control projects, wetland regulation under the Clean Water Act's Section 404, the management of COE project lands, implementation of EMP, and the construction of projects under Section 1135 of the Water Resources Development Act.
- Fish and Wildlife Service. The FWS is responsible for managing the River's Upper Mississippi, Trempealeau, and Mark Twain National Fish and Wildlife Refuges, implementing the National Wetland Inventory, protecting threatened and endangered species, managing migratory species, evaluation of fish and wildlife impacts of projects under the authority of the Fish and Wildlife Coordination Act, and participation in developing habitat restoration projects under the EMP.
- Geological Survey is responsible for implementing the EMP's Long Term Resource Monitoring Program, operating stream gauging networks throughout the basin, and conducting water quality studies both in the River and in selected sub-basins under the National Water Quality Assessment.
- Environmental Protection Agency. EPA is responsible for ensuring water quality standards are met as defined under the Clean Water Act, they serve as the primary Federal response agency for oil and hazardous materials spills from land-based sources, and oversees other Federal Agency's compliance with the Clean Water Act and the National Environmental Policy Act.
- Department of Agriculture. DA regulates wetlands under the Swampbuster provisions of the 1985 Farm Bill, it administers the Conservation Reserve and Wetland Reserve programs, it constructs small watershed and flood control projects, and provides technical assistance to land owners.
- Coast Guard. The Coast Guard is the primary Federal responder to oil and hazardous materials spills from vessels and from marine transfer facilities. They regulate river traffic and maintain aids to navigation, inspect commercial vessels and marine transfer facilities, sponsor recreational boater safety classes, and license commercial vessel operators.
- Federal Emergency Management Agency. FEMA is responsible for coordinating Federal emergency response operations, administering the National Flood Insurance Program including monitoring community compliance with floodplain standards, and they implement floodplain mapping, mitigation, and other floodplain management activities.
- National Park Service. NPS administers the National Wildlife and Senic Rivers program (Upper portion of the St. Croix River) and management of the Mississippi National River and Recreation Area in the Minneapolis/St. Paul area.
- Federal Energy Regulatory Commission. FERC regulates and permits non-federal
- Maritime Administration. This agency administers federal programs in support of river born shipping.

This vast and often disjunct coordination system continues to struggle to manage the multitude of Federal and State programs that impact the Upper Mississippi River and its rich natural and cultural resources. Attempts to integrate and create efficiency are typically interlaced with personal and agency agendas and politics. There are a large number of both Federal and State employees who primary job is to attend the great number of resulting meetings this network generates. These folks try their best to represent their agencies', but it is a daunting and difficult task.

The current effort attempting to coordinate this vast network of programs and its varied sets of often obscure objectives, is the Upper Mississippi River Stewardship Initiative. One of its objective is to create a process to systematically coordinate Federal, State, and local programs resulting in a set of multi-scaled Watershed management objectives. It also proposes public involvement to the overall process, and increased Federal resources to address the issues of watershed management. This effort was developed by many organizations and individuals, and then organized and presented to the Basin network and Congress by the Resource Studies Center at St. Mary's University of Minnesota. Parts of the Initiative have been introduced by Congressman Ron Kind as H.R. 4013. The politics and debates continue.

THE FUTURE OF THE RIVER SYSTEM

Unimpounded, open river systems have the ability to traffic energy and nutrients through their biological systems at somewhat predetermined rates. Sediments are periodically flushed and rearranged during periods of high discharge, particularly when landforms on the floodplain are-overtopped by flooding. Sediments are commonly exposed to the atmosphere for prolonged periods of time during periods of low flow.

This provides a mechanism whereby oxidation processes can occur in the sediments and subsequently reduce the biochemical oxygen demand (BOD) within the system. Rivers and streams meander as a function of bed slope and composition of bed material. This results in the natural creation of new wetlands. Rivers discharge sediments at their mouths and commonly approach or reach an equilibrium with regard to sediment input and discharge.

When rivers such as the Upper Mississippi are impounded, however, their capacity to accomplish these functions is reduced or eliminated. In other words, the processes that normally occur in flowing water environments are changed to reflect those which occur in lake environments. Assimilative capacities become reduced, and nutrients accumulate in excessive quantities, particularly in non-channel areas. Flushing of sediments during flood stages is reduced in non-channel areas. Water levels become stabilized and low flow conditions occur less frequently. This retards the rate of oxidation of sediments that have a high biochemical oxygen demand. Accumulations of sediments in downstream reaches of the pools reduce the intra-pool slope and cause meandering processes to either be attenuated or stopped altogether. Increased trapping efficiencies caused by the closure of the dams result in sedimentation and concomitant increases in rates of eutrophication within the pools.

These processes have been observed in the Upper Mississippi River system and are probably responsible for the observable decline in the general quality of the resource. It is apparent that the value of the river resource will continue to decline unless the inputs of sediments, nutrients, and toxic substances are reduced or eliminated. The most obvious result of the aforementioned processes will be an accelerating rate of transformation of productive wetlands to relatively unproductive floodplain forests.

Any obstruction in a stream, which lessens the stream's competence, will promote deposition. The rate of aggradation of the flood plain of the Upper Mississippi was increased by the early channel improvement structures. The dams associated with the 9-foot channel have further increased the rate. Following the closure of a dam, sedimentation begins. Usually, sedimentation can be expected to continue until the sediment level throughout most of the pool reaches the crest of the spillway of the dam. Bed level can be expected to be raised upstream to the point at which the water surface of the reservoir intersects the original bed.

On the Upper Mississippi River, where the watershed is intensively agricultural, and the river's tributaries often run heavy with sand and silt, the slackwater navigation pools make excellent sediment traps, severely curtailing their useful life. The ecological prognosis for the Upper Mississippi River is poor. Generally, degradation of a river begins downstream and proceeds upriver, and this especially true of the Upper Mississippi River. To see what the Upper Mississippi will look like in the future, one must only see the modern Illinois River, which has a longer history of abuse.

We now maintain barge habitat at the expense of other habitats. Tributary streams have had 60 years to adapt to navigation pools, and their lower reaches have adjusted their base levels upward. They have stored massive amounts of sediment in the floodplains of their lower reaches and as deltas. Removing the navigation dams would result in lowering Mississippi water levels and base level. Consequently, tributaries would cut their beds downward, pouring countless tons of stored sediment into the Mississippi.

Most of the states that border the Upper Mississippi River have floodplain zoning laws in effect and in the future non-water-dependent developments will be difficult to locate there. Farm economics may even dictate that some levee and drainage districts be sold back to the government for fish and wildlife habitat. Navigation enhancement projects will be limited by the 1986 enactment of the Waterways Trust Fund whereby new expansion must be costshared by the industry. Mississippi River resources will apparently be increasingly difficult to exploit without providing adequate mitigation.

Ecologists generally agree that "Dust Bowl" conditions may be far from unusual for the Great Plains and the Upper Mississippi River Basin. The region has suffered repeated droughts for thousands of years, but the last 700 years have in fact been unusually wet. Studies of lake sediments reveal that in the past, extreme dry spells not only persisted for centuries at a time but occurred much more frequently than they do today. No one knows what caused the cycle of droughts in the past. Today humans are apparently altering the climate with greenhouse gases, and doing things to the climate that have never happened before.

General circulation computer models indicate that central North America is likely to become warmer and drier, probably causing northern Minnesota's coniferous forests to be replaced by hardwood forests. Mid- or short-grass prairies may replace present tallgrass prairies. Agriculture will be forced to adapt to the climate change, with farmers growing very different crops, perhaps cotton and peanuts. Wetlands and lakes will lose water, and many will dry up. We can be sure that these natural and/or human-induced changes will profoundly impact the Mississippi River.

In 1999, for only the second time since monitoring began in 1912 after the sinking of the Titanic, no icebergs were reported in the North Atlantic shipping lanes. Normally, several hundred or even several thousand bergs drift from Western Greenland to the Grand Banks off Newfoundland during the iceberg season from February to the end of July. Although global warming could be to blame, local winds and natural climate cycles also play a role. Although most scientists agree that global warming is upon us, no one yet knows how much of it - if any - could be due to a recurring natural temperature cycle.

We can only be sure of two things, first, the River in some form will be here, and second, human beings will be here exerting significant impacts on it.

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THE UNIVERSITY OF MICHIGAN

FIELD DISTRIBUTION AND ENTRAINMENT OF FISH LARVAE AND EGGS AT THE DONALD C. COOK NUCLEAR POWER PLANT, SOUTHEASTERN LAKE MICHIGAN, 1980-1982

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Under Contract With
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Ronald Rossmann, Project Director

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INTRODUCTION

PURPOSE OF THE STUDY

Mortality induced by entrainment of fish eggs and larvae and impingement of juvenile and adult fishes may be the most important biological influence power-generating plants exert on nearshore fish populations. These impacts clearly overshadow thermal discharge effects. Entrainment could significantly affect local Lake Michigan fishes by reducing the reproductive potential of important forage or gamefish populations. Because of this potential impact of the Donald C. Cook Nuclear Power Plant, we have intensively documented species, sizes, and numbers of fish larvae and eggs that were entrained at the plant from 1975 to 1982. In this report we will attempt to identify, interpret, and predict the effects of fish larva and egg entrainment on southeastern Lake Michigan's nearshore fish populations. Data in this report will cover the period 1980-1982. See Bimber et al. (1984) for 1973-1979 data summaries.

Schubel and Marcy (1978) defined two forms of entrainment - intake or pump entrainment and plume entrainment. Intake entrainment is the capture and inclusion of organisms, in our case fish eggs and larvae, into water used for condenser cooling. Plume entrainment is the attraction or mixing of adults and larvae from lake water near the discharge into the thermal plume. We did not sample plume-entrained eggs or larvae because of difficulties encountered in adequately and safely collecting organisms from this area. Effects of plume entrainment on adults are discussed in the adult and juvenile fish report prepared by the Great Lakes Research Division as part of the Cook Plant study (Tesar et al. 1985, Jude and Tesar 1985). In this report, entrainment, unless otherwise noted, will refer specifically to intake entrainment.

To more clearly define the effects of entrainment on southeastern Lake Michigan's fish community, we must (in addition to documenting species, sizes, and numbers entrained) relate those losses to the distribution, abundance, and life cycles of fishes near the Cook Plant and assess the associated effects on individual fish populations and community structure. The ultimate effect of entrainment losses will be dictated by the system's "resiliency", i.e., environmental stability, productivity, population compensation, and the ecological and economic importance of individual species. To attain these goals, we conducted field studies to identify the species, sizes, numbers, spatial distribution, and seasonal occurrence of adult fish, fish larvae, and eggs near the Cook Plant.

Most fishes in our study areas have similar seasonal movement patterns, usually related to spawning activity. They move inshore for spawning in early spring or summer where they remain until moving into deeper water in fall. Salmon, trout, and coregonines differ from this basic pattern and are usually present in spring, fall, and during upwellings. Entrainment losses generally peak during and shortly following spawning and are sporadic thereafter. Mortality of eggs and larvae during entrainment is the result of a combination of mechanical, thermal, and chemical stresses.

Field studies were used to identify the species, sizes, numbers, spatial distribution, and season of occurrence of fish larvae and eggs near the Cook Plant. We compared field and entrainment results to determine the amount of agreement between them, elucidate the biological causes for disagreement, and evaluate the adequacy of the two sampling programs. Lastly, we suggested how the location, design, and seasonal schedule of operation of water intakes on southeastern Lake Michigan could affect the rate of entrainment of eggs and larvae of inshore fishes. Our findings and interpretations are the subject of this report.

STUDY AREA

The Donald C. Cook Nuclear Power Plant occupies part of a 263-ha site on the southeast shore of Lake Michigan that includes approximately 1,326 m of dunes shoreline. The plant is located about 3 km northeast of Bridgman, Michigan, in Lake Township, Berrien County (Fig. 1).

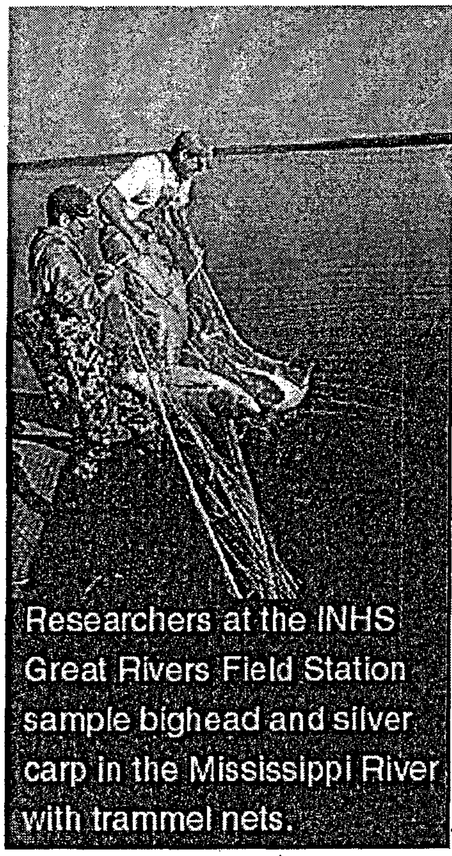
With both reactors on line, the Cook Plant has a generating capacity of 2,200 megawatts of electricity. The plant utilizes a once-through cooling system capable of a maximum service water flow rate of 104 m^3/s to dissipate an estimated heat rejection rate of 3.9 X 10^9 Kg-calorie/h (AEC 1973). Condenser design modifications account for differential flow rates for Unit 1 (45 m^3/s) and Unit 2 (59 m^3/s). Temperature increases (Δ T) over ambient lake water temperatures are 12.1 C° (Unit 1) and 9.3 C° (Unit 2) at maximum generating capacity (AEC 1973). Decreased flow rates and slightly increased Δ Ts occur in winter when heated water is pumped back through the intake structures via one of the three intake pipes to reduce ice formation.

Water for both condenser units is drawn from Lake Michigan through three intake structures 686 m offshore in 7.3 m of water (mean lake level - 176.5 m above sea level). Intake structures rest on a concrete and riprap base structure approximately 2 m

Chick 2002

Asian Carp in the Upper Mississippi River System

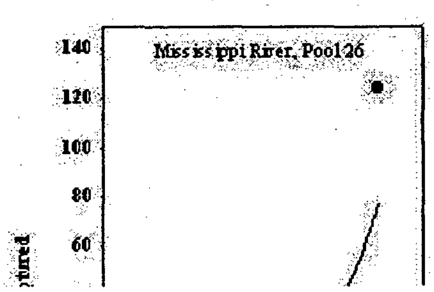
Illinois Natural History Survey Reports Spring 220, No. 371, p. 6

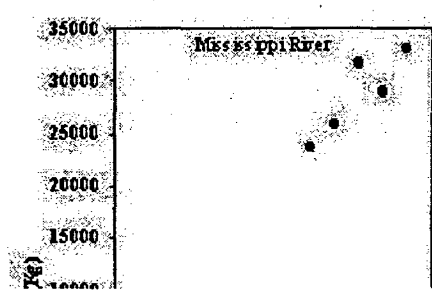


Researchers at the INHS Great Rivers Field Station sample bighead and silver carp in the Mississippi River with trammel nets.

The introduction of zebra mussels to the Great Lakes and Upper Mississippi River System (UMRS) in the 1980s and 1990s increased public awareness of the problem of invasive species. In response, the United States Congress passed the Non-indigenous Aquatic Nuisance Prevention and Control Act in 1990 and the National Invasive Species Act in 1996. Zebra mussels, however, are not the first, nor will they be the last, non-native species to invade our freshwater ecosystems. Introductions of fishes and other aquatic organisms into inland waters of North America have been increasing dramatically for the past 150 years. The invasion of the UMRS by several Asian carp species provides an excellent illustration of the history and continuing challenge posed by introductions of invasive species.

Presently, four species of Asian carp are established in the UMRS and a fifth species is waiting in the wings. The first Asian carp species to become established in North American was the common carp (Cyprinus carpio), which was introduced in the 1800s by the U.S. Fish Commission to establish recreational and commercial fisheries. Today, common carp are abundant throughout the UMRS. Because this species was established so long ago, data are not readily available to demonstrate the effects of their invasion on native fish communities. Nevertheless, common carp are known to adversely affect aquatic habitats by uprooting vegetation and increasing turbidity.





Three additional species of Asian carp--grass carp (Ctenopharyngodon idella), bighead carp (Hypophthalmichthys nobilis), and silver carp (Hypophthalmichthys molotrix)--have become established in the

UMRS during the past two decades. All three species were initially brought to the U.S. in the 1960s and 1970s for use in aquaculture, and became established in the UMRS through accidental and deliberate releases. Data from the Long Term Resource Monitoring Program and catch data from commercial fishers show that the abundance of these species, especially bighead and silver carp, has increased dramatically during the past few years (Fig. 1). Bighead and silver carp are filter feeders, consuming a variety of planktonic organisms, and are capable of significantly reducing zooplankton abundance in ponds and lakes. Because all fishes forage on planktonic organisms during their early life history stages, bighead and silver carp have the potential to adversely affect every species of fish in the UMRS and connecting aquatic systems.

If nothing is done to halt the upstream spread of bighead and silver carp in the Illinois River, they will soon enter the Great Lakes. A potential check on the upstream movement of bighead carp is the electric dispersal barrier being constructed on the Illinois Waterway near Chicago. However, this barrier was originally designed to stop the spread of the round goby (Neogobius melanstomus) from the Great Lakes to the UMRS, and it is unknown whether this barrier will be effective for bighead and silver carp. Researchers at the INHS Great Rivers Field Station and Illinois River Biological Station have initiated projects to assess dietary overlap of bighead carp with filter feeding fishes native to the UMRS, and the effectiveness of various barrier designs for preventing the spread of this invasive species to the Great Lakes.


Catch of bighead and silver carp from one 30-minute set of a trammel net.

The black carp (Mylopharyngodon piceus) is waiting in the wings. This species is a molluscivore that was brought to the United States for use in aquaculture ponds. The previous invasions by Asian carp suggest that it is just a matter of time before this species becomes introduced and established into the UMRS, where it will pose a threat to endangered freshwater mussel populations. Once a non-native species successfully invades an ecosystem, it is often difficult or impossible to eradicate. Therefore, it is critical that state and federal management agencies make concerted efforts to stop the establishment and spread of black carp in the UMRS.

John H. Chick, Center for Aquatic Ecology

Talmadge & Opresko 1981

Literature Review: Response of Fish to Thermal Discharges

EA-1840
Research Project 877
ORNL/EIS-193

Final Report, May 1981

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ABSTRACT

Information on the response of fish species to thermal discharges is reviewed in this report. The review is based on the literature contained in the Cooling Systems Effects Data Base that was compiled under contract to the Electric Power Research Institute. The compiled data reveal that fish species generally respond to thermal effluents according to their natural thermal preferences. These preferences differ from species to species and they vary seasonally, as do discharge water temperatures; consequently there are often temporal and spatial changes in the local fish fauna in the immediate area of a thermal discharge. Species normally adapted to cold water may be absent from a particular thermally-influenced area throughout most or all of the year. Conversely, some thermophilic species become year-round residents of discharge canals. Species with intermediate thermal tolerances may be absent from discharge areas during maximum summertime temperatures but they are often very abundant in the same areas at other times of the year. For many species, field temperature preferences are slightly above laboratory derived values, but field avoidance thresholds are substantially below lethal levels. Although individuals of many species are occasionally found in thermal effluents at lethal temperatures, populations as a whole avoid such effluents.

USGS 1999

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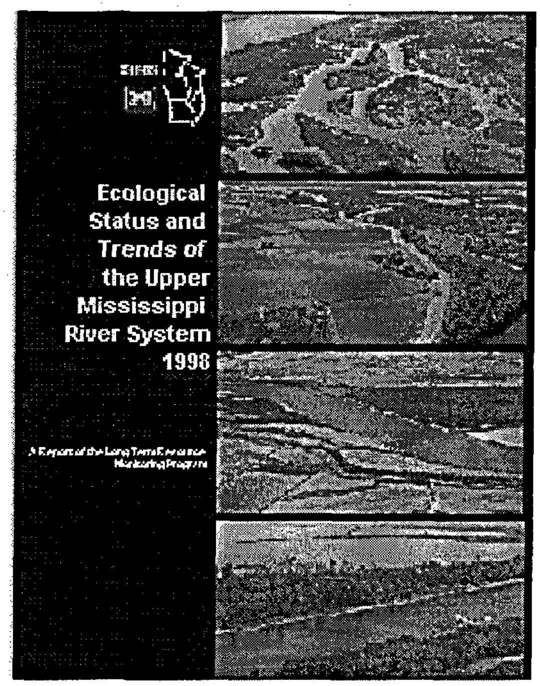
Upper Midwest Environmental Sciences Center

Ecological Status and Trends of the Upper Mississippi River System 1998

A Report of the Long Term Resource Monitoring Program

Press Release: "Old Man River Gets Health Check Up"

The purpose of this report is to present, analyze, and discuss information about the ecological condition of the Upper Mississippi River System (UMRS). The report includes, but is not limited to data and results from the initial years of the Long Term Resource Monitoring Program (LTRMP), the largest monitoring program in the country. The *mission of the* LTRMP *is to provide* decision makers with information they need to maintain the UMRS as a sustainable large river ecosystem given its multiple-use character.



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A Report of the Long Term Resource Monitoring Program

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FWS 1976

Title 50—Wildlife and Fisheries

CHAPTER I—UNITED STATES FISH AND WILDLIFE SERVICE, DEPARTMENT OF THE INTERIOR

PART 17—ENDANGERED AND THREATENED WILDLIFE AND PLANTS

Endangered Status for 159 Taxa of Animals

The U.S. Fish and Wildlife Service hereby determines 159 taxa of U.S. and foreign vertebrates and invertebrates which appear on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, to be Endangered species, pursuant to Section 4 of the Endangered Species Act of 1973 (16 U.S.C. 1531–1543, 87 Stat. 884: hereinafter, the Act).

BACKGROUND

On May 22, 1975, the Fund for Animals, Inc., requested the U.S. Fish and Wildlife Service to list as Endangered species, pursuant to the Act, 216 taxa of plants and animals which appear on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora which are not already on the U.S. List of Endangered Wildlife.

The Convention was drafted at an international conference held in Washington, D.C., from February 12 to March 2, 1973: it is a treaty for the conservation of wild flora and fauna. Membership is open to all nations, whether interested primarily as producers or consumers of wildlife, that wish to reduce the impact of international trade on Endangered species. The Convention consists of two interdependent parts: the text, which establishes basic principles, operating procedures and organizational implementation; and Appendices I, II, and III which list only those species that participating States agree meet the criteria for inclusion in the appendices. Appendix I includes all species threatened with extinction which are or may be affected by trade. No party to the Convention may allow trade in specimens of species included on Appendix I except in accordance with the provisions of the Convention. The provisions for export of Appendix I species require the prior grant and presentation of an export permit; the import of an Appendix I species requires the prior grant and presentation of an import permit and either an export permit or a re-export certificate.

The United States Government signed the Final Act of the Conference on March 3, 1973; the United States Senate gave its Advice and Consent on August 3, 1973. On September 13, 1973, the Convention was ratified by the President of the United States, and shortly thereafter the United States deposited its instrument of ratification with the Convention's Depository Government in the Swiss Confederation. By July 1, 1975, the Convention had been ratified by enough nations (10) to enter into force, and the State Department has now been notified of 23 nations that have ratified it.

Acting upon the May 22, 1975, request from the Fund for Animals, Inc., to place all Appendix I species on the United States list of Endangered Fauna and Flora, the Fish and Wildlife Service published in the FEDERAL REGISTER (40 FR 44329) on September 26, 1975, a proposed rulemaking that would determine all of the 216 taxa on Appendix I that are not already on the U.S. List, as Endangered species under the Act. Certain necessary conditions of the Act had to be met with regard to final determinations of Endangered species, and based upon those considerations, the Fish and Wildlife Service now issues a final rulemaking that determines 159 of the 216 taxa proposed on September 26, 1975, to be Endangered species. No determinations are made in the present rulemaking on 56 of the remaining 57 taxa for the following reasons:

(1) A considerable amount of data was received on the Mexican beaver (*Castor canadensis mexicanus*), and particularly on the Southern sea otter (*Enhydra lutris nereis*). Data for the beaver and otter are still being analyzed to determine what action will be taken.

(2) We have been notified by the International Council for Bird Preservation that the Peregrine falcon (*Falco peregrinus babylonicus*), Himalayan monal (*Tophopporus imepejanus*), Tibetan snowcock (*Tetraogallus tibetanus*), Bengal florican (*Eupodotis bengalensis*), New Zealand parakeet (*Cyanoramphus novaezelandiae*), and the Principe parrot (*Psittacus erithacus princeps*) may be neither Threatened nor Endangered species. We are holding in abeyance a determination on these species pending clarification of their actual status.

(3) The Governors of the States (and Trust Territories) in which two of the pearly mussels (*Lampsilis satura* and *Epioblasma* (=*Dysnomia*) *walkeri*) and the Marianas mallard (*Anas oustakti*) are resident were inadvertently not notified of our proposal as required by the Act. They are now being notified and a final determination on these species will be postponed until the mandatory 90-day periods allowed Governors for comments have expired.

(4) Seventy-four of the species (45 taxa) on Appendix I of the Convention were plants. Regulations governing plants have not as yet been finalized, and consequently we are delaying action on listing of plants pending their publication.

A determination has been made in the present rulemaking on one of the 57 species not determined to be Endangered herein, the so-called Glacier bear. We have concluded, based on evidence provided by the State of Alaska, that the Black bear (*Ursus americanus emmonsii*) is neither an Endangered nor Threatened species. The so-called Glacier bear is an uncommon color variety of *Ursus americanus emmonsii*. Consequently it does not qualify for listing under the Act.

SUMMARY OF COMMENTS

A total of 309 letters were received pertaining to the proposed rulemaking published on September 26, 1975. Five of these letters opposed the overall listing; the remainder favored the proposal entirely, or had only minor reservations. Three of the five opposing letters implied that the Fish and Wildlife Service had not based the proposal on a finding that each species proposed was "in danger of extinction throughout all or a significant portion of its range" as required by the Act, nor had it shown satisfactorily that any of the five factors to be considered in determining a species to be Endangered or Threatened had been adequately addressed. The Fish and Wildlife Service's response to these criticisms is contained in the "Description of the Rulemaking" section of the current rulemaking. The two additional opposing letters to the proposal offered no substantive data or interpretations of the Act to support their views.

Several letters pointed out that *Hippotragus niger variani* should bear the vernacular name "Giant sable antelope" rather than "Sable antelope" as it appeared in the proposal. Also, the range of the species should have read "Angola" rather than "Southern Africa." These errors have been corrected in the present rulemaking.

The State of Alaska, Department of Fish and Game, presented substantial data to demonstrate that the Glacier bear should not be determined as an Endangered species. These data have been analyzed and we have concluded that the so-called Glacier bear is neither an Endangered nor Threatened species. It is an uncommon color variety of the black bear, *Ursus americanus emmonsii*, and as such does not qualify for listing under the Act.

The New Mexico Department of Game and Fish, and the Texas Parks and Wildlife Department objected to a determination of the Mexican beaver (*Castor canadensis mexicanus*) as an Endangered species. They provided substantial data to support their opposition, and no action is taken herein pending an appraisal of the status of this species.

Of the 309 letters received concerning the proposal, 291 specifically spoke to the Southern sea otter (*Enhydra lutris nereis*). Petitions signed by many hundreds of persons were received. Only two letters were in opposition to determining this species as Endangered; 289 favored the determination. In support of the listing, several organizations provided voluminous data that are currently being analyzed; one of the opposing letters contained no substantive data. The other opposing letter was from the State of California, which submitted several volumes of information supporting their claim. In view of the quantity and complexity of data received, we are delaying action on this species so that we may more adequately evaluate all the data that was submitted in support of listing the otter as well as that submitted by the State of California in opposition to the determination.

A circus group requested that the Bactrian camel (*Camelus bactrianus*) and the Asian elephant (*Elephas maximus*), traditional circus animals, be excluded from the final rulemaking, but presented no substantive data to support the request. There are large domesticated populations of both of these species, but the Bactrian camel is extremely endangered, if not extinct, in the wild, and the Asian elephant is very depleted. A proposal to list domesticated Asian elephants and Bactrian camels as "captive self-sustaining populations" may be initiated within the near future.

Several other letters noted errors in spellings and ranges for various species. These have been corrected in the present determination.

As a result of the September 1975 proposal, the Fish and Wildlife Service received only one comment (favorable) on the molluscs. However, all of the mollusks in that proposal, as well as a number of other molluscan and crustacean species, appeared in a Notice of Review published in the FEDERAL REGISTER (39 FR 37078) on October 17, 1974. That Notice of Review received many comments, some pertaining to the species listed in the September proposal. We therefore feel that it is appropriate to discuss comments pertaining to these species even though the comments were not received directly as a result of the proposal but rather from the earlier Notice. Of the comments received on the molluscs, only the Tennessee Valley Authority and the States of Kentucky and Michigan had objections to listing any of the species. These objections, and the Service's response to them are as follows:

The TVA believes that *Dysnomia florentina* is extinct. Isom and Yokely recently reported *Dysnomia florentina* in the Duck River (The American Midland Naturalist, 1955). Isom and Yokely presently are employed or on contract with the TVA. We will consider this mussel as facing extinction until such time as it has been more explicitly demonstrated that it is extinct.

The TVA stated that the subspecific designation *gubernaculum* is of questionable value. Our information, however, is that it is at least a subspecies (Ohio State University Museum of Zoology, Museum of Fluviatile Molluscs and others) and very likely a true species (U.S. National Museum).

The TVA stated that *Dysnomia turgidula* was synonymous with *D. deviata* and *D. curtisi*. The animal formerly classified as *D. deviata* now is known to be the female of *D. Turgidula* according to reports we have from the U.S. National Museum, the Museum of Fluviatile Molluscs and the Ohio State University Museum of Zoology. Records of *D. deviata* were considered in our determination of the status of *D. turgidula*. *D. turgidula* is not synonymous with *D. curtisi*. Even if it were, it would be seriously threatened by channelization and pollution in *curtisi's* only habitat: the Black River in Missouri.

The TVA synonymizes *Lampsilis orbiculata* and *Lampsilis higginsi*. It considers the total distribution as widespread. Our information from the U.S. National Museum, the Ohio State University Museum of Zoology and the Illinois Natural History Survey is that these are at least separate subspecies.

The TVA stated that *Lampsilis virescens* is probably a form of the widespread *L. anodontoides*. We can find no evidence of this in the recent literature where Isom, Yokely, Stansbery, and others have all considered this as a distinct species.

The TVA considers *Pleurobema plenum* to be a form of *P. cordatum*. It is, however, recognized in the literature as a species by Stansbery, Morrison, Williams, and Athearn, and as a subspecies by Burch, Van der Schalie, and others. The provisions of the Endangered Species Act of 1973 apply to subspecies as well as species.

The TVA synonymizes *Quadrula sparsa* with *Quadrula metanevra*. However, this is at variance with comments we have received from the U.S. National Museum, the Museum of Fluviatile Molluscs, and the Ohio State University Museum of Zoology.

The TVA questioned the taxonomic status of *Toxolasma cylindrella* and suggested that it was probably a form of *Carunculina moesta*. Information from Dr. David H. Stansbery concerning soft part anatomy shows that *Toxolasma cylindrella* is a valid species.

The State of Michigan considers *Dysnomia sulcata perobliqua* in Michigan to be *Dysnomia sulcata delicata* and possibly extinct. We have no objections to the name change and have made the correction in the current listing.

The State of Kentucky stated that *Pleurobema plenum* does not seem to be especially rare and is not endangered at the present time. We concur with Kentucky that *Pleurobema plenum* is the least endangered of the mussels listed herein. Nevertheless, data available to us indicate that this species is more properly classified as Endangered than Threatened and therefore it appears in the present determination.

DESCRIPTION OF THE RULEMAKING

Section 4(a) of the Act states that the Secretary may determine a species to be an Endangered species or a Threatened species because of any of the following five factors:

(1) The present or threatened destruction, modification, or curtailment of its habitat or range;

(2) Overutilization for commercial, sporting, scientific, or educational purposes;

(3) Disease or predation;

(4) The inadequacy of existing regulatory mechanisms; or

(5) Other natural or manmade factors affecting its continued existence.

With regard to each of the species determined by this rulemaking to be Endangered species, there has been a decline in numbers due to factors 1, 2, or 4 above, or to a combination of all three. The United States Government recognized this endangerment when it signed the Convention's Final Act, when the Senate gave its Advice and Consent, and when the President ratified the Convention. The species determined herein to be Endangered have entered, or could potentially enter, heavily into hitherto unregulated international commerce. Some of these, such as the Clouded leopard, have been exposed to over-utilization for commercial purposes involving the fur trade; others, such as the Giant Sable antelope, have been over-exploited for food and sport. Given the precarious position of each species, international trade is detrimental to the survival of all, but presently no satisfactory mechanism to control or regulate such trade is effectively in operation. Also, many of these species have suffered habitat losses which added to the other factors, creates cumulative effects very detrimental to their survival.

The Convention has now been ratified by a sufficient number of nations to make it operational. As more nations ratify, it should become a stronger international regulator. Until such time, however, the high commercial importance of each of the species herein determined to be Endangered, and the inadequacy of existing regulatory mechanisms to control international trade continue to be factors of major concern. It is primarily for these reasons that the listing action is imperative, e.g., to provide an interim regulatory mechanism to restrict U.S. trade in these species, and ultimately a supportive measure to further insure the intent of the Convention.

EFFECT OF THE RULEMAKING

For foreign species herein determined to be Endangered species, the principal effect of this rulemaking will be to restrict their importation and exportation into and from the United States. Except under permit, it will be unlawful to import or to export any of these species. Any shipment in transit through the United States is considered an importation and an exportation whether or not it has entered the country for customs purposes. In addition, it will be unlawful, except under permit, to deliver, receive, carry, transport, or ship in interstate commerce in the course of a commercial activity any of these species; and to sell or to offer them for sale in an interstate or foreign commercial activity. A commercial activity is considered to mean the actual or intended transfer of wildlife from one person to another person in the pursuit of gain or profit.

All of the above prohibitions will apply to native species herein determined to be Endangered species and, in addition, it will be unlawful, except under permit or in special circumstances, to take such species within the United States. "Take" is defined by the Act as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

Upon receipt of a complete application, the Fish and Wildlife Service may issue a permit authorizing any of the above activities for scientific research or for enhancing the propagation or survival of the species determined herein to be Endangered. Persons who may be effected by this rulemaking are advised to consult sections 17.21 through 17.23 (see FEDERAL REGISTER, Vol. 40, No. 188, pp. 44423–44425, or the Code of Federal Regulations, Title 50, Part 17) for details on prohibited acts and permits relative to Endangered species listed under the Act.

The determination of the United States species listed herein as Endangered species will make them eligible for the protection provided by Section 7 of the Act which reads as follows:

INTERAGENCY COOPERATION

SEC. 7. The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this act. All other Federal departments and agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this act and by taking such action necessary to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of such endangered species and threatened species or result in the destruction or modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with the affected States, to be critical.

No critical habitat is presently being determined for United States species. That action, if and when it occurs, will be a separate rulemaking.

This rulemaking is issued under the authority contained in the Endangered Species Act of 1973 (U.S.C. 1531–1543; 87 Stat. 884). The amendments will be come effective on July 14, 1976.

Dated: June 1, 1976.

LYNN A. GREENWALT,
Director,
U.S. Fish and Wildlife Service.

Accordingly, Part 17, Subpart B, Sec tion 17.11 Title 50 of the Code of Feder Regulations, is amended as set fort below:

1. Accordingly, Part 17, Subchapter of Chapter I, Title 50 of the Code Federal Regulations is amended as s forth below:

In Section 17.11, add the following:

§ 17.11 Endangered and threaten wildlife.

* * * * *

Species			Range				
Common name	Scientific name	Population	Known distribution	Portion of range where threatened or endangered	Status	When listed	Specia rules
MUSSELS							
Birdwing pearly mussel	*Conradilla caelata*	Not available	Powell and Clinch Rivers in Virginia and Tennessee, Duck River in Tennessee.	Entire range	E	14	Not av able
Dromedary pearly mussel	*Dromus dromas*	do	Powell and Clinch Rivers in Virginia and Tennessee.	do	E	14	Do.
Curtis' pearly mussel	*Epioblasma (-Dysnomia) florentina curtisi.*	do	Black River in Missouri	do	E	14	Do.
Yellow-blossom pearly mussel	*Epioblasma (-Dysnomia) florentina florentina.*	do	Duck River in Tennessee	do	E	14	Do.
Sampson's pearly mussel	*Epioblasma (-Dysnomia) sampsoni.*	do	Wabash River in Indiana and Illinois.	do	E	14	Do.
White cat's paw pearly mussel	*Epioblasma (-Dysnomia) sulcata delicata* (including *perobliqua*).	do	Detroit River in Michigan and the St. Joseph River in Ohio, Michigan, and Indiana.	do	E	14	Do.
Green-blossom pearly mussel	*Epioblasma (-Dysnomia) torulosa gubernaculum.*	do	Clinch River in Virginia and Tennessee.	do	E	14	Do.
Tuberculed-blossom pearly mussel	*Epioblasma (-Dysnomia) torulosa torulosa.*	do	Lower Ohio River in Kentucky and Illinois, Nolichucky River in Tennessee, and Kanawha River in West Virginia.	do	E	14	Do.
Turgid-blossom pearly mussel	*Epioblasma (-Dysnomia) turgidula.*	do	Duck River in Tennessee	do	E	14	Do.
Fine-rayed pigtoe pearly mussel	*Fusconaia cuneolus*	do	Clinch River in Virginia and Tennessee, Powell River in Virginia and Tennessee, and Paint Rock River in northern Alabama.	do	E	14	Do.
Shiny pigtoe pearly mussel	*Fusconaia edgariana*	do	Powell River in Virginia and Tennessee, Clinch River in Virginia and Tennessee, Paint Rock River in Alabama, and Holston River in Virginia.	do	E	14	Do.
Higgins' eye pearly mussel	*Lampsilis higginsi*	do	Mississippi River in Minnesota, Wisconsin, and Illinois; Merameo River in Missouri; St. Croix River in Wisconsin and Minnesota.	do	E	14	Do.
Pink mucket pearly mussel	*Lampsilis orbiculata orbiculata*	do	Green River, Ky.; Kanawha River in West Virginia; Tennessee River (Tenn. and Ala.); Muskingum River, Ohio.	do	E	14	Do.
Alabama lamp pearly mussel	*Lampsilis virescens*	do	Paint Rock River system in Alabama.	do	E	14	Do.
White warty-back pearly mussel	*Plethobasis cicatricosus*	do	Tennessee River Tennessee and Alabama.	do	E	14	Do.
Orange-footed pimpleback	*Plethobasis cooperianus*	do	Tennessee River, Tennessee and Alabama, Duck River, Tennessee.	do	E	14	Do.
Rough pigtoe pearly mussel	*Pleurobema plenum*	do	Tennessee River, Tenn.; Green River, Ky.; Clinch River, Va. and Tenn.).	do do	E E	14 14	Do. Do.
Fat pocketbook pearly mussel	*Potamilus (-Proptera) capax*	do	White River, Ark., St. Francis River (Ark. and Mo.).	do	E	14	Do.
Cumberland monkeyface pearly mussel.	*Quadrula intermedia*	do	Powell and Clinch Rivers (Va. and Tenn.), Duck River, Tenn.	do	E	14	Do.
Appalachian monkeyface pearly mussel.	*Quadrula sparsa*	do	Powell and Clinch Rivers (Va. and Tenn.).	do	E	14	Do.
Pale lilliput pearly mussel	*Toxolasma (-Carunculina) cylindrella.*	do	Duck River, Tenn., Paint Rock River, Ala.	do	E	14	Do.
Nicklin's pearly mussel	*Unio* (possibly *Megalonaias*) *nicklinlana.*	do	Mexico	do	E	14	Do.
Tampico pearly mussel	*Cyrtonaias tampicoensis tecomatensis.*	do	do	do	E	14	Do.
Cumberland bean pearly mussel	*Villosa (-Micromya) trabilis*	do	Cumberland and Rockcastle Rivers, Ky.	do	E	14	Do.
FISH							
Asian bonytongue	*Scleropages formosus*	do	Borneo, Banka, Sumatra, Malaya, Thailand.	do	E	14	Do.
Ikan temolek	*Probarbus jullieni*	do	Menam River (Thailand); Mekong River (Cambodia, Laos, and Vietnam); Pahang River (Malaya).	do	E	14	Do.

Species: Common name	Species: Scientific name	Species: Population	Range: Known distribution	Range: Portion of range where threatened or endangered	Status	When listed	Special rules
REPTILES							
Chinese alligator	*Alligator sinensis*	do	Lower Yangtze River drainage of China.	do	E	14	Do.
Black caiman	*Melanosuchus niger*	do	Amazon basin	do	E	14	Do.
Apaporis River caiman	*Caiman crocodilus apaporiensis*	do	Apaporis River of Columbia	do	E	14	Do.
Broad-snouted caiman	*Caiman latirostris*	do	Brazil, Uruguay, Argentina, Paraguay.	do	E	14	Do.
Tomistoma	*Tomistoma schlegelii*	do	Borneo, Sarawak, Sumatra, Southern Malay Peninsula.	do	E	14	Do.
African dwarf crocodile	*Osteolaemus tetraspis tetraspis*	do	West Africa	do	E	14	Do.
Congo dwarf crocodile	*Osteolaemus tetraspis osborni*	do	Congo River drainage	do	E	14	Do.
African slender-snouted crocodile	*Crocodylus cataphractus*	do	Western and Central Africa	do	E	14	Do.
Siamese crocodile	*Crocodylus siamensis*	do	Southeast Asia, Malay Peninsula	do	E	14	Do.
Mugger crocodile	*Crocodylus palustris palustris*	do	India, Pakistan, Bangladesh, Iran	do	E	14	Do.
Ceylon mugger crocodile	*Crocodylus palustris kimbula*	do	Ceylon	do	E	14	Do.
Philippine crocodile	*Crocodylus novaeguineae mindorensis.*	do	Philippine Islands	do	E	14	Do.
Spotted pond turtle	*Geoclemmys (-Damonia) hamiltonii.*	do	Northern India, Pakistan	do	E	14	Do.
Three-keeled Asian turtle	*Geomyda (-Nicoria) tricarinata*	do	Central India to Bangladesh and Assam.	do	E	14	Do.
Indian sawback turtle	*Kachuga tecta tecta*	do	Ganges, Brahmaputra, and Indus drainages of India.	do	E	14	Do.
Burmese peacock turtle	*Morenia ocellata*	do	Southern Burma	do	E	14	Do.
Geometric turtle	*Geochelone (-Testudo) geometrica*	do	Cape Province, South Africa	do	E	14	Do.
Angulated tortoise	*Geochelone (-Testudo) yniphora*	do	Madagascar	do	E	14	Do.
Indian flap-shell tortoise	*Lissemys punctata punctata*	do	Ganges and Indus drainages of India, Pakistan, and Bangladesh.	do	E	14	Do.
Cuatro Cienegas soft-shell turtle	*Trionyx ater*	do	Cuatro Cienegas basin, Mexico	do	E	14	Do.
Black soft-shell turtle	*Trionyx nigricans*	do	Pond near Chittatong, East Pakistan.	do	E	14	Do.
Indian soft-shell turtle	*Trionyx gangeticus*	do	Pakistan, India, Bangladesh, and Nepal.	do	E	14	Do.
Peacock soft-shell turtle	*Trionyx hurum*	do	Ganges and Brahmaputra drainages of India and Bangladesh.	do	E	14	Do.
Komodo Island monitor	*Varanus komodoensis*	do	Komodo, Rintja, Padar, and western Flores Islands of Indonesia.	do	E	14	Do.
Yellow monitor	*Varanus flavescens*	do	West Pakistan through India to Bangladesh.	do	E	14	Do.
Bengal monitor	*Varanus bengalensis*	do	Persia, Afganistan, India, Ceylon, Burma, Thailand, South Vietnam, Malay Peninsula, Java.	do	E	14	Do.
Desert monitor	*Varanus griseus*	do	North Africa to Near-east, Caspian Sea through U.S.S.R. to West Pakistan, Northwest India.	do	E	14	Do.
Indian python	*Python molurus molurus*	do	Ceylon and India	do	E	14	Do.
AMPHIBIANS							
Japanese giant salamander	*Andrias (-Megalobatrachus) davidianus japonicus.*	do	Honshu and Kyushu Islands, Japan	do	E	14	Do.
Chinese giant salamander	*Andrias (-Megalobatrachus) davidianus davidianus.*	do	Western China	do	E	14	Do.
Cameroon toad	*Bufo superciliaris*	do	Equatoricl Africa	do	E	14	Do.
Monteverde toad	*Bufo periglenes*	do	Monteverde, Coast Rica	do	E	14	Do.
African viviparous toads	*Nectophrynoides* spp.	do	Tanzania, Guinea, Africa	do	E	14	Do.
Panamanian golden frog	*Atelopus varius zeteki*	do	Panama	do	E	14	Do.
BIRDS							
Solitary tinamou	*Tinamus solitarius*	do	Brazil, Paraguay, Argentina	do	E	14	Do.
Abbott's booby	*Sula abbotti*	do	Christmas Island in Indian Ocean	do	E	14	Do.
Frigate bird	*Fregata andrewsi*	do	East Indian Ocean Islands	do	E	14	Do.
Campbell Island flightless teal	*Anas aucklandica nesiotis*	do	Campbell Island, New Zealand	do	E	14	Do.
Pink-headed duck	*Rhodonessa caryophyllacea*	do	India	do	E	14	Do.
Harpy eagle	*Harpia harpyja*	do	Mexico, Central America, Bolivia, Brazil, Argentina.	do	E	14	Do.
Greenland white-tailed eagle	*Haliaeetus albicilla groenlandicus.*	do	Greenland and adjacent Atlantic Islands.	do	E	14	Do.
Peregrine falcon	*Falco peregrinus peregrinus*	do	Europe, Russia	do	E	14	Do.
Black-fronted piping-guan	*Pipile jacutinga*	do	Argentina	do	E	14	Do.
Mitu	*Mitu mitu mitu*	do	Amazonian Colombia, Brazil, Peru, Bolivia.	do	E	14	Do.
Elliot's pheasant	*Syrmaticus ellioti*	do	Southeastern China	do	E	14	Do.
Montezuma quail	*Cyrtonyx montezumae merriami.*	do	Mexico	do	E	14	Do.
Cuba sandhill crane	*Grus canadensis nesiotes*	do	Cuba, Isle of Pines	do	E	14	Do.
Black-necked crane	*Grus nigricollis*	do	Tibet	do	E	14	Do.
White-naped crane	*Grus vipio*	do	Mongolia	do	E	14	Do.
Lord Howe wood rail	*Tricholimnas sylvestris*	do	Lord Howe Island	do	E	14	Do.
Nordmann's greenshank	*Tringa guttifer*	do	Assam, Pakistan, Sakhalin Island, Siberia, Ussuriland, Japan, Korea, Malaya, Burma.	do	E	14	Do.
Khar turunt tsakhiai	*Larus relictus*	do	India, China, Tibet, South America	do	E	14	Do.

Species			Range				
Common name	Scientific name	Population	Known distribution	Portion of range where threatened or endangered	Status	When listed	Special rules
Mindoro zone-tailed pigeon	*Ducula mindorensis*	do	Philippines	do	E	14	Do.
Bahaman or Cuban parrot	*Amazona leucocephala*	do	West Indies (Cuba, Bahamas, Cayman Islands).	do	E	14	Do.
Red-spectacled parrot	*Amazona pretrei pretrei*	do	Brazil, Argentina	do	E	14	Do.
Vinaceous breasted parrot	*Amazona vinacea*	do	Brazil	do	E	14	Do.
Glaucous macaw	*Anodorhynchus glaucus*	do	Paraguay, Uruguay, Brazil	do	E	14	Do.
Indigo macaw	*Anodorhynchus leari*	do	Brazil	do	E	14	Do.
Little blue macaw	*Cyanopsitta spixii*	do	do	do	E	14	Do.
Red-capped parrot	*Pionopsitta pileata*	do	do	do	E	14	Do.
Golden parakeet	*Aratinga guaruba*	do	do	do	E	14	Do.
Hook-billed hermit	*Ramphodon dohrni*	do	do	do	E	14	Do.
Resplendent quetzel	*Pharomachrus mocinno mocinno.*	do	Central America	do	E	14	Do.
Do	*Pharomachrus mocinno costaricensis.*	do	Costa Rica	do	E	14	Do.
Giant scops owl	*Otus gurneyi*	do	Islands of Marinduque and Mindanao, Philippines.	do	E	14	Do.
Helmeted hornbill	*Rhinoplax vigil*	do	Malaya, Sumatra, Borneo	do	E	14	Do.
Banded cotinga	*Cotinga maculata*	do	Brazil	do	E	14	Do.
White-winged cotinga	*Xipholena atro-purpurea*	do	do	do	E	14	Do.
Koch's pitta	*Pitta kochi*	do	Philippines	do	E	14	Do.
Western rufous bristlebird	*Dasyornis broadbenti littoralis*	do	Australia	do	E	14	Do.
White-breasted silvereye	*Zosterops albogularis*	do	Norfolk Island	do	E	14	Do.
Red siskin	*Spinus cucullatus*	do	South America	do	E	14	Do.
MAMMALS							
Howler monkey	*Alouatta palliata (villosa)*	do	Mexico, Ecuador, Colombia	do	E	14	Do.
Golden langur	*Presbytis geei*	do	Assam, Bhutan	do	E	14	Do.
Langur	*Presbytis pileatus*	do	Assam, India, Burma	do	E	14	Do.
Do	*Presbytis entellus*	do	Tibet, India, Nepal, Ceylon, Pakistan, Kashmir, Sikkim, Bangladesh.	do	E	14	Do.
Proboscis monkey	*Nasalis larvatus*	do	Borneo	do	E	14	Do.
Gibbons	*Hylobates* spp	do	China, Burma, India, Assam, Thailand, Sumatra, Java, Borneo.	do	E	14	Do.
Siamang	*Symphalangus syndactylus*	do	Malay Peninsula, Sumatra	do	E	14	Do.
Giant armadillo	*Priodontes giganteus (-maximus).*	do	Venezuela, Guyana, Argentina	do	E	14	Do.
Scaly anteater	*Manis temminckii*	do	Africa	do	E	14	Do.
Hispid hare	*Caprolagus hispidis*	do	India, Nepal	do	E	14	Do.
Beaver	*Castor fiber birulai*	do	Mongolia	do	E	14	Do.
Australian native mouse	*Zyzomys pedunculatus*	do	Australia	do	E	14	Do.
Do	*Notomys aquilo*	do	do	do	E	14	Do.
Chinchilla	*Chinchilla brevicaudata boliviana.*	do	Bolivian Andes	do	E	14	Do.
Gray wolf	*Canis lupus monstrablis*	do	Texas, New Mexico, Mexico	do	E	14	Do.
Spotted linsang	*Prionodon pardicolor*	do	Nepal, Assam, Burma, Indochina	do	E	14	Do.
Brown bear	*Ursus arctos pruinosus*	do	Tibet	do	E	14	Do.
Do	*Ursus arctos*	do	Italy	do	E	14	Do.
Long-tailed otter	*Lutra longicaudis*	do	South America	do	E	14	Do.
Marine otter	*Lutra felina*	do	Peru, Chiloe Island, Straits of Magellan.	do	E	14	Do.
Southern river otter	*Lutra provocax*	do	Chile, Argentina	do	E	14	Do.
Flat-headed cat	*Felis planiceps*	do	Malay Peninsula, Borneo, Sumatra	do	E	14	Do.
Black-footed cat	*Felis nigripes*	do	Southern Africa	do	E	14	Do.
Costa Rican puma	*Felis concolor costaricensis*	do	Nicaragua, Costa Rica, Panama	do	E	14	Do.
Temminchk's cat	*Felis temmincki*	do	Tibet, Sumatra	do	E	14	Do.
Leopard cat	*Felis bengalensis bengalensis*	do	Eastern Asia	do	E	14	Do.
Jaguarundi	*Felis yagouaroundi cacomitli*	do	Mexico	do	E	14	Do.
Do	*Felis yagouaroundi fossata*	do	Mexico, Nicaragua	do	E	14	Do.
Do	*Felis yagouaroundi panamensis*	do	Nicaragua, Costa Rica, Panama	do	E	14	Do.
Do	*Felis yagouaroundi tolteca*	do	Mexico	do	E	14	Do.
Marbled cat	*Felis marmorata*	do	Nepal, Malaya, Burma, Sumatra, Borneo.	do	E	14	Do.
Andean cat	*Felis jacobita*	do	Chile, Peru, Bolivia, Argentina	do	E	14	Do.
Bobcat	*Felis (Lynx) rufus escuinapae*	do	Central Mexico	do	E	14	Do.
Clouded leopard	*Neofelis nebulosa*	do	Southeast Asia	do	E	14	Do.
Asian elephant	*Elephas maximus*	do	India, Burma, Thailand, Indochina, Malay Peninsula, Sumatra, Ceylon.	do	E	14	Do.
Przewalski's horse	*Equus przewalskii*	do	Mongolia	do	E	14	Do.
Mountain zebra	*Equus zebra zebra*	do	Southern Africa	do	E	14	Do.
Asian tapir	*Tapirus indicus*	do	Burma, Thailand, Indochina, Sumatra.	do	E	14	Do.
Babirousa	*Babyrousa babyrussa*	do	Celebes, Togian Islands, Buru Island, Sula Island.	do	E	14	Do.
Bactrian camel	*Camelus bactrianus*	do	Mongolia, China	do	E	14	Do.
Musk deer	*Moschus moschiferus moschiferus.*	do	South-central Asia	do	E	14	Do.
Hog deer	*Axis (Hyelaphus) porcinus annamiticus.*	do	India, Thailand, Indochina	do	E	14	Do.

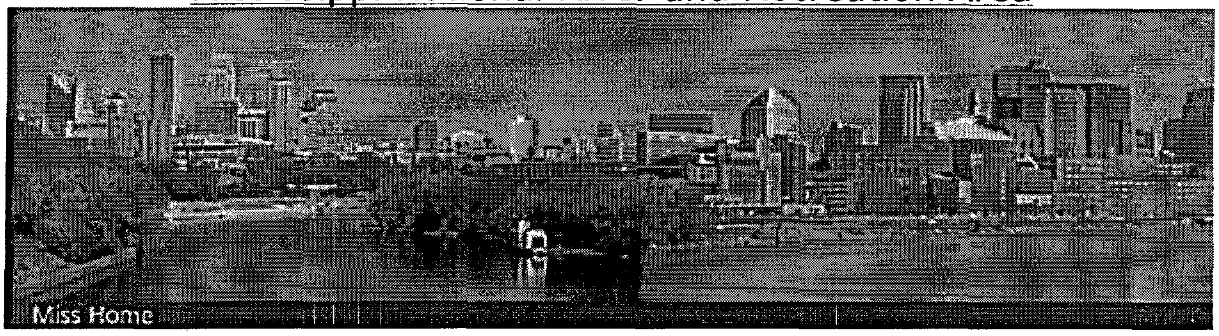
Species			Range				
Common name	Scientific name	Population	Known distribution	Portion of range where threatened or endangered	Status	When listed	Special rules
Philippine deer	*Axis (Hyelaphus) calaminensis*	do	Calamian Islands in Philippines	do	E	14	Do.
South Andean huemal	*Hippocamelus bisulcus*	do	Chile, Argentina	do	E	14	Do.
North Andean huemal	*Hippocalamelus antisensis*	do	Ecuador, Peru, Bolivia, Chile, Argentina.	do	E	14	Do.
Pampas deer	*Ozotoceras bezoarcticus*	do	Brazil, Paraguay, Uruguay, Argentina.	do	E	14	Do.
Pudu	*Pudu pudu*	do	Southern South America	do	E	14	Do.
Mountain anoa	*Bubalus (Anoa) quarlesi*	do	Celebes	do	E	14	Do.
Lechwe	*Kobus leche*	do	Southwest Africa	do	E	14	Do.
Giant sable antelope	*Hippotragus niger variani*	do	Angola	do	E	14	Do.
Dorcas gazelle	*Damaliscus dorcas dorcas*	do	South Africa	do	E	14	Do.
Saiga antelope	*Saiga tatarica mongolica*	do	Mongolia	do	E	14	Do.
Goral	*Naemorhedus goral*	do	East Asia	do	E	14	Do.
Sumatran serow	*Capricornis sumatraensis*	do	Sumatra	do	E	14	Do.
Chamois	*Rupicapra rupicapra ornata*	do	Italy	do	E	14	Do.
Straight-horned markhor	*Capra falconeri jerdoni*	do	Pakistan-Afghanistan border	do	E	14	Do.
Kabal markhor	*Capra falconeri megaceros*	do	Afghanistan, Pakistan	do	E	14	Do.
Chiltan markhor	*Capra falconeri chiltanensis*	do	Pakistan	do	E	14	Do.
Urial	*Ovis orientalis ophion*	do	Cyprus	do	E	14	Do.
Argali	*Ovis ammon hodgsoni*	do	Tibet	do	E	14	Do.
Shapo	*Ovis vignei*	do	Kashmir	do	E	14	Do.

2. Add the following footnote to the end of the table in § 17.11:
14—41 FR ____; June ____, 1976

[FR Doc.76-17040 Filed 6-11-76;8:45 am]

NATIONAL PARK SERVICE 2004

National Park Service
Mississippi National River and Recreation Area



NPS

Welcome

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- Bureau of Mines Project
- Calender of Events
- News & Reports
- Places to Visit
- Programs & Services
- The River's Stories
- Trail User Guide
- Volunteers-In-Parks
- The Whole Mississippi

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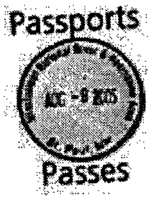
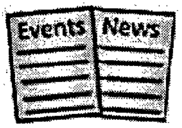


About the Area

Learn about the Mississippi River and the surrounding area by reading the The River's Stories.



Get information on Calendar of Events that are happening within the area. Read the latest news releases on our News & Reports page.

Things to Do

The Mississippi National River and Recreation Area's rich history & great location between the Twin Cities of Minneapolis and St. Paul offer a wide array of Places to Visit for visitors of all ages. Also, discover a variety of Trails along or around the river.

If you are traveling north or south of the area, use the The Whole Mississippi Guide to search for attractions from the headwaters at Itasca to the Gulf of Mexico.

Mississippi Webspace

Text by Bernard E. Sietman
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Photographs by Deborah Rose
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SIETMAN 2003

Field Guide to the Freshwater Mussels of Minnesota

Bernard E. Sietman

Hatch + Schmidt 2004

FISHES OF MINNESOTA
Distribution in 8 Major Drainage Basins

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Updated 21 January 2004

At present we recognize 159 species (139 native) as historically occurring in Minnesota waters with an additional 2 species in waters contiguous to Minnesota (*Apeltes quadracus,* introduced to Lake Superior in Ontario, and *Fundulus dispar,* a native in Lower Mississippi of Wisconsin). The latest arrival is the bighead carp (*Hypophthalmichthys nobilis*). There are 82 genera (69 native) plus 1 introduced in contiguous waters and 27 families (25 native). We have not included failed intentional or inadvertant introductions.

i = introduced to the drainage, L = below Taylor's Falls, U = above Taylor's Falls, X = native to and present today in drainage, # = present prior to 1975, R = native and reintroduced, IA = Iowa portion of drainage, ND = North Dakota portion of drainage, OT = Ontario portion of drainage, SD = South Dakota portion of drainage, WI = Wisconsin portion of drainage, ? following any letter or symbol indicates we are investigating questionable records; Totals at bottom of table do not count questionable recor

Conservation status symbols (ETS species): en = state endangered, th = state threatened, sc = state special concern; E = federally endangered

										C

Taxon	Common name	Red R	Rainy R	U Miss R	Superior	St Croix	Minn R	Mo River	L Miss R	onser Stat
Petromyzontiformes										
Petromyzontidae										
Ichthyomyzon castaneus	chesnut lamprey	X				X			X	
Ichthyomyzon fossor	northern brook lamprey		X		X	WI			X	sc
Ichthyomyzon gagei	southern brook lamprey					X				sc
Ichthyomyzon unicuspis	silver lamprey	X	X		X	X	X		X	
Lampetra appendix	American brook lamprey					L	X		X	
Petromyzon marinus	sea lamprey				i					
Acipenseriformes										
Acipenseridae										
Acipenser fulvescens	lake sturgeon	R	X		X	X	X		X	sc
Scaphirhynchus platorynchus	shovelnose sturgeon					L	X		X	

Polyodontidae										
Polyodon spathula	paddlefish					L	X	IA,SD	X	th
Semionotiformes										
Lepisosteidae										
Lepisosteus osseus	longnose gar	#				L	X	IA,SD	X	
Lepisosteus platostomus	shortnose gar			X		L	X		X	
Amiiformes										
Amiidae										
Amia calva	bowfin	X		X		X	X		X	
Osteoglossiformes										
Hiodontidae										
Hiodon alosoides	goldeye	X	#			L#	X	IA,SD	X	
Hiodon tergisus	mooneye	X	X			L#			X	
Anguilliformes										
Anguillidae										
Anguilla rostrata	American eel			X	X	L	X	SD	X	
Clupeiformes										
Clupeidae										
Alosa chrysochloris	skipjack herring					L#	#		X	sc
Alosa pseudoharengus	alewife				i					
Dorosoma cepedianum	gizzard shad			X		L	X	IA,SD	X	
Cypriniformes										

Cyprinidae										
Campostoma anomalum	central stoneroller	X		X		X	X	X	X	
Campostoma oligolepis	largescale stoneroller	ND				U	X		X	
Carassius auratus	goldfish			i			i		i	
Clinostomus elongatus	redside dace								X	
Couesius plumbeus	lake chub		ONT		X					
Ctenopharyngodon idella	grass carp							IAi	i	
Cyprinella lutrensis	red shiner							X	IA	
Cyprinella spiloptera	spotfin shiner	X	X	X		X	X	IA	X	
Cyprinus carpio	carp	i		i	i	i	i	i	i	
Erimystax x-punctatus	gravel chub								X	sc
Hybognathus hankinsoni	brassy minnow	X	X	X	X	X	X	X	X	
Hybognathus nuchalis	Mississippi silvery minnow								X	
Hybopsis amnis	pallid shiner					#			X	sc
Hypophthalmichthys nobilis	bighead carp								i	
Luxilus cornutus	common shiner	X	X	X	X	X	X	X	X	
Lythrurus umbratilis	redfin shiner								X	
Macrhybopsis (Hybopsis)	speckled chub					L	X	IA	X	

aestivalis										
Macrhybopsis (Hybopsis) storeriana	silver chub	X				X	#	IA	X	
Margariscus margarita	pearl dace	X	X	X	X	X	#		X	
Nocomis biguttatus	hornyhead chub	X	X	X	X	X	X	IA	X	
Notemigonus crysoleucas	golden shiner	X	X	X	X	X	X	IA	X	
Notropis anogenus	pugnose shiner	X		X	X	WI	X	IA	X	sc
Notropis atherinoides	emerald shiner	X	X	X	X	L	X	X	X	
Notropis blennius	river shiner	X	X			L#	X		X	
Notropis dorsalis	bigmouth shiner	X	X	X		X	X	X	X	
Notropis heterodon	blackchin shiner	X	X	X	#	X	X		X	
Notropis heterolepis	blacknose shiner	X	X	X	X	X	X	IA	X	
Notropis hudsonius	spottail shiner	X	X	X	X	X	X	X	X	
Notropis nubilus	Ozark minnow								X	sc
Notropis rubellus	rosyface shiner	X					X		X	
*Notropis stramineus**	sand shiner	X		X		X	X	X	X	
Notropis texanus	weed shiner	X		X		L#	X		X	
Notropis topeka	Topeka shiner							X	#	E
Notropis volucellus	mimic shiner	X	X	X	X	X	X		X	
Opsopoeodus emiliae	pugnose minnow					L			X	
Phenacobius mirabilis	suckermouth minnow							IA	X	

Phoxinus eos	northern redbelly dace	X	X	X	X	X	X	SD	X	
Phoxinus erythrogaster	southern redbelly dace							X	X	
Phoxinus neogaeus	finescale dace	X	X	X	X	X			X	
Pimephales notatus	bluntnose minnow	X	X	X	#	X	X	X	X	
Pimephales promelas	fathead minnow	X	X	X	X	X	X	X	X	
Pimephales vigilax	bullhead minnow			X					X	
Platygobio gracilis	flathead chub	i						IA,SD		
Rhinichthys atratulus	blacknose dace	X	X	X	X	X	X	X	X	
Rhinichthys cataractae	longnose dace	X	X	X	X	X			X	
Semotilus atromaculatus	creek chub	X	X	X	X	X	X	X	X	
Catostomidae										
Carpiodes carpio	river carpsucker						X	X	X	
Carpiodes cyprinus	quillback	X	X			X	X	X	X	
Carpiodes velifer	highfin carpsucker					L	X		X	
Catostomus catostomus	longnose sucker		X		X					
Catostomus commersoni	white sucker	X	X	X	X	X	X	X	X	
Cycleptus elongatus	blue sucker					X	X	SD	X	sc

Hypentelium nigricans	northern hogsucker	X		X		X	X		X	
Ictiobus bubalus	smallmouth buffalo	X				L	X	IA,SD	X	
Ictiobus cyprinellus	bigmouth buffalo	X		X		L	X	X	X	
Ictiobus niger	black buffalo						X	IA	X	sc
Minytrema melanops	spotted sucker					L	#		X	
Moxostoma anisurum	silver redhorse	X	X	X	X	X	X		X	
Moxostoma carinatum	river redhorse					X	#		X	
Moxostoma duquesnei	black redhorse								X	
Moxostoma erythrurum	golden redhorse	X	X			X	X	X	X	
Moxostoma macrolepidotum	shorthead redhorse	X	X	X	X	X	X	X	X	
Moxostoma valenciennesi	greater redhorse	X	#	X		X	X		X	
Siluriformes										
Ictaluridae										
Ameiurus melas	black bullhead	X	X	X	X	X	X	X	X	
Ameiurus natalis	yellow bullhead	X		X	X	X	X	X	X	
Ameiurus nebulosus	brown bullhead	X	X	X	X	X	X	IA	X	
Ictalurus furcatus	blue catfish					i				
Ictalurus punctatus	channel catfish	X		i	X	X	X	X	X	

Noturus exilis	slender madtom								X	sc
Noturus flavus	stonecat	X		X	X	X	X	X	X	
Noturus gyrinus	tadpole madtom	X	X	X	X	X	X	X	X	
Pylodictis olivaris	flathead catfish			i		X	X	IA,SD	X	
Esociformes										
Esocidae										
Esox lucius	northern pike	X	X	X	X	X	X	X	X	
Esox masquinongy	muskellunge	i	X	X	X	i		IAi	i	
Umbridae										
Umbra limi	central mudminnow	X	X	X	X	X	X	X	X	
Osmeriformes										
Osmeridae										
Osmerus mordax	rainbow smelt		i	i	i	i			i	
Salmoniformes										
Salmonidae										
Coregonus artedi	lake herring (cisco)	X	X	X	X	U				
Coregonus clupeaformis	lake whitefish	X	X	X	X	L#				
Coregonus hoyi	bloater				X					
Coregonus kiyi	kiyi				X					sc
Coregonus nipigon	Nipigon cisco		X							
Coregonus zenithicus	shortjaw cisco		X		X					sc
Oncorhynchus										

gorbuscha	pink salmon				i					
Oncorhynchus kisutch	coho salmon				i					
Oncorhynchus mykiss	rainbow trout	i	i	i	i	i	i		i	
Oncorhynchus tshawytscha	chinook salmon				i					
Prosopium coulteri	pygmy whitefish				X					
Prosopium cylindraceum	round whitefish				X					
Salmo salar	Atlantic salmon				i					
Salmo trutta	brown trout	i	i	i	i	i	i		i	
Salvelinus fontinalis	brook trout	i	i	i	X	X	X		X	
Salvelinus namaycush	lake trout		X	i	X	i				
Percopsiformes										
Percopsidae										
Percopsis omiscomaycus	trout-perch	X	X	X	X	X		X	X	
Aphredoderidae										
Aphredoderus sayanus	pirate perch								X	sc
Gadiformes										
Lotidae										
Lota lota	burbot	X	X	X	X	X	X		X	
Atheriniformes										
Atherinidae										

Labidesthes sicculus	brook silverside			X	i	X			X	
Cyprinodontiformes										
Fundulidae										
Fundulus diaphanus	banded killifish	X	X	X		X	X	IA,SD	X	
Fundulus dispar	starhead topminnow								WI	
Fundulus sciadicus	plains topminnow							X		sc
Gasterosteiformes										
Gasterosteidae										
Apeltes quadracus	fourspine stickleback				OTi					
Culaea inconstans	brook stickleback	X	X	X	X	X	X	X	X	
Gasterosteus aculeatus	threespine stickleback				i					
Pungitius pungitius	ninespine stickleback		X	X	X					
Scorpaeniformes										
Cottidae										
Cottus bairdi	mottled sculpin	X	X	X	X	X			X	
Cottus cognatus	slimy sculpin		X	X	X	L			X	
Cottus ricei	spoonhead sculpin		X		X					
Myoxocephalus thompsoni	deepwater sculpin		X		X					

Perciformes										
Moronidae										
Morone americana	white perch				i					
Morone chrysops	white bass	i				L	X	IA,SD	X	
Morone mississippiensis	yellow bass								X	sc
Centrarchidae										
Ambloplites rupestris	rock bass	X	X	X	X	X	X		X	
Lepomis cyanellus	green sunfish	X	X	X	X	X	X	X	X	
Lepomis gibbosus	pumpkinseed	X	X	X	X	X	X	X	X	
Lepomis gulosus	warmouth		i			LWI			X	
Lepomis humilis	orangespotted sunfish	X		X			X	X	X	
Lepomis macrochirus	bluegill	X	X	X	X	X	X	X	X	
Lepomis megalotis	longear sunfish		X	X		UWI				
Micropterus dolomieu	smallmouth bass	i	i	X	X	X	X	IA	X	
Micropterus salmoides	largemouth bass	X	X	X	X	X	X	i	X	
Pomoxis annularis	white crappie	i				X	X	IA,SD	X	
Pomoxis nigromaculatus	black crappie	X	X	X	X	X	X	X	X	
Percidae										
Ammocrypta clara	western sand darter					L	#		X	

Crystallaria asprella	crystal darter					L			X	sc
Etheostoma asprigene	mud darter					L			X	
Etheostoma caeruleum	rainbow darter	X				L	X		X	
Etheostoma chlorosoma	bluntnose darter								X	
Etheostoma exile	Iowa darter	X	X	X	X	X	X	X	X	
Etheostoma flabellare	fantail darter					L	X		X	
Etheostoma microperca	least darter	X		X	X	WI	X		X	sc
Etheostoma nigrum	johnny darter	X	X	X	X	X	X	X	X	
Etheostoma zonale	banded darter						X		X	
Gymnocephalus cernuus	ruffe				i					
Perca flavescens	yellow perch	X	X	X	X	X	X	X	X	
Percina caprodes	logperch	X	X	X	X	X	X	IA,SD	X	
Percina evides	gilt darter					X			WI	sc
Percina maculata	blackside darter	X	X	X		X	X	X	X	
Percina phoxocephala	slenderhead darter					X	X		X	
Percina shumardi	river darter		X			L	X		X	
*Sander canadense***	sauger		X			L	X	IA	X	
*Sander vitreus***	walleye	X	X	X	X	X	X	i	X	
Sciaenidae										

Aplodinotus grunniens	freshwater drum	X			i	X	X	IA,SD	X	
Gobiidae										
Neogobius melanostomus	round goby				i					
Proterorhinus marmoratus	tubenose goby				i					
	No. of families	20	17	18	21	25	21	10	26	
	No. of genera	49	41	47	51	63	56	29	70	
	Total no. of species	82	73	75	83	106	95	42	127	
	No. of introduced species	9	6	10	16	7	4	3	8	
	No. of native species	73	67	65	67	99	91	39	119	
	No. of ETS species	3	3	2	6	8	7	2	16	21

* International Commission on Zoological Nomenclature Opinion 1991, specific epithet, *stramineus*, was conserved, making *Notropis ludibundus* invalid. see *Bulletin of Zoological Nomenclature* 59(1), 27 March 2002: 58-59.

** *Sander* recognized as the senior synonym of *Stizostedion*. see Kottelat, M. 1997. European freshwater fishes. An heuristic checklist of the freshwater fishes of Europe (exclusive of former USSR), with an introduction for non-systematics and comments on nomenclature and conservation. *Biologia* 52 (supplement 5):1-271.

Last updated 21 January 2004

Minnesota Department of Health
Protecting, maintaining and improving the health of all Minnesotans

MDH

Fish Consumption Advice

Most fish are healthy to eat. And fish are an excellent source of low-fat protein. Eating fish may also reduce the risk of heart disease, diabetes and other chronic illnesses. But any fish (store-bought or sport-caught) could contain contaminants such as mercury and PCBs that can harm human health - especially the development of children and fetuses. You can't see, smell, or taste the mercury or PCBs in fish. That's why it is important to know which fish are safer than others to eat.

The Minnesota Department of Health provides two types of advice on how often fish can safely be eaten:

- **Statewide Safe Eating Guidelines** - general guidelines to help you decide if you and your family need to make changes in your fish-eating habits.
- **Site-Specific Advice** - detailed consumption guidelines for lakes and rivers where fish have been tested for contaminants. These consumption guidelines are also searchable by lake on the Department of Natural Resources Lake Finder website.

For questions about this page, please contact our Environmental Health Division: ehweb@health.state.mn.us

Updated Thursday, 11-Aug-05 14:19:53

Minnesota Department of Health
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MDH

Fish Consumption
Safe Eating Guidelines

Safe Eating Guidelines* for Pregnant Women, Women who may become pregnant and Children under age 15

Kind of fish	How often can you eat it?
Fish caught in Minnesota:	
Sunfish, crappie, yellow perch, bullheads	1 meal a week (see exceptions)*
Walleyes shorter than 20 inches, northern pike shorter than 30 inches, smallmouth bass, largemouth bass, channel catfish, flathead catfish, white sucker, drum, burbot, sauger, carp, lake trout, white bass, rock bass, whitefish, other species	1 meal a month (see exceptions)*
Walleyes larger than 20 inches northern pike longer than 30 inches, muskellunge	**Do not eat**
Commercial Fish:	
Salmon, cod, pollock, canned "light" tuna (6 oz.), catfish, talapia, herring, sardines, shrimp, crab, scallops, oysters	2 meals a week
Canned "white" tuna (6 oz.), tuna steak, halibut, lobster	2 meals a month
Shark, swordfish, tile fish, king mackerel	**Do not eat**

*Fish from some Minnesota Lakes and rivers have been found to have higher levels of mercury or PCBs. If you eat certain fish from these waters, you should eat it less often than these guidelines. See exceptions tables (above) for further information on restrictions for eating fish from the specific Minnesota lakes and rivers.

There is no change in these guidelines for eating fish just during vacation or one season.

Go to > top.

Safe Eating Guidelines for Men and Women not planning to be pregnant

Kind of fish		How often can you eat it?
Fish caught in Minnesota:		
Sunfish, crappie, yellow perch, bullheads	→	unlimited amount
Walleyes, northern pike, smallmouth bass, largemouth bass, channel catfish, flathead catfish, white sucker, drum, burbot, sauger, carp, lake trout, white bass, rock bass, white fish, other species	→	1 meal a week
Commercial Fish:		
Limit the following species: shark, swordfish, tile fish, king mackerel	→	1 meal a month

In general, adults who eat fish just during vacation or one season can eat fish twice as often as recommended in these guidelines.

Go to > top.

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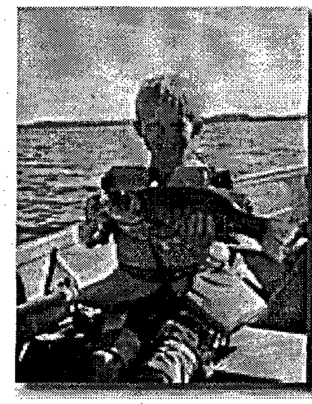
Fish Consumption

Site-Specific Meal Advice for Tested Lakes and Rivers



The Minnesota Department of Natural Resources (DNR), the Minnesota Pollution Control Agency (MPCA), and the Minnesota Department of Health collaborate in producing the fish consumption advisory. Each year, the DNR collects fish from lakes and rivers for testing. Minnesota has 6,000 fishable lakes. Fish from nearly 1,000 lakes and streams in Minnesota have been tested for contaminants.

All waters from which fish have been tested are listed in the tables below. The waters that have been tested are not necessarily more contaminated than those not tested. Waters are selected for sampling where angling is popular, where there is a known or suspected pollution source, or where fish contaminant trends are being tracked. Mercury is found in most fish tested from Minnesota lakes. PCBs are found mainly in Lake Superior and major rivers such as the Mississippi River. These guidelines are based on the contaminant level measured in fillets.

Consumption Advice for Bodies of Water Where Fish have been Tested:

Lakes - Fish Consumption Guidelines

Pregnant Women, Women who may become pregnant, and Children under age 15 (PDF 490KB/144 pages)

General Population - Men and Women not planning to be pregnant (PDF 483KB/136 pages)

Rivers - Fish Consumption Guidelines

Pregnant Women, Women who may become pregnant, and Children under age 15 (PDF 575KB/17 pages)

General Population - Men and Women not planning to be pregnant (PDF 71KB/15 pages)

Lake Superior - Fish Consumption Guidelines

For Everyone

Information on the mercury and PCB levels corresponding to the meal advice categories (PDF 56KB/1 page) **more »**

NOTE:
The Fish Consumption Guidelines listed above for lakes and rivers are Adobe Acrobat PDF files, except for the advice for Lake Superior. The lake files are large documents (130 pages). If you plan on referring to the Guidelines frequently, you may find it more efficient to download the files to your hard drive so you can refer to them without connecting to the Internet.

To download any of the Guidelines, right-click on the link and select either "Save Link As" or "Save Target As," depending on your browser. Select a location on your hard drive (drive C:) where you want to save the file. In the future you can view the document by simply double-clicking on the file name.

Go to > top.

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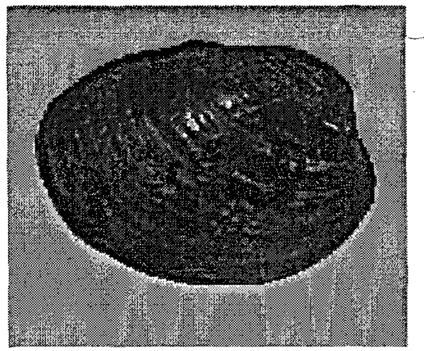
Updated Thursday, 11-Aug-05 14:04:23

U.S. Fish and Wildlife Service, Rock Island, Illinois

HIGGINS' EYE PEARLY MUSSEL RECOVERY
Lampsilis higginsi



The Higgins' eye pearly mussel is a freshwater clam that is found only in the Mississippi River, the St. Croix River in Wisconsin, the Wisconsin River and the Rock River in Illinois below the first dam. It was listed as an endangered species on June 24, 1976. It was never abundant and where it is found it only comprises approximately 0.5% of the mussel population. At the time the original recovery plan was written in 1982, data indicated that this species had undergone a 53% decrease in its known range.

Recovery Team Members

In 1994, the Higgins' Eye Recovery Team was reconstituted and reconvened to gather data and reassess the current distribution and status of the species, and to revise the recovery plan as necessary.

Robert Whiting Team Leader	Corps of Engineers	St. Paul, MN
Dr. Daniel Hornbach	Macalester College	St. Paul, MN

Dr. Diane Waller	National Biological Service	LaCrosse, WI
Dr. Andrew Miller	Corps of Engineers, Waterways Experiment Station	Vicksburg, MS
Dr. Mark Hove	University of Minnesota	St. Paul, MN
Pamela Thiel	U.S. Fish and Wildlife Service	LaCrosse, WI
David Heath	Wisconsin Department of Natural Resources	Rhinelander, WI
Mike Davis	Minnesota Department of Natural Resources	Lake City, MN

Recovery Team's Activities

- Conducted site characterizations of 10 or more mussel beds where Higgins' eye is known to occur, including several essential and secondary habitats that had not been surveyed for over 10 years. Dr. Andrew Miller, Dr. Daniel Hornbach, Mike Davis and David Heath have completed these characterizations.
- Conducted a literature search and synthesis of all published, unpublished and gray literature since the original recovery plan was written in 1982. Dr. Edward Cawley, Loras College, Dubuque, IA compled this task.
- Write a Revised Recovery Plan to incorporate new data and, potentially, to revise the recovery criteria. Dr. Daniel Hornbach completed this task.

Schedule

- August, 1998 - technical/agency draft Revised Recovery Plan completed and sent out for public review. Comments have been received and are being evaluated by the Team
- Fall, 2000 - completion of a final Revised Recovery Plan

Recovery Criteria (from the 2000 Revised Recovery Plan)

- L higginsi may be considered for reclassification to threatened when at least 5 of the essential habitat areas contain reproducing, self-

sustaining populations.
- *L. higginsi* may be considered for delisting when at least 5 of the essential habitat areas contain reproducing, self-sustaining populations of sufficient security to assure long term viability to the species.

Essential Habitats

The Team has identified ten mussel beds that it determined to be essential to the survival of the species. These are NOT designated critical habitats. The essential habitats are as follows:

WATERBODY	RIVER MILE	LOCATION
Mississippi River, Pool 9 (Whiskey Rock)	RM 655.8-658.4	opposite Ferryville, WI
Mississippi River, Pool 10 (Harper's Slough)	RM 639.0-641.4	Harper's Ferry, IA
Mississippi River, Pool 10 (Main and East Channels)	RM 633-637	Prairie du Chien, WI
Mississippi River, Pool 10 (McMillan Island)	RM 616.4-619.2	Guttenburg, IA
Mississippi River, Pool 14	RM 503.0-505.4	Cordova, IL
Mississippi River Pool 15 (Sylvan Slough)	RM 485.5-486.0	Rock Island, IL
St. Croix River	RM 16.2-17.6	near Hudson, WI
St. Croix River		at Prescott, WI
St. Croix River		at Franconia, MN
Wisconsin River		near Orion, WI

VEITZELL et al. 2003

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Conservation Priorities for Freshwater Biodiversity in the Upper Mississippi River Basin

Upper Mississippi River ©U.S.G.S

NatureServe and The Nature Conservancy

July 2003

Conservation Priorities for Freshwater Biodiversity in the Upper Mississippi River Basin

Citation:
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The Nature Conservancy's mission is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

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Conservation Priorities for Freshwater Biodiversity in the Upper Mississippi River Basin

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Chuck Theiling, U.S. Army Corps of Engineers, Rock Island Field Office

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Executive Summary

The extensive network of streams, mainstem river and its floodplains, thousands of lakes, and the uplands that make up the Upper Mississippi River Basin (UMRB) provide habitat for a significant portion of the Earth's biological diversity. A considerable fraction of the world's population also depends on this area — the nation's heartland — for food, transportation and municipal water supply. Human land use in the basin has greatly altered the terrestrial and riverine ecosystems of the UMRB. This study evaluates the components and patterns of the freshwater biodiversity of the basin, and identifies the most significant places to focus conservation opportunities to maintain it.

Many aspects and portions of the UMRB are well studied. Yet, we have lacked the information to guide focused and comprehensive conservation action to sustain freshwater biodiversity throughout the whole UMRB. To address this need, NatureServe and The Nature Conservancy, with the financial support of the McKnight Foundation and Region 5 of the U.S. Environmental Protection Agency, have assembled data on the variety, distribution and condition of freshwater species and ecosystems of the basin. This report provides detailed information on three major aquatic taxonomic groups — fishes, mussels, and crayfishes. We have also classified all of the freshwater components of the basin as ecological system types based on their physical attributes and surrounding landscapes. We assessed their ecological integrity using spatial data on land use patterns which provide information on large-scale and non-point sources of impacts, as well as more site-specific information such as dams and industrial facility locations.

Through working with regional experts with these data, we have identified the set of areas of biodiversity significance (ABS), that together represent the full array of places that harbor the best remaining examples of the rare and imperiled aquatic species and the ecological systems that contain them as well as those ecological systems that contain the best examples of common and representative species and communities.

Using a suite of terrestrial areas identified in previous conservation planning exercises, we have assembled a set of fifty priority areas in the basin for both terrestrial and aquatic biodiversity. We have included a detailed description of each priority area, which includes a map and a list of the freshwater and terrestrial conservation targets found in each area

We have a high level of confidence that, if protected and/or restored, both sets of priorities (freshwater alone or freshwater combined with terrestrial) will ensure the viability of the common species and a majority of the imperiled aquatic species in the basin. Given that the basin is home to one quarter of the species of freshwater fishes in the United States and 20% of the mussel species found in the United States and Canada, successful conservation in the UMRB is critical to the conservation of a significant component of global freshwater biodiversity.

Our analysis of these data was for the specific purpose of selecting priority river systems that would be representative of the biodiversity of the basin. However, these data can be used for many additional purposes. This report explains how several data sets for fish and mussels have been assembled into a standardized database format with spatial locations for all of the samples. We explored using these fish data to identify biological communities, to use as biological attributes of ecological systems in addition to the physical attributes we used to derive them. We used the northern glaciated watersheds of Wisconsin and Minnesota as a pilot region to explore and develop methods to identify communities. This analysis also showed the complexities involved in relating community data to the ecological classification.

We have included with this report appendices and electronic databases containing all of the data sets used to identify conservation priorities among river systems and conduct the community analysis, with the exception of point locations of sensitive species. These data can be used for conservation area planning at specific locations within the basin, to identify and set reference conditions for biological monitoring of stream health, and to design sampling frameworks for species inventories.

1. Introduction

1.1. Purpose and Scope of Work

The Upper Mississippi River Basin (UMRB) is a national, natural treasure, the crown of one of the world's major river systems in size, habitat diversity, and biological productivity. The upper basin's river and its adjacent forest and wetlands provide important refuge to thousands of species and natural communities, representing the largest area of contiguous fish and wildlife habitat in the Central United States (Wiener et al. 1998, USACE 2002). The entire basin is a globally significant for fish evolution, having served as a refuge during times of glaciation for the fish fauna of central North America and in its current role as a refuge for ancient fishes and other aquatic or semi-aquatic vertebrates (Burr and Ladonski 2000).

However, in its current state, the UMRB is also a highly regulated and degraded ecosystem: the mainstem Mississippi River bears little resemblance to the natural, free-flowing river system of the past, and the lands surrounding the tributary watersheds have been extensively changed by human settlement and commerce. Over 95% of the original native prairies, savannas, and prairie/forests of the UMRB have been converted to agricultural uses (National Audubon Society 2000), with drastic affects on both terrestrial and aquatic species and communities. Land conversion, in conjunction with widespread alteration of the natural hydrologic regime, has lead to an overall loss in native aquatic diversity and ecosystem resiliency. This high degree of alteration, and measurable downward trends in the status of aquatic species and communities creates a compelling need to examine what remains of the basin's native biodiversity and the issues that must be addressed to ensure the future health and sustainability of the Upper Mississippi River ecosystem.

With the support of the McKnight Foundation and Region V of the U.S. Environmental Protection Agency (USEPA) and help from many outside partners, scientists from NatureServe and The Nature Conservancy (TNC) have identified the UMRB's areas of freshwater biodiversity significance as well as the top "fifty" areas where aquatic and terrestrial conservation priorities overlap. Our primary purpose for the assessment was to answer the question — where are the areas of greatest freshwater biodiversity significance? This report was intended to provide a comprehensive vision that will galvanize conservation and restoration action by all stakeholders at the critical places within the UMRB.

Given the years of research on the UMRB, we started by evaluating and gathering existing data. The designation of the Upper Mississippi River as "a nationally significant ecosystem" (Water Resources Development Act of 1986), has led to coordinated research efforts and greatly increased our understanding of aquatic biodiversity patterns and natural and altered ecosystem functions. However, these federal, state and academic efforts (Appendix 1) have largely focused on only small components of the basin without considering the broader basin context. A comprehensive assessment of the status of aquatic species and system diversity across the UMRB has been lacking. The Nature Conservancy has also completed conservation plans for several ecoregions that overlap the basin. While these plans provide priority areas for terrestrial and aquatic biodiversity, ecoregions were not the most appropriate assessment units to address aquatic species and systems within the UMRB as a whole. In addition the plans vary in their completeness for aquatic targets (Table 1).

Table 1. Aquatic scope of ecoregional plans in the Upper Mississippi River basin

ECOREGION	COMPREHENSIVE FOR AQUATICS	# OF AQUATIC TARGET SPECIES	% OF AQUATIC TARGET SPECIES CAPTURED IN PORTFOLIO	# OF AQUATIC SYSTEM TARGETS	% OF AQUATIC SYSTEM TARGETS CAPTURED IN PLAN
Northern Tallgrass Prairie	No	10	0%	0	0%
Superior Mixed Forest	Yes	21	42%	37	65%
Prairie-Forest Border	Yes	23	83%	24	67%
Interior Low Plateau	No	97	87%	0	0%
Central Tallgrass Prairie	No	28	57%	0	0%
Great Lakes	Yes	31	100%	231	89%

These valuable efforts have provided us with a very good understanding of the current distribution and status of aquatic species and systems on the mainstem Mississippi River, or in selected sub-watersheds. However, the work described above does not cover the basin sufficiently to support creating a comprehensive and integrated vision for the conservation of freshwater biodiversity across the whole basin. Little has been done to establish and understand the full extent of ecological linkage between the mainstem Mississippi Rivers, its major tributaries and the smaller inland sub-watersheds. By focusing only on the mainstem, for instance, the significance of tributaries to ecosystem processes and to many species can be overlooked. From an aquatic systems perspective, the mainstem represents only a small range of ecological settings, many of which exist along a continuum, well beyond the borders of the floodplain.

This report details the NatureServe/TNC assessment of freshwater biological diversity done in the context of the whole upper basin. The report begins with an overview of the Upper Mississippi system — its physical setting, the biota and the impact of its human history. We then present the methods and results of applying the Conservancy's conservation process to identify the areas of freshwater biodiversity significance. This section includes the methods used to select targets for conservation, which include rare and imperiled species and representative aquatic ecological systems. We also present the classification framework developed to describe and map aquatic ecological systems. The next sections then describe the conservation goals set for each target and the information layers used to identify the best opportunities for conservation of these targets, which included expert interviews and spatial analysis of indicators of ecological integrity.

This information was synthesized to create a network of areas that together represent the full diversity of target species and aquatic ecological systems. This network will inform conservation work across the UMRB. Our funders were also interested in what are the top fifty areas where aquatic and terrestrial conservation priorities overlap. We used the previous ecoregional analyses completed by Nature Conservancy staff as our source for terrestrial priorities and designated forty-eight Priority Areas. We show for both networks of areas how well each met the conservation goals for our targets.

Additionally, we used the wealth of biological data to create an integrated data base of all spatially located samples (Section 9) and complete a pilot analysis of biological communities (Section 10). We were able to discern 13 fish community types and from this work and gained valuable insight about what is required to create a comprehensive biological community classification and relate the communities to the physically-defined aquatic systems. In the last section, we address the data gaps encountered during this assessment.

1.2 Background: The Upper Mississippi River Basin

The Upper Mississippi River Basin is a vast floodplain river system, emerging from its source at Lake Itasca, and flowing over 1300 miles to the confluence with the Ohio River at Cairo, IL (Figure 1). Its watershed drains an area of nearly 190,000 mi^2, equivalent to 15% of the entire Mississippi River drainage, or 6% of the area of the lower 48 United States.

The Upper Mississippi River and its tributary systems operate as an ecosystem, with biota having evolved to their current (pre-European settlement) forms over millennia, in response to large-scale geologic and climatic processes. The resident aquatic species and communities, in turn, have adapted to these processes, and rely on regular cycles of environmental conditions to fulfill their life history requirements. Many species rely on small areas or single habitat types for their needs, while others are wide-ranging, utilizing multiple habitats across large areas. Under natural conditions, the backwaters of this large temperate river system created extensive fish nursery habitat and supported fish production that made the Mississippi River fishery unparalleled in North America (Burr and Ladonski 2000).

Currently, the waters of the UMRB are home to nearly 200 native, regularly occurring fishes, roughly 25% of approximately 800 species occurring in the United States (Page and Burr 1991). The basin also holds a rich diversity of freshwater mussels, crayfish, and an as yet untold number of other aquatic invertebrates. See Section 1.3 for a more detailed discussion of the composition and status of these groups. It is a globally important flyway for 60% of all North American bird species (UMRCC 2000), and also harbors diverse amphibian, reptile, and mammal faunas. The river currently supports no less than 286 state-listed or candidate species, and 36 federally-listed or candidate species of threatened or endangered plants and animals endemic to the basin (Theiling 1996, Theiling et al. 2000).

Box 1. Upper Mississippi River acronyms.

Throughout this report and other publications on the Upper Mississippi River, several acronyms are used to describe the river system.

UMRB — Upper Mississippi River Basin (Figure 1)
Includes the entire drainage area of the Upper Mississippi River, from its source at Lake Itasca, MN, downstream to its confluence with the Ohio River at Cairo, IL. The Missouri River and its tributaries are not included.

UMR — Upper Mississippi River
Northern, navigable portion of the Mississippi River, extending approximately 850 miles from St. Anthony Falls in Minneapolis, MN, to the mouth of the Ohio River at Cairo, IL.

IR — Illinois River
Begins at the confluence of the Des Plaines and Kankakee Rivers, near Channahon, IL, flowing more than 270 miles to Grafton, IL, where it joins the UMR.

IRWW — Illinois River Waterway
Includes the entire IR, and continues approximately 60 additional miles upstream along portions of several rivers and man-made channels to Lake Michigan (USACE 1987; Appendix A, Theiling et al. 2000).

UMRS — Upper Mississippi River System
The natural floodplain between the head of navigation at Minneapolis, MN, and the confluence with the Ohio River at Cairo, IL, as defined by the Water Resources Development Act of 1986, Public Law 99-662 (Figure 2).

UMR_IRWW — Upper Mississippi River — Illinois River Waterway
Equivalent to UMRS.

Upper Mississippi River Basin

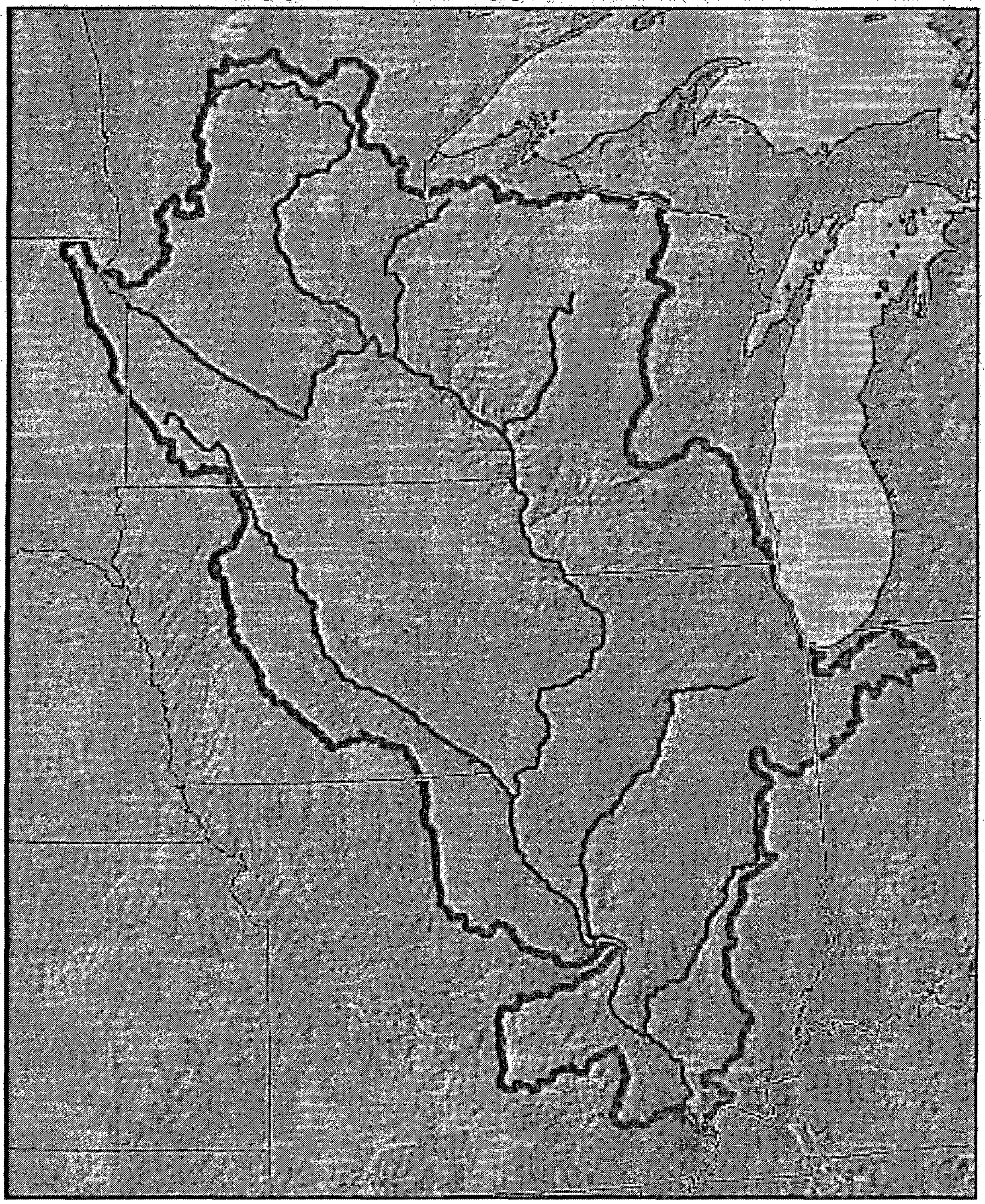

Figure 1. Map of the Upper Mississippi River Basin showing state boundaries and major rivers.

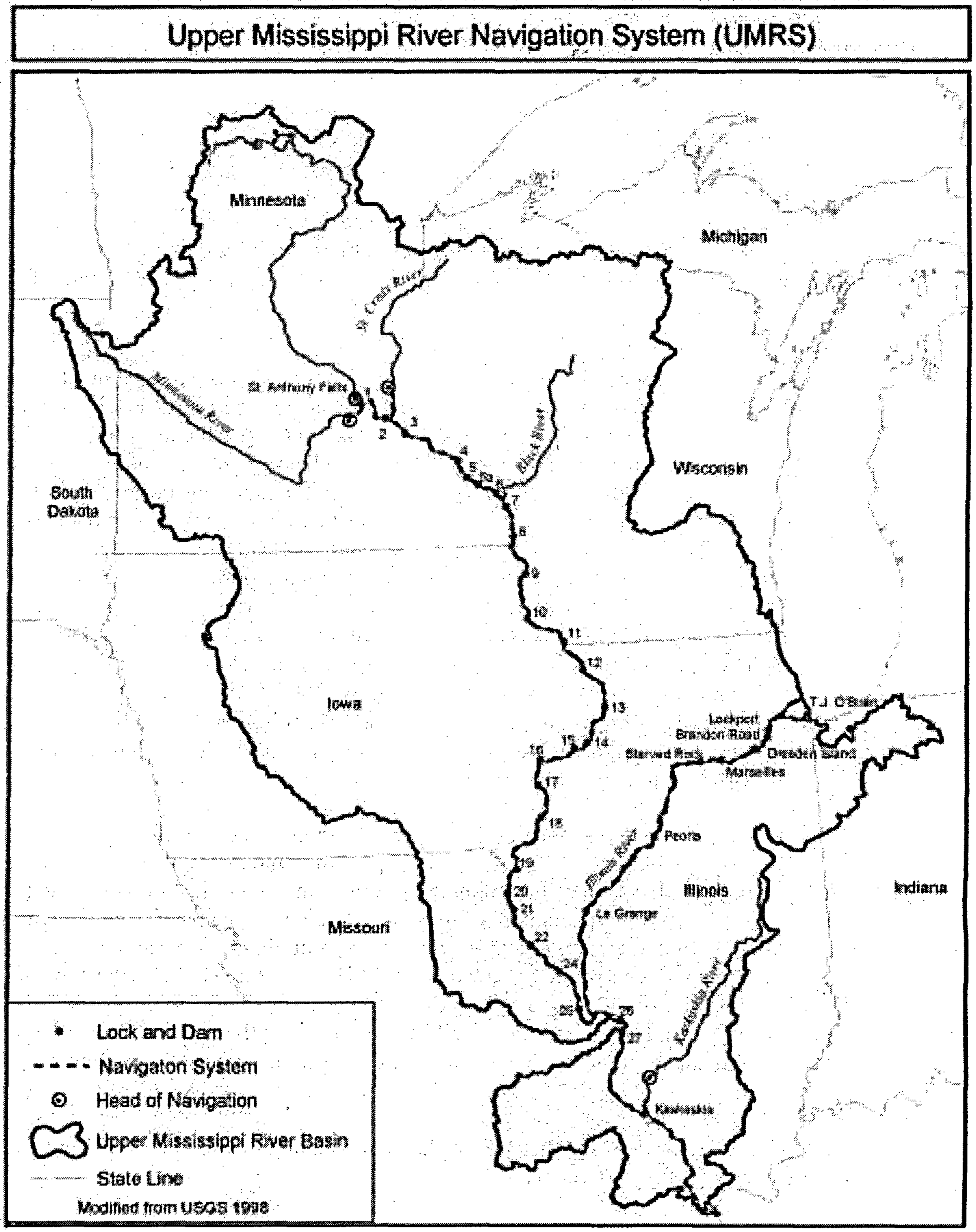

Figure 2. Upper Mississippi River System (UMRS).

The river system, its flora, and fauna have always provided diverse ecological benefits, and since its settlement, the Mississippi has supported many human uses as well. Humans have lived in the UMRB for over 11,000 years, relying upon the rich soils and waters of the basin for the cultivation of crops, and an amazing bounty of wild plants, game, and fish. The river was a transportation route for prehistoric peoples, facilitated the trade of goods from abroad, and served as a conduit for cultural exchange across long distances (Fremling and Drazkowski 2000). During most of this time, the effects of native peoples on the river was relatively minor, especially when compared to the 150 years since European "discovery", in which the river, its floodplain, and basin have been significantly influenced by the human presence (Theiling 1999). See Carlander (1954), Fremling and Drazkowski (2000), and USACE (2003) for more detailed timelines and discussion of the early exploitation of the river and its resources.

Today, the river's natural resources, scenic beauty, and cultural heritage continue to provide billions of dollars in annual revenues to local and national economies. Over 15 million people rely directly on the waters of the Mississippi River and its tributaries for drinking water (UMRCC 2000), and for many commercial and industrial uses, including pulp and paper mills, chemical and food processing, power generation, and transportation (Robinson and Marks 1994). The navigation system provides for the bulk-commodity transport of approximately 126 million tons of grain, coal, chemicals, and petroleum products per annum, and thus serves to tie Midwestern farms and industry to international markets (Robinson and Marks 1994, Theiling et al. 2000). Recreational activities including sport fishing, hunting, birding, camping, and other historical and cultural attractions draw over 12 million visitors to the basin each year, generating over 1 billion dollars in annual revenues, and supporting over 18,000 recreation related jobs (USACE 1994, Theiling 1999, Theiling et al. 2000). The river also supports a modest commercial fishery, valued at 2.4 million dollars in 1996, and a commercial mussel harvest, mostly for use in the Japanese pearl industry, valued at roughly 6 million dollars (Duyvejonk et al. 2002).

These economic benefits have, thus far, come largely at the expense of the natural ecosystem (UMRCC 2000). Development of the basin for agriculture, navigation, and industry has drastically altered the landscape, disrupting the physical and ecological processes that shape and maintain the river system, and having substantial effects on the basin's biota. Ongoing analyses have shown that certain native species and communities have declined across much of the basin, signaling deterioration in the health of the ecosystem (USGS 1999), while high public demand for use of the river's resources continues to intensify (Johnson 1992). Nevertheless, the National Research Council identified the UMRS as one of three large river floodplain systems that retain sufficient ecological integrity necessary for restoration (NRC 1992).

The following sections describe the current status of aquatic fauna in the UMRB and the major threats to aquatic biodiversity.

1.3 Aquatic Biota of the Upper Mississippi River Basin Ecosystem: an overview of diversity and imperilment.

The diversity of fauna and the patterns of its distribution across the UMRB reflect the glacial history of the basin. While at the same time the long history of glacial activity left the basin with an array of habitats, the presence of glaciers until 10,000 years ago has given the fauna little time to evolve, resulting in low levels of endemism (Robison 1986; Burr and Page 1986). Thus, while the aquatic fauna is diverse and includes nearly 300 species of fishes, mussels, and crayfishes, as well as an unknown number of other aquatic macroinvertebrates (see Appendix 2 for full species lists), the basin's fauna exhibits a relatively low degree of endemism, with possibly 18 endemic species, including 4 species of fishes (all currently awaiting formal description), 3 crayfish, 1 mussel, and 10 other aquatic macroinvertebrates. Much of the endemism is centered in the extreme southern portion of the basin in areas largely untouched by past glacial advances.

Sixty-nine aquatic species within the UMRB are currently ranked by NatureServe as globally critically imperiled (G1, 13 species), globally imperiled (G2, 14 species), or globally vulnerable (G3, 42 species) (See Appendix 3 for definitions), based on factors such as rarity, viability, trends, threats, and fragility (Master 2000). Natural resource specialists affiliated with the American Fisheries Society recognize a total of 33 fishes, mussels, and crayfish as endangered, threatened, or of special concern (Williams et al. 1989, Williams et al. 1993, Talyor et al. 1996). Nine species within the UMRB are federally listed as endangered (U. S. Endangered Species Act of 1973), with one additional fish species (Grotto Sculpin, *Cottus sp. cf. carolinae*) under consideration for future listing (Appendix 2).

Despite the relatively low endemism and diversity, the basin contains several areas recognized as nationally important areas for biodiversity. Chaplin et al. (2000) identified the Meramec River basin of Missouri, and the "driftless area" of northeast Iowa/southeast Minnesota as hotspots of rarity and species richness. The World Wildlife Fund lists an additional three sites as "important for the conservation of freshwater biodiversity in North America", including the Cache River of southern Illinois, the Fox River in Illinois, and the St. Croix River of Minnesota and Wisconsin (Abell et al. 2000).

Below, we provide a brief overview of fish, mussels and crayfish, which comprise the best known groups of freshwater organisms. For each taxa group, we briefly describe the diversity within the basin, degree of endemism, percentage of imperiled taxa within the UMRB, as well as the ecological importance, and specific major threats. Comprehensive treatment of the distribution and status of aquatic obligate herptofauna and aquatic plants was not attempted, nor have we seen it addressed in other studies.

1.3.1. Fishes

The UMRB harbors approximately 200 native, regularly occurring species of freshwater fish (Appendix 2: Table A), representing roughly one quarter of the 800 or so fish species known to occur in the United States (Lee et al. 1980, Page and Burr 1991), or about 19% of the total North American fish fauna (Burr and Mayden 1992). Seventy-eight genera of fishes in 27 families are represented in the basin, dominated by the Cyprinidae (minnows, 62 spp.), Percidae (Darters and relatives, 29 spp.), Catostomidae (suckers, 19 spp.), Centrarchidae (bass and sunfish, 19 spp.), and the Ictaluridae (bullhead catfishes, 11 spp.). The fauna also includes a number of less abundant, yet remarkable representatives of the "ancient" ichthyofaunas (Miller 1965), including the sturgeons, gars, bowfin, goldeye, and other evolutionary holdouts with origins in the pre- and early-Tertiary periods.

At the present, there are no formally described, endemic fishes in the UMRB, although there are at least four forms awaiting description that appear to be confined to the southern portion of the basin. In Missouri, there is a form of the Missouri Saddled Darter (*Etheostoma tetrazonum*), known only from the Meramec River basin (A. M. Simons, personal communication), and two forms of the Grotto sculpin (*Cottus* spp.), both associated with a single cave/stream system in the karst area of Perry County (G. Adams, personal communication). Additionally, there is an undescribed, small-eyed form of the Stonecat (*Noturus flavus*) known only from the mainstem Mississippi River between St. Louis, Missouri, and Cairo, Illinois (B. M. Burr, personal communication).

Twelve species of fish within the UMRB are currently ranked by the NatureServe as globally imperiled (G1 — G3). Two species, the Pallid Sturgeon (*Scaphirhynchus albus*) and the Topeka Shiner (*Notropis topeka*), are federally listed as endangered with a third, undescribed species, the Grotto Sculpin (*Cottus* sp.), currently being considered for listing. The American Fisheries Society (Williams et al. 1989) recognizes seven UMRB species as endangered, threatened, or of special concern, with the only consistency among the three groups being the Pallid Sturgeon. Following the NatureServe conservation ranking system (the most conservative), and including the undescribed Grotto Sculpin, roughly 6.5% of the basin's fauna are imperiled, compared with national estimates of 37% (Master et al. 2000) or 1/3 of all North American freshwater fishes (Williams et al. 1989).

Fishes have a number of direct and indirect effects on the functionality of freshwater systems. Most are predators, feeding on a variety of aquatic invertebrates as well as other fishes, directly influencing prey behavior, and controlling the abundance and species composition of aquatic assemblages. Others are grazers, consuming phytoplankton, vascular plants and algae, facilitating the transfer of nutrients from primary production. Mussels depend on fishes as hosts for their larvae, many having evolved elaborate lures to ensure the attraction of the proper host species (Mathews 1998). Fish can also serve as "ecosystem engineers", changing the physical conditions of the environment, modifying, creating, or maintaining habitats through their daily activities (Jones 1994).

The causes of decline and imperilment of freshwater fishes in the UMRB are numerous, mostly related to poor land use practices associated with agricultural and urban development, and the continued damming and severe regulation of aquatic ecosystems. The drainage of wetlands is also pervasive, responsible for direct habitat destruction and further disruption of the natural hydrologic regime. Additionally, predation and resource competition with non-indigenous species is taking an ever-increasing toll on native fishes. See Section 1.4 for a more detailed discussion of the primary threats to aquatic ecosystems in the UMRB.

1.3.2. Mussels

Sixty-two mussel species are known from within the UMRB (Appendix 2: Table B), approximately 20% of the 300 species currently known from the United States and Canada (Williams et al. 1993). Thirty-two genera are represented in two families, the vast majority in the Unionidae, and a single species, *Cumberlandia monodonta*, from the Margaritiferidae. The unionids are an ancient fauna, with evolutionary origins as early as the Middle Paleozoic, some 400 Million years ago (Smith 1976). Oesch (1995) suggests that modern day representatives of the North American fauna were most likely in place by Pleistocene times. Many populations were, undoubtedly, wiped out by advancing glaciers, but have since repopulated the upstream areas of the UMRB using fishes as host for their parasitic larvae (glochidia).

The Higgin's Eye Pearly mussel (*Lampsilis higginsi*) is the one true endemic mussel in the UMRB. Another, once widespread species, the Winged Maple Leaf (*Quadrula fragosa*), is now known from only one small area of the St. Croix River between Minnesota and Wisconsin. These two species, along with 3 others, are listed as federally endangered, representing 8% of the total UMRB fauna (62 spp.). This is in stark contrast to the 26% imperilment (16 spp.) recognized by the NatrueServe, or the 39% (24 species) of the fauna considered endangered, threatened, or of special concern by fisheries resource professionals (Williams et al. 1993). An additional 16 species appear imperiled from a basin-wide perspective, due to low average state ranks within the states constituting the UMRB, although they are not considered imperiled across their entire range. Overall, 65% of the mussel fauna in the UMRB should be considered imperiled. This is slightly lower than the national average of 69% (Master et al. 2000) or 72% (Williams et al. 1993), but underscores the status of mussels as the most imperiled of the freshwater groups. A more detailed discussion of the methodologies used to calculate mussel imperilment can be found in Section 2.1.

Mussels are sedentary filter feeders, straining plankton, organic detritus, and bacteria from the water column, and from the sediments in which they are buried. As such, they not only serve to clarify the water, but act as sinks for organic nutrients, facilitating the transfer of energy from primary producers to higher trophic levels in the ecosystem. They also create shoal habitats when in great abundance, as in historic times, and also provide substrate for algae and other organisms. They are fed upon by a wide array of terrestrial and aquatic organisms, chiefly the muskrat, but also mink, raccoons, fish, turtles, and water birds. Freshwater mussels are very sensitive to changes in water quality, and are regarded as important indicators of the health of aquatic ecosystems.

Ongoing threats to the mussel fauna of the UMRB include habitat destruction from dams, channel modification, chemical pollution, siltation, introduced species, and the loss of appropriate fish hosts. Hydrologic alterations caused by dams create unfavorable conditions for most mussels, eliminating flows, and disrupting natural nutrient, thermal, oxygen, and sediment regimes. Excessive siltation impairs respiration and feeding, and can reduce light penetration into the water column, diminishing populations of algae that mussels rely on as a food source.

Many mussels are host specific, or use only a limited range of hosts for the microscopic, dispersal stage of juveniles (gloechidia), so the distributions of mussels may be intimately linked to and influenced by the distribution of fishes (Mathews 1998). Dams block the upstream migration of fishes, and therefore limit the ability of mussels to colonize new habitats, or perpetuate existing mussel metapopulation dynamics. For instance, the blocked migration of skipjack herring, the only known host of the ebony shell mussel (*Fusconaia ebena*), has been implicated in the near eradication of the mussel species above Lock and Dam 19, at Keokuk, Iowa (Tucker and Theiling 1999). Many mussel populations in the UMRB consist only of older adults because the absence of an appropriate host species leads to recruitment failure.

1.3.3. Crayfish

Twenty-two species of crayfish can be found in the UMRB (Appendix 2: Table C), representing 6.5% of the 338 species known from the US and Canada (Taylor et al. 1996). Five genera are represented, all in the Family Cambaridae, dominated numerically by the genus *Orconectes* (11 species). Other genera represented in the basin include: Cambarus (4 spp.), Procambarus (4 spp.), Cambarellus (2 spp.), and Fallicambarus (1 sp.). UMRB crayfish inhabit a variety of flowing and standing water habitats, including subterranean and semi-aquatic systems. The highest diversity within the UMRB is evident in the southern portion of the basin, where past geological and hydrologic activities have created highly variable physical features. In this area, one finds lowland sloughs and swamps, Ozarkian uplands, prairie and big river habitats, each with its own, characteristic faunal assemblage.

Three endemic crayfish are known from the basin (*Cambarus maculatus*, *Orconectes harrisoni*, and *O. medius*), all located in the Meramec River drainage of Missouri. There are no federally listed crayfish species in the basin, and no candidates, although resource professionals consider two species, *O. illinoiensis* and *O. harrisoni*, to be of special concern (Taylor et al. 1996). The NatureServe ranks one species, *Cambarus hubrichtii*, as imperiled (G2), due to its small range and the sensitivity of its subterranean habitat, and two species, *O. illinoiensis* and the endemic *O. harrisoni* as vulnerable (G3). Considering these three species, the crayfish fauna of the UMRB exhibits a relatively low degree of imperilment (12.5%) when compared to estimates for the US imperilment of 48% (Taylor et al. 1996) and 51% (Master et al. 2000).

Crayfish are invaluable components of aquatic ecosystems, facilitating the cycling of nutrients, and serving as an important food source for many animals. They are omnivores, feeding opportunistically on a wide variety of plant and animal materials, both live and dead.

Crayfish serve as an important link in the food chain between plants and vertebrates, breaking down dead plant material (detritus) otherwise resistant to decomposition (Pflieger 1996). Organisms that rely on crayfish as a major food source, include numerous fishes, birds, reptiles, mink, and other mammals.

Threats to crayfishes in the UMRB are similar to those affecting other aquatic taxa, including degradation and destruction of habitat, chemical pollution, excess sedimentation, introduction of non-indigenous species, and the small natural range of many species (Williams et al. 1993, Warren and Burr 1994, Taylor et al. 1996). Crayfish are particularly affected by dredging and channelization of streams, as removal of gravel, boulders, woody debris, and vegetation reduces the amount and quality of available cover, increasing susceptibility to predation (Taylor et al. 1996). In the northern portion of the basin, introduction of the non-indigenous Rusty Crayfish (*Orconectes rusticus*) represents a serious threat to native species. Introduced through bait-bucket introduction, the Rusty Crayfish is a large-bodied, highly aggressive species that displaces native species through direct resource competition and hybridization (Taylor 2000).

1.3.4. Other Macroinvertebrates

The UMRB harbors a rich diversity of other aquatic macroinvertebrate groups, including, but not limited to, insects, gastropod mollusks, and non-crayfish crustaceans such as isopods and amphipods. For these groups, the total number of species inhabiting the basin is currently unknown, due largely to the patchiness of sampling across the entire basin, and instability in the nomenclature of many groups. However, over 350 macroinvertebrates have been documented from the mainstem UMRS alone (Theiling et al. 2000), suggesting the possible occurrence of one to several thousand species basin-wide. Of the species currently known to inhabit the UMRB, 42 species are currently listed by the NatureServe as globally rare (G1 — G3). Of these species, only two are federally listed as endangered, the Illinois Cave Amphipod (*Gammarus acherondytes*), and the Hine's Emerald Dragonfly (*Somatochlora hineana*).

These organisms play an extremely important role in aquatic ecosystems, serving as food for fish, grazers of algae, links in the life cycles of parasites, and processors of organic materials, including leaves and biofilms (Strayer 2000). A concerted effort to enumerate and evaluate the status of the total aquatic invertebrate fauna in the basin is necessary. A more complete discussion of data needs for aquatic invertebrates can be found in Section 10.

1.4. Major Threats to Aquatic Biodiversity in the UMRB

The aquatic ecosystems of the UMRB have been altered extensively. Declines in freshwater fauna can be attributed primarily to the intensive human use of their habitats (Master et al. 1998). Anthropogenic effects of dam construction, water withdrawals for municipal and industrial uses, incompatible land conversion, and the widespread introduction of exotic species have taken their toll, as evidenced by decreases in species abundance, an increased frequency of extreme floods, and an ever-growing list of endangered species (Mac 1995).

Since the passage of the Clean Water act of 1972, the United States has improved its regulation of pollution discharges from various industrial and municipal discharge points around the basin. These actions have caused some encouraging trends, with marginal water quality improvements accompanied by an increase of diversity in some aquatic communities. But degradation of the UMRB continues as our use of the landscape continues to alter the character of the riverine ecosystems.

The major threats to aquatic biodiversity in the Upper Mississippi today are consistent with those affecting aquatic ecosystems across all of North America: alteration of natural land cover; water quality degradation; alteration of hydrologic integrity; habitat fragmentation; and the proliferation of exotic species (Abell et al. 2000). Although it does not occur at historic levels, direct exploitation of aquatic species is an ongoing threat to some taxa. Global climate change has been hypothesized as a future concern (WEST 2000), with projected changes in rainfall and seasonal temperatures thought to pose a significant threat to the especially sensitive climatic zones of the UMRB (Bryson 1966). We will discuss three sources of these threats — land cover alteration, drainage and dams, and exotic species – in greater detail.

1.4.1. Land Cover Alteration: sediments, nutrients and altered hydrology

The most pervasive impact to aquatic systems in the UMRB is from alteration of natural land cover and associated degradation of water quality. The degree of land cover alteration in North America is strongly correlated with human population density in areas of urban growth (Abell et al. 2000), but in the UMRB, conversion of rural lands for agriculture is the larger contributor. Nearly 66% of the UMRB is managed for agricultural uses (NLCD 1992), significantly above the national average of 45% (Allen 1995, Knutson et al. 1990). Urban and suburban development in the basin is largely confined to cities along the rivers, and accounts for roughly 3% of the basin area (NLCD 1992). Only about 20% of the UMRB now remains in natural cover.

The loss of natural cover has led to dramatic increases in non-point sources of pollution, including increased water and sediment flow, and excessive chemical and nutrient inputs. Cropland is often cleared right up to the stream bank, removing vegetation that once functioned to slow the flow of water from upland areas, trapping sediments and other toxins before they could enter streams and lakes. A large proportion of the agricultural area of the upper Midwest is underlain with subsurface drainage tiles, which further speeds the delivery of excess water, sediment, and chemical pollutants to streams. Unnatural sediment inputs alter the physical character of streams, and can smother the stream bottom, destroying critical habitat for aquatic organisms. Excess nutrients are known to cause dramatic changes in energy flow in aquatic systems, increasing primary productivity and possibly shifting the composition of the biotic communities (Fajen and Layzer 1993). Other effects associated with the loss of riparian cover, such as increased light and temperature levels, and the reduced inputs of organic matter to streams, can also have detrimental effects on the ecological function of aquatic systems.

The effects of non-point source pollution resulting from urbanization are no less detrimental, although in the UMRB, they are much more localized than those of agriculture. Storm water and other runoff can carry sediments, heavy metals, oil, and large amounts of organic matter that can deplete oxygen levels in streams (Master et al. 1998), making them inhospitable to aquatic life. Other sources of pollution associated with urban areas include municipal waste, household chemicals, sediments and other contaminants from construction activities, and the large-scale use of fertilizers and pesticides on lawns, golf courses, and parklands.

In urban areas, a greater threat from land use change is altered water flows resulting from impervious surface runoff. Impervious surfaces consist of two primary components, rooftops and the transportation system, consisting of roads, driveways, and parking lots (Schueler 2000). A number of studies show that water quality is significantly degraded once the impervious cover in a watershed reaches ~10% (Booth 1991, Booth and Reinelt 1993, MWCG 1995). As the percent impervious cover increases, urban pollutant loads increase (Schueler 1987), stream temperature increases (Galli 1991), channel stability and fish habitat quality decreases (Booth 1991), as do aquatic insect diversity and abundance (Klein 1979, Jones and Clark 1987).

1.4.2. Drainage and Dams: alteration of hydrologic integrity and habitat fragmentation

The aquatic species and communities in the UMRB have evolved over thousands of years in response to the natural variability in the hydrologic regime, and are dependant on the seasonal availability of nutrients and specialized habitats to complete their life cycles. Even subtle changes in habitat availability may lead to drastic declines in the productivity or diversity of aquatic systems (Mac 1995). More than two hundred years of human activity in the basin have had profound effects on the natural hydrologic regime, greatly altering in-stream habitat, and affecting the abundance and distribution of aquatic species (Wiener et al 1998).

The highly modified drainage networks in the UMRB include millions of acres of wetland drainage, thousands of miles of field tiles, road ditches, channelized streams and stormwater sewers, all designed to convey water off of the land as quickly and efficiently as possible. This modern efficiency means that water reaches rivers more quickly, with greater velocity, and at higher stages than in the past (Bellrose et al. 1983, Gowda 1999). Thus, severe flood events are more frequent and the hydrologic integrity of the stream systems has changed dramatically. In response to higher flows, stream channels typically increase their cross-sectional area, either through widening of the stream banks, down-cutting of the stream bed, or both (Schueler 2000). The cumulative effects of these erosion processes are not confined to the stream channel, but can cause disruption of the flood regime, which changes critical river-floodplain interactions, thereby degrading adjacent floodplain ecosystems (Shankman 1999).

The presence of dams in the UMRB represents one of the most serious threats to the hydrologic and ecologic integrity of aquatic ecosystems. There are no less than 4600 major dams across the basin, i.e., those greater than 6 feet in height *and* with more than 50 acre-feet in storage (USACE 1999). The distribution of dams is biased towards large rivers, as the relatively small size of headwater streams do not lend themselves to large, flow-harnessing structures (Abell et al. 2000), although there are perhaps many thousands of additional small dams scattered throughout the smaller creek and headwater systems of the basin. These smaller dams, many unregistered and therefore innumerable, were originally built to serve a number of purposes, including small-scale flood prevention, water for livestock and irrigation, milling, and to create habitat for recreational fisheries. Due to changes in historical land use and the societal needs, many are now obsolete, even dangerous, their negative effects on aquatic ecosystems greatly outweighing their human benefits.

Dams and their associated operations have widespread and pervasive effects on freshwater life (Collier et al. 1996). Their construction alters natural flow and temperature regimes, and disrupts nutrient and sediment pathways. Reservoirs flood valuable riffle and swift-water habitat necessary for many species life cycles (Fahlund 2000). Dams pose a direct barrier to species dispersal, including the continuous downstream drift necessary for the development of eggs and larvae of many riverine species. The downstream effects of a single dam can alter the character of an entire watershed (Master et al. 1998), resulting in the destruction of native plant and animal communities, and an overall reduction of natural biodiversity. On the other hand, there are potential benefits of small dams, which can isolate upstream areas from invasion from exotic species.

Nowhere are the effects of dams and associated water control structures more prevalent than on the mainstem Mississippi and Illinois Rivers. Once free-flowing, and characterized by a mosaic of braided channels, islands, and wetlands, the Upper Mississippi River is now a severely regulated river, controlled by a series of 40 locks and/or dams from the headwaters at Lake Itasca, MN, to St. Louis, MO (Fremling et al. 1989). The series of dams upstream of Minneapolis are essentially managed for flood control, wildlife habitat, and recreation, while the downstream locks and dams are operated primarily for commercial navigation. An additional 8 dams with locks exist on the mainstem Illinois River, and together, they constitute the Upper Mississippi River Navigation System (UMRS) (Figure 2).

The federal government has extensively altered the river and its backwaters to make the river safe for large-scale commercial navigation, and make it feasible to farm the rich alluvial soils of the floodplain. Their actions, which began in 1824 and continue to this day, have included with snag and sandbar removal, removal of rock rapids and the closing of side channels, and construction of hundreds of wing and closing dams, shoreline protection areas, 29 navigation dams, and hundreds of kilometers of levees (Burr and Ladonski 2000).

The dams have formed a series of broad, shallow impoundments, creating a continuous 9-foot deep, slack-water navigation channel throughout the system. In many pools, the natural character of the river has been replaced with a repetitive longitudinal habitat structure (Lubinski 1999). The upper portion of each pool still maintains many original riverine qualities, and is relatively free-flowing, with habitat proportions similar to those that existed before impoundment. The lower end of many pools contain a significant area of open water, and are more lake-like in nature. Each area supports a species assemblage most suited to its particular conditions, and there is often a variably sized transition zone between the two ends that harbors species adapted to both (Lubinski 1999).

The inundation resulting from dam construction has caused major shifts in the availability of aquatic habitats and the land cover of the river floodplain. In general, aquatic habitats for fish and wildlife were initially increased, but at the expense of terrestrial cover classes. Any benefits for aquatic species that may have once existed have been reduced substantially by the erosion and deposition cycles associated with the reservoir aging process (Wlosinski et al. 1995). Areas just upstream of the dams are filling with sediment, resulting in the homogenization of depth across the river channel. The immediate downstream effects of the dams are equally problematic. Increased water flow below dams has resulted in channel deepening, which in turn, draws water out of side channels and backwater areas, causing these critical habitats to dry up (Sheehan and Rasmussen 1993).

Much of the mainstem Mississippi and Illinois Rivers have also been leveed for flood control, destroying the lateral connectivity between the river and its floodplain. Many aquatic species have adapted to rely on a natural, seasonal "flood pulse" to cue migrations, and provide access to areas outside the main channel important for feeding and reproduction. In natural situations the wetlands and forests of the floodplain perform valuable ecosystem services, providing storage area for flood waters, managing sediment loads, and providing critical habitat to wildlife species. Isolation of the floodplains by levees alters the natural "flood pulse", denies critical access to the floodplains for fish and wildlife, and prevents the transfer of sediments and nutrients critical to wetland and floodplain forest ecosystems. Approximately 40%, or 998,000 acres of the original floodplain area in the UMRB is currently behind levees, isolated from the river during all but the highest discharge rates (USACE 2000).

Wing dams and closing dams have further constrained the river, diverting the power of the river waters into a single channel. These structures, in conjunction with levees, have had drastic effects on river habitat by changing the relationship between discharge and water-surface elevations (Wlosinski et al. 1995). Wing dams have narrowed and deepened the main channel, while levees restrict the lateral flow of water onto the floodplain. The result has been lower water elevations at low discharge, and higher water elevations during high discharge, well outside of historical levels. This, in turn, has led to an increase in the frequency and severity of floods and increased delivery rates for sediment and nutrients to downstream areas. Overall, the hydrological characteristics of the Upper Mississippi River bear little resemblance to pre-impoundment conditions.

1.4.3. Non-indigenous Species: trophic disruption

Perhaps the most severe rising threat to native biodiversity in the UMRB is the introduction and establishment of non-indigenous species — species introduced beyond their native range by humans. Introductions in the UMRB started with the first European immigrants to the basin, and biological invasions continue today, with some species becoming established and spreading at alarming rates. The spread of non-indigenous species threatens to homogenize the basin's flora and fauna, which represent thousands of years of unique evolutionary history (Williams and Meffe 2000).

Non-indigenous species arrived in the basin from a variety of sources. Intentional stocking of fishes for sport and commercial purposes began in the late 1800's (Burr and Ladonski 2000), and continues today. Initially, this practice was viewed by many as positive enrichment of the native biota, with some introductions providing economic and recreational benefits, including enhanced sport fishing opportunities and a reliable, high-quality food source via aquaculture (Bjergo et al. 1995). Many others have proven economically and ecologically expensive (Williams and Meffe 2000). Several species have been intentionally introduced through the release of unwanted aquarium specimens, although most are unable to become established due to low winter temperatures or the lack of conspecifics with which to mate. Still others have become established as a result of inadvertent release of unused fishing bait. Whether intentional or not, the environmental consequences of the introductions are generally harmful, and can be catastrophic (Taylor et al. 1984).

Many of the most recent invasions have occurred by means of natural dispersal following release in areas outside the UMRB. In 1900, the Chicago Sanitary and Ship Canal was built to remove municipal waste removal from the Chicago-metropolitan area. The Canal connected Lake Michigan to the Des Plaines River, representing the first permanent connection between the Mississippi River and the Great Lakes. Since that time, at least one highly invasive species the Zebra Mussel (*Dreissena polymorpha*), has colonized much of the UMRB by way of the canal. Another, potentially more dangerous invader from the Great Lakes, the Round Goby (*Neogobius melanostomous*), is now common in the Upper Illinois Waterway, poised to wreak havoc in the UMRB. More highly invasive fish such as the Asian carp are moving into the basin from the south, causing profound changes in the aquatic ecosystem.

An examination of the USGS Nonindigenous Aquatic Species database (USGS 2003) reveals that no less than 55 nonindigenous aquatic animals and 12 nonindigenous plant species have been recorded from the UMRB (Appendix 4). Fifty-three percent (47 species) consist of fish species, subspecies, and hybrids native to North America, now distributed beyond their native range. Most were intentionally stocked as game- and forage-fish but many were unintentionally established through the inappropriate release of unused baitfish. There are at least 17 additional species of exotic fishes, seven mollusks (three bivalves, two gastropod snails), two crustaceans (a crayfish and an amphipod), two hydrozoans, and a single exotic cladoceran known to occur in the UMRB. Additionally, there are 12 nonindigenous plant species found in the basin. Three highly invasive species have now become established across vast areas of the basin: Eurasian Watermilfoil (*Myriophyllum spicatum*), found in 16 of 17 sub-basins within the UMRB; Curly Pondweed (*Potamogeton crispus*), 14 of 17 sub-basins; and Purple Loostrife (*Lythrurum salicaria*), 11 of 17 sub-basins.

Often, habitat degradation and the disruption of natural ecological processes allow exotics to gain a foothold. Aquatic species in the UMRB may be especially vulnerable, as the effects of nonindigenous species are magnified by widespread habitat disturbance. Once established, nonindigenous aquatic species can profoundly change biological diversity and habitat composition in ecosystems, which may result in substantially increased rates of extinction of native aquatic species (Bjergo et al. 1995). Miller et al. (1989) credit nonindigenous species with causing the extinction of 27 species and three subspecies of fish in the United States over the past 100 years.

The effects of nonindigenous species on the population structure and function of native ecosystems is well documented. Native species are often displaced through predation, or direct competition for food and habitat, causing profound disruptions in the natural trophic structure of communities. When invasive species substantially modify the existing habitat, they eliminate refugia, and interfere with natural reproductive cycles. Miller et al. (1989) document the decline of native fish species by genetic swamping through hybridization with nonindigenous species. In some cases, exotics have introduced non-native parasites and disease, decimating native populations of aquatic taxa.

The resultant alterations of water, nutrient, and energy cycles, and of the productivity and biomass of ecosystems, directly affects human society (Williams and Meffe 2000), yet the long-term extent of problems associated with non-indigenous species remains largely unknown. In most cases, biological invasions are not noticed until the situation becomes critical, and the elimination of the transgressors is all but impossible. As the world becomes more accessible to people and goods from abroad, the opportunity for future biological invasions will no doubt increase, representing a substantial future threat to the biodiversity of the UMRB.

2. Conservation targets

The biodiversity of the UMRB is comprised of numerous species and communities, making it impractical, and given data limitations, impossible, to evaluate each for conservation planning. Conservation targets are a sub-set of species and communities, and all ecological systems, which are selected to comprehensively represent the biodiversity of the basin. The conservation targets for the Upper Mississippi River Basin assessment included imperiled and rare species and aquatic ecological systems, and a few representative natural communities. The following sections describe the methods used to select these species and system targets. Representative natural communities were described by experts on an ad-hoc basis without a formal classification and hence are not listed in this report. Information on intact native assemblages was one of the factors to designate Areas of Biodiversity Significance.

2.1 Species

A total of 153 species targets were addressed in this assessment (Table 2 and Appendix 5). The initial step to identify species-level conservation targets involved generating complete lists of all fish, mussel, and crayfish taxa known to occur in the UMRB (Appendix 2). We did not attempt to compile a full list of non-crayfish macroinvertebrate fauna in the UMRB. Species were then categorized based on their conservation status, and distribution relative to the UMRB, and those species in the following categories were considered as targets.

- Imperiled Species (G1-G3 ranked species)
- Federally listed Threatened and Endangered Species
- Other species of special concern
  - declining species
  - endemic species
  - disjunct species
  - vulnerable species
  - focal species — keystone and wide-ranging species

Species of special concern were identified from a series of publications, including those from the American Fisheries Society, which listed fish, mussel, and crayfish taxa as threatened, endangered, or of special concern (Williams et al. 1989, Williams et al. 1992, Taylor et al. 1996).

For fishes, mussels, and crayfish, individual species distributions within the basin were analyzed, revealing several examples of species whose global distribution was stable, but were imperiled within the basin. This trend was especially evident in the freshwater mussels. Each mussel species was investigated state-by-state, and ten species with an average state rarity rank (S-Rank) of 2.5 or less were added to the list. Fish and crayfish targets falling in this category tended to be peripheral species, characteristic to the Ozark and Coastal Plain habitats in the southern portion of the basin. While these species were better represented in habitats outside the basin, several were added to the list to ensure that this aspect of ecosystem diversity would be captured.

Only G1-G3 macroinvertebrate (insects, snails, non-crayfish crustaceans) taxa were considered as targets. Additionally, a number of herptile species were considered as targets due to their limited distribution within the basin, and their requirements for both high quality terrestrial and aquatic habitats.

Table 2. Number of Species Targets by Taxa Group. Not all taxa known to occur in the basin have point location data available.

TAXA GROUPS	TOTAL TARGETS	TARGETS WITH SPATIAL DATA
Fish	36	31
Mussels	40	40
Crayfish	10	8
Herptiles	23	14
Insects, Snails, Amphipods	44	36
TOTAL	153	129

2.2 Aquatic Ecological Systems

Identifying aquatic ecological systems as conservation targets for this assessment involved developing and applying a hierarchical classification framework. Spatially hierarchical classification provides a specific advantage to understand freshwater ecosystems. Freshwater habitats and their biological components are shaped by a hierarchy of spatial and temporal processes (Frissell et al. 1986; Mathews 1998). Patterns of continental and regional aquatic zoogeography result from drainage connections that changed over time in response to climatic and geologic events (Bussing 1985; Hocutt and Wiley 1986). Regional patterns of climate, drainage, and physiography influence aquatic ecosystem characteristics such as morphology and hydrologic, temperature and nutrient regimes, which in turn influence biotic patterns (Swanson et al. 1988; Pflieger 1989; Poff and Allan 1995). Within regions, finer-scale patterns of stream and lake morphology, size, gradient, and drainage network position result in distinct aquatic assemblages and population dynamics (e.g., Tonn and Magnuson 1982; Angermeier and Winston 1999, Lewis and Magnuson 1999; Mathews 1998).

In this assessment, we employed the freshwater ecosystem classification framework developed by The Nature Conservancy (Higgins 2003). The framework, depicted in Figure 3, classifies environmental features of freshwater landscapes at four spatial scales, Aquatic Zoogeographic Unit, Ecological Drainage Unit, Aquatic Ecological System and Macrohabitat.

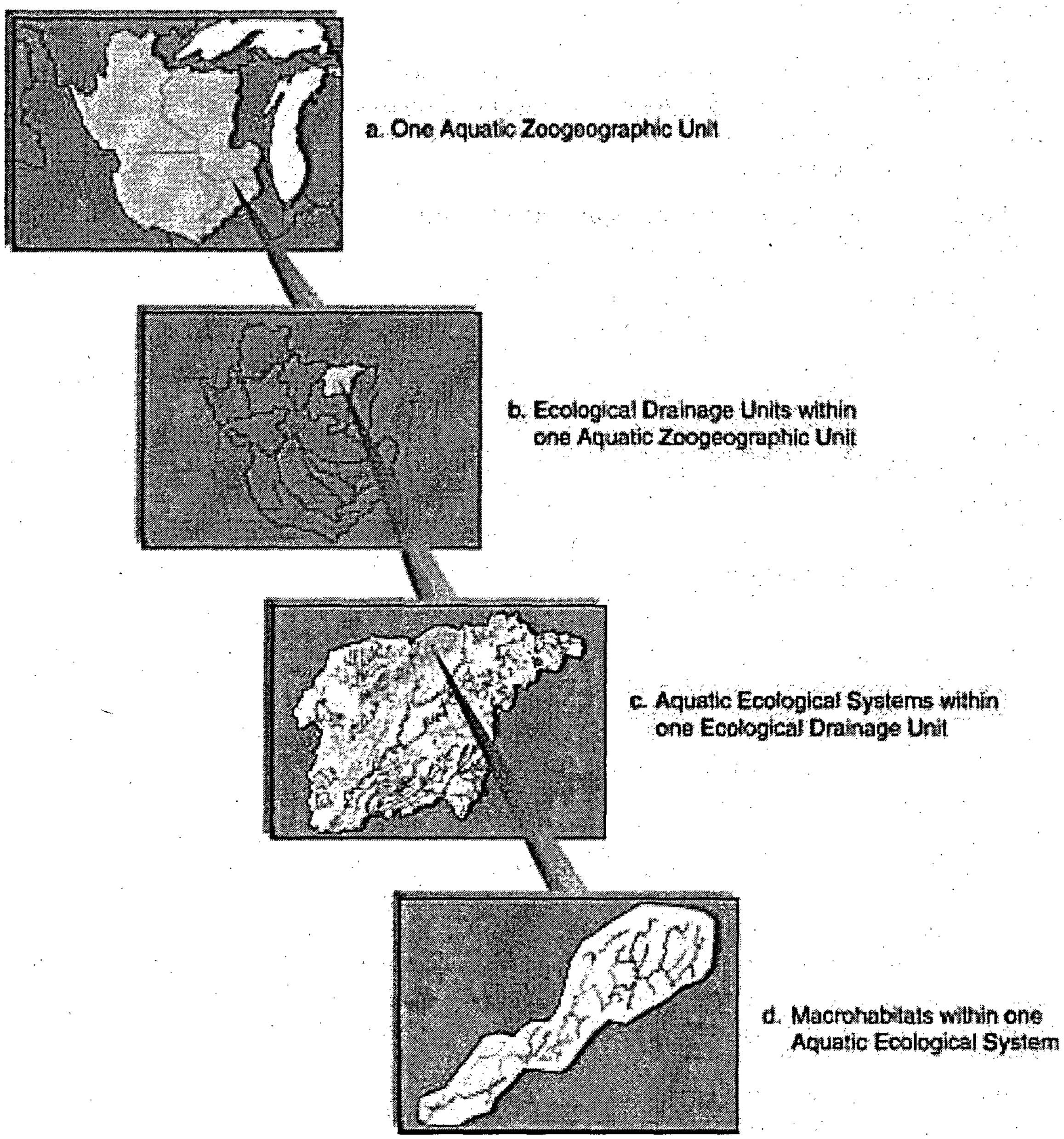

Figure 3. The Nature Conservancy's freshwater ecological classification framework.

2.2.1 Aquatic Zoogeographic Units

The broadest level of the classification is **Aquatic Zoogeographic Units,** which are large-scale drainage basins distinguished by patterns of native fish distribution. Aquatic zoogeographic units account for the geologic, climatic, and biologic history shaping present freshwater ecosystems: the fish distribution patterns are a result of large-scale geoclimatic processes (e.g., ice age glacial activity) and evolutionary history (Maxwell et al. 1995; Abell et al. 2000). In the UMRB, we defined three aquatic zoogeographic units, coinciding with portions of three aquatic subregions (Figure 4) as defined by Maxwell et al. 1995. Aquatic subregions were delineated qualitatively, after Hocutt and Wiley (1986) and various "Fishes of..." books (Clayton Edwards, USFS, personal communication). The UMRB contains the Upper and Middle Mississippi sub-regions entirely and a small portion of the Central Prairie Subregion.

The spatial patterns of aquatic fauna that we see in the UMRB today reflect the unique geomorphic history of the area. Repeated glacial advance and retreat during the Pleistocene forced the dispersal and isolation of fish and other aquatic species, allowing unique faunal elements to develop. The final glacial retreat, created new drainage patterns and subsequent mixing of faunas that has resulted in the present patterns of subregions in the Upper Mississippi River Basin (Maxwell et al. 1995). For a detailed discussion of drainage evolution in the UMRB and its implications for the aquatic fauna, see Burr and Page (1986), Cross et al. (1986), and Robison (1986).

The most distinctive aquatic subregion, in terms of both zoogeographic and physiographic characteristics, is the Central Prairie subregion portion of the southwest UMRB. This area, consisting of the Meramec River basin of Missouri, is part of the Interior Highlands physiographic province (Cross et al. 1986), and remained unglaciated through the Pleistocene. Nevertheless, the series of glacial advances had pronounced effects on the fauna, creating a large and complex assemblage of fishes, with a higher level of fish diversity and endemism than elsewhere in the basin. Pflieger (1971) cites numerous examples of the apparent southward dispersal of northern fishes through connections that developed with glaciation, and varying patterns of dispersal and isolation subsequent to glacial retreat. Similar patterns have been documented in boreal caddisflies and stoneflies (Ross 1965), amphibians (Smith 1957), and crayfish (Pflieger 1996).

The zoogeographic distinctions between the Upper and Middle Mississippi sub-regions are not as clear. Maxwell et al. (1995) provide no accounting for the specific zoogeographic characteristics used in their delineation of the two. Overall, the fish faunas of these two sub-regions are relatively uniform, with neither exhibiting any real degree of endemism. One notable exception is an undescribed form of the Stonecat, *Noturus flavus,* known only from the mainstem Mississippi River between the mouths of the Missouri and Ohio river (B.M. Burr, personal communication).

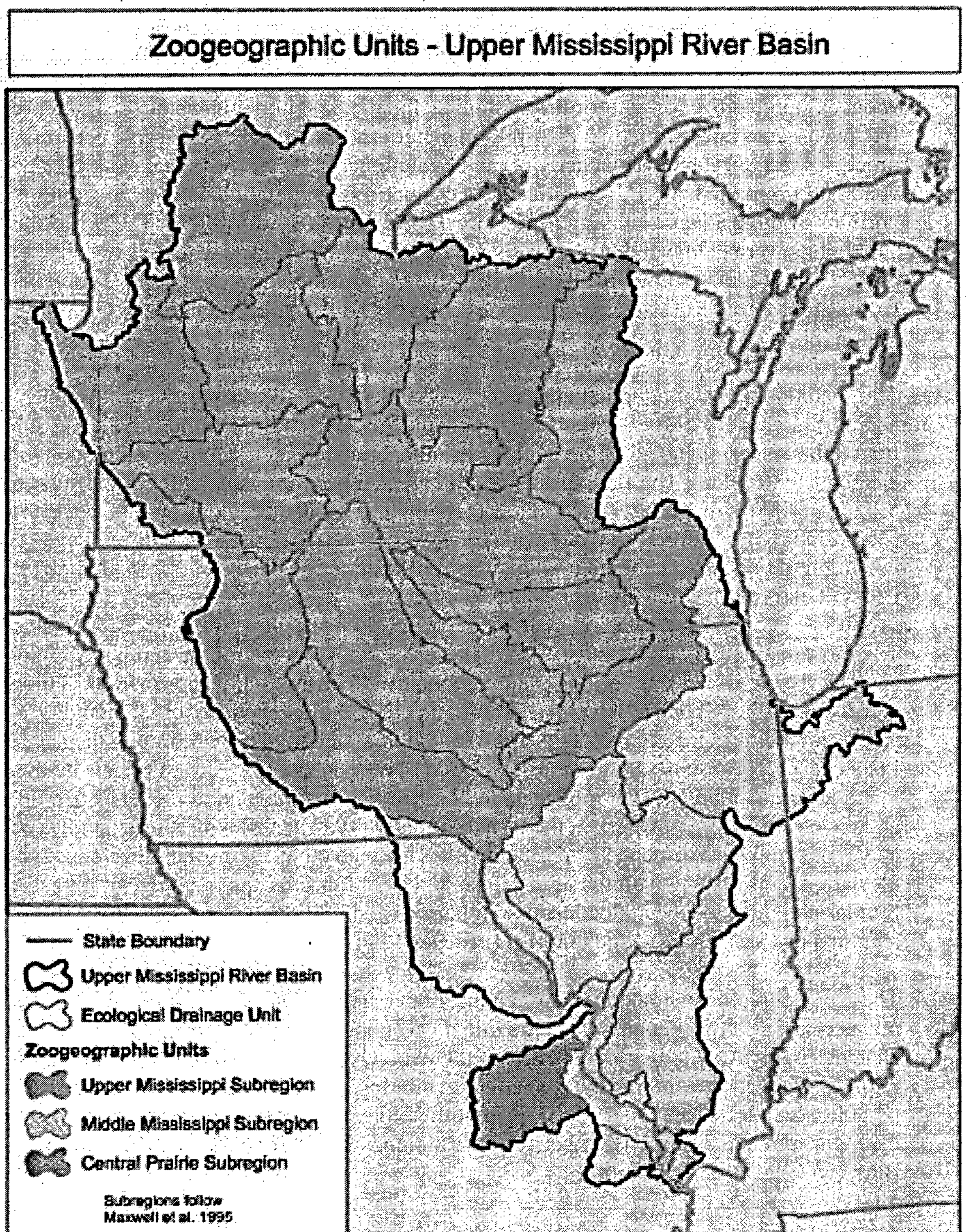

Figure 4. Aquatic Zoogeographic Units in the UMRB.

In an analysis of 19 major drainages within the Lower Ohio-Upper Mississippi River Basin, Burr and Page (1986) identified two phenetic basin groupings based on percent shared fish taxa: (1) the Ohio River Fauna and (2) the Mississippi River fauna. Within the Mississippi River fauna, they observed an additional two major clusters: a southern and central cluster of four drainage units (Cache, Kaskaskia, Illinois, and Kankakee rivers) and a northern cluster of eight drainage units (Des Moines, Iowa-Cedar, Rock, Wapsipinicon, Wisconsin, Chippewa, St. Croix, and Minnesota rivers). These two clusters agree with Maxwell et al. (1995), and provide to recognize to two separate Mississippi subregions.

There are examples of unique habitat and fauna within each of the sub-regions, due to the differential geomorphological history of each area and/or patterns in post-Pleistocene dispersal from adjacent subregions. For instance, the extreme southern portion of the Middle Mississippi Subregion in Illinois includes a thin band of unglaciated, Ozarkian streams and associated taxa in the Shawnee Hills, and a number of lowland habitats and taxa associated with the northern boundary of the Mississippi Embayment. Nevertheless, with the exception of the Cache River basin of Southern Illinois, naturally an Ohio River tributary (now directly connected to the Mississippi River through a flood control channel), no two watersheds within the two sub-regions exhibit less than 62 % similarity in their fish faunas (Burr and Page 1986).

2.2.2. Ecological Drainage Units

Where Aquatic Zoogeographic Units reflect major patterns in endemism and fish community structure, Ecological Drainage Units (EDUs) account for the variability within zoogeographic units due to finer-scale drainage basin boundaries and physiography. EDUs are groups of watersheds that not only share a common zoogeographic history but also share physiographic and climatic characteristics. EDUs likely have a distinct set of species assemblages and habitats and provide ecologically-meaningful stratification units that insure that we are protecting conservation targets across key environmental gradients. Sources of mapped physiographic and climatic data include ecoregion descriptions, surficial geology and lithology maps and hydrography data (Figure 5). We used the three zoogeographic subregions to guide the development of the EDUs.

Additional sources of information used in the delineation of EDUs for the UMRB included: zoogeography (Hocutt and Wiley 1986, Maxwell et al. 1995); ecoregional sections and subsections (Albert 1995, Bailey et al. 1995, Keys et al. 1995, Omernik 1987 and 1988); and numerous state fish books and peer-reviewed publications. To gain further insight into zoogeographic patterns in the basin we performed a cluster analysis (PC-ORD version 4.x) of fish distributional data by 8-digit hydrologic catalog unit (NatureServe 2001). While not definitive, repeating spatial patterns in fish distributions were observed, allowing greater confidence in many of the EDU designations. A complete list and brief description of each EDU can be found in Appendix 6.

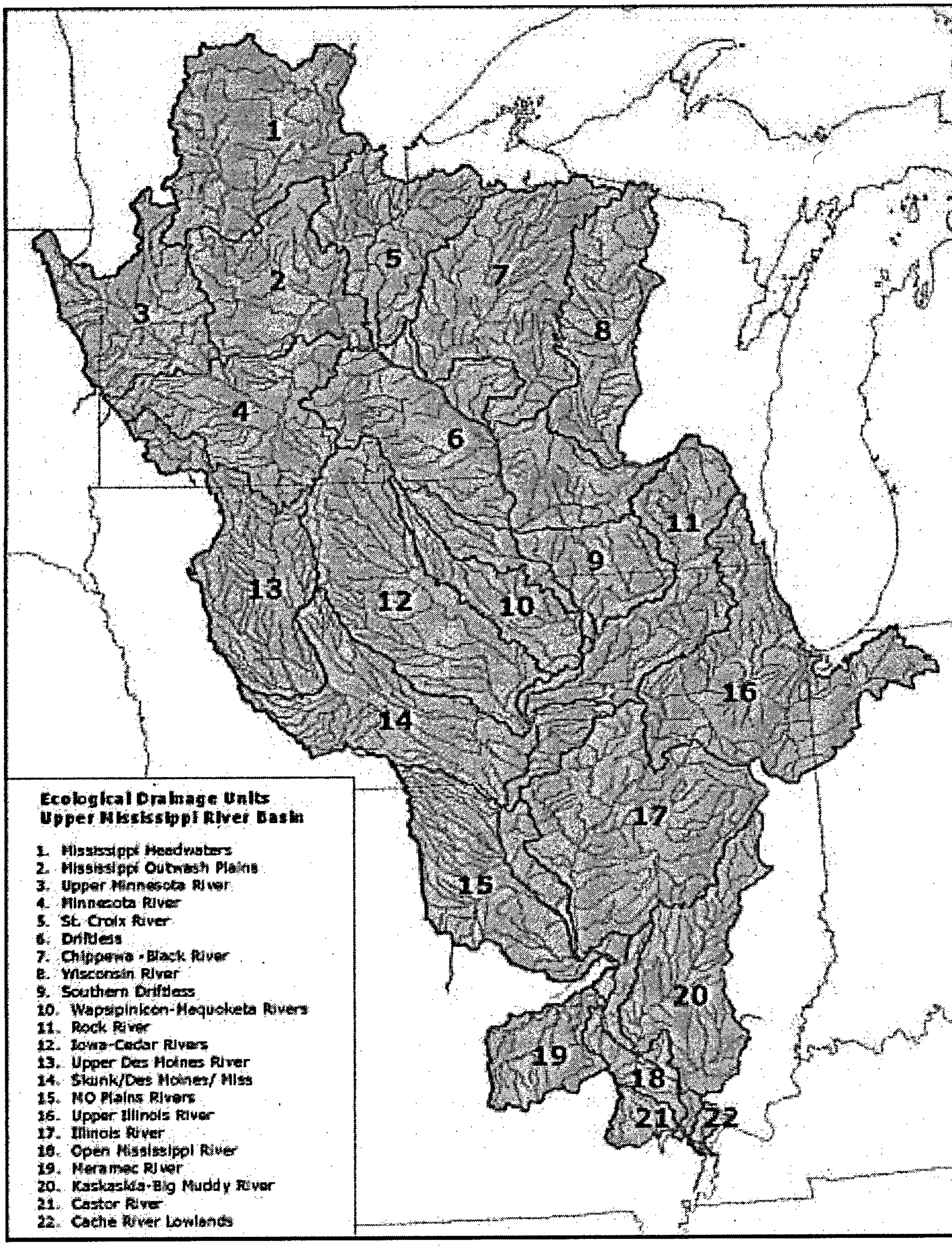

Figure 5. Ecological Drainage Units in the UMRB.

2.2.3 Aquatic Ecological Systems

The next finer level of the classification framework is the Aquatic Ecological System. Given that sufficient biological information to classify or describe freshwater communities or freshwater ecosystems seldom exists, we rely on models to classify and map environmental patterns in freshwater ecosystems that are known to influence the distribution and abundance of freshwater biodiversity. Aquatic ecological systems are ecological units that represent stream, lake and wetland networks that are distinct in terms of the nutrient flow, energy exchange and have distinct characteristics that have been shown to influence the types and distributions of communities and individual species. Aquatic ecological systems are characterized by distinct combinations of key ecological factors. These factors may vary by region. We defined aquatic ecological systems based on the distribution of finer-scale units we call Macrohabitats, which are discussed in detail below along with the specific factors used to define distinct ecological settings (Tables 3 and 4). The aquatic ecological systems are essentially aggregations of macrohabitats that show a repeating pattern. The following sections describe how this basic method was applied to classify headwater, creek, medium river, large river and big river systems, and lake systems. A total of 238 unique stream and river system types and 28 lake types were identified across the UMRB. The aquatic systems types are defined in Appendix 7.

The first step to define aquatic ecological systems was to define size classes of streams that correspond to significant changes in habitat characteristics (see Table 5). We then delineated watersheds for each of the five sizes of streams. The second step was to assign a system type to each watershed. For the smallest three size classes we assigned the system type based on the macrohabitat types found within each drainage. We used cluster analysis, which grouped the watersheds into types based on how similar each was in terms of its macrohabitats, measured as total length of stream of each type occurring within the watershed. Treating the cluster types as a draft classification, we then overlayed the clusters on maps of geology, hydrography, and elevation to determine if the clusters made ecological sense. For the 27 large rivers in the UMRB, we classified each as a unique system type either because of the landscape setting or because it occurred in a different ecological drainage unit.

The big river systems types were defined using a classification framework parallel to but distinct from that described above. The federal and state agencies (USGS, USFWS, State DNR's) accountable for the mainstem Mississippi River recognize three hierarchical management units, the Floodplain Reach, Geomorphic Reach, and Navigation Pool (Figure 6), USGS 1999, Thieling et al. 2000, WEST 2000). While these management units are constrained by the presence of man-made structures (locks and dams), their boundaries were designed to coincide as closely as possible with the natural breaks in environmental gradients and habitats that existed prior to impoundment. This framework creates 18 unique, mainstem Big River system types (Appendix 7), with a total of 32 occurrences.

The Floodplain Reach (FPR) level of classification was delineated based on physiography and land use characteristics, including width, habitat composition, vegetation coverage, presence of dams or levees, and geomorphological characteristics (USGS 1999). This level of classification is similar in scale to that of the EDU, and stratifies the mainstem Mississippi River into meaningful assessment and management units.

Units at the Geomorphic Reach (GMR) level are fully nested within the Floodplain Reaches and are based on valley and floodplain morphology, geologic controls, gradient properties, and sediment transport characteristics (WEST 2000). These factors create the template upon which plant and animal communities and habitats develop (Theiling et al. 2000). We used the 18 Geomorphic Reaches defined by the US Army Corps of Engineers (WEST 2000) as the spatial unit on the mainstem UMR-IWW that would best approximate the Aquatic Ecological System level of the classification hierarchy.

The Navigation Pools are bounded on each end by lock and dam structures. Each Navigation Pool within a particular Geomorphic Reach is an occurrence of that system type. The pools vary in terms of hydrologic regime and number of aquatic/geomorphic habitats (USGS 1999), which are controlled by the flow regime and structure of the navigation channel imposed on the pool to maintain adequate navigation. There is some degree of biological exchange between pools, but essentially, each pool can be thought of as a separate ecosystem, within which the resident organisms must account for all aspects of their life-history. Within the pools the lateral connectivity to the original floodplain varies, depending on the extent of levees and other modifications existing along a particular reach. Overall, roughly 50% of the original floodplain area of the two rivers remains unleveed (Mills et al. 1966, Starrett 1972, Delaney and Craig 1997).

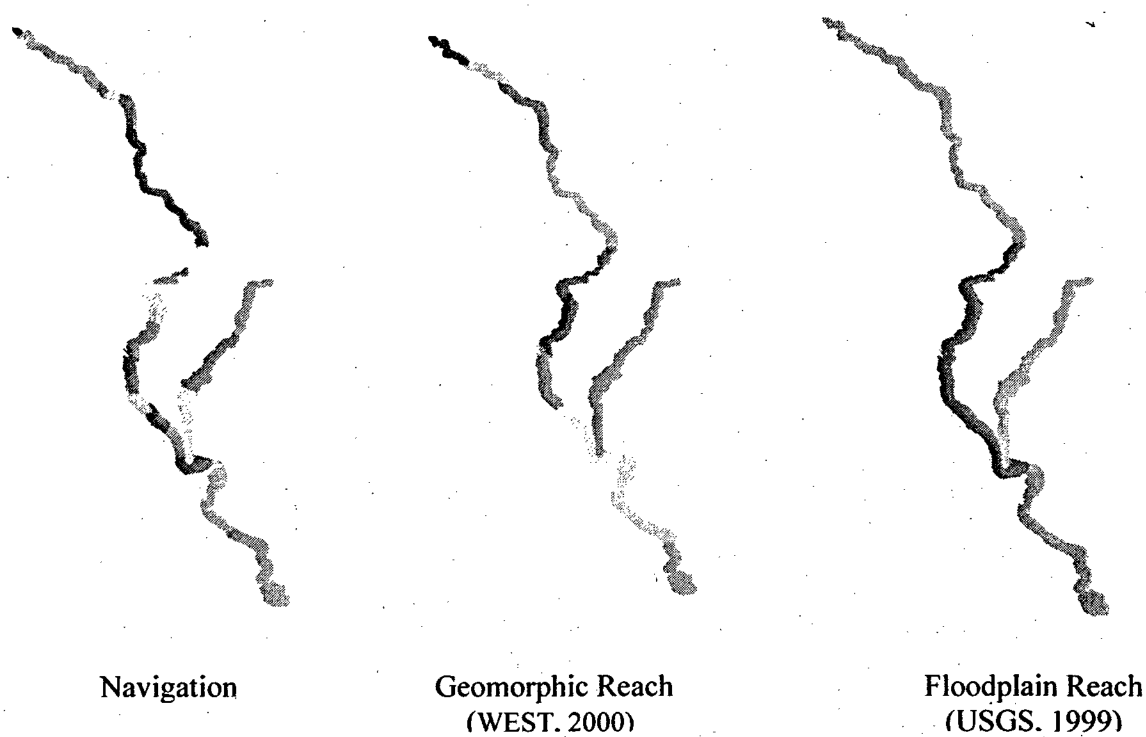

Figure 6. Management units on the mainstem Upper Mississippi River.

2.2.4. Stream Macrohabitats

Macrohabitats are small to medium-sized lakes and valley segments of streams defined by hydrology and map-based criteria (stream size, gradient, connectivity) to represent local environmental patterns and processes. Macrohabitats are river valley segments (typically 1 to 10 km in length) and small- to medium-sized lakes or lake basins (typically < 1000 hectares) that are relatively homogeneous with respect to hydrologic regime, temperature, chemistry and morphology. We hypothesize that macrohabitats have potentially distinct biological assemblages, i.e., they represent the community-level diversity of freshwater ecosystems. This approach to classifying and mapping stream macrohabitats is based on work by Seelbach et al. (1997) describing stream valley segments in Michigan, and the description of valley types in Washington by Cupp (1989). Macrohabitats also correspond to the valley segment types defined by Paustian (1992), and lake classification methods are similar to those reviewed by Busch and Sly (1992).

A set of attributes for each river and lake reach within the basin was generated in a GIS using three primary layers of spatial data: hydrography (EPA rf3), surficial geology, and a digital elevation model (DEM). We stitched together surficial geology maps from each state to develop a comprehensive surficial geology map for the region (see Box 2). A framework of abiotic variables known to influence the distributions of freshwater organisms was developed, and applied to each river and lake reach in the UMRB (Tables 3 and 4). Each reach was then assigned a numerical code, based upon the combination of values for each of the framework variables. A total of 159,733 river and lake reaches were classified. Each unique numerical code represents a distinct macrohabitat type. A total of 610 stream macrohabitat types were delineated across the basin (1728 unique combinations of variables were possible). These macrohabitat types represent the finest scale unit in the spatial hierarchy of our classification system and were used to differentiate the range of aquatic ecological systems found within the basin.

2.2.5. Lake system types (non-mainstem)

Lake classification poses many challenges because the information most critical to distinguishing lake types requires direct measurement. Although efforts have been made to predict lake characteristics from spatial data, studies show that the variability that shapes lake faunal assemblages is not sufficiently accounted for with spatial data only (Tonn 1990). However, given the density of lakes in the northern region of the UMRB, we wanted to include what information we could about their variety and distribution. Thus we applied a simple macrohabitat classification to about 32,500 lakes using key factors that distinguish lakes and that can be mapped (Table 4). This classification created 71 types. We then overlayed the stream system boundaries and used multivariate cluster analysis to group the stream systems into types based on the composition of lakes within their drainages. This process defined 28 lake system types (Appendix 7b). Headwater and creek stream systems, for example, have one grouping of lakes that includes a low number of lakes whose dominant geology is fine, calcareous rock as well as several large lakes. Another lake grouping associated with headwater and creek systems includes many large riverine lakes with complex shorelines and coarse calcareous geology and small lakes in coarse calcareous and neutral/acidic geology.

There is great variety within many of the lake types and these types are found associated with multiple stream types. We recommend that the lake system type be used as an attribute that can distinguish further occurrences of the same stream type.

Box 2. Surficial geology classification.

A digital coverage of surficial geology is one of three basic input layers necessary for the classification of macrohabitat types following the methods of Higgins et al. 1998. At the outset of the project, no comprehensive coverage of surficial geology existed in digital format for the entire UMRB. For many of the states overlapping the basin, there exist very detailed digital coverages for surficial geology, although they exhibit differences in scale and geologic nomenclature that limit their comparability.

A complete, digital map of surficial geology for the UMRB was assembled by combining those coverages readily available from the individual states across the basin (IL, IN, MI, MN, MO, WI: see surficial geology metadata for sources). For South Dakota and Iowa, no digital maps were available, necessitating the hand digitization of surficial features from several different sources (Goebel et al. 1983, Fullerton et al. 1995, and Halberg et al. 1991, Giglierano and Howes 1992, Soller and Packard 1998). Once assembled into a common coverage, the degree of resolution of the geologic features and the differing nomenclature for geologic classes were both standardized (Appendix 4) following the appropriate 4° x 6° quadrangle maps from the USGS Quarternary Geologic Atlas of the United States (Goebel et al. 1983, Lineback et al. 1983, Whitfield et al. 1993, Farrand et al 1984, Fullerton et al. 1995, Gray et al. 1991, and Halberg et al. 1991). A total of 39 unique geological classes were defined across the UMRB.

Due to the large number of variable classes in our classification framework (Tables 3 and 4) and data limitations of the software program (Microsoft Excel) used to attribute the macrohabitat information to river and lake reaches, the 39 original geology classes were re-classified into eight (8) broad geologic classes based three characteristics: texture, chemistry, and relative permeability (Tables 3 and 4), characters believed to influence the distribution and structure of biological communities in aquatic ecosystems.

Table 3. UMRB stream macrohabitat classification framework.

VARIABLE	DESCRIPTION	CLASSES	CODE	JUSTIFICATION
Size	Link# = the number of first order streams upstream of the classified segment.	Link# 1-10 (Headwater) Link# 11-50 (Creek) Link# 51-200 (Small River) Link# 201-700 (Medium River) Link# 701-2500 (Large River) Link# >2500 (Big River)	1 2 3 4 5 6	Stream size is a critical factor for determining biological assemblages (Vannote et al. 1980, Mathews 1998, S. Sowa, personal communication)
Gradient	A unit-less measurement of rise over run.	Gradient < 0.003 (Low) Gradient 0.003 — 0.013 (Medium) Gradient > 0.013 (High)	1 2 3	Stream gradient is correlated with flow velocity, substrate material, and types of cannel units (e.g., pools and riffles) and their patterns (Rosgen 1994). A gradient of 0.003 generally separates streams with a well-developed pool-riffle-run habitat structure from flat streams (Wang et al. 1998). The presence of riffles is a key factor determining the types of fish and invertebrate assemblages present (Lyons 1996).
Flow	USGS designation in digital line graph.	Intermittent (Ln2at2 = 610) Perennial (Ln2at2 ≠ 610)	1 2	Hydrologic regime is a dominant characteristic of freshwater ecosystems and influences the types and distributions of freshwater assemblages (Poff and Ward 1989, Poff and Allan 1995, Lyons 1996).
Network Position	Dlink# - the link number of the next downstream segment.	Dlink# 1-50 (Stream) Dlink# 51-700 (River) Dlink# >700 (Large River)	1 2 3	Drainage network position has been shown to correspond to patterns in freshwater community structure (Vannote et al. 1980, Mathews 1998, Lewis and Magnuson 1999, Newall and Magnuson 1999). Network position refers to the size of the next downstream stream segment. Osborne and Wiley (1992) showed that for warmwater streams in Illinois, the downstream-connected habitat (downstream link) was the most influential factor in determining stream fish community structure.

Table 3. Continued.

Dominant Geology	Numerical code identifying the dominant geologic type within the catchment area of the classified segment. Each code contains information on texture, chemistry, and relative permeability of the substrate.	Coarse, neutral-acidic, high permeability. Coarse, calcareous, high permeability. Fine, calcareous, low permeability. Fine, neutral-acidic, low permeability. Peat and muck, neutral-acidic, low permeability. Bedrock: calcareous, limestone, dolomite. Bedrock: non-calcareous (volcanic, igneous, crystalline). Man-made: strip mines, quarries, made land, artificial till.	1 2 3 4 5 6 7 8	Geology contributes to substrate characteristics, chemistry and hydrologic regime.
Temperature	Based on state Trout Stream coverages.	Coldwater Warmwater	1 2	Stream temperature sets the physiological limits for where stream organisms can persist (Allan 1995).

Table 4. UMRB lake macrohabitat classification framework.

VARIABLE	DESCRIPTION	CLASSES	CODE
Size	Surface area of the lake	Small (Area $\leq$ 1,000,000 m^2) Medium (1,000,000 m^2 < Area $\leq$ 10,000,000 m^2) Large (10,000,000 m^2 < Area $\leq$ 100,000,000 m^2) Very Large (Area > 100,000,000 m^2)	1 2 3 4
Connectivity	Number of surface connections	Unconnected [seepage] (0 connections) Catchment [drainage] (1 connection) Riverine ($\geq$2 connections)	1 2 3
Shoreline Complexity (development)	Function of area and perimeter (D_L)*	Round ($D_L < 2$) Complex ($D_L \geq 2$)	1 2
Geology	Numerical code identifying the dominant geologic type within the catchment area of the classified segment. Each code contains information on texture, chemistry, and relative permeability of the substrate.	Coarse, neutral-acidic, high permeability. Coarse, calcareous, high permeability. Fine, calcareous, low permeability. Fine, neutral-acidic, low permeability. Peat and muck, neutral-acidic, low permeability. Bedrock: calcareous, limestone, dolomite. Bedrock: non-calcareous (volcanic, igneous, crystalline). Man-made: strip mines, quarries, made land, artificial till.	1 2 3 4 5 6 7 8

* Shoreline Development (Wetzel 1983, p. 32) = the ratio of the length of the shoreline [L] to the circumference of a circle of area [A] equal to that of the lake.

$$D_L = \frac{L}{2\sqrt{\pi A_0}}$$

Box 3. Effects of temperature.

Temperature unquestionably sets limits on where a species presently can live (Allan 1995). From the literature, it is well documented that thermal regime has diverse effects on the life-histories of aquatic organisms. Seasonal changes in water temperature often cue development or migration, influence growth rates of eggs and juveniles, and can affect the body size, and therefore the fecundity of adults. Many aquatic species have adapted over millennia to very specific temperature regimes, and are intolerant of even slight changes in average water temperatures.

In addition to limiting effects on biological productivity, temperature extremes may directly preclude certain taxa from inhabiting a water body. Lyons et al. (1996) found that high quality coldwater streams in Wisconsin have lower fish species richness than comparable high quality warmwater streams, and that many of the taxonomic groups that are important in the warmwater streams are rare or absent in the coldwater streams. They also found that the fish assemblages of the two stream type responded differently to environmental degradation, necessitating alternative management strategies to protect natural levels of biological diversity.

The temperature of running waters usually varies on seasonal and daily time scales, and among locations due to climate, elevation, extent of streamside vegetation, and the relative importance of groundwater inputs (Allan 1995). Elevation is not a serious consideration in the UMRB, as the topography is relatively level across most of the basin. Climate and riparian cover can be relatively easily accounted for using readily available spatial data in a GIS. At the present, no comprehensive method exists for modeling groundwater input at the appropriate scale (stream reach) across the entire UMRB.

In order to account for the importance of stream temperature in structuring biological communities, we developed a spatial coverage of coldwater streams using several trout stream classifications (WI DNR, MNDNR 2001) and coldwater stream designations (IADNR 1994) completed for the region. Additional trout streams in the Kankakee River basin of Indiana were identified and hand-digitized from a state list of stocked trout streams (INDNR 2003). No trout stream or other coldwater stream designations are maintained by Illinois or South Dakota, and so were not included in the coverage, although several of the streams draining the eastern Prairie Coteau support introduced trout populations.

3. Conservation Goals for the UMRB

Establishing a set of numerical goals for species targets creates benchmarks against which to measure the success of a particular set of conservation areas in capturing biodiversity. The goals are created with the aim of ensuring the long-term viability of species and ecosystems. Viable species can be defined as those with a high probability of continued existence over time (90% certainty of surviving 100 years and/or 10 generations). In other words, goals are meant to ensure that, if met, each species targeted will possess sufficient genetic variability across their range to adapt naturally in the face of continually changing environmental conditions. Viable systems are those that function within an historic range of variation, and demonstrate a high level of ecological integrity. Depending on the context of the region in question, viable occurrences of all species and system types may not exist, in which case, the deficit in viable occurrences represents a set of restoration goals.

3.1 Species Goals

The distribution and general life history requirements of each species target within the UMRB was assessed. Numerical goals for each species target (Appendix 5) were calculated individually, based on the following factors:

- Proportional range representation - the target's range-wide distribution relative to the basin.
- Spatial pattern - the geographic scale of spatial patterns exhibited by the species (Poiani et al. 2000, Figure 7).

Localized, endemic species were considered the most susceptible to extirpation and were assigned the highest conservation goals. Peripheral species, most with far better representation outside the basin, were assigned the lowest goals. Regional species are to be considered on a case-by-case basis, depending on habitat requirements and issues of connectivity.

The exact number of individual occurrences or populations needed to ensure the long-term viability of most species is uncertain. We simply do not have the knowledge and data available to set concrete goals with any degree of confidence. Out of a total of 1100 individual occurrences of species targets from the natural heritage program databases, we have viability information for 341. The data points from non-Heritage sources do not have a viability rank. The conservation goals for target species within the UMRB should be considered provisional, and should be adapted over time as new information on each species and its life requirements are made available.

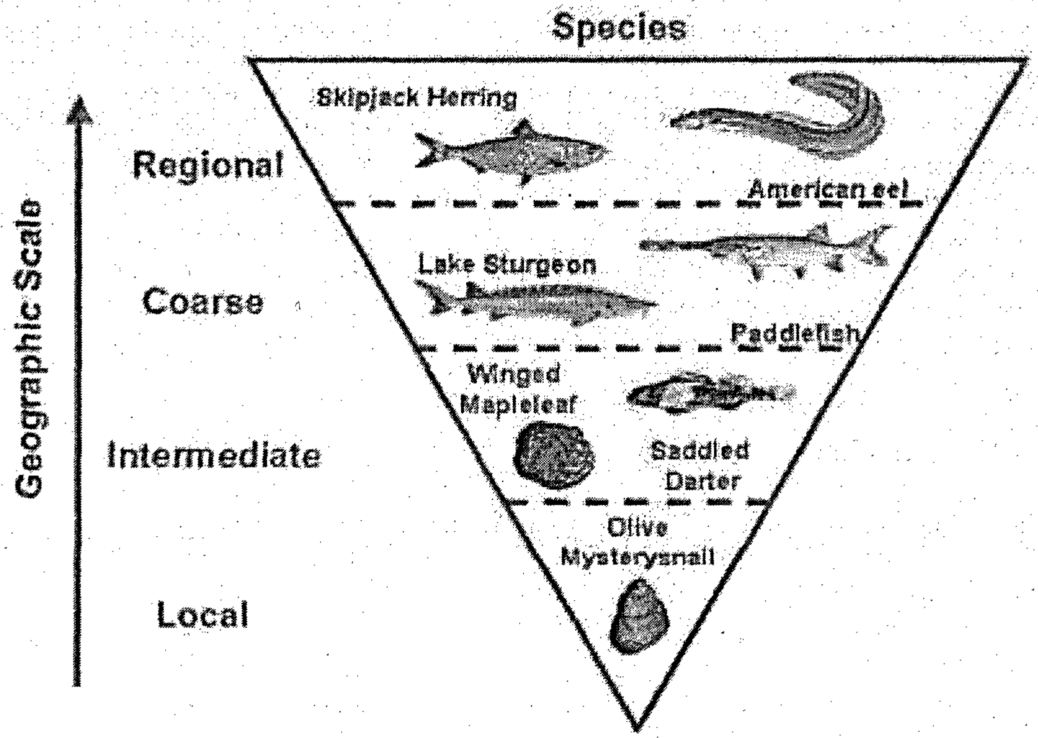

Figure 7. Freshwater biodiversity at four geographic scales including local, intermediate, coarse and regional. After Poiani et al. 2000.

3.2. Systems Goals

The minimum goal for aquatic systems was to conserve one example of each unique system type across the basin. Ideally, each occurrence captured will be functioning within a historic range of natural variation, and will demonstrate a high level of ecological integrity. In the case that no high quality examples of a particular type yet exist, the example with the greatest potential for successful restoration will be identified. See the section below on "Identifying Freshwater Areas of Biodiversity Significance" for further details regarding the criteria for selecting representative systems occurrences.

4. Integrity Assessment

A critical step in prioritizing conservation areas is to determine the condition and suitability of potential conservation targets (Groves et al. 2002). Key to developing an accurate assessment of condition and suitability is understanding the intensity and spatial arrangement of a range of stressors to aquatic ecosystems, including dams, agricultural areas, point sources of pollution, and invasive species. Such information greatly enhances efforts to identify potential aquatic conservation areas with high ecological integrity, low conservation cost, and a high likelihood of conservation success. Additionally, data describing the location and intensity of anthropogenic stressors can indicate potential locations of high integrity systems in locations where biological data and expert information to guide conservation site selection are absent or limited.

To evaluate the relative integrity of freshwater system occurrences across the UMRB, we analyzed threats to biodiversity using several basin-wide spatial data sources (Table 5). Many of the leading stressors to aquatic ecosystem integrity have been mapped digitally, including hydrologic alterations, and point and non-point sources of pollution, and therefore lend themselves well to GIS analysis. For each system occurrence we calculated a series of potential habitat integrity indicators known to influence the biological integrity of streams (Bryan and Rutherford 1993). These data are available in the Conservation Planning Tool (CPT) database on the accompanying CD-ROM.

Table 5. Indicators of ecological integrity and their sources.

CLASS	DATA SOURCE	UNITS	COMMENTS
Land Cover /Land Use	National Land Cover Data (USGS 1992)	Area percentage	Cultivated Lands, Urban Area, Natural Vegetation, and Wetlands.*
Impervious Cover	National Land Cover Data (USGS 1992)	Area percentage	Low Density Residential, High Density Residential, Commercial/Industrial/Transportation.†
Road Density	1999 TIGER Roads (USDOC 1999)	road length/area	Includes all road classes
Road/Stream Crossing Density	1999 TIGER Roads (USDOC 1999)	# crossings/ total km streams	
Dams	National Inventory of Dams. (USACE 1999)	# dams/area	
Point Sources	BASINS 3.0 (USEPA 2001)	# point sources/area	Superfund Sites (CERLIS), Industrial Facility Discharges (IFD), and Toxic Release Inventory (TRI).
Mines	BASINS 3.0 (USEPA 2001), MINES97 (IADNR 1997)	# mines/area	Includes both active and abandoned mines.
303d Streams	EPA BASINS 3.0	km 303d streams/ total km streams	

* Land Cover/Land Use classes in this study include the following NLCD categories:
Cultivated Lands = Pasture/Hay, Row Crops, and Small Grains.
Urban Area = Low Density Residential, High Density Residential, Commercial/Industrial/Transportation.
Natural Vegetation = Deciduous Forest, Evergreen Forest, Mixed Forest, Shrubland.
Wetlands = Woody Wetlands, Emergent Herbaceous Wetlands.

† Impervious Cover = (Low Density Residential x 0.55) + (High Density Residential x 0.90) + (Commercial/Industrial/Transportation x 0.75)

Indicators for headwater through large river systems were calculated using a set of GIS tools (FitzHugh 2002) that characterize the watershed upstream of every stream reach. For big river systems (size 5), values were calculated for the area immediately adjacent to the river. Given that the contributing areas of these rivers are extremely large, we concluded that entire-watershed indicators might not be meaningful at that scale. Integrity indicators were calculated for an area extending five kilometers beyond the floodplain laterally and longitudinally from one pool boundary to the next. This buffer was designed to capture the small, bluff tributaries, the lower parts of the larger tributaries, and also the entire floodplain including the main channel, and all the backwaters and lateral channels. The entire contributing area of a mainstem can be derived from totaling the values for each tributary system. For the non-mainstem Mississippi River big river systems (e.g. Des Moines River, Wisconsin River, etc.), the contributing area was defined as extending five kilometers to either side of the river.

The values assigned for most quality indicators are straight calculations of percent area coverage or simple counts of features (e.g., percent of total system area in cultivated land cover, or the number of dams), with no weighting of the variables. The impervious cover value for each system, however, represents the sum of the three urban land use classes, each multiplied by a factor representing its relative degree of imperviousness (Table 5). We compared values of individual indicators within each system type to identify high quality system occurrences, and in selecting the Areas of Biodiversity Significance. This information was particularly useful where we had no other means to distinguish among system occurrences.

The indicator values vary across the Ecological Drainage Units, reflecting land use patterns and the underlying landscape features. Agricultural cultivation is highest in the EDUs in Iowa and southeastern Minnesota (Upper Des Moines, Upper Minnesota, Iowa-Cedar). The highest concentrations of wetlands are found in the Mississippi River Headwaters and the St. Croix EDUs. With the exception of mines, point sources appear to be most concentrated in Illinois, particularly industrial facility dischargers. However, the variability in values is also a result of inconsistencies in data collection across states. Road density and road crossings are even across the whole region.

Land use measures varied little among size classes of streams. The most striking difference in land use among size classes is in urban land use. For all sizes of streams except the mainstem rivers, the average percent urban land use is approximately 2%. Urban development is more concentrated in the buffer of the mainstem — where it constitutes 9% of the land use type.

The frequency of point sources increased with drainage area. However, because the big river values were based on a buffered area, the large river and medium rivers consistently had the highest values for point sources such numbers of dams, numbers of industrial dischargers, number of mines. Big rivers had the highest average percentage of stream miles that do not meet their designated uses.

5. Experts meetings

Expert recommendations for areas important to freshwater biodiversity conservation constituted one of the more important sources of information used in setting conservation priorities across the UMRB. With most experts actively working in the field, they have unparalleled knowledge of condition and extent of species and systems, and represent potential partners to develop and implement conservation strategies for the region.

Expert recommendations came from two sources for this analysis. First, we consulted the Conservancy's ecoregional plans to identify streams and rivers highlighted by experts in those previous planning efforts. Where the information from the ecoregional plans needed to be augmented, we held new expert workshops, which took place in Iowa, Missouri and Minnesota. Experts either participated in these meetings or phone interviews, and provided up-to-date knowledge of the aquatic species and systems of the UMRB, including information on distribution and status, and threats to their viability.

Each of the state or river-basin focused meetings, included representatives of major resource management agencies, academic institutions, and non-profit organizations working in each region. Experts provided feedback on the initial selection of conservation targets, shared new records for target species, and provided information on current trends, distribution, and threats for each target. Also provided were innumerable helpful publications, data sets, and contacts for further experts around the region.

Products of the workshops and phone interviews included refined lists of species targets and specific streams, rivers or lakes recommended based on the presence of viable target species occurrences, high overall species and/or habitat diversity, high water quality and intact ecosystem processes, and exceptional occurrences of common species or native assemblages.

In total experts recommended 186 sites covering 77 species targets. Eighty-one of these sites are captured in the final set of freshwater areas of biodiversity significance. The expert recommended areas and their attributes are listed in Appendix 9.

6. Freshwater Areas of Biodiversity Significance:

6.1. Creating the network of ABS

The freshwater Areas of Biodiversity Significance (ABS) (Figure 8) were selected to represent all aquatic ecological systems types found in the UMRB and capture examples in sufficient number of the globally rare and imperiled aquatic species targets in the basin. This analysis involved synthesizing several layers of information including the systems classification, quality assessment, species target locations, expert workshop recommendations, and ecoregional planning data (see Appendix 10 for the attributes of each ABS). This represents the recommendation for the suite of areas that comprise the remaining best examples of aquatic biodiversity representative of the UMRB.

The small river systems provided the initial set of systems on which the network of ABS was built. We chose to start with the small rivers as it was more practical to select among 350+ small river than 3200+ headwaters and creeks. Comparisons of the small river systems within system type were made, with the goal of selecting at least one example of each system type. Priority was given to those systems that captured target species occurrences, were expert recommended, were ecoregional priorities in prior plans, represented the best quality example based on a suit of quality indicators, or was simply the only example available. Clear priorities were given a value of 1. If the quality of the "best" or only example was in question or poor, the ABS was assigned a value of 2. The map of the ABS shows these lower confidence choices in a lighter shade. Land use quality shown for agriculture, urban and natural vegetation on average is higher for ABS with a rank of 1 (Table 6).

Table 6. Values for three land use types summarized by system size and ABS confidence rank.

SYSTEM SIZE	ABS	%AG	%URBAN	%NATVEG
1	1	58	1	33
1	2	74	2	19
2	1	55	1	31
2	2	68	2	24
3	1	64	2	25
3	2	83	2	10
4	1	66	2	24
5	1	49	10	26

Following the selection of the 74 small river ABS, we selected all of their headwater and creek systems for inclusion as ABS. Again, if we had concern about quality or a question, a value of 2 was assigned to that system. We selected these connected headwaters because we reasoned that these areas would need to be addressed in protecting the small rivers and should be included. This initial selection captured about three-fourths of the headwater and creek system types, so a few additional headwater systems were selected to meet representation goals.

The medium rivers immediately downstream of the selected small rivers were also automatically included, to emphasize the importance of connectivity. Other examples were added as necessary to meet the goal of representing each system type. Finally, all the large river and big river systems, including the entire mainstem UMR_IWW were selected as ABS. Due to their position in the drainage network and the characteristics of their tributaries, each of these rivers are unique, and as such need to be included to meet the goal of representing all the system types at least once.

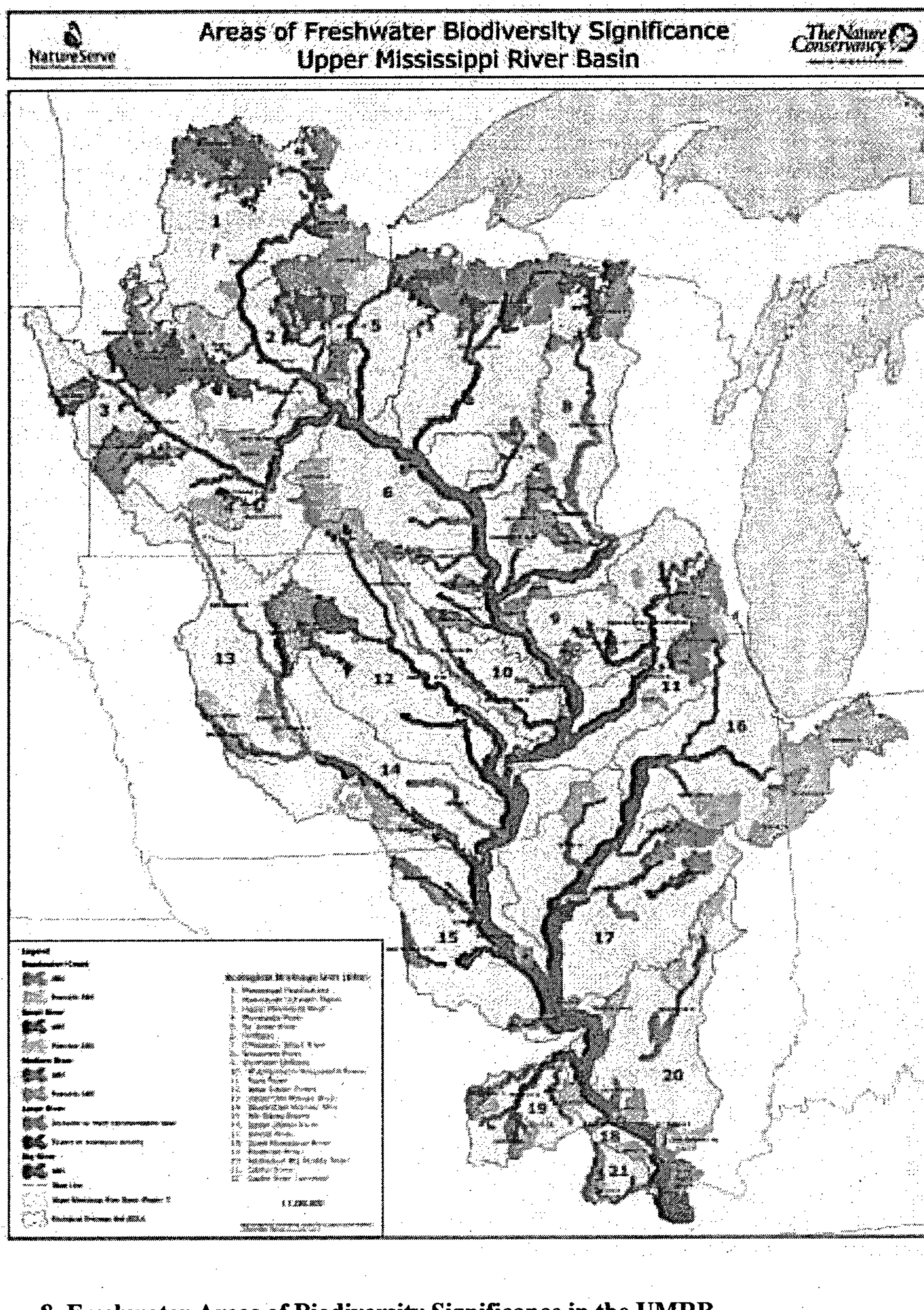

Figure 8. Freshwater Areas of Biodiversity Significance in the UMRB.

6.2. Goals Met by Freshwater ABS network

We used the goals for species and systems to evaluate the conservation impact of the freshwater ABS network. The network of ABS captures of the aquatic ecological systems and a high proportion of the target species. We evaluated both the number of occurrence captured within the entire UMRB as well as by Ecological Drainage Unit. The system results are summarized in Table 7. The species results are summarized in Table 8. Given the lack of viability data for individual species occurrences, we used the systems selected as ABS to select the species occurrences. We presumed these were the most viable as we selected ABS that are the most viable.

6.2.1. System goals met

As described in Section 6.1, the ABS network was constructed to represent all of the systems types within each EDU. Goals were met at 100% for all targets. Once we had the set of systems to represent each type, we then assessed how well this network of aquatic systems would capture the target species. As the two scale score for the ABS suggests, not all of these systems are viable in their current condition. For example, the lack of longitudinal connectivity on the mainstem Mississippi River jeopardizes the long-term viability of regional or wide-ranging species, and some coarse-scale species. The ABS are the places to maintain or improve ecological integrity, where one should measure the success of conservation actions in the UMRB.

Table 7. Systems goals met by ABS network.

SYSTEM SIZE	TOTAL NUMBER OF SYSTEM TYPES	NUMBER OF SYSTEMS CAPTURED	% OF TYPES CAPTURED
Headwater/Creeks	89	447	100
Small Rivers	54	78	100
Medium Rivers	40	43	100
Large Rivers	27	27	100
Big River	11	11	100

6.2.2. Evaluating species goals met: data sources and how species were counted

For all taxa we used species occurrences from the natural heritage programs in the basin. In addition, for fish and mussels, we compiled species occurrences from several additional data sets. The data used to meet conservation goals is no older than 1988. Details regarding these additional data sources are described in Section 8. For both the mussel and fish data, sampling points do not necessarily represent actual occurrences of species — for example, some points represent single individuals while some represent repeated sampling at the same location over a series of years. In order to standardize the count of species occurrences, we created what we have termed functional occurrences based on separation distances specified by NatureServe and the spatial scale over which a given taxa ranges (Figure 7). The species table (Appendix 5) includes the categorization of the species as local, intermediate, course and regional species.

All mussels were classified as intermediate and we used a separation distance of 15 km to group together sampling points into single occurrences. The original data set has 3365 points, which has been reduced to 906 functional occurrence based on application of this rule.

For the fish, the separation distance varied from 3 km for such local species as Western sand darter (*Ammocrypta clara*) to 200 km for such wide-ranging species as Lake sturgeon (*Acipenser fulvescens*). The original fish data set for the target species has 2522 points, now reduced to 422 functional occurrences.

A few of the invertebrate taxa data points were also grouped into functional occurrences based on a 5 km separation distance.

We identified a total of 153 target species. We lack spatial data for three undescribed sub-species of fish found in Missouri, two of which are cave obligates, and for one dragonfly thought to occur in the UMRB. Ten species have not been found in the basin since 1987. Nine more have occurrences in the basin, but were not captured in the ABS network.

Out of 131 species for which we have spatial occurrences, 102 are captured in this network of stream systems. Those not captured include taxa that historically occurred in the basin, have very limited occurrences, whose status is in question, or are simply under sampled. The most complete data are available for fishes and mussels. Of those, 71 percent of the fish and 55 percent of the mussel species are captured at or above the goals set for each species. Overall, 77% of the species for which we have location data within the UMRB were captured by the ABS network, with approximately 45% of these meeting their conservation goal.

Table 8. Species targets captured by ABS network.

TAXA	TOTAL NUMBER OF TARGET SPECIES*	# CAPTURED (AT LEAST ONE EXAMPLE)	# MEETING GOAL	% MET GOAL
Fish	34	30	22	71
Mussels	40	32	22	55
Insects, Snails and Amphipods	34	25	5	15
Crayfish	9	7	4	44
Herptiles	14	8	5	36
Total	131	102	58	45

*includes only taxa for which we have occurrences

7. Selection of Priority Areas

7.1. Identification of Priority Areas for Biodiversity Conservation

The Priority Areas (Figure 9) are intended to highlight the top fifty areas of general biological diversity significance. The areas selected are locations where freshwater areas of biodiversity significance overlap extensively with terrestrial priority areas identified in the Conservancy's ecoregional plans, with a couple of exceptions. We identified at least one Priority Area in each ecological drainage areas. This led to the identification of aquatic-only Priority Areas in a few cases. We also created Priority Areas to capture significant lake and subterranean complexes. Appendix 11 provides maps and a detailed description of each Priority Area .

The Priority Areas were not selected to represent the full array of aquatic species or aquatic system types found in the basin. However, we analyzed these areas to see what level of protection this set of forty-seven places provides for the aquatic conservation targets.

Table 9. Systems captured by priority areas.

SYSTEM SIZE	TOTAL SYSTEM TYPES CAPTURED	% CAPTURED	TOTAL SYSTEM TYPES
Headwater/Creek	65	73	89
Small River	34	63	54
Medium River	25	63	40
Large River	24	89	27
Big River	11	100	11
Total	159	72	221

Table 10. Conservation target species capture by Priority Areas.

TAXA	TOTAL NUMBER OF TARGET SPECIES*	# CAPTURED (AT LEAST ONE EXAMPLE)	# GOAL MET	% MET GOAL
Fish	34	30	20	65
Mussels	40	32	21	53
Insects, Snails and Amphipods	34	17	6	18
Crayfish	9	5	3	33
Herptiles	14	10	4	29
Total	131	94	54	42

*includes only taxa for which we have occurrences

Although less than the ABS network, the Priority Areas capture significant biological diversity in the basin. The Priority Areas capture 72% of the aquatic system types (Table 9) and 94 of the species for which we have spatial locations (72%, Table 10). The ABS and Priority Areas both achieve approximately 42% of the conservation goals for the species that occur within them.

The consistency between results for target species represented is in part due to the fact that both the ABS network and the set of Priority Areas include the entire mainstem Mississippi River and the mouths of its major tributaries (the big river habitat). The mainstem Mississippi has occurrences of all but 21 of the target species. However, the mainstem Mississippi represents only 11 of the 237 aquatic system types (<5%). Thus, both the mainstem Mississippi and the upstream systems are important. The big rivers contain most of the imperiled taxa and large numbers of common taxa. The upstream areas also harbor widespread and common species, as well as many that are highly localized. While at a local scale declines are of concern (many taxa are listed as state imperiled that we did not include as targets), when viewed from a basin perspective, these taxa appear secure. Taking the approach that we have here of proposing representative aquatic systems for conservation is a means to prevent the declines in the more common assemblages of aquatic fauna across the basin.

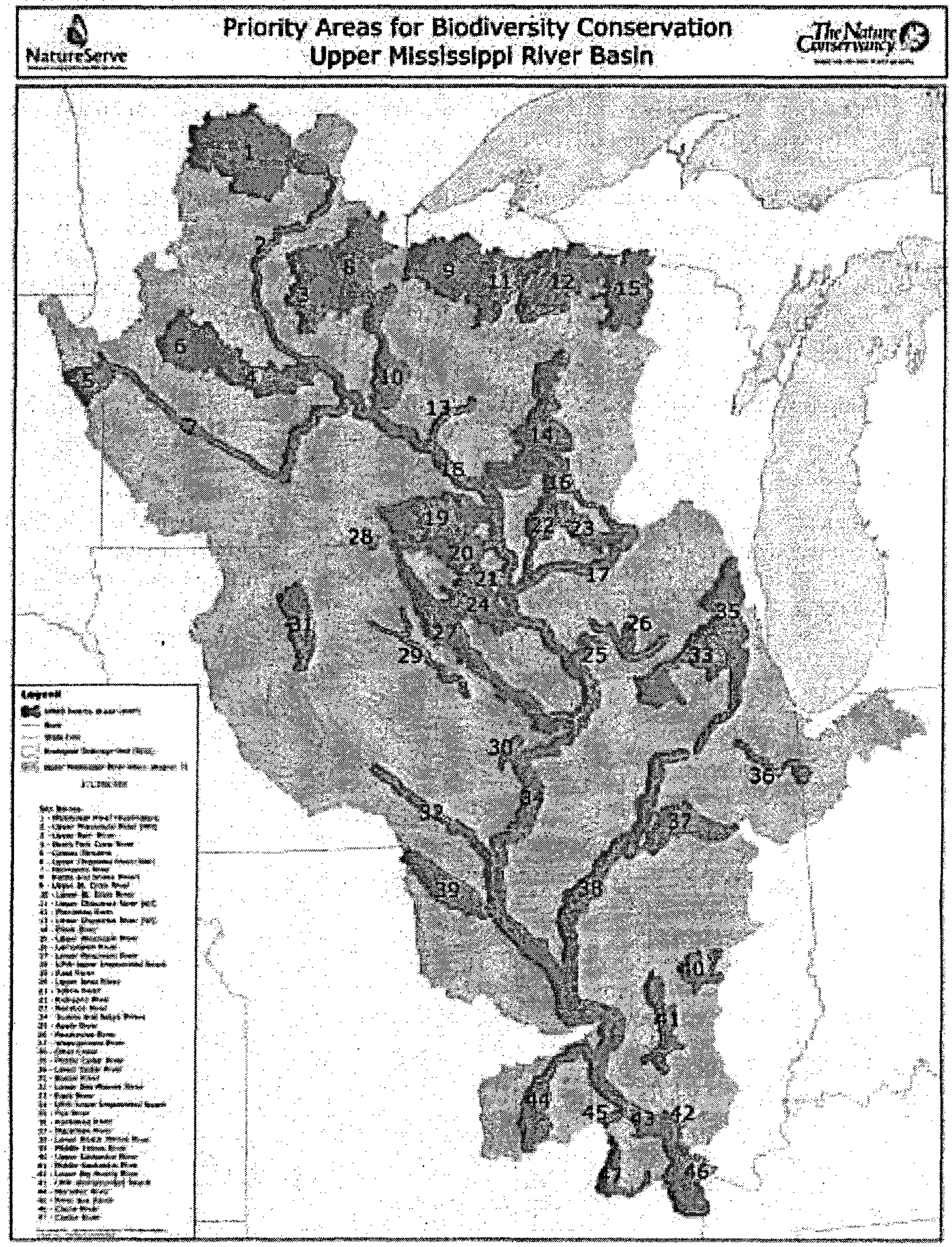

Figure 9. Priority areas for freshwater and terrestrial biodiversity.

7.2. Special note on the UMR-IRWW

You will recall from the discussion of the selection of ABS on the mainstem that the entire extent of the UMR-IRWW was identified as significant for aquatic biodiversity. When we compared the ABS with ecoregional planning data, the overlap of ABS and terrestrial portfolio sites was nearly complete. Therefore, the entire mainstem system qualifies as a Priority Area following the criteria listed above.

While it makes sense that the whole UMR-IRWW would be a priority site from an ecological standpoint, the vast scale of the ecosystem, not to mention the complexities associated with the large number of political and resource management entities at work on the river, make it unrealistic to attempt to manage the system as a single unit. The challenge, therefore, is to devise a way to subdivide the river into smaller, more manageable units that still make sense ecologically.

Again, as with the ABS, we chose to work within the bounds of the existing management structure on the UMR-IRWW. We divided the mainstem river system into four Priority Areas, corresponding with the Floodplain Reach sub-units as outlined above. Each of these reaches can be distinguished from another by its unique geomorphological, biological , and anthropogenic characteristics, requiring that the ecological health of each be evaluated separately (USGS 1999). Concentrating conservation efforts separately on each of these reaches will allow practitioners to focus on abating the threats specific to each reach.

8. UMRB Freshwater Species Database

8.1. Purpose of Database

Analysis and planning for conservation must be grounded in a firm understanding of the distribution of elements of biodiversity ranging from species to landscapes. Often, such information is limited or lacking, hampering efforts to achieve a sound conservation plan. In the Upper Mississippi Basin, researchers ranging from academics to federal, state and local agency personnel have compiled abundant data on freshwater species occurrences, including records that date from the late 19th century. These datasets are dispersed across all of the states of the UMRB, and are variously maintained, accessible, and quality-controlled. For the purposes of conservation planning and analysis, we sought to gather these datasets, record available metadata regarding collection methods, and structure them in a standardized format.

Freshwater species occurrence data collected through this effort were used to inform the selection of conservation areas (see Section 6 for further details), assess the strength of the systems classification framework for the UMRB, identify characteristic fish assemblages in the UMRB (see section 9 for details), and test landscape metrics of aquatic system integrity. They may also be used in local site conservation area planning efforts and future analyses of UMRB aquatic species and communities such as developing lists of aquatic biota found within specific ecological systems and system types.

8.2. Biological Data Search

The search for freshwater biological datasets was limited to fish, mussel, crayfish and macroinvertebrate occurrence records. Survey and collection methods were not restricted; data ranged from incidental-take notes to community and relative abundance surveys collected using standardized methods. The date of data collection was also not restricted, however data were required to have relatively precise locality information, such as latitude/longitude coordinates. Primary sources of available data included academics and federal, state and local government agency personal. A small number of individuals not associated with research institutions or government agencies were also contacted regarding available datasets.

8.3. Data Acquisition and Standardization

Freshwater biological datasets were acquired from approximately 60 sources, between March, 2001 and January, 2003; 30 of these datasets were included in the final database (Table 11: Data Sources). Collections ranged in age from the late 1800's to 2002. All sources were questioned for minimal metadata information, including research notes, collection methods, and accompanying reports and publications. From the datasets provided, selected data were queried, transferred into a standardized format, and merged into a relational database consisting of four primary tables: "species," "sites," "samples," and "projects" (Table 12: Relational Database Structure). All locations of species occurrences were to converted to a common projection, and stored in a GIS.

At the time of publication, data processing has been completed for fish and mussel datasets only. The final dataset includes approximately 885,000 records of species occurrences from over 60,000 survey locations in all states of the UMRB (Figures 10 and 11).

Table 11. Data sources for the UMRB Freshwater Biological Database.

Source Code	Taxon	Title	Source/Contact	Coverage	Site ID Range
IA02	Fish	Iowa Baseline Fish Survey (Paragamian Study)	Clay Pierce — Iowa State University	61 sites within the UMRB	7120-7188
IA03	Mussels	Iowa Mussels Dataset	John Downing — Iowa State University	211 sites in UMRB, 118 sampled twice	36908-37107
IA05	Fish and Inverts	IA DNR (1/2 of the Iowa Contemporary Dataset)	Tom Wilton — Iowa Department of Natural Resources	200 reference sites across Iowa	58057-58167 (fish sites only)
IA06	Fish	Manchester dataset (1/2 of the "Iowa Contemporary	Greg Gellwicks - Iowa State University	60 sites in Iowa	4259-4299
IL01	Fish	IL DNR Streams Data	Dave Day — Illinois Department of Natural Resources	305 sites across the UMRB of Illinois	1-305
IL02	Fish		Frank Hutto - Illinois Natural Heritage Biodiversity Section	34,128 samples across the UMRB of IL	1000-3429
IL03	Mussels		Frank Hutto - Illinois Natural Heritage Biodiversity Section	10,952 samples across the UMRB of IL	37108-37874
IL06	Fish		Bill Bertrand — Illinois Department of Natural Resources	2467 records from 243 stations along Mississippi mainstem of IL	306-548
IL07	Fish	Illinois River Electrofishing Dataset	Mark Pegg - Illinois Department of Natural Resources - Havana	6 pools on the Illinois River	30646-30651
IL10	Mussels	IL River Starett Mussel Data	Kevin Irons		

IN02	Fish	IDEM 1990-1994 IBI	Stacey Sobat — Indiana Department of Environmental Management	Indiana statewide; 155+ sites within the UMRB	3500-4258
IN03	Fish	IDEM 1995 REMAP	Stacey Sobat — Indiana Department of Environmental Management	Indiana statewide	7773-7961
IN04	Fish	IDEM 1996-2000 IBI	Stacey Sobat — Indiana Department of Environmental Management	Indiana statewide; 86 sites within the UMRB	30652-30986
MN01	Fish	PCA Fish	Scott Nimela — Minnesota Pollution Control Agency	9692 records at 831 stations throughout Minnesota	7198-7772
MN02	Mussels	MN Mussel Data (DNR)	Mike Davis — Minnesota Department of Natural Resources	5337 records from 672 sites in Minnesota	37990-38928
MN03	Fish	Konrad's Personal Dataset	Konrad Schmidt — Minnesota Department of Natural Resources	33139 records from sites in Mississippi, St. Croix, Minnesota and Des Moines River drainages	4300-7113
MN08	Fish	MN Lake Surveys	Konrad Schmidt — Minnesota Department of Natural Resources	65,536 records from MNDNR Lakes database	30987-34844
MN14	Fish	Konrad's MS River Pool 1-9	Konrad Schmidt — Minnesota Department of Natural Resources	1437 records from pools 1-9 on Mississippi River	37875-37989
MO01	Fish	MoRAP Dataset (Fish)	Scott Sowa - MoRAP	14355 records from UMRB of MO	34845-36907
MO04	Fish	MDC-Fish_Winston	Matt Winston — Missouri Department of Conservation	15927 records from UMRB of MO	MO04a= 710-792; MO04b=793-970; MO04c=8031-8455
MO05	Mussels	MoRAP Dataset	Scott Sowa — Missouri	7423 records from UMRB of MO	38929-39552

		(Mussels)	Resource Assessment Partnership		
SD01	Fish	Backlund Dataset	Chad Kopplin — South Dakota Aquatic GAP	51 records from UMRB of SD	39553-39901
SD02	Fish	Dietermann Dataset	Chad Kopplin - South Dakota Aquatic GAP	Records from 19 sites in UMRB of SD	600-618
SD03	Fish	Bailey and Allum Dataset	Chad Kopplin - South Dakota Aquatic GAP	Records from 10 sites in UMRB of SD	620-702
UMR01	Fish	LTRMP-Fish	Upper Midwest Environmental Sciences Center	739197 sampling points in six study reaches in the	39902-53619
UMR03	Fish	NAWQA-UMR	Kathy Lee - USGS	1850 records from Upper Mississippi Drainage in MN and WI	549-596
UMR12	Fish, Mussel, Crayfish, Reptiles, Amphibians, Aqua	Natureserve Aquatic Element Occurrences for IA, IL, IN, MN, MO, SD, and WI	Roy Weitzell - NatureServe	IA, IL, IN, MN, MO, SD and WI	58168-62969
UMR13	Mussels	Natureserve Aquatic Element Occurrences for IA, IL, IN, MN, MO, SD, and WI	Roy Weitzell - NatureServe	IA, IL, IN, MN, MO, SD and WI	63446-65340
WI01	Fish	Fago Master Fish Database	Don Fago — Wisconsin Department of Natural Resources	1135906 records from 15607 collections in the UMRB	8456-30645
WI03	Fish and Crayfish	Wisconsin Wadeable Streams data	Li Wang, John Lyons - Wisconsin Department of Natural Resources	2985 records from WI; about 250 sites	7962-8008

Table 12. Contents and structure of UMRB Freshwater Biological Database.

Table	Field Name	Field Definition and Codes	Field Type
Sites	*Site ID	Unique number assigned to each survey site in UMRB database	Numeric
	*Source Code	Unique identifier assigned to source dataset	Text
	*EDU ID	Ecological Drainage Unit	Text
	System Type	Watershed group type	Text
	*System ID	Watershed identification number	Text
Samples	*Site ID	Unique number assigned to each survey site in UMRB database	Numeric
	Year	Year of Survey	Text
	Source Scientific Name	Scientific species name, as identified by the source	Text
	Corrected Scientific Name	Scientific species name, corrected for misspellings, nomenclature updates, etc.	Text
	*GEL Code	Natural Heritage Element Code	Text
	Sample Method	Notes on gear or survey method, if available	Text
	EO Code	Element occurrence code, for natural heritage data	Text
	*Source Code	Unique identifier assigned to source dataset	Text
Species	*GEL Code	NatureServe Element Code	Text
	Scientific Name	Scientific name of species	Text
	Common Name	Common name of species	Text
	Grank	NatureServe Global Rank	
	USESA	Federal Conservation Status	Text
Projects	*Source Code	Unique identifier assigned to source dataset	Text
	Taxon	Focal taxonomic group of survey (Fish, Mussel, Crayfish, etc.)	Text
	Title	Name of dataset	Text
	Source/Contact	Person from whom dataset was acquired	Text
	Coverage	Spatial extent of survey data	Text
	Time Span	Approximate range of survey dates	Text
	Methodology	Notes on survey methodology, if available	Text
	Site ID Range	Site ID numbers assigned to dataset	Text

- Indicates fields by which data tables can be linked.

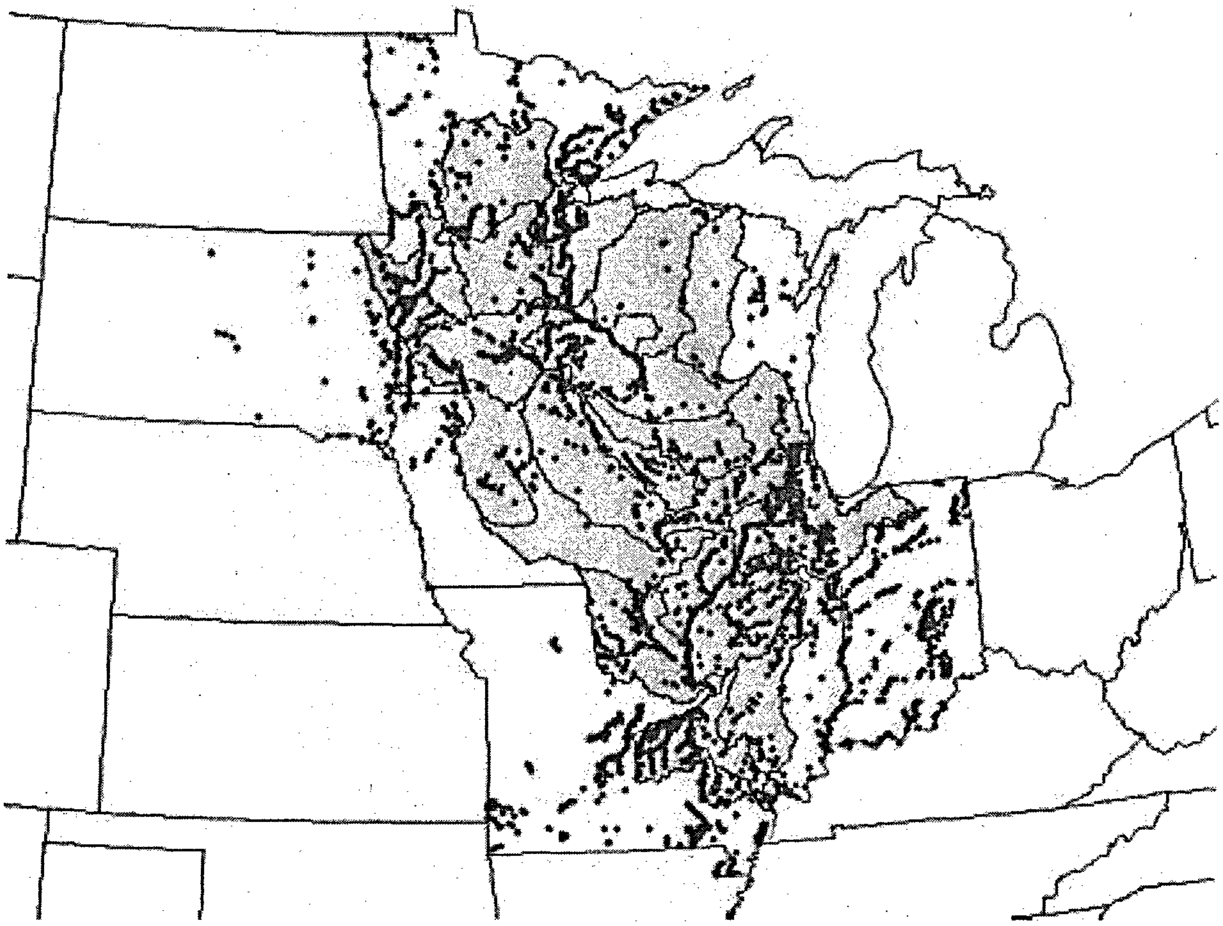

Figure 10. Location of mussel survey information in the UMRB Freshwater Biological Database. Blue dots represent survey locations. Green polygons represent EDUs in the UMRB.

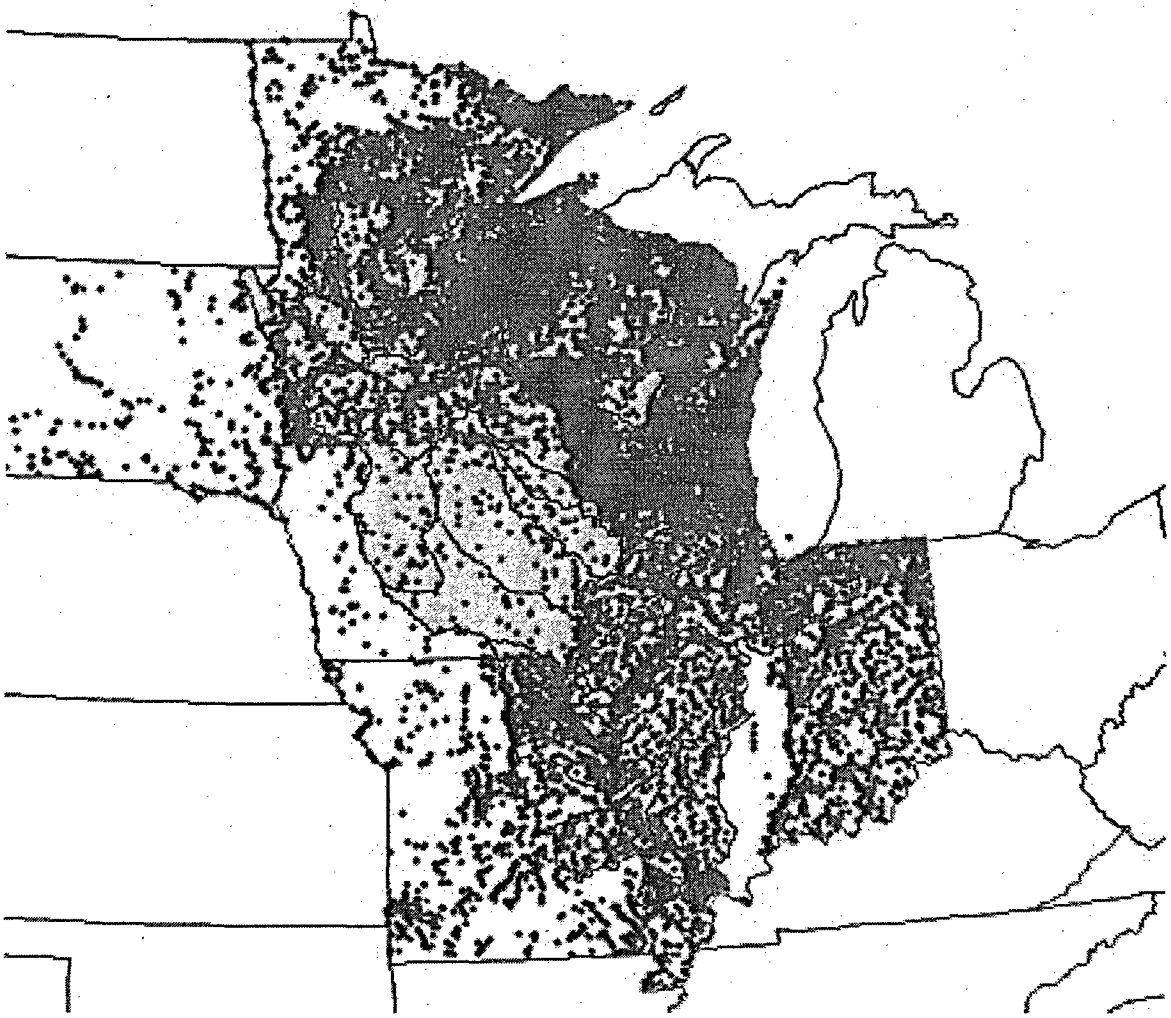

Figure 11. Locations of fish survey information in the UMRB Freshwater Biological Database. Green polygons represent EDUs in the UMRB.

9. Assessment of Fish Communities across Aquatic Systems of the Northern Glaciated Zone

9.1. Introduction and Objective

As coarse-filter targets for conservation, aquatic ecological systems must serve to capture elements of biological diversity at finer levels of organization, including communities and species which are common and representative of a region. Rarely do we have the opportunity to describe the full range of biological diversity captured by individual aquatic ecological system types or assess the degree to which they are successful in capturing all subsequent elements of biodiversity. Most frequently, aquatic systems are defined primarily in terms of physical factors, and we are left to infer the types and distribution of biological elements occurring within them based on experimental knowledge of species habitat preferences and distribution patterns.

This study presented a rare opportunity to better describe the biological elements associated with aquatic system types. The fish fauna of the northern glaciated portion of the UMRB has been examined extensively. The availability of high quality fish community data from hundreds of locations, and the relative diversity of stream habitats in this zone, makes this an ideal place for more detailed biological descriptions of aquatic system types of the UMRB (Figure 12).

Our objective to identify groups of fish species ("assemblage types") occurring within the northern glaciated portion of the UMRB and describe the distribution of these groups within the aquatic systems that occur there. Furthermore, we sought to describe the strength of the association between fish assemblage types and system types.

9.2. Methods

9.2.1. Study Area

The northern glaciated portion of the UMRB includes five ecological drainage units: the Upper Mississippi Headwaters, Mississippi Outwash Plains, St. Croix River, Chippewa-Black Rivers and Wisconsin River EDUs (Figure 12). The primary land cover is forest, and streams are generally low-gradient and underlain by glacial deposits ranging from coarse to fine in texture. Streams are also characterized by mixed chemistry, including calcareous and non-calcareous. Fishes ranged from coldwater to warmwater species and from lake-dwellers to stream and riverine forms. Sixty system types were identified for the region. Systems ranged from low-gradient headwater-creeks to low-gradient large rivers. For a description of all of the system types that occur in the study area, see Appendix 7A.

9.2.2. Data Selection and Acquisition

Fish community survey data from the northern glaciated zone of the UMRB were sought from local sources, including academic institutions and federal, state and local governmental agencies (Table 11). Data were required to have been collected since 1979 and include community survey information (i.e., the incidence or abundance of *all* fish species at a survey site, to the extent practicable through standard survey methods). Our search resulted in six datasets appropriate for this analysis (Table 13).

9.2.3. Data Preparation

To avoid the use of assemblage data from locations with high anthropogenic impacts or insufficient sampling, all sites containing fewer than four species or draining catchments with less than 20 percent natural cover were omitted. To narrow the analysis to native communities only, all non-native and hybrid species occurrence records were deleted. All records of fishes not identified to the species level were also omitted.

9.2.4. Analysis Methods

Two hierarchical agglomerative cluster analyses were conducted to identify fish assemblages from the presence/absence information provided by site survey data. Both cluster analyses used PCOrd 4.17 (McCune and Mefford 2002) with the Sorenson/Bray-Curtis distance measure and Ward's linkage method (McCune and Grace 2002). The first cluster analysis included only common species; rare species (taxa occurring at fewer than 5% of survey sites) were eliminated from the dataset to prevent them from unduly weighting the analysis. The second analysis was conducted using the full complement of species found in the basin. Results of the two analyses were compared for consistency. Species groups were considered valid fish assemblage types if member species had similar instream habitat requirements (Page and Burr 1991; Becker 1983; Lyons 1989, 1996; Niemela and Fiest 2000, 2002), if they occupied similar waterbody types (i.e., large river vs. headwater creek vs. lake), or if the assemblage type seemed to be limited to a particular area in the northern glaciated zone.

We also assessed the validity of the cluster groupings using non-metric multidimensional scaling (NMDS). This analysis allowed us to visually inspect ordinations of fish species (labeled with cluster group membership) to determine their relative proximity to species within the same group and species in other cluster groups. Greater clustering and isolation of a particular assemblage's species in the ordination diagram was interpreted as stronger assemblage validity.

To assess the distribution of fish assemblage types among EDUs and system types, we calculated the ratio of assemblage sites (defined as a location with at least 49% of assemblage-type species) occurring within each classification unit to the number of assemblage sites across the whole study area. The degree of assemblage fidelity and constancy for specific classification units was also determined (Boesch 1977). Constancy was calculated by summing the number of sites in which each assemblage occurred for each classification unit, and dividing by the total number of sites in that unit. Fidelity of an assemblage for a classification unit was the ratio of its constancy for that classification unit to its constancy for all sites. Finally, we mapped the locations of sites where species of each assemblage type were found, and visually inspected these figures to identify assemblage associations with particular system types, system sizes and EDUs.

9.3. Results

9.3.1. Fish Assemblages

Our initial database of sites and species included 10,931 survey locations and 253 taxa (including hybrids and non-native species). After eliminating potentially disturbed sites and non-native and hybrid species occurrences, the final dataset included 2207 sites (Figure 12) and 111 species, of which 65 were considered rare (taxa occurred at fewer than 5% of survey sites).

Cluster analysis resulted in 10 fish assemblage groups in the reduced (common species) dataset, and 16 groups in the full-species dataset (Table 14). Finer cluster groupings (i.e., more groups with fewer taxa) could not be explained by patterns in species ecological requirements. Larger groupings resulted in clusters with little ecological affinity; they appeared to be formed mostly on the basis of rarity and very broad trends in fish assemblage structure. Cluster analyses of the reduced and full-species datasets showed considerable similarity in group structure and composition; common species in the full dataset were broken into groups that were very close to group divisions in the reduced dataset (Appendix 11 Table 3). Because of the close similarity, we chose to focus on the cluster groups derived from the full dataset, in order to include rare species in our assemblage groups.

Of the 16 groups in the full-species dataset, 13 cluster groups were considered valid fish assemblage types (Appendix 11 Table 3), because species habitat requirements of component species were similar within each group. Three groups were determined to be invalid groups (groups 1, 69 and 85), because they consisted only of rare species with dissimilar habitat requirements. Our assessment of the structure, ecological affinity and validity of the groups was based on published reports of fish habitat requirements, NMDS of fishes in the study area, and figures of the occurrences of each assemblage type (Appendix 12 Figures 1-13). A summary of these assessments is provided in the final three columns of Table 14. Also provided in the table (in the column entitled "confidence of cluster") is a rating of the degree to which we felt confident that the assemblage type was valid, based on the previous assessment.

NMDS analysis provided moderate support for the fish group structure identified in the cluster analysis. In particular, the NMDS of common species distinguished the 10 cluster units identified in the cluster analysis (Figure 13). In the ordination diagram, species of the same assemblage type were generally tightly clustered, although multiple assemblage groups overlapped slightly.

9.3.2. Relating Fish Assemblages to Aquatic Systems

The strength or weakness of assemblage type association with each classification unit is assessed using the distribution (Appendix 11 Table 1), constancy (Appendix 11 Table 2), and fidelity (Appendix 11 Table 3) scores. High values in each of these tables are an indication that the assemblage is closely tied to a specific unit type. Assemblage groups were distributed unevenly among the classification units: system types, EDUs and system size classes (Appendix 11 Table 1). Units contained a range of 0 to 100 percent of all assemblage type occurrences (defined as the presence of 50 percent or more of the assemblage type species at a given location). Several groups showed close affiliation with specific EDUs (e.g., Assemblage M; Appendix 12 Figure 12), and other groups were closely aligned with specific systems and system size classes (e.g., Assemblages B and C; Appendix 11 Table 1; Appendix 12: Figures 2 and 3). One group was strongly associated with a wide range of system types and EDUs (Assemblage G; Appendix 12 Figure 8; Appendix 11 Table 1) while another demonstrated little association with any system type, EDU, or system size class (e.g., Assemblage I; Appendix Figure 9; Appendix 11 Table 1).

Constancy scores ranged from 0 to 0.50 and fidelity scores ranged from 0 to 61 (Appendix 11 Tables 2 and 3). Again, assemblages showed varying levels of constancy and fidelity for specific system types, EDUs and size classes, demonstrating considerable variation in the spatial patterns of the biological communities inhabiting each of the classification units.

9.4. Discussion

Characterizing aquatic system types using biological community information poses multiple challenges. Primary among these is the selection of the appropriate grain of ecological information with which to characterize the systems. To be effective, the biologic community characteristic must be ecologically meaningful, relatively easy to measure across broad spatial scales, and representative of a larger range of ecologic features. They must also must strike a balance between providing sufficient information to distinguish system types, and limiting that information appropriately to offer broad generalities.

In this assessment, we chose to describe the biological nature of aquatic system types by quantifying the distribution, constancy and fidelity of fish assemblage types (defined by a cluster analysis of basin taxa) among these systems. Fish assemblages provide sufficient biological information to characterize a system, are indicative of functional and trophic processes within a system, and are thought to be sensitive to changes in habitat structure at the system scale (Poff and Allan 1994). Furthermore, component taxa are widely understood and familiar to many scientists and conservation practitioners. The primary concern we had with this approach was that the presence and absence of particular assemblage types would not vary sufficiently among similar systems to demonstrate the ecological distinctions represented by the systems.

9.4.1. Clustering of Fish Assemblages

We arrived at 13 fish assemblage types, which utilize a broad diversity of freshwater habitats across the range of the northern glaciated zone. Fish assemblage types generally appear to be accurate representations of fish community structure throughout the study area, but our confidence in the validity of this analysis is mediated by several factors.

First, species within Assemblages E and I appear to be very weakly associated by ecological characteristics and may not be considered valid assemblage types. We are also concerned about the validity of groups that appear to have considerable ecological overlap with other assemblage types, and may, in fact represent nested fish groups rather than distinct assemblage types. For example, assemblages C and J are very closely affiliated riverine fish communities. Group C appears to consist of more common species, while J is generally comprised of more rare and sensitive taxa. These assemblages may have overlapping distributions, with the latter group species simply co-occurring with assemblage C species where habitats are less disturbed. Rather than draw a distinction between these groups based on their relative rarity in rivers, it may be more appropriate to combine them into one assemblage type. Potentially nested assemblages and groups with questionable ecological association require more investigation, and may need to be reclassified.

Also problematic is the fact that a few species appear to be misclassified. In particular, the central stoneroller, which is classified in Assemblage E, is not a species of lakes, ponds and backwaters, but rather one of rocky riffles and runs in streams. In addition, the southern brook lamprey appears to be misclassified in Assemblage I, a large-river taxa group. These errors may be due to misidentifications in one or more of the datasets (Wang et al. 1997), which were not corrected before this analysis was conducted.

In reviewing the results of this analysis, we realize that our study design may have introduced some error. For example, by eliminating sites with fewer than four species we may have omitted high quality small trout streams. In eliminating sites with less than 20% natural land cover in the catchment area, we may have omitted other high-quality sites and retained highly impaired sites. For example, sites with good riparian buffers may have been excluded and conversely, those with large amounts of urban impacts may have been included. We also did not purposefully eliminate impoundments and other unnatural habitats, which are likely to be represented in the datasets. Finally, we have concerns about the use of multiple datasets for this analysis, and inconsistencies in sample design and effort among these data. Further analysis should be directed at testing whether these problems unduly influence the fish cluster analysis and the resulting assemblage types.

Overall, our confidence in the fish assemblage groups is bolstered by the large sample database, which should provide sufficient coverage to ensure accurate representation of most system types. In addition, there is general concurrence between the cluster analyses and the common-species NMDS, indicating that we have captured broad patterns of assemblage structure.

We purposefully excluded non-native taxa from the analysis in order to characterize system types as they might historically have occurred. We would expect considerable changes in the assemblage groups developed for this analysis had we included all non-native taxa. However, this analysis may benefit from an approach that includes these taxa, because it would allow us to identify assemblage types that have been most reconfigured due to species invasions, as well as system types most characterized by non-native taxa. Finally, the inclusion of non-indigenous species would probably provide a more accurate representation of current assemblage composition related to system types.

9.4.2. Fish Assemblages and Aquatic Systems

Fish assemblages showed varying degrees of specificity to aquatic system types in the UMRB. In a few cases, systems and assemblages show a very tight correspondence. More often, subtle differences in the distribution, fidelity and constancy of multiple assemblage types among different classification units demonstrate the biological differences among system types and provide the information needed to fully characterize the fish community found within a particular system. For example, four of the five northern glaciated EDUs include system types described as "low density, perennial creek systems with low gradient with low to moderate gradient headwaters, in coarse ground moraines with local areas of outwash, peat and muck" (system types: *1* 1A 18, *2* 1A 18, *5* 1A 18 and *7* 1A 18). Each of these systems would seem to be probable locations where Assemblage A species (taxa typical to rocky, riffle habitats) could be found. However, this assemblage type is not distributed evenly across all of these system types, despite their relative similarity in habitats. The distribution, constancy and fidelity scores for Assemblage A in system 7 1A 18 are 0.32, 0.027 and 2.37, respectively (Appendix 11 Tables 1, 2, and 3). In contrast, Assemblage A scores are 0 for distribution, constancy and fidelity in the 1A 18 system types in the other three EDUs. Assemblage A appears to be much more specific to system 7 1A 18 than any other similar system type in the northern glaciated region. Other assemblage types (e.g., Assemblages F and K) appear to favor system 1 1A 18 over other similar systems (e.g., *2* 1A 18, *5* 1A 18 and *7* 1A 18) in the study area, based on Appendix 11 Tables 1, 2, and 3. In summary, the biological distinctiveness of aquatic systems lies in the relative affinities of different fish assemblage types for each system type. This affinity is described in the distribution, constancy and fidelity scores.

Several factors challenge our ability to characterize the relationship between fish assemblages and aquatic system types. First, among Upper Mississippi aquatic systems, the northern glaciated zone contains diverse habitats and a considerable diversity of system types. Despite the relative diversity of habitats, fish assemblages are comparatively depauperate and quite uniform across the region. Many taxa are generalists, and reside in a range of habitat conditions. Because there are a limited number of fish assemblage types (13) and an abundance of different system types (60), there is considerable overlap in fish assemblage composition across multiple system types. Had we clustered fish assemblages into smaller groups, defined them using more detailed information (e.g., relative abundance data) or chosen a different characteristic of the biological community to measure (e.g., the relative abundances of different species), we may have been more successful in documenting a finer level of correspondence between biological elements and aquatic ecological systems. Finally, our analysis demonstrated that fish assemblages may be associated with different spatial units, ranging in scale from EDUs to ecological systems. Although we did not test this possibility, some assemblages may be tied to even finer spatial levels of classification units, such as macrohabitats.

Despite relatively low endemism and taxonomic diversity, fish communities of the northern glaciated portion of the UMRB may be effectively used to describe the biological nature and distinctiveness of aquatic systems of this region. Patterns in fish assemblage distribution offer insight into the suite of biological communities inhabiting the diversity of aquatic system types that occur there. Because fish assemblages vary in their specificity to aquatic system types, factors such as assemblage distribution, fidelity and constancy allow us to draw modest conclusions about the biological characteristics that differentiate system types. Future analyses should evaluate the degree to which aquatic system types and selected conservation areas capture the diversity of fish assemblage types in the region.

Table 13. Data sources for the biological community analysis.

Source Code	Taxon	Title	Source/Contact	Coverage
MN01	Fish	PCA Fish	Scott Niemela — Minnesota Pollution Control Agency	9692 records at 831 stations throughout Minnesota
MN03	Fish	Konrad's Personal Dataset	Konrad Schmidt — Minnesota Department of Natural Resources	33139 records from sites in Mississippi, St. Croix, Minnesota and Des Moines River drainages
UMR01	Fish	LTRMP-Fish	USGS -Upper Midwest Environmental Sciences Center	739197 sampling points in six study reaches in the UMRB
UMR03	Fish	NAWQA-UMR	Bob Goldstein and Kathy Lee — USGS Mounds View, MN	1850 records from Upper Mississippi Drainage in MN and WI
WI01	Fish	Fago Master Fish Database	Don Fago — Wisconsin Department of Natural Resources	1135906 records from 15607 collections in the UMRB
WI03	Fish	Wisconsin Wadeable Streams data	Li Wang, John Lyons - Wisconsin Department of Natural Resources	2985 records from WI; about 250 sites

Table 14. Cluster analysis results and final assemblage groupings in the northern glaciated portion of the UMRB. All fishes included in the analysis are listed. Those identified as common species are listed in italics.

Assemblage Type Letter	Species Code	SCIENTIFIC NAME	Common Name	Group affiliation in common species dataset (10 groups)	Group affiliation in full dataset (16 groups)	Confidence of Cluster	Habitat	Geographic Distribution	Waterbody type
Assemblage A	LSS	CAMPOSTOMA OLIGOLEPIS	LARGESCALE STONEROLLER		2	high	rocky riffle	concentrated in central reaches of Wisconsin and Chippewa-Black Basins	streams and small rivers
	RAD	ETHEOSTOMA CAERULEUM	RAINBOW DARTER		2				
	FAD	ETHEOSTOMA FLABELLARE	FANTAIL DARTER		2				
	BAD	ETHEOSTOMA ZONALE	BANDED DARTER		2				
	NBL	ICHTHYOMYZON FOSSOR	NORTHERN BROOK LAMPREY		2				
	ROS	NOTROPIS RUBELLUS	ROSYFACE SHINER		2				
Assemblage B	LED	ETHEOSTOMA MICROPERCA	LEAST DARTER		3	high	shallow, quiet margins of vegetated lakes, ponds and and streams; pools and slow runs in streams; usually over sand or mud	lake-dominated systems (headwaters of most EDUs, particularly Wisconsin and Upper Mississippi EDUs)	lakes and low gradient streams
	BAK	FUNDULUS DIAPHANUS	BANDED KILLIFISH		3				
	LES	LEPOMIS MEGALOTIS	LONGEAR SUNFISH		3				
	PUS	NOTROPIS ANOGENUS	PUGNOSE SHINER		3				
	BCS	*NOTROPIS HETERODON*	*BLACKCHIN SHINER*	1	3				
	BNS	*NOTROPIS HETEROLEPIS*	*BLACKNOSE SHINER*	1	3				
Assemblage C	GIS	DOROSOMA CEPEDIANUM	GIZZARD SHAD		5	high	main channels, pools, backwaters; over sand, silt or gravel	major mainstems of all EDUs	medium to big rivers
	GOE	HIODON ALOSOIDES	GOLDEYE		5				
	SIC	MACRHYBOPSIS STORERIANA	SILVER CHUB		5				
	WHB	MORONE CHRYSOPS	WHITE BASS		5				
	BUM	PIMEPHALES VIGILAX	BULLHEAD MINNOW		5				
	FHC	PYLODICTIS OLIVARIS	FLATHEAD CATFISH		5				
	SAR	STIZOSTEDION CANADENSE	SAUGER		5				
	BIB	*ICTIOBUS CYPRINELLUS*	*BIGMOUTH BUFFALO*	2	5				
	NOP	*ESOX LUCIUS*	*NORTHERN PIKE*	3	6	high	clear, cool-water streams associated with lake habitat or rivers with slow-moving backwater habitats; vegetated areas;	widespread across all EDUs	streams and rivers
	PUD	*LEPOMIS GIBBOSUS*	*PUMPKINSEED*	3	6				
	BLL	*LEPOMIS MACROCHIRUS*	*BLUEGILL*	3	6				
	LAB	*MICROPTERUS SALMOIDES*	*LARGEMOUTH BASS*	3	6				
	YEP	*PERCA FLAVESCENS*	*YELLOW PERCH*	3	6				
	BKC	*POMOXIS NIGROMACULATUS*	*BLACK CRAPPIE*	3	6				

Assemblage Type Letter	Species Code	SCIENTIFIC NAME	Common Name	Group affiliation in common species dataset (10 groups)	Group affiliation in full dataset (16 groups)	Confidence of Cluster	Habitat	Geographic Distribution	Waterbody type
	ROB	*AMBLOPLITES RUPESTRIS*	*ROCK BASS*	28	6				
	MUE	*ESOX MASQUINONGY*	*MUSKELLUNGE*	28	6				
	SMB	*MICROPTERUS DOLOMIEU*	*SMALLMOUTH BASS*	28	6				
	WAE	*STIZOSTEDION VITREUM*	*WALLEYE*	28	6				
Assemblage E	BON	AMIA CALVA	BOWFIN		7	medium -low	lakes, ponds, pools and backwaters	concentrated in St. Croix and Mississippi headwaters and Mississippi outwash EDUs	
	CES	CAMPOSTOMA ANOMALUM	CENTRAL STONEROLLER		7				
	ORS	LEPOMIS HUMILIS	ORANGESPOTTED SUNFISH		7				
	BMS	NOTROPIS DORSALIS	BIGMOUTH SHINER		7				
	TRH	PERCOPSIS OMISCOMAYCUS	TROUT-PERCH		7				
	BKS	*LABIDESTHES SICCULUS*	*BROOK SILVERSIDE*	4	7				
	SOS	*NOTROPIS HUDSONIUS*	*SPOTTAIL SHINER*	4	7				
Assemblage F	BLB	*AMEIURUS MELAS*	*BLACK BULLHEAD*	5	8	high	slow water (pools, backwaters and sluggish areas); soft substrates	pretty widespread in western portions of Northern Glaciated zones	creeks, streams, rivers, ponds and impoundments
	YBH	*AMEIURUS NATALIS*	*YELLOW BULLHEAD*	5	8				
	BRB	*AMEIURUS NEBULOSUS*	*BROWN BULLHEAD*	5	8				
	IOD	*ETHEOSTOMA EXILE*	*IOWA DARTER*	5	8				
	GRS	*LEPOMIS CYANELLUS*	*GREEN SUNFISH*	5	8				
	GOS	*NOTEMIGONUS CRYSOLEUCAS*	*GOLDEN SHINER*	5	8				
	TAM	*NOTURUS GYRINUS*	*TADPOLE MADTOM*	5	8				
Assemblage G	WHS	*CATOSTOMUS COMMERSONI*	*WHITE SUCKER*	6	9	high			streams and lakes
	JOD	*ETHEOSTOMA NIGRUM*	*JOHNNY DARTER*	6	9				
	COS	*LUXILUS CORNUTUS*	*COMMON SHINER*	6	9				
	BLD	*RHINICHTHYS ATRATULUS*	*BLACKNOSE DACE*	6	9				
	CRC	*SEMOTILUS ATROMACULATUS*	*CREEK CHUB*	6	9				
	CEM	*UMBRA LIMI*	*CENTRAL MUDMINNOW*	6	9				
	GRR	MOXOSTOMA VALENCIENNESI	GREATER REDHORSE		11	medium -high	clear, rocky runs		small-medium rivers
	SPS	*CYPRINELLA SPILOPTERA*	*SPOTFIN SHINER*	8	11				
	MIS	*NOTROPIS VOLUCELLUS*	*MIMIC SHINER*	8	11				
	BLM	*PIMEPHALES NOTATUS*	*BLUNTNOSE MINNOW*	8	11				
	NHS	*HYPENTELIUM NIGRICANS*	*NORTHERN HOG SUCKER*	11	11				

Assemblage Type Letter	Species Code	SCIENTIFIC NAME	Common Name	Group affiliation in common species dataset (10 groups)	Group affiliation in full dataset (15 groups)	Confidence of Cluster	Habitat	Geographic Distribution	Waterbody type
	BUT	*LOTA LOTA*	*BURBOT*	11	11				
	SIR	*MOXOSTOMA ANISURUM*	*SILVER REDHORSE*	11	11				
	GOR	*MOXOSTOMA ERYTHRURUM*	*GOLDEN REDHORSE*	11	11				
	SHR	*MOXOSTOMA MACROLEPIDOTUM*	*SHORTHEAD REDHORSE*	11	11				
	HOC	*NOCOMIS BIGUTTATUS*	*HORNYHEAD CHUB*	11	11				
	LOH	*PERCINA CAPRODES*	*LOGPERCH*	11	11				
	BSD	*PERCINA MACULATA*	*BLACKSIDE DARTER*	11	11				
	LOD	*RHINICHTHYS CATARACTAE*	*LONGNOSE DACE*	11	11				
	STT	NOTURUS FLAVUS	STONECAT		11				
	GID	PERCINA EVIDES	GILT DARTER		11				
	SHD	PERCINA PHOXOCEPHALA	SLENDERHEAD DARTER		11				
	CHL	*ICHTHYOMYZON CASTANEUS*	*CHESTNUT LAMPREY*	11	11				
Assemblage I	MUD	ETHEOSTOMA ASPRIGENE	MUD DARTER		12	medium-low		mostly confined to St. Croix, Chippewa and Wisconsin EDUs	large rivers
	WAH	LEPOMIS GULOSUS	WARMOUTH		12				
	BLR	MOXOSTOMA DUQUESNEI	BLACK REDHORSE		12				
	WES	NOTROPIS TEXANUS	WEED SHINER		12				
	PAH	POLYODON SPATHULA	PADDLEFISH		12				
	WHC	POMOXIS ANNULARIS	WHITE CRAPPIE		12				
	LAS	ACIPENSER FULVESCENS	LAKE STURGEON		12				
	SBL	ICHTHYOMYZON GAGEI	SOUTHERN BROOK LAMPREY		12				
	SIL	ICHTHYOMYZON UNICUSPIS	SILVER LAMPREY		12				
	WSD	AMMOCRYPTA CLARA	WESTERN SAND DARTER		13	high		Mississippi and lower reaches of the largest tributaries	large rivers
	RIC	CARPIODES CARPIO	RIVER CARPSUCKER		13				
	HIC	CARPIODES VELIFER	HIGHFIN CARPSUCKER		13				
	BLS	CYCLEPTUS ELONGATUS	BLUE SUCKER		13				
	MOE	HIODON TERGISUS	MOONEYE		13				
	SAB	ICTIOBUS BUBALUS	SMALLMOUTH BUFFALO		13				
	LOG	LEPISOSTEUS OSSEUS	LONGNOSE GAR		13				
	RRS	NOTROPIS BLENNIUS	RIVER SHINER		13				

Assemblage Type Letter	Species Code	SCIENTIFIC NAME	Common Name	Group affiliation in common species dataset (10 groups)	Group affiliation in full dataset (18 groups)	Confidence of Cluster	Habitat	Geographic Distribution	Waterbody type
	CRD	CRYSTALLARIA ASPRELLA	CRYSTAL DARTER		13				
	SHS	SCAPHIRHYNCHUS PLATORYNCHUS	SHOVELNOSE STURGEON		13				
	RID	PERCINA SHUMARDI	RIVER DARTER		13				
Assemblage K	FID	PHOXINUS NEOGAEUS	FINESCALE DACE		18	high	small streams; beaver ponds, small lakes		
	BRS	*CULAEA INCONSTANS*	*BROOK STICKLEBACK*	10	18				
	BSM	*HYBOGNATHUS HANKINSONI*	*BRASSY MINNOW*	10	18				
	PED	*MARGARISCUS MARGARITA*	*PEARL DACE*	10	18				
	NRD	*PHOXINUS EOS*	*NORTHERN REDBELLY DACE*	10	18				
	FAM	*PIMEPHALES PROMELAS*	*FATHEAD MINNOW*	10	18				
Assemblage L	FWD	APLODINOTUS GRUNNIENS	FRESHWATER DRUM		26	high		occur in mainstem of Mississippi outwash and lower reaches of Chippewa, Black and WI rivers;	Uncommon or occasional in large rivers and small streams and creeks;
	QUB	CARPIODES CYPRINUS	QUILLBACK		26				
	CHC	ICTALURUS PUNCTATUS	CHANNEL CATFISH		26				
	RIR	MOXOSTOMA CARINATUM	RIVER REDHORSE		26				
	EMS	NOTROPIS ATHERINOIDES	EMERALD SHINER		26				
	SAS	NOTROPIS LUDIBUNDUS	SAND SHINER		26				
Assemblage M	SLS	COTTUS COGNATUS	SLIMY SCULPIN		19	medium-high	cool, coldwater assemblage		
	BRT	SALVELINUS FONTINALIS	BROOK TROUT		19				
	RED	CLINOSTOMUS ELONGATUS	REDSIDE DACE		19				
	SRD	PHOXINUS ERYTHROGASTER	SOUTHERN REDBELLY DACE		19				
not valid	PIP	APHREDODERUS SAYANUS	PIRATE PERCH		1	low	fishes inhabiting moderate-gradient streams flowing into large rivers (Wisconsin)		
	ABL	LAMPETRA APPENDIX	AMERICAN BROOK LAMPREY		1				
	RGP	ESOX AMERICANUS	REDFIN OR GRASS PICKEREL		1				
	YEB	MORONE MISSISSIPPIENSIS	YELLOW BASS		1				
not valid	SDS	MINYTREMA MELANOPS	SPOTTED SUCKER		69	low	rare		
	PUM	OPSOPOEODUS EMILIAE	PUGNOSE MINNOW		69				
Not valid	SHG	LEPISOSTEUS PLATOSTOMUS	SHORTNOSE GAR		85	low	rare		
	SDC	MACRHYBOPSIS AESTIVALIS	SPECKLED CHUB		85				

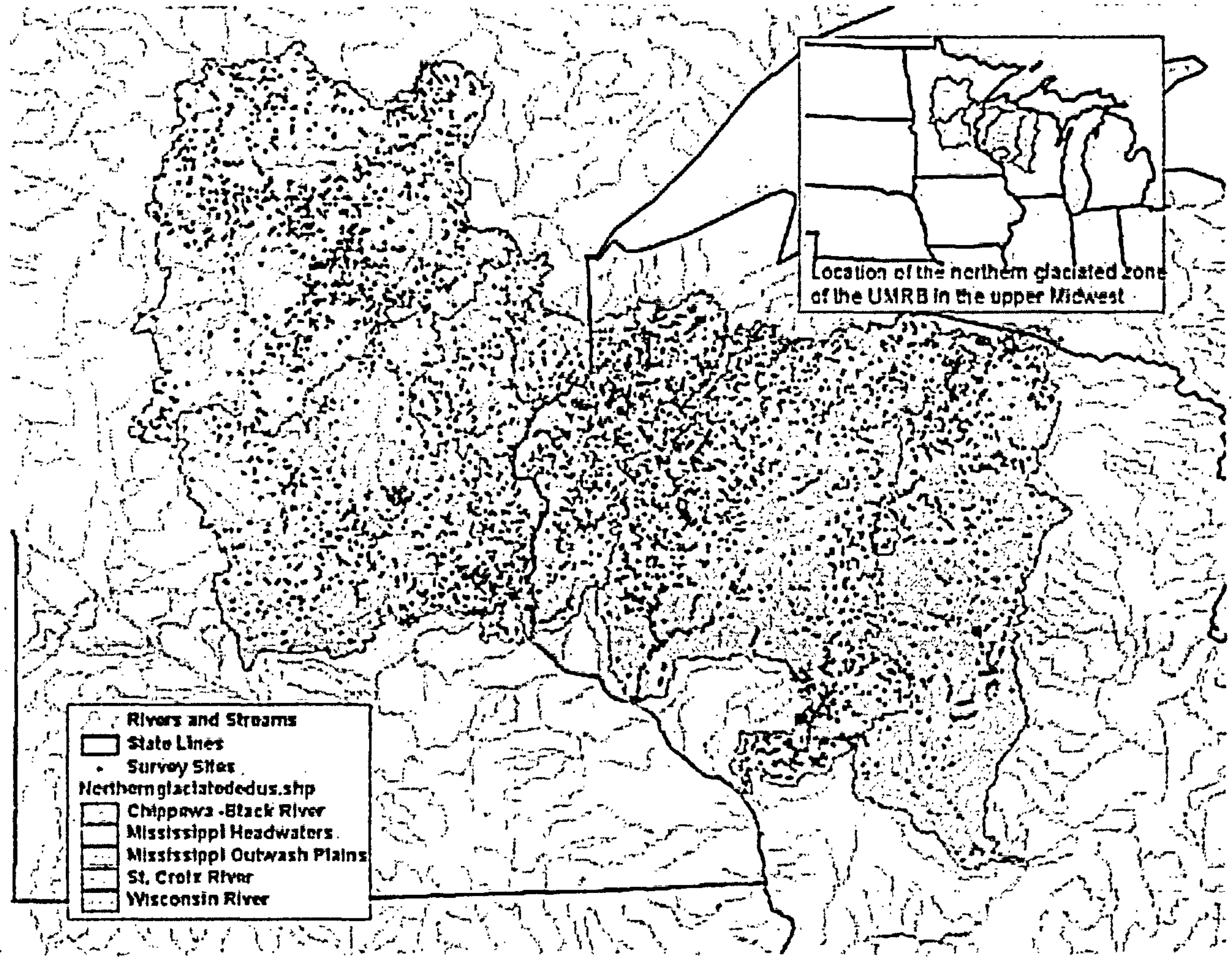

Figure 12. Northern Glaciated portion of the UMRB with locations of all survey data included in this study (red dots).

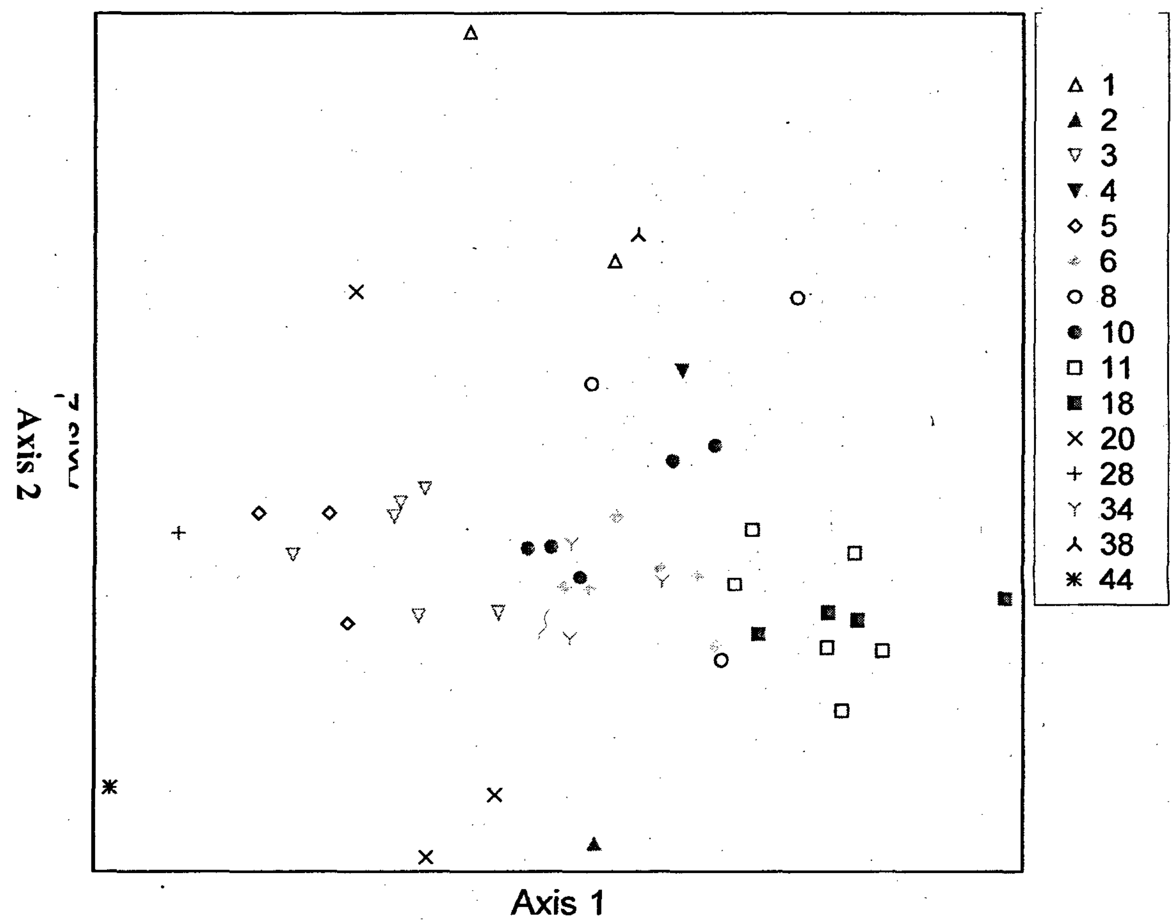

Figure 13. Non-metric multidimensional scaling ordination of common species in the northern glaciated zone of the UMRB. Cluster group numbers correspond to group numbers in Table 14, column 5, entitled "Group affiliation in common species dataset."

10. Future Needs and Information Gaps

Future Needs and Information Gaps

The information gathered, analyzed, and generated for this project has significantly advanced our understanding of the Upper Mississippi River ecosystem, yet there are several issues relating to freshwater biodiversity yet to be adequately addressed. Some revolve around the physical aspects of aquatic ecosystems, such as methods to adequately model stream temperatures or map surficial geology across larger geographic areas (both discussed in the section on defining conservation targets), but the majority center on the biological and ecological aspects of these ecosystems. Further consultation with regional experts may be sufficient to address several of these needs, but many can only be addressed through the concerted efforts of resource professionals across the basin, and beyond.

Major informational needs for the UMRB, and aquatic ecosystems as a whole, include:

Species inventory:
There is a strong need for further sampling and taxonomic work in many aquatic groups, especially for the lesser-studied groups of invertebrates. Existing datasets are not consistent in their level of taxonomic resolution, with the lack of taxonomic experts and published keys for the more obscure groups serving as the limiting factors. Given the spotty and incomplete knowledge of the distributions of many freshwater invertebrates, it is impossible to know whether populations are declining or endangered, and to precisely identify the major threats to their existence.

Electronic data development:
A concerted effort is needed to computerize historic datasets. There exists a wealth of distributional information for many aquatic groups, inaccessible to researchers because it is hidden in private files, obscure papers, or sometimes only in the brains of researchers. The addition of this information to computerized databases would add to our knowledge of past distributions of aquatic taxa, and help to identify long-term trends in population numbers, providing historical context to discussions of the current status of species.

Ecological Research:
A better understanding of the life-histories, habitat needs, and community relationships for many aquatic taxa is necessary to account for the effects of environmental change, and to develop more refined and defensible conservation goals (the number and distribution of occurrences) for target species. This information is also critical to rank the viability of species occurrences. Currently, very few species occurrences have viability information.

Thresholds of Biological Response:
Specific thresholds of biological response to various landscape-scale alterations are not known, yet are essential in creating more meaningful measures of ecosystem integrity.

In future aquatic conservation assessments, every effort should be made to include the full array of aquatic ecosystem types, including rivers, lakes, wetlands, and subterranean habitats. These habitat types are interconnected, hydrologically and ecologically, with many species relying on two or more of these distinct habitats to complete their life-history. Alternatively, numerous species are restricted to a single habitat type, and the failure to include all types therefore paints an incomplete picture of the aquatic diversity in an area. Unfortunately, adequate and comparable classification methodologies for each habitat type have not been developed.

Lakes

Lake ecosystems dominate large areas of the upper Midwest, USA, and southern Ontario, Canada. Despite decades of monitoring and research, our knowledge of the biodiversity of these systems is cursory, as most data comes from the management of lakes for recreational and commercial fisheries. While this reports provides information on the distribution of lake types across the landscape, it is mainly focused on the riverine aquatic systems. Our intention was to address lakes in greater detail, but we found it was beyond the scope of this document to develop a robust classification and assessment of current lake conditions. However, the need for such work is great and it would create a more complete picture of freshwater biodiversity in the UMRB.

Minnesota and Wisconsin have the largest concentrations of inland lakes, with more than 22,000 located within the bounds of the UMRB (Figure 27). These glacial lakes are among the most endangered of aquatic systems, currently threatened with a multitude of anthropogenic disturbances. Drainage of shallow lakes and wetlands for agriculture has altered local and regional surface and groundwater flows, while the widespread conversion of land for lakeshore properties has led to the wholesale destruction of riparian, emergent, and submergent plant communities. Subsequent nutrification and other pollution from lawn fertilizers and septic systems, increased runoff from impervious surfaces, and the widespread introduction of exotic species are having serious negative effects on the structure and function of these ecosystems.

An accurate assessment of lake types and their associated physical and biological components, will allow us to monitor how human manipulations are affecting the biodiversity of lake ecosystems. We recommend that a systematic methodology for classifying inland lake ecosystems be developed and applied. The products of this work would provide:

- a complete description of lake ecosystem types, based on physical, chemical, and biological variables.
- insight into the variables limiting the distribution of aquatic plants and animals.
- detailed reference conditions on ecosystem integrity with which to monitor future changes.
- the basis for predictive distribution models for aquatic organisms.
- critical information for the design of sampling regimes that would appropriately characterize lake community assemblages and physical habitat attributes.

- a flexible framework that could be adapted and applied to other regions of the U.S. and Canada.

Caves

The UMRB also contains a number of subterranean aquatic ecosystems, with the highest density occurring in the karst areas of southern basin, along the border between Missouri and Illinois (Figure 28). The caves and springs of this region are inhabited by a highly specialized, and very diverse biota, including many species of snails, fishes, salamanders, crustaceans, and many other obscure invertebrate groups. Relative to our knowledge of the surface fauna, we know little about the full diversity and distribution of cave species and communities in the basin, due in large part to a lack of accessibility of underground habitats. Where data on the distribution of cave species does exist, it is often very hard to obtain due to concerns over the possible exploitation of the caves and their biota by rogue cavers and collectors.

Subterranean aquatic systems and their faunas are relatively fragile and highly susceptible to perturbation. High degrees of endemism, limited distributions, small populations sizes, and highly specialized morphological, physiological, and ecological adaptations all contribute to the highly sensitive nature of cave biota (Walsh 2000). Ongoing threats to subterranean biodiversity stem from a variety of incompatible human activities, including habitat destruction and the alteration of hydrologic regimes from mining and urbanization, environmental pollution from agricultural and industrial runoff, and the introduction of exotic or pest species and their associated pathogens (Elliot 1998).

Karst systems are generally linked to both local and regional groundwater systems, and are not confined by surficial drainage boundaries, thus, groundwater species may be affected by disturbance events over long distances. In fact, a single, catastrophic event has the potential of eliminating entire species or communities. Given the vulnerability of cave systems, and our inadequate knowledge of the distribution and life history requirements of much of the fauna, urgent attention is warranted. More baseline faunal and ecological surveys are clearly needed, as well as a more clear understanding of the connectivity of surficial and subterranean systems in the region.

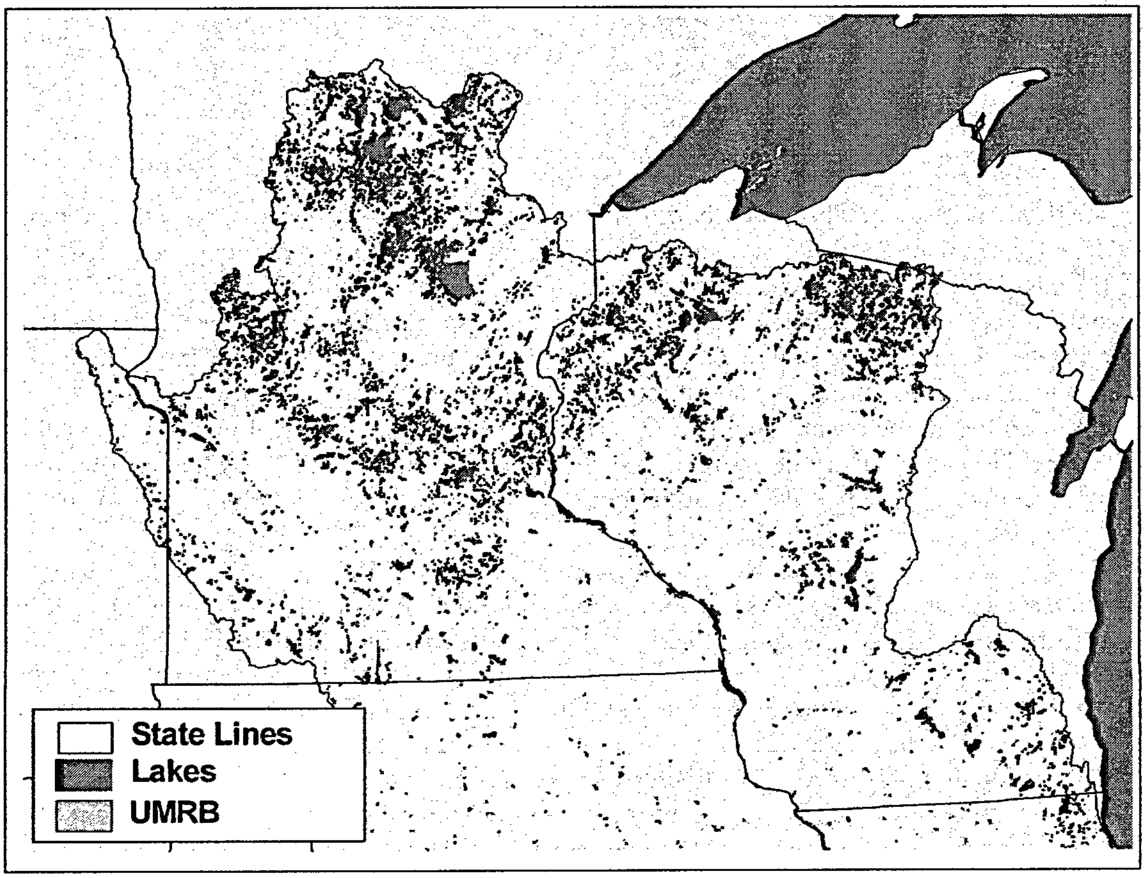

Figure 14. Distribution of lakes in the northern UMRB. (Inland lakes outside the basin were omitted for clarity.)

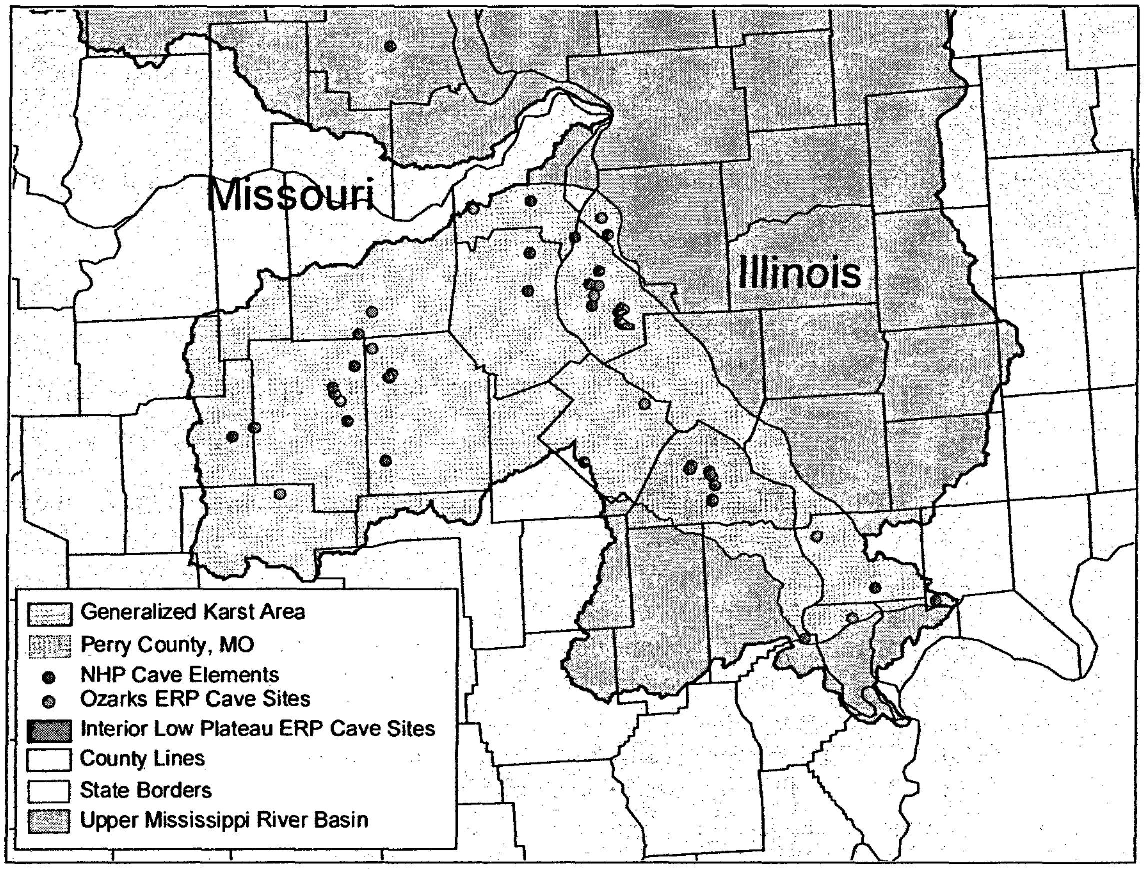

Figure 15. Priority karst region of the southern UMRB.

11. How to use the information in this report.

This report includes all of the underlying data sets used in the analysis of Areas of Biodiversity Significance and Priority Areas. There are several tables included in the appendix as well as databases available only with electronic versions of this report.

The following data sets are included as tables in the main text of the report or in the appendices:

- Species information:
  APPENDIX 2: Species Lists for the UMRB.
  Table A: Fish, Table B: Mussels, Table C: Crayfish
  APPENDIX 4: List of non-indigenous aquatic animals and plants in the UMRB.
  APPENDIX 5: Species conservation targets.
- Community information:
  Table 14. Cluster analysis results and final assemblage groupings in the northern glaciated portion of the UMRB.
- Aquatic Ecological System information:
  APPENDIX 6: Descriptions of the EDUs.
  APPENDIX 7: Aquatic systems descriptions. A: stream systems, B: lake systems.
  APPENDIX 8: Standardization of surficial geology
- Priority areas information
  APPENDIX 10: Areas of biodiversity significance attributes
  APPENDIX 11: Priority Areas maps and reports.
- Expert recommended site information:
  APPENDIX 9: Expert recommended streams and lakes
  APPENDIX 11: Priority areas maps and reports.

The CD also contains several electronic files that are separate from the report. These include the following:

- UMRB fishes and mussels database
  This database is described in detail in Section 8 of the report. It is in Microsoft Access 2000. The fields are listed and described in Table 12.
- Conservation Planning Tool (public version: species location information is not included). This database is in the standard format created by The Nature Conservancy to manage ecoregional and basin planning data. This relational database is in MS Access 2000. Each field is defined in the table definitions. There are standard tables and user defined tables that include attributes not standard across The Nature Conservancy. The following types of tables are included:
  - Conservation Targets descriptions (species and ecological systems)
  - Conservation Target occurrences (species and ecological systems)
  - Additional attributes of system occurrences
  - Expert site information
  - Expert contact information
  - Priority areas

The tables are cross-referenced so that, for example, species can be linked to systems or Priority Areas, or aquatic systems can be linked to the Priority Areas.

- Spatial data: The following files are also included on the CD. Shapefiles are in the following projection:

  Albers
  NAD 1927
  Units: meters
  Parameters:
  Central Meridian: -96
  Central Latitude: 23
  1st parallel: 29.5
  2nd parallel: 45.5
  False Easting: 0
  False Northing: 0

  - Shapefiles for each size class of aquatic ecological systems
  - (Note: attributes for these shapefiles can be exported from the conservation planning tool.)
  - Geologic layer for the UMRB
  - Stream Hydrography with sequenced arcs (ReachFile3 — 1:100,000)
  - Ecological Drainage Units
  - Aquatic Zoogeographic Units
  - Priority Area polygons

For further information regarding these data, contact Mary Lammert Khoury, The Nature Conservancy, mkhoury@tnc.org, (312) 759-8017.

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FWS 2005

U.S. Fish & Wildlife Service — Great Lakes - Big Rivers

Endangered Species

Region 3

Minnesota's Federally-Listed
Threatened, Endangered, Proposed, and Candidate Species' County Distribution
PDF Version

For more information about threatened and endangered species in Minnesota,
contact the U.S. Fish & Wildlife Service office at
4101 E. 80th Street, Bloomington, Minnesota 55425-1665 (612-725-3548)

Species' common names are linked to fact sheets

Species	Status	County	Habitat
Mammals			
Canada lynx *(Lynx canadensis)*	Threatened	Aitkin, Beltrami, Carlton, Cass, Clearwater, Cook, Itasca, Koochiching, Lake, Lake of The Woods, Marshall, Pine, Roseau, St. Louis	Northern forested areas
Gray wolf *(Canis lupus)*	Threatened	Aitkin, Beltrami, Becker, Benton, Carlton, Cass, Chisago, Clearwater, Cook, Crow Wing, Hubbard, Isanti, Itasca, Kanabec, Kittson, Koochiching, Lake, Lake of the Woods,	Northern forested areas

		Mahnomen, Marshall, Mille Lacs, Morrison, Pennington, Pine, Polk, Red Lake, Roseau, St. Louis, Sherburne, Todd, Ottertail, Wadena	
Gray wolf *(Canis lupus)*	Critical Habitat	Areas of land, water, and airspace in Beltrami, Cook, Itasca, Koochiching, Lake, Lake of the Woods, Roseau, and St. Louis Counties with boundaries (4th and 5th Principal meridians) identical to those of zones 1, 2, and 3, as delineated in 50 CFR 17.40 (d)(1)." Contact FWS at (612)725-3548 for further information.	
Birds			
Bald eagle *(Haliaeetus leucocephalus)*	Threatened	Aitkin, Anoka, Becker, Beltrami, Benton, Big Stone, Blue Earth, Brown, Carlton, Carver, Cass, Chippewa, Chisago, Clearwater, Cook, Crow Wing, Dakota, Douglas, Fillmore, Goodhue, Grant, Hennepin, Houston, Hubbard, Isanti, Itasca, Kanabec, Kandiyohi, Kittson, Koochiching, Lac Qui Parle, Lake, Lake of The Woods, Le Sueur, Mahnomen, Marshall, McLeod, Meeker, Mille Lacs, Morrison, Nicollet, Olmsted, Otter Tail, Pennington, Pine,	Mature forest near water

		Polk, Pope, Ramsey, Redwood, Renville, RIce, Roseau, Scott, Sherburne, Sibley, St. Louis, Stearns, Swift, Todd, Traverse, Wabasha, Wadena, Washington, Winona, Wright, Yellow Medicine	
Piping plover (*Charadrius melodus*) Great Lakes Breeding Population	Endangered	St. Louis County	Sandy beaches, islands
Piping plover (*Charadrius melodus*) Northern Great Plains Breeding Population	Threatened	Lake of The Woods	Sandy beaches, islands
Piping plover (*Charadrius melodus*) Great Lakes Breeding Population	Critical Habitat	St. Louis County	
Piping plover (*Charadrius melodus*) Northern Great Plains Breeding Population	Critical Habitat	Lake of the Woods	
Reptiles			
Eastern massasauga (*Sistrurus catenatus catenatus*)	Candidate	Houston, Wabasha, Winona	Floodplain wetlands and nearby upland areas along the Mississippi River and Tributaries in Houston, Wabasha, and Winona Counties

Fish			
Topeka shiner (*Notropis topeka*)	Endangered	Lincoln, Murray, Nobles, Pipestone, Rock	Prairie rivers and streams
Topeka shiner (*Notropis topeka*)	Critical Habitat	Lincoln, Murray, Nobles, Pipestone, Rock	
Insects			
Dakota skipper (*Hesperia dacotae*)	Candidate	Big Stone, Chippewa, Clay, Cottonwood, Kittson, Lac Qui Parle, Lincoln, Murray, Norman, Pipestone, Polk, Pope, Swift, Traverse, Yellow Medicine	Native prairie habitat
Karner blue butterfly (*Lycaeides melissa samuelis*)	Endangered	Winona	Pine barrens and oak savannas on sandy soils and containing wild lupines *(Lupinus perennis)*, the only known food plant of larvae.
Mussels			
Higgins eye pearlymussel (*Lampsilis higginsii*)	Endangered	Chisago, Dakota, Goodhue, Hennepin, Houston, Ramsey, Wabasha, Washington, Winona	Mississippi and St. Croix Rivers
Sheepnose (*Plethobasus cyphyus*)	Candidate	Wabasha, Washington, Winona	Mississippi River in Wabasha and Winona counties, St. Croix River in Washington county

Spectaclecase (*Cumberlandia monodonta*)	Candidate	Chisago, Pine, Washington	St. Croix River and Rush Creek
Winged mapleleaf (*Quadrula fragosa*)	Endangered	Chisago, Washington	St. Croix River
Plants			
Minnesota dwarf trout lily (*Erythronium propullans*)	Endangered	Dakota, Goodhue, Rice, Steele	North facing slopes and floodplains in deciduous forest
Leedy's roseroot (*Sedum integrifolium ssp. leedyi*)	Threatened	Fillmore, Olmsted	Cool, wet groundwater-fed limestone cliffs
Prairie bush clover (*Lespedeza leptostachya*)	Threatened	Brown, Cottonwood, Dakota, Dodge, Goodhue, Houston, Jackson, Mower, Olmsted, Redwood, Renville, Rice	native prairie on well-drained soils
Western prairie fringed orchid (*Platanthera praeclara*)	Threatened	Clay, Dodge, Kittson, Lincoln, Mower, Nobles, Norman, Pennington, Pipestone, Polk, Red Lake, Rock	Wet prairies and sedge meadows

Revised October 2004

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U.S. Fish and Wildlife Service
Division of Endangered Species
BHW Federal Building
1 Federal Drive
Fort Snelling, Minnesota 55111-4056

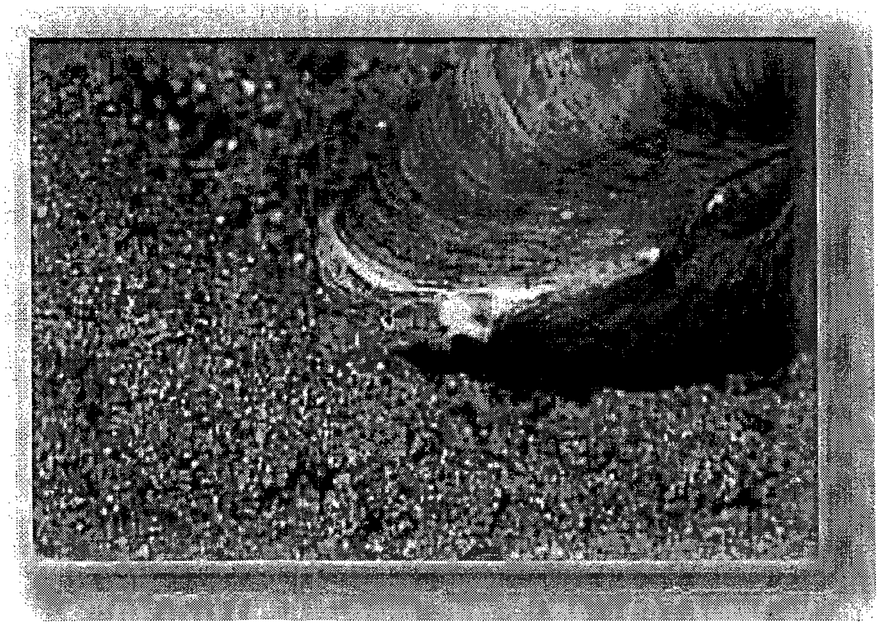
U.S. Fish & Wildlife Service Great Lakes - Big Rivers

Endangered Species

Region 3

Endangered Species Facts
(pdf version)

Saving the Higgins Eye Pearlymussel
Propagation at Genoa National Fish Hatchery
May 2001



Background
The Higgins' eye pearlymussel is native to the Mississippi River and some of its northern tributaries. It is usually found in areas of swift current and buries itself in mud-gravel bottoms in water up to 15 feet deep with only the edge of its shell and its feeding siphons exposed. Higgins' eyes measure 3 to 4 inches and have thick, round, olive-brown shells with dark rings.

The Higgins' eye was listed

The mantle flap of the female Higgins' eye has the appearance of a small minnow. When larger fish are lured near the mussel, the female expels her glochidia.

as endangered under the federal Endangered Species Act in 1976. Under the Act, an endangered species is one likely to become extinct in the foreseeable future. At the time the Higgins' eye was listed, major threats included its diminished range and numbers, and loss and degradation of habitat. In recent years, a more immediate threat is the presence of the non-native zebra mussel.

The Zebra Mussel Threat

Zebra mussels are small mussels native to Eastern Europe and Asia. They are believed to have arrived in the United States in the ballast of ocean-going vessels which emptied their tanks in Great Lakes ports. Zebra mussels were discovered in Lake St. Clair (between Lake Huron and Lake Erie) in 1988; since then, these prolific mussels have spread to most major river systems in the Midwest, as well as all the Great Lakes. They move from one area to another by attaching to boats and barges. Zebra mussels established themselves in the Upper Mississippi River by 1992 and have continued to spread.

The increase in zebra mussel populations has been matched by a decline among many native mussels. Zebra mussels compete with native species for oxygen and food, and are so prolific that they can virtually smother native mussel beds. One section of the Upper Mississippi River once supported one of the upper river's most diverse and dense mussel beds, with more than 30 species reported in 1996. By 1999, only seven species were reported, no Higgins' eyes were found, and the native mussel bed was covered by a carpet of zebra mussels several inches thick.

One contributing factor to the spread of zebra mussels in the Upper Mississippi River is the operation of the navigation system of locks and dams on the river to facilitate barge traffic and other river users. In an Endangered Species Act consultation with the Corps of Engineers on the navigation system, the Service determined that operation of the system would jeopardize the existence of the Higgins' eye pearlymussel. As a result of that consultation, the Service and Corps agreed to measures that would lessen the impacts on the Higgins' eye. Measures included relocation and propagation of mussels threatened by the presence of zebra mussels.

The Propagation Project

Higgins' eye populations are in immediate danger of being eliminated in the Upper Mississippi River. If that occurs, the only remaining Higgins' eyes will be found in small populations in the St. Croix and Wisconsin Rivers. One of the strategies to save the species is the propagation of the Higgins' eye at Genoa National Fish Hatchery. The project is a partnership effort among the Service and the states of Minnesota and Wisconsin.

As with other freshwater mussels, Higgins' eye pearlymussels need host fish in order to complete their life cycles. Tiny larval mussels, released by the female, must attach to the gills of a host fish, where the microscopic larvae - called glochidia - spend several weeks before dropping to the streambed. Mussels use different species of host fish; Higgins' eyes are thought to use sauger, freshwater drum, largemouth bass, smallmouth bass and walleye.

The propagation process for Higgins' eye begins in the spring with the collection of adult females from the St. Croix River. Divers trained to identify female Higgins' eye pearlymussels collect about 15 gravid females, or those that contain glochidia within them. The adult mussels are taken to Genoa National Fish Hatchery, where hatchery workers carefully remove the glochidia using a syringe. The microscopic glochidia are then placed with host fish in a bucket where the glochidia attach to the host's gills. The infected fish are then placed in aquariums or raceways.

After 2 or 3 weeks, some of the infected fish are taken to sites in suitable habitat where they are either released directly into the river, or held in underwater cages over suitable mussel habitat. Fish remaining in the hatchery are checked periodically, and hatchery staff collect glochidia once they have matured enough to leave the host fish. These juvenile mussels remain at the hatchery until mid-summer when many are released into areas where zebra mussels are not a threat.

The propagation project began in 2000, using funding from a grant from the National Fish and Wildlife Foundation. Work is done at Genoa National Fish Hatchery in Genoa, Wisconsin, in a specially constructed facility known as the "Clam Palace." In 2000, workers released 3,750 juvenile Higgins' eye pearlymussels in the Wisconsin River, and placed another 1,100 juveniles in special screened trays in the river to be monitored periodically.

National Fish Hatcheries and Endangered Species

Genoa is one of 69 fish hatcheries in the National Fish Hatchery System, administered by the U.S. Fish and Wildlife Service. The system also includes seven fish technology centers, and nine fish health centers. Hatcheries and technical centers are working with 44 aquatic species federally listed as endangered or threatened. Among them are fish, five species of freshwater mussels, as well as toads, salamanders, and horseshoe crabs. These facilities play an important role in conservation and recovery through the development of state-of-the-art captive propagation techniques and by providing genetic refugia for listed species.

May 2001

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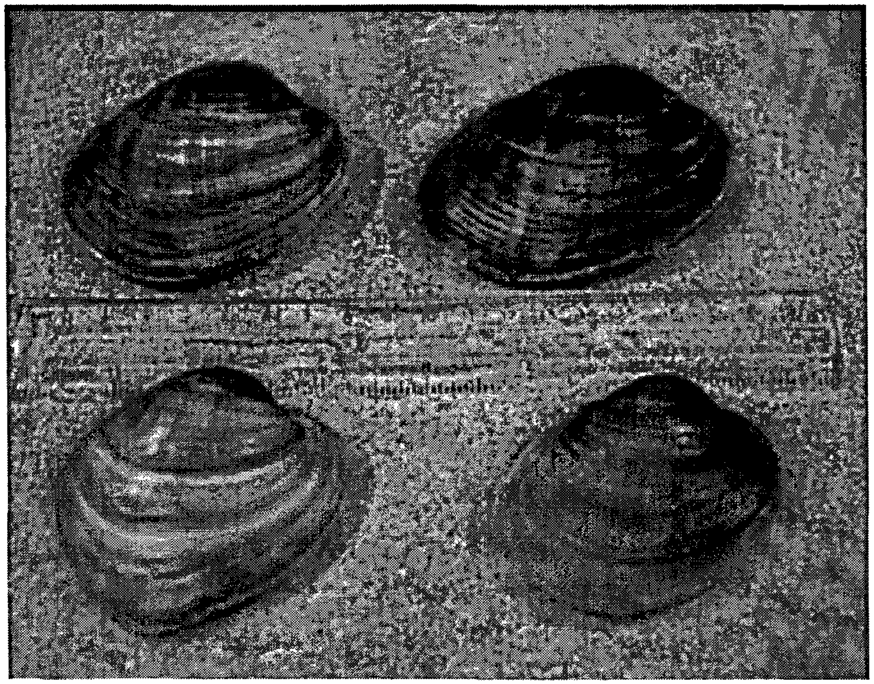
Endangered Species

Endangered Species Facts
(pdf version)

Higgins Eye Pearlymussel



The Higgins eye pearlymussel is an *endangered species*. Endangered species are animals and plants th danger of becoming extinct. *Threatened species* are animals and plants that are likely to become endangered in the foreseeable future. Identifying, protecting, and restoring endangered and threatened species is the primary objective of the U.S. Fish and Wildlife Service's endangered species program.

What is the Higgins eye pearlymussel?

Scientific Name - *Lampsilis higginsii*

Appearance - Higgins eye pearlymussel is a freshwater mussel with a rounded to slightly elongate smooth-textured shell that is usually yellowish brown with green rays. The shell, made up of 2 hinged, inflated halves, is up to 4 inches in length and has a rounded side and a pointed (males) or squared (females) side. The inside of the shell is white with portions that are iridescent and areas that may be tinged with cream or salmon. The soft body enclosed by the shell consists of gills for breathing, a digestive tract for processing food, and a large muscled foot for locomotion and anchoring in the stream bottom.

Range - Since 1980, live Higgins eye pearlymussels have been found in parts of the following rivers: the upper Mississippi River north of Lock and Dam 19 at Keokuk, Iowa, and in 3 tributaries of the Mississippi River - the St. Croix River between Minnesota and Wisconsin, the Wisconsin River in Wisconsin, and the lower Rock River between Illinois and Iowa. The species' current range is about 50% of its historic distribution which extended as far south as St. Louis, Missouri, and in several additional tributaries of the Mississippi River.

Habitat - The Higgins eye is a freshwater mussel of larger rivers where it is usually found in areas with deep water and moderate currents. The animals bury themselves in the sand and gravel river bottoms with just the edge of their partially-opened shells exposed. The river's currents flow over the mussels as they siphon water for microorganisms such as algae and bacteria, which they use as food. The role of Higgins' eye pearlymussels in the natural river ecosystems is as a food source for wildlife like muskrats, otters, and raccoons and as a filter which improves water quality.

Reproduction - The male Higgins eye releases sperm into the river current and downstream females siphon in the sperm to fertilize their eggs. After fertilization, the females store the developing larvae (glochidia) in their gills until they're expelled into the river current. Some of the glochidia are able to attach themselves to the gills of host fish, where they develop further. After a few weeks, the juvenile mussels detach from the gills of the fish and settle on the river bottom, where they can mature into adult mussels and possibly live up to 50 years. The sauger, walleye, yellow perch, largemouth and smallmouth bass, and freshwater drum are considered suitable hosts for Higgins eye glochidia.

Why is the Higgins eye pearlymussel endangered?

Habitat Loss or Degradation - Higgins eye pearlymussels depend on deep, free-flowing rivers with clean water. Much of their historic habitat was changed from free-flowing river systems to impounded river systems. This resulted in different water flow patterns, substrate characteristics, and host fish habitat and movement which affect how the Higgins eye feed, live, and reproduce. Municipal, industrial, and farm run-off degrade water quality. As a filter-feeder, this species concentrates chemicals and toxic metals in body tissues and can be poisoned by such chemicals in the water. Dredging and waterway traffic produce siltation which cover the substrate and mussel beds.

Exotic Species - The invasive zebra mussel is the greatest known threat to Higgins eye.The zebra mussel is a freshwater mussel native to the Black and Caspian Seas that was introduced into Lake Erie in the late 1980's from ship ballast water discharge. This small mussel is less than 2 inches in length, but tens of thousands can colonize a square meter area. They attach to any hard surface, including shells of other mussels. They compete for food with native species and, when attached to the shells, prevent normal travel, burrowing, and opening and closing of the shells. Several Higgins eye populations in the Mississippi River have been hit hard by zebra mussel colonization, reducing the population at Prairie du Chien, WI, from one of the most numerous Higgins eye populations to one of the least. Technology to control zebra mussel populations is under development, but no successful measures have been developed that could reliably limit zebra mussel colonization and not harm the native mussel species, such as Higgins eye.

What is being done to prevent extinction of the Higgins eye pearlymussel?

Listing - The Higgins eye pearlymussel was added to the U.S. List of Endangered and Threatened Wildlife and Plants in 1976. As a result of the listing, the U.S. Fish and Wildlife Service developed a recovery plan that describes actions needed to help this species survive. This plan subsequently was revised in 2004 to incorporate new information and address the more recent threat of zebra mussels.

Research - Researchers are continuing studies of zebra mussels and their impacts on Higgins eye, of commercial navigation impacts on mussels, and of water quality and contaminant relationships to the species.

Habitat Protection - A variety of government and private conservation agencies are working to preserve Higgins eye pearlymussel and its habitat.

What Can I Do to Help Prevent the Extinction of Species?

Learn - Learn more about Higgins eye pearlymussel and other endangered and threatened species. Understand how the degradation and destruction of endangered and threatened species and our nation's plant and animal diversity. Tell others about what you have learned.

Join - Join a conservation group; many have local chapters.

Protect - Protect water quality by minimizing use of lawn chemicals (i.e., fertilizers, herbicides, and insecticides), recycling used car oil, and properly disposing of paint and other toxic household products.

Follow - When boating, please follow any rules established to prevent the spread of exotic pests like the zebra mussel.

May 2004

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BIOLOGICAL OPINION
FOR THE OPERATION AND MAINTENANCE
OF THE 9-FOOT NAVIGATION CHANNEL
ON THE UPPER MISSISSIPPI RIVER SYSTEM

SUMMARY OF FINDINGS

In this Biological Opinion, the U.S. Fish and Wildlife Service (Service) has determined that the continued operation and maintenance of the 9-foot Navigation Project will jeopardize the continued existence of the Higgins' eye pearly mussel (*Lampsilis higginsi*) and the pallid sturgeon (*Sacphirhynchus albus*). We have also provided reasonable and prudent alternatives that will allow the continued operation and maintenance of the 9-foot Navigation Project while offsetting adverse impacts to the species and avoiding jeopardy. If the reasonable and prudent alternatives are not implemented, then the likelihood of survival and recovery of these species will be appreciably reduced. The Corps of Engineers (Corps) is required to notify the Service of its final decision on the implementation of the reasonable and prudent alternatives described herein.

In addition, we have found that the project will not jeopardize the least tern (*Sterna antillarum*) and winged mapleleaf mussel (*Quadrula fragosa*) but will result in incidental take. We have provided an Incidental Take Statement with reasonable and prudent measures that will minimize the impacts of this take on these species.

We also have determined that the proposed action will likely adversely affect the bald eagle (*Haliaeetus leucocephalus)* and the Indiana bat *(Myotis sodalis)*. However, while the project may affect individuals, the impacts will be offset by management actions proposed by the Corps or will be negligible, and will not rise to the level of incidental take (i.e., harm and harassment). For the decurrent false aster *(Boltonia decurrens)* we found that while adverse effects will result, the species will not be jeopardized. Because it is a plant, take is not prohibited.

The Service considered including the sturgeon chub (*Macrhybopsis gelida*) and sicklefin chub (*Machrybopsis meeki*), which are candidate species, in this biological opinion. However, because it appears that these species are more than a year away from a listing proposal, we chose not to include them at this time. When they are proposed for listing, we recommend that you request use of the conferencing process to consider project effects on these species.

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BACKGROUND

This programmatic (Tier I) consultation considers the systemic impacts of the operation and maintenance of the 9-Foot Channel Navigation Project on the Upper Mississippi River System (UMRS) on listed species as projected 50 years into the future. This consultation does not include individual, site specific projects or new construction. These will be handled under separate (Tier II) consultations if it is believed that they may affect a listed species. This consultation establishes a baseline on which any future expansion of the navigation system on the UMRS can be assessed.

This consultation was conducted by an interagency Corps of Engineers (Corps) - U.S. Fish and Wildlife Service (Service) Consultation Team composed of representatives of the three Corps Districts (St. Paul, Minnesota, Rock Island, Illinois and St. Louis, Missouri) and the three Service Field Offices involved (Twin Cities, Minnesota, Rock Island, Illinois and Marion, Illinois). The Team members cooperated with each other in exchanging information preparing and reviewing the Biological Assessment and this Opinion. Each team member took responsibility for one or more species covered in the consultation. Ultimate responsibility for the content of the Biological Assessment rests with the Corps of Engineers, however, and for this Opinion, with the U.S. Fish and Wildlife Service.

The outline for the Biological Assessment was recommended by the Service to insure that all the necessary topics would be addressed and that the need for additional information would be minimized once the Assessment was completed. An impacts matrix was jointly developed by the Team in an attempt to identify all the potential impacts for each species that would be addressed.

Oversight of the consultation process was provided by the Service's Field Office Supervisors and the Corps' Mississippi Valley Division Office Staff. Conflict resolution was the primary responsibility of the Service's Regional Office and the Corps' Division Office but, generally, all parties to the consultation took part in these discussions. A set of guidelines or ground rules were jointly developed by the two agencies to guide the process.

SPECIES COVERED IN THIS CONSULTATION

This consultation covers the following species: Indiana bat (*Myotis sodalis*), decurrent false aster (*Boltonia decurrens*), bald eagle (*Haliaeetus leucocephalus*), Higgins' eye pearlymussel (*Lampsilis higginsi*), winged mapleleaf mussel (*Quadrula fragosa*), least tern (*Sterna antillarum*), and pallid sturgeon (*Scaphirynchus alba*). During informal consultation, the Interagency Corps/Service Consultation Team concluded that pink mucket pearly mussel (*L. abrupta*) and fat pocketbook mussel (*Potamilis capax*) have been extirpated from the UMRS and need not be addressed. By letter dated June 10, 1999, the Service concurred with the Corps' findings in its Biological Assessment that the project may adversely affect the pallid sturgeon and Higgins' eye pearly mussel. However, the Service did not concur with the Corps that the project would not adversely affect the Indiana bat, bald eagle, winged mapleleaf mussel and decurrent false aster.

The Service considered including the sturgeon chub (*Macrhybopsis gelida*) and sicklefin chub (*Machrybopsis meeki*), which are candidate species, in this biological opinion. However, because it appears that these species are more that a year away from a listing proposal, we chose not to include them in this opinion. When they are proposed for listing, we recommend that you request use of the conferencing process to consider project effects on these species.

CONSULTATION HISTORY

February 23, 1993 - The Service's Rock Island Field Office transmits a letter to the St. Louis Corps District Engineer requesting that the District initiate Section 7 consultation on various construction (operation and maintenance) activities on the Mississippi River.

November 22, 1993 - The Service's Rock Island Field Office transmits a letter to the Rock Island Corps District with a species list for Section 7 consultation for their expanded navigation study. In that letter the Service urged the Corps to address operation and maintenance of the navigation channel.

July 8, 1994 - St. Louis Corps District requests a list from the Service's Rock Island Field Office of threatened and endangered species that may occur within the area of the Upper Mississippi 9-Foot Navigation Project.

November 25, 1994 - The Service's Rock Island Field Office transmits a species list to the St. Louis District for preparation of a Biological Assessment for the operation and maintenance of the Upper Mississippi River 9-Foot Navigation Project.

May 15, 1995 - St. Louis Corps District transmits a Tier I (programmatic) biological assessment (BA) for the operation and maintenance of the UMR Navigation Project within the St. Louis District to the Service's Rock Island Field Office.

June 16, 1995 - The Service's Rock Island Field Office responds to St. Louis District's BA concurring with a tiered approach but noting that the Corps did not request formal consultation on the Tier I assessment and recommended that the two agencies continue in informal consultation until it is determined which species should be consulted on, what data are required, and how any formal consultation should be accomplished.

August 7, 1995 - St. Louis Corps District responds to the Service's June 16, 1995 letter concurring that the two agencies should remain in informal consultation for the present time.

April 12, 1997 - The Service's Deputy Assistant Secretary for Fish, Wildlife and Parks transmits a letter to the Assistant Secretary of the Army requesting assistance in resolving the issue of the Corps' reluctance to address operation and maintenance of the navigation channel in its navigation improvements study.

May 20, 1997 - The Service's Rock Island Field Office transmits a letter to the Rock Island Corps District Engineer again requesting that the Corps address impacts of the operation and maintenance of the navigation channel on endangered and threatened species.

October 1, 1997 - Rock Island District Corps District notifies the Service's Rock Island Field Office that it intends to prepare a BA for the operation and maintenance of the O&M Project, and a separate BA for their Navigation Study.

December 21, 1997 - Conference call between the Service's Rock Island Field Office and Rock Island Corps District to discuss the approach of preparing a separate BA for operation and maintenance and one for the Navigation Study.

March 27, 1998 - Rock Island Corps District transmits a draft biological assessment for the UMR Expanded Navigation Study to the Service's Rock Island Field Office.

April 1, 1998 - Service's Regional Office transmits a letter to Mississippi Valley Division Engineer expressing concern regarding Section 7 compliance for the O&M Project and the Corps' Navigation Study. The Service recommends that the Corps initiate a single consultation with the Service on the systemic impacts of the O&M Project for all three UMR Corps Districts. This programmatic consultation would then form the baseline on which to assess the impacts of the Corps' Navigation Study.

April 17, 1998 - Meeting between Service's Regional Director and Mississippi Valley Division Engineer to discuss a Plan of Action completing a systemic consultation on the O&M Project. The Plan calls for establishing a Consultation Team consisting of Corps and Service representatives. The Corps assigned the St. Louis District as their lead and the Service assigned the Rock Island Field Office as their lead. Regional and Division Office Staff will serve as advisors and facilitators.

May 15, 1998 - Service's Rock Island Field Office transmits a letter to St. Louis Corps District enclosing an outline for the consultation and a draft impacts matrix for the Corps to use in preparation of its biological assessment.

May 20, 1998 - Meeting between Corps and Service Consultation Teams to discuss the consultation process, impacts matrix, and the preparation of the Corps' biological assessment.

June 9, 1998 - Service's Rock Island Field Office transmits a letter to St. Louis Corps District enumerating the listed species found in the O&M Project area.

June 14, 1998 - The Service's Rock Island Field Office transmits a letter to the Corps indicating that the Higgins' eye pearly mussel occurs in an additional six counties.

August 4, 1998 - Meeting between Corps and Service Consultation Teams to discuss a revised impacts matrix and other consultation issues.

September 28, 1998 - Corps and Service Consultation Team Leaders finalize a set of Ground Rules for completing the consultation.

November 1998 - Corps Consultation Team members transmit draft sections of the biological assessment to their Service counterparts for review and comment.

January 26, 1999 - Service's St. Paul and Rock Island Field Offices and St. Paul Corps District meet with the Higgins' eye pearlymussel and winged mapleleaf mussel Recovery Teams to discuss O&M Project related impacts on these species.

January/February, 1999 - Service Consultation Team members provide comments to the Corps Consultation Team members on individual sections of the draft Biological Assessment.

February 4, 1999 - Service and Corps Consultation Teams meet to discuss progress on the biological assessment, areas of agreement and disagreement, and to establish a schedule for the remainder of the consultation.

March 30, 1999 - The Service's Marion Illinois Sub-office provides information to the St. Louis Corps District regarding the collection of a young-of-the-year pallid sturgeon at approximate Mississippi River Mile 49.5L.

May 3, 1999 - Corps' Division Engineer transmits its biological assessment to the Service's Regional Director requesting the initiation of formal consultation on the O&M Project.

June 10, 1999 - Service's Assistant Regional Director responds to Corps' Division Engineer's biological assessment requesting additional information.

July 28, 1999 - Corps' Division Engineer transmits a letter to the Service' Regional Office amending page 1 of its Biological Assessment to include language that the Corps "... is not required ... to provide the attached BA ..., the BA is being voluntarily submitted to the ... Service ... for the purpose of fulfilling the Corps' commitment to conservation of endangered species."

August 2, 1999 - Corps' Division Engineer responds to Service's June 10 letter providing some of the information requested and enumerating the reasons why the remainder will not be provided.

August 31, 1999 - Service's Regional Office transmits a letter to the Corps' Division Engineer acknowledging the receipt of additional information and that formal consultation has been initiated as of August 6, 1999.

September 27, 1999 - Meeting between the Service's Rock Island Field Office and St. Louis Corps District at which the Service presented its anticipated finding of jeopardy for the pallid sturgeon and a Reasonable and Prudent Alternative (RPA) to avoid jeopardy.

October 21, 1999 - Meeting between Service and Corps Consultation Teams, the Service's Regional Office and the Corps' Mississippi Valley Division to discuss RPA's and reasonable and prudent measures (RPM's) for all species, and the consequences of jeopardy findings for *L. higginsi* and *S. alba*. It was agreed to extend the consultation period one month to December 3, 1999.

October 27, 1999 - Meeting among representatives of the Service's Rock Island Field Office, St. Louis Corps District, Corps' Mississippi Valley Division, the Waterways Experiment Station, Southern Illinois University, and the Long Term Resource Monitoring Station (Cape Girardeau, MO) to discuss and attempt to develop a mutually acceptable RPA for pallid sturgeon. No agreement was reached on the RPA but the Service offered to provide a list of benchmarks (performance measures) for the Corps to use in estimating costs of the RPA.

November 2, 1999 - Service's Regional Office transmits a letter to Corps' Mississippi Valley Division acknowledging an extension of the consultation period to December 3, 1999.

November 8, 1999 - Service's Marion, IL suboffice faxes draft benchmarks to the Corps' St. Louis District for review and comment.

November 18, 1999 - Meeting between Service Regions 3 and 6 to discuss the status of pallid sturgeon, the validity of a jeopardy opinion in this consultation, and to refine the RPA and RPM's.

November 19, 1999 - Telephone conversation between George Rhodes, Corps' Mississippi Valley Division, and John Blankenship, Assistant Regional Director, FWS Region 3, Twin Cities, MN to discuss an extension of the consultation for 90 days.

November 23, 1999 - Letter from Service's Regional Office to the Corps' Mississippi Valley Division Engineer confirming a joint agreement to extend the consultation period for an additional 90 days to March 2, 2000.

November 30, 1999 - Conference call between FWS staff Rock Island, IL, Twin Cities, MN, and Marion, IL and Corps staff St. Louis, MO and Vicksburg, MS to discuss the 90 day extension of the consultation period. The Corps requested it be modified to 60 days because of a concern for the timely completion of a future consultation for the Navigation Expansion Study and the Service agreed.

December 6, 1999 - Letter from Service's Regional Office to Corps' Mississippi Valley Division Engineer confirming a revised extension of the consultation period for an additional 60 days to February 2, 2000. In addition, the Service notifies the Corps that if a Biological Assessment for the least tern is not received by January 3, 2000, the Service will proceed with the consultation for this species using existing information.

December 9, 1999 - St. Louis Corps District faxes review comments on the Service's draft benchmarks for habitat restoration in the Middle Mississippi River to the Service.

December 15, 1999 - Meeting between Service's Regional Office, Rock Island Field Office and Marion Sub-office staff and Corps' St. Louis District and Mississippi Valley Division Staff to develop a workable RPA. Tentative agreement was reached on the elements of the RPA, prioritization of RPA actions, and benchmarks for the 4 years following this consultation.

December 28, 1999 - Service receives Biological Assessment for the least tern from Corps' Mississippi Valley Division.

January 11, 2000 - Service transmits preliminary draft sections of the Biological Opinion for the pallid sturgeon and Higgins' eye pearly mussel to the Corps for review and comment.

January 12, 2000 - Corps transmits comments on preliminary draft sections of the Biological Opinion to the Service.

February 2, 2000 - The Mississippi Valley Corps Division transmits a letter to Service's Regional Office providing comments on draft sections of the Biological Opinion for the Higginsi' pearly mussel and pallid sturgeon.

February 4, 2000 - Consultation Period Ends

February 9, 2000 - Corps transmits a document entitled "Future Corps of Engineers and Fish and Wildlife Service Actions to Improve the Status of the Pallid Sturgeon in the Middle Mississippi River" to the Service as a supplement to its Biological Assessment.

On or about February 14, 2000 - The St. Louis Corps District forwarded a revised Reasonable and Prudent Alternative for the pallid sturgeon to the Service.

February 17, 2000 - Meeting between the Service's Regional, Rock Island and Marion, Illinois offices and the Corps' Division and St. Louis District offices to discuss the draft Reasonable and Prudent Alternative for the pallid sturgeon.

February 18, 2000 - Draft Biological Opinion provided to the Corps for review and comment.

February 24, 2000 - The Service transmits a revised draft Reasonable and Prudent Alternative for the pallid sturgeon to the Corps' Mississippi Valley Division.

April 2, 2000 - Corps' comments on Draft Biological Opinion received by the Service.

April 19, 2000 - Meeting between Service and Corps representatives to discuss the final findings of the Biological Opinion, implementation of the RPMs and RPAs, and outreach.

May 15, 2000 - Final Biological Opinion delivered to the Corps.

BIOLOGICAL OPINION

1.0 Description of the Proposed Action

1.1 Action Area

The UMRS 9-Foot Navigation Project includes the commercially navigable portions of the Mississippi, Illinois, Kaskaskia, Minnesota, St. Croix, and Black Rivers. As the impacts of the proposed action affect pallid sturgeon populations in the lower Missouri and Mississippi rivers, the action area also encompasses these river stretches (see section 8.3 below for further discussion).

The U.S. Army Corps of Engineers is responsible for maintaining navigation by means of a series of 37 locks and dams, channel training structures, and dredging on over 1,200 miles of navigable waterway. Flood control is maintained to a large extent by a system of agricultural and urban levees, some of which were designed and built by the Corps of Engineers. In addition, the Corps operates and maintains 31 recreational areas and provides for stewardship of the natural resources on project lands and waters. There are also outgrants to Federal, State, public and private institutions and individuals for various purposes, including cottage leases, wildlife management, and recreation.

The 9-Foot Channel Navigation Project encompasses three separate Corps of Engineers districts. Its area is defined as the entire Illinois Waterway from the confluence with the Mississippi River at Grafton, Illinois (River Mile 0.0), to T. J. O'Brien Lock in Chicago, Illinois (River Mile 327.0). The segment of the UMR starts at the confluence with the Ohio River (River Mile 0.0) and extends to Upper St. Anthony Falls Lock in Minneapolis-St. Paul, Minnesota (River Mile 854.0). It also includes the navigable portions of the Kaskaskia, Minnesota, Black and St. Croix Rivers.

The St. Louis District includes the UMR from its confluence with the Ohio, River Mile 0.0 to River Mile 300. 1, near Saverton, Missouri, and the navigable portion of the Kaskaskia River. It also includes the Illinois River from its confluence with the Mississippi at Grafton, Illinois, to immediately below La Grange Lock and Dam at River Mile 79.8. The Rock Island District includes the UMR (River Mile 300. 1) near Saverton, Missouri, through Guttenberg, Iowa (River Mile 615), and the Illinois River from the junction of the Calumet-Sag Channel and the Chicago Sanitary Canal (River Mile 303.4) to the La Grange Lock and Dam (River Mile 79.8). The St. Paul District includes the UMR from Guttenberg, Iowa (River Mile 615), to Minneapolis-St. Paul, Minnesota (River Mile 854.0), as well as the navigable portions of the Minnesota, Black, and St. Croix Rivers.

1.1.1 Middle Mississippi River

The first modification to the river for navigation began in 1824 with clearing and snagging to remove hazards for wooden hull vessels. In the 1830's, the first channel stabilization works were built. In 1881, a comprehensive plan was authorized to maintain an 8-foot channel through bankline revetments and permeable dikes. Congress authorized the existing 9-foot channel project in 1927 for the purpose of securing a 9-foot-deep by 300-foot-wide channel between St. Louis, Missouri, and Cairo, Illinois.

1.1.2 Upper Mississippi River

Modifications to the UMR for navigation began in 1824 when the Government authorized removal of snags, shoals, and sandbars; excavation of rock at several rapids; and closing off of meandering sloughs and side channels to maintain flows in the main channel. The first comprehensive modification of the river was authorized by the Rivers and Harbors Act of June 18, 1878.

A 4½ foot channel was maintained from the mouth of the Missouri River to St. Paul, Minnesota, by constructing dams at the headwaters of the UMR to impound water for low-flow supplementation, and by bank revetments, closing dams, and longitudinal dikes. In 1890, the 4½ foot channel was extended to Minneapolis, Minnesota. A 6-foot channel was authorized by the Rivers and Harbors Act of March 2, 1907. The additional depth was obtained primarily by construction of rock and brush wingdams designed to constrict low-water flows to a narrower channel.

Dam 19 at River Mile 364.2 (Keokuk, Iowa) was constructed in 1913 and is the only dam not federally-owned or operated. It is one of two sites generating hydropower on the system, the other being at Lock and Dam 1 in the Twin Cities which is partially owned by the Ford Motor Company. Congress authorized the 9-Foot Channel Navigation Project in the Rivers and Harbors Act of July 3, 1930, to be achieved by a series of locks and dams and supplemented by dredging. The project extended from the mouth of the Missouri River to Minneapolis, Minnesota. The Rivers and Harbors Act of August 26, 1937, authorized a 4.6-mile extension of the project to ascend St. Anthony Falls.

1.1.3 Illinois River

Between 1871-1878, the State of Illinois built two locks and dams for navigation on the Illinois River and the Federal Government built two locks and dams for the 7-foot navigation project. The 1900 completion of the Chicago Sanitary and Ship Canal created a connection between Lake Michigan and the Illinois River. This increased Illinois River flows and diverted urban wastes into the Illinois River. By 1930, the State had completed 75% of the 9-Foot Channel Navigation Project but was unable to raise funds for completion. The Rivers and Harbors Act of July 3, 1930, authorized the Corps of Engineers to complete the project and assigned responsibility to the Federal Government. The Rock Island District is responsible for operating and maintaining eight locks and dams along 327 miles of the system, and the St. Louis District is responsible for the lower 80-mile reach from La Grange Lock to Grafton, Illinois, the Illinois Waterway portion of Alton Pool.

1.1.4 Kaskaskia River

The Kaskaskia River Navigation Project was authorized by the 1962 Rivers and Harbors Act to provide a navigation channel 9 feet deep and 225 feet wide on the lower 50.5 miles of the

Kaskaskia River. The project shortened the river between its mouth and Fayetteville, Illinois, from 52 to 36 miles. Meanders were left as cutoffs, much of the channel was excavated, and flow was partially regulated by a lock and dam near the river's mouth.

1.1.5 Minnesota River

A 4-foot navigation channel on the Minnesota River to Mile 25.6 near Shakopee, Minnesota, was authorized by the Rivers and Harbors Act of July 13, 1892. Congress authorized a 9-foot channel on the Minnesota River up to Mile 14.7 near Savage, Minnesota, in the Rivers and Harbors Act of July 3, 1958. The Peavey Company maintains a 9-foot channel from Mile 14.7 to its grain terminal at Mile 21.8.

1.1.6 St. Croix River

The Rivers and Harbors Act of June 18, 1878, authorized a 3-foot navigation channel on the St. Croix River from the mouth to Mile 51.8 at Taylors Falls, Minnesota. A 6-foot channel to Mile 24.4 at Stillwater, Minnesota, was authorized by the Rivers and Harbors Act of January 2 1, 1927. The present 9-foot channel to Stillwater was authorized by the Rivers and Harbors Act of August 30, 1935, and was assured as a result of the completion of Lock and Dam 3 in 1938.

1.1.7 Black River

The Rivers and Harbors Act of August 26, 1937, authorized a 9-foot navigation channel on the Black River at La Crosse, Wisconsin, to a point 1.4 miles above the mouth. Dredging a channel approximately 300 feet wide, which is considered adequate for existing commerce, was completed in 1941.

1.2 Proposed Action

The proposed action is the continuance, for the next 50 years, of the operation and maintenance of the 9-Foot Navigation Channel Project on the UMRS which has been on-going for the past 60-70 years.

1.2.1 Lock and Dam Operations

Water levels upstream of the dams are based upon depths needed for navigation and are controlled by systematically raising or lowering the dam gates. Water elevations at all of the dams are regulated based upon discharge. The goal is to maintain a target water level at a control point within each pool. Control ranges are defined within each district. Water level control is described completely in pool operation plans for each lock and dam. An analysis of water level management on the Upper Mississippi River System was completed by the Long Term Resource Monitoring Program and is available in Wlosinski and Hill (1995).

Maintenance at locks and dams is performed on a daily basis or at longer intervals for major work. Personnel perform day-to-day maintenance of operating machinery and minor repair work on the facilities. During major maintenance and rehabilitation, lock gates and valves are removed, sandblasted, and repaired, as are dam gates when necessary. Major rehabilitation at Locks and Dams 2-22 and the Illinois Waterway was evaluated in a Programmatic Environmental Impact Statement (USACE 1989b). The associated Biological Assessment is hereby incorporated by reference.

1.2.2 Recreation

The three Corps districts operate and maintain 31 recreation areas along the river. Seventy-three additional recreation areas are located on Corps lands but are leased to other organizations that are responsible for operation and maintenance. Twenty-two major public parks are located along the river. Boating access to the river is provided by approximately 360 boat access points and/or marinas and 11,500 marina slips along the Upper Mississippi River, excluding the St. Croix and Minnesota Rivers. Carlson *et al.* (1995) estimated that over 12 million daily visits occurred throughout the Upper Mississippi River System during the study year. The study also determined that the top three activities in which those visitors engaged were recreational boating, boat fishing, and sightseeing.

The guiding documents governing operation and management of Corps of Engineers' administered recreational facilities and grounds is the Operational Management Plan (OMP) Part II. Currently, the St. Paul and Rock Island Districts have completed OMP's that include a detailed synopsis describing a 5-year plan of action on how facilities will be operated and maintained. Annual updates of the OMP Part II are reviewed for appropriateness and to ensure that long-term management is provided in an environmentally sound manner. The St. Louis District is currently developing a comprehensive master plan for the river projects and concurrently developing OMP's. The OMP'S will be similar in scope to those described above and completed after Master Plan approval. The Kaskaskia OMP was recently approved (USACE 1998). Complete description of operation and maintenance of recreation areas can be found in the OMP (USACE 1992, USACE 1993). Additional information is found in Land Use Allocation Plans and Master Plans (USACE 1969-1973, 1983, 1989a).

The St. Paul District manages one major recreation area and three boat ramps. Blackhawk Park, about 25 miles south of La Crosse, Wisconsin, is the only full service staffed campground/park that the district operates on the Mississippi River above Guttenberg, Iowa. The district has a few real state outgrants, but 460 private recreational facilities and a few hundred others on municipal leases are managed in accordance with the Shoreline Management Plan, which allows private structures and use while affirming public ownership and management.

The Mississippi River recreational facilities that the Rock Island District directly manages include six Class A campgrounds (modern facilities), one Class B campground (semi-modern facilities), two Class C campgrounds (primitive facilities), six no-fee primitive campgrounds, 10 day-use areas with day-use fee boat ramps, 10 free day-use areas with boat ramps, 10 no-fee day-use areas with picnic shelters, four lock and dam overlooks, and one Class B project visitor center.

In calendar year 1997, there were approximately 55 million visitor hours of use on Rock Island District Mississippi River Project lands and waters, with about 10% or 5.5 million visitor hours occurring at Corps-administered recreational facilities. Visitor assistance and resource management at these facilities are administered by the Mississippi River Project Office staff located at Pleasant Valley, Iowa; and by park ranger staff assigned to remote field station offices located in Dubuque and Muscatine, Iowa, and Thomson, Rock Island, and Quincy, Illinois. In addition to managing developed recreational facilities, these park rangers are also responsible for managing dispersed recreational activities occurring on all 93,600 land and water acres of the Rock Island District, Mississippi River Project. Mississippi River Natural Resource Management staff are empowered to enforce Part 327, Title 36 of the Federal Code of Regulations in order to protect recreational and natural resource features found within project lands and waters of the Mississippi River Project.

In the Rock Island District, approximately 565 private recreational and residential leases encompass 465 acres of land. Public Law 99-662 allows for these leases to continue indefinitely until terminated by the lessee or the Secretary of the Army. New leases are not being issued, but existing sites are maintained. If leased areas are returned to the Corps, natural resource management prescriptions are implemented, which include closure or removal of the access road and conversion to natural habitat. The OMP contains additional information on other types of leases.

The St. Louis District manages seven recreation areas, 18 access areas, and five marinas. Eighteen cabin subdivisions (350 recreational cottage leases are still active on 244 acres) dot the riverbanks. The States of Illinois and Missouri operate three recreation areas and 17 accesses on Corps-owned land. The city of Alton operates one marina on Corps land. Local governments, as well as the states, operate an additional 23 access areas. Marinas, harbors, and boating clubs on the Mississippi and Kaskaskia Rivers total 27 and 2, respectively, providing some 3,198 boat slips. The Rivers Project Office operates a regional visitor center at the Melvin Price Locks and Dam area and Class C visitor centers at Locks 27 and Kaskaskia Lock and Dam.

The rivers of the St. Louis District are a major recreational resource for the people living in the bi-state area. A portion of the Great River Road from Melvin Price Locks and Dam visitor center to Hardin, Illinois, was recently designated a National Scenic Byway. Recreational points of interest are the Mark Twain National Wildlife and Fish Refuge, Lewis and Clark State Historical Park, the Corps' Riverlands Environmental Demonstration Area adjacent to Melvin Price Locks and Dam, the multi-agency confluence greenway (Mississippi and Missouri Rivers), and the regional bike trail system. According to a recent survey, recreational use of the area is varied. Fishing from a boat is the most popular (23.4%), followed closely by sightseeing (19.6%) and recreational boating (17.9%). Bank fishing (14.6%) is the fourth most popular activity, followed by waterskiing (7.1%), hiking (6.4%), and swimming (4.1%). Picnicking is participated in by 2.7%, only slightly above camping at 2.7%. All other activity totals approximately 1.6%.

1.2.3 Natural Resource Management

The Corps of Engineers maintains primary administrative authority over all fee title lands and waters acquired for construction and operation of the Mississippi River Project. The Corps has the responsibility and authority to manage the natural resources on fee title lands, which includes forest, fish and wildlife, water, aesthetic, and vegetative resources. Detailed descriptions of the projects are included in the Rock Island District, Natural Resource Management, Operational Management Plan Part I (USACE 1992) and the St. Paul District, Mississippi River Operational Management Plan (USACE 1993). With the exception of the Kaskaskia River OMP that was recently approved (USACE 1998), the St. Louis District OMP will be completed after approval of the Comprehensive Rivers Project Master Plan.

Estimates from 1989 satellite data indicate that approximately 304,000 acres of the UMR floodplain remains forested (Yin 1998). The St. Louis District has mapped a total of 800,000 acres of floodplain forest as of 1994 (USACE 2000). Much of this remaining bottomland forest is managed for natural resource benefits in the St. Paul and Rock Island Corps Districts, and efforts are under way to maintain forest age class and diversity. The St. Louis District does not directly manage any of its forest lands; rather, it oversees the management of its fee title lands managed by state and federal agencies such as the Fish and Wildlife Service.

The goals of the forest management in the Corps' Rock Island District are as follows:

1. Complete and maintain a detailed comprehensive stand-mapping database to use in future forest management decisions.

2. Promote size class diversity through continued silvicultural practices such as TSI's, tree plantings, and timber sales to maintain and improve forest quality for wildlife habitat and provide a regulated and sustained yield of forest products.

3. Protect habitat for all endangered and threatened species found on project lands.

4. Maintain existing and future nesting sites for colonial nesting birds.

5. Manage habitat to provide nesting and feeding sites for local and migratory birds.

6. Maintain and enhance communication with coordinating agencies and the general public.

Specific management practices are outlined in the OMP, and the Management Plan is updated annually. At that time, review and coordination ensure that management is provided in an environmentally sound manner.

In addition to lands managed by the Corps, other fee title lands are managed by the U.S. Fish and Wildlife Service and several of the states under Cooperative Agreements. These lands include portions of the Upper Mississippi National Wildlife and Fish Refuge, the Mark Twain National Wildlife Refuge, the Minnesota Valley National Wildlife Refuge, the Illinois River

National Wildlife and Fish Refuge, and a number of state conservation areas in Minnesota, Wisconsin, Illinois, Iowa, and Missouri. At the present time, all Service Refuges in the action area are preparing Comprehensive Conservation Plans (CCPs) which will address forest land management. While still in draft stage, these plans will likely include goals similar to the following:

- reduce forest fragmentation by conserving and enhancing the size of bottomland forest blocks;

- enhance forest structural diversity within blocks (age class, species, canopy, understory, etc.);

- ensure adequate spatial distribution of bottomland forest along the river corridor for neotropical migrants;

- promote natural biological diversity through the protection, restoration, and management.

1.2.4 Channel Maintenance

The navigation channel is maintained by periodic maintenance dredging and regulatory structures (wing and closing dams and revetment). Description of channel maintenance in the three districts varies slightly due to differing river conditions. A general description of channel maintenance follows, along with a list of documents in which more specific information can be found.

1.2.4.1 Dredging

Periodic dredging is required in order to maintain a 9-foot channel. In required locations, dredging occurs with hydraulic cutterhead, mechanical, or dustpan dredge. In accordance with the Federal Standard, dredged material placement sites are identified that represent the least costly alternative with sound engineering practices and meet environmental standards pursuant to the Clean Water Act. Placement of dredged material has occurred within the thalweg, shoreline, bottomland forests, agricultural fields, and beneficial use sites and for environmental restoration. Where recurrent dredge cuts occur, long-term site plans have been and are being developed. Placement sites are chosen in conjunction with On-Site Inspection Teams (OSITs), public coordination, and various other committees of river managers and biologists.

Detailed description of the St. Paul District's process and program can be found in their Channel Maintenance Management Plan (CMMP) (USACE 1996) and associated Environmental Impact Statement dated March 20, 1997. A Biological Assessment was prepared for the district and is included within the Environmental Impact Statement. That Biological Assessment is hereby incorporated by reference.

Detailed description of the Rock Island District's program is found in the Long Term Management Strategy for Dredged Material Placement, Main Report Mississippi River

(USACE 1990) and Illinois River (USACE 1995) and associated Dredged Material Management Plans.

Detailed description of channel maintenance dredging in the St. Louis District is found in the Environmental Impact Statement on operation and maintenance of Pools 24, 25, and 26, Mississippi and Illinois Rivers (USACE 1975). Dredged material is generally placed adjacent to the main channel where beneficial uses may occur, such as recreational beach creation, least tem island habitat, and island creation. Approximately 150 sites have been dredged in the past, with between 30 to 50 locations in the district dredged regularly for a total of approximately 8 million cubic yards annually.

1.2.4.2 River Regulatory Structures

The Corps of Engineers began building regulatory structures in 1878 with the authorization of the 4.5 foot channel. Since that time, many wingdams, closing dams, and bank-line revetment have been constructed and maintained to assist in channel maintenance. Regulatory structures help to reduce channel maintenance dredging, reduce costs and environmental effects of channel maintenance, restore or maintain natural river processes, and restore and enhance habitat quality. Use of structures is mainly limited to the Mississippi River with few used on the Illinois River.

Regulatory structures are described in more detail within various documents, including the 9-Foot Channel Environmental Impact Statements for each district, the CMMP (USACE 1996), and various other project-specific documents. In addition to meeting the goal of reducing channel maintenance, the planning and design of regulatory structures includes consideration of environmental impacts and compliance with various regulations. The process varies within each district, but involves coordination with other agencies. In St. Paul District, the process includes project review by the River Resources Forum. The Rock Island District has the Committee to Assess Regulatory Structures (CARS), which consists of representatives from the engineering, operations, and environmental officer and the U.S. Fish and Wildlife Service. In addition, a document produced by the St. Louis District describes their environmental river engineering project in which biologists and engineers cooperate to improve navigation and habitat diversity through the use of river structures (USACE, no date).

1.2.4.3 Clearing and Snagging

While clearing and snagging was once widespread prior to the completion of the current project, it now takes place only on the St. Croix and Minnesota Rivers. Snags on the river are recognized as providing valuable aquatic habitat and are only removed when safety is a concern. Removal of trees snagged in the navigation channel of the Minnesota River is an infrequent requirement. They are only removed when they become a navigation concern. On the St. Croix River, snag removal is limited to requests from the National Park Service and takes place only during safety concerns and channel blockage (USACE 1996).

1.3 Conservation Measures

Conservation Measures to minimize harm to listed species which are proposed by the action agency are considered part of the proposed action and their implementation is required under the terms of the consultation. The Corps included the following Conservation Measures in its April 1999 Biological Assessment:

1.3.1 Indiana bat

- Any activities that are determined to impact potential Indiana bat habitat will prohibit tree removal/clearing during the period of April 1 to September 30, unless mist net surveys indicate that no bats are present and there is no known roosting at the site. If a site is within a 5-mile radius of hibernacula, the period is April 1 to November 15.

- Forest management efforts within the range of the Indiana bat will be carried out to establish and maintain forest species and size class diversity in order to ensure a long-term supply of potential Indiana bat roosting trees.

- Current Corps of Engineers operations and maintenance programs will be evaluated to determine if additional opportunities exist to promote hardwood regeneration and species diversity in floodplain forests.

1.3.2 Decurrent false aster

- Each project that requires bankline or upland dredged material placement, or bankline habitat modification along the Illinois River or the UMR (within the known range of the species) will be addressed in a separate site-specific Tier II Biological Assessment to the U.S. Fish and Wildlife Service. An inspection of bankline habitat or upland placement sites will be conducted by Rock Island District personnel, St. Louis District personnel, or an expert contractor prior to habitat modification. If plants are encountered, Section 7 coordination will be completed prior to any habitat disturbance.

- All Section 10/404 actions for fleeting, port development or recreation-related facilities will be reviewed for potential impacts to federally proposed species and threatened or endangered species. Appropriate Section 7 review will include consideration of habitat potential at the project site by Corps regulatory staff and coordination with the U.S. Fish and Wildlife Service when necessary. Applicants for projects that require bankline or floodplain habitat modifications along the Illinois River or UMR within the existing range of the species may be required to conduct a survey for *B. decurrens*. If plants are encountered, Section 7 consultation will be completed prior to any habitat disturbance.

1.3.3 Pallid Sturgeon

- The St. Louis District will continue to conduct maintenance dredging outside the presumed "window" of pallid sturgeon reproduction of April 12 - June 30. In cases where emergency dredging is required, the U.S. Fish and Wildlife Service will be contacted.

- The St. Louis District's Avoid and Minimize Team will be asked to prioritize physical-biological monitoring of point-bar habitat of bendway weirs in the Middle Mississippi River in FY 2000.

1.4 Literature Cited

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5.0 Higgins' Eye Pearlymussel

5.1 Status of the Species

The Higgins' eye pearlymussel (*Lampsilis higginsi*) was listed as an endangered species by the Service on June 14, 1976 (Federal Register, 41 FR 24064). The major reasons for the listing of Higgins' eye was the decrease in both the abundance and range of the species. As stated in the original recovery plan [U.S. Fish and Wildlife Service (USFWS) 1983], Higgins' eye was never abundant and Coker (1919) indicated it was becoming increasingly rare around the turn of the century. The fact that there were few records of live specimens from the early 1900s until the enactment of the Endangered Species Act in 1973 was a major factor in its listing in 1976 (Hornbach 1999). A variety of factors have been listed as affecting Higgins' eye over time including commercial harvest, impoundment from the project, channel maintenance dredging and disposal activities, changes in water quality from municipal, industrial and agricultural sources, unavailability of appropriate glochidial hosts, exotic species and disease (USFWS 1983).

The historical distribution of Higgins' eye is not known with certainty. Although nowhere abundant, it is believed to have been widely distributed, inhabiting the UMR from just north of St. Louis, Missouri, to Minneapolis-St. Paul, Minnesota (Coker 1919). It was also found along the mainstem of the UMR and several of its tributaries including the Ohio, Illinois, Sangamon, Iowa, Cedar, Wapsipinicon, Rock, Wisconsin, Black, Minnesota, and St. Croix Rivers (USFWS 1983). The range of Higgins' eye has been reduced approximately 50 percent from its historic distribution to a 302-mile (485.9 km) reach of the UMR (Havlik 1980, Havlik 1987) and is now found only in the UMR upstream of Lock and Dam 19 at Keokuk, Iowa, in the St. Croix River between Wisconsin and Minnesota, the Wisconsin River, Wisconsin, and in the lower Rock River in Illinois (USFWS 1983). The southern-most population is believed to be pool 19 at River Mile 407 (Cawley 1984).

Higgins' eye occurs most frequently in medium to large rivers with current velocities of 0.49

to 1.51 ft/sec and in depths of 3.3 to 19.7 ft. It appears to prefer water with dissolved oxygen greater than 5 ppm and calcium carbonate levels greater than 50 ppm. The species is significantly correlated with a firm, coarse sand substrate (Hornbach *et al.* 1995a). Higgins' eye are usually found in large, stable mussel beds with relative high species and age diversity. Hornbach *et al.* (1995a) conclude Higgins' eye seems to be associated with areas of higher mussel species richness and generally higher mussel population densities.

The reproductive cycle of Higgins' eye is typical of the family Unionidae (Cummings and Mayer 1992). Males discharge sperm to the surrounding water; females obtain the sperm as they siphon water for food and respiration. Eggs are fertilized in gill sacs (marsupia) in the female; fertilized eggs are retained in the marsupia until they mature into glochidia and are released. The mantle edge near Higgins' eye's posterior end resembles a small swimming fish that attracts predator fish. Gill tissue containing glochidia protrudes between the mantle flaps. When the gill tissue is attacked by a fish, glochidia are released, thus enhancing the probability that glochidia will come into contact with a host fish. Released glochidia attach themselves to the gills of host fish. Successfully attached glochidia mature and excyst from hosts' gills as juvenile mussels; they settle to the substrate and become sedentary in the substrate, if it is suitable. The species is bradytictic (*i.e.*, a long-term breeder) retaining developing glochidia throughout the year, except for the period following glochidia release. Baker (1928) and Holland-Bartels and Waller (1988) indicate glochidia are carried in the gill marsupia through winter and released the following spring or summer.

Holland-Bartels and Waller (1988) tested 15 species of UMR fish and reported walleye (*Stizostedion vitreum*) and largemouth bass (*Micropterus salmoides*) as the most successful glochidia host fish for Higgins' eye, as determined by glochidial persistence and maturation to juvenile stage in the fish. Their study did not investigate sauger (*Stizostedion canadense*) nor smallmouth bass (*Micropterus dolomieui*). Waller (1995) considers these species also likely host fish in the UMR, particularly the sauger, whose range overlaps with Higgins' eye's more than smallmouth bass.

The Higgins' Eye Pearlymussel Recovery Team designated seven "Essential Habitat Areas" for Higgins' eye (USFWS 1983). The Essential Habitat Areas are believed to contain viable reproducing Higgins' eye populations. The Team believed recovery of the species could not be accomplished without maintaining the Essential Habitat Area populations. The seven Essential Habitat Areas are (1) the St. Croix River at Hudson, Wisconsin (River Mile 16.2 - 17.6); (2) the UMR at Whiskey Rock, at Ferryville, Wisconsin, Pool 9 (River Mile 655.8 - 658.4); (3) the UMR at Harpers Slough, Pool 10 (River Mile 639.0 - 641.4); (4) the UMR Main and East Channel at Prairie du Chien, Wisconsin, and Marquette, Iowa, Pool 10 (River Mile 633.4 - 637); (5) the UMR at McMillan Island, Pool 10 (River Mile 616.4 - 619.1); (6) the UMR at Cordova, Illinois, Pool 14 (River Mile 503.0 - 505.5); and (7) the UMR at Sylvan Slough, Quad Cities, Illinois, Pool 15 (River Mile 485.5 - 486.0). Three additional Essential Habitat Areas have been proposed by the Higgins' Eye Pearlymussel Recovery Team; the St. Croix River at Prescott, Wisconsin, and near Taylors Falls, Minnesota (Interstate Park), and the Wisconsin River near Muscoda, Wisconsin (Orion mussel assemblage) (Hornbach1999).

A recent threat to Higgins' eye comes from zebra mussels (*Dreissena polymorpha*), freshwater mussels native to the Black and Caspian Seas. Zebra mussels were introduced into Lake Erie in the late 1980s from ship ballast water discharge (Benson and Boydstun 1995). The species is now reproducing and invading North America's lakes and rivers, including the UMR.

5.2 Environmental Baseline

The environmental baseline is an analysis of effects of past and ongoing natural and human factors, excluding the proposed project, pertinent to the current status of the species and its habitat. The UMR and tributaries are the only remaining habitat for Higgins' eye; it is found only in the UMR upstream of Lock and Dam 19 at Keokuk, Iowa, in the St. Croix River between Wisconsin and Minnesota, the Wisconsin River, Wisconsin, and in the lower Rock River in Illinois (USFWS 1983). The southern-most population is believed to be pool 19 at River Mile 407 (Cawley 1984). Nearly all of the remaining habitat for Higgins' eye is within the 9-Foot Channel Project.

In the mainstem of the UMR, approximately 50 species of freshwater mussels have been recorded over time, although only 30 species are found at present [U.S. Geological Survey (USGS) 1999]. Natural processes and features that made the UMR valuable mussel habitat in general include moderate to high flow currents, stable substrates, the presence of aquatic vegetation and relatively high water quality. Water quality has generally improved in recent times in many navigation pools due in part to improved waste water and stormwater treatment, and improved agricultural land treatment and erosion control measures.

The environmental baseline for this Biological Opinion includes the time period from construction of the 9-Foot Channel Project to the present. It includes impacts to Higgins' eye from construction of the original project and approximately 60 years of operation and maintenance activities which, except for maintenance dredging and disposal activities, have not substantially changed during this period. As will be discussed in Section 5.2.2.3, Modern Dredging and Disposal Activities, maintenance dredging and disposal practices have substantially changed since the mid 1970's to avoid and minimize environmental impacts. The environmental baseline also includes effects of the exotic zebra mussel on Higgins' eye which has become established in the project area since approximately 1991 (Refer to Section 5.2.5, Exotic Species). The following parameters are addressed in the environmental baseline.

5.2.1 Water Level Regulation and Impoundment

The impoundment of the UMR increased the area of benthic habitat for freshwater mussels, and changed the character of the original floodplain. However, it is unclear how impoundment of the UMR affected Higgins' eye. Archeological (Theler 1987) and historical (Ellis 1936, Coker 1919) pre-dam mussel studies in Pool 10 suggest the relative abundance of Higgins' eye may have been higher after construction of the navigation project (Thiel 1981, Duncan and Thiel 1983, Wilcox *et al.* 1993). This may in part be attributable to increased abundance/availability of host fish and stable water conditions associated with the navigation project. Baker and Hornbach (1997) associated Higgins' eye with areas of low velocity (<0.3 m/s), but not areas with no flow. Post-lock and dam (post-impoundment) conditions probably contained more area of low velocity habitat that Higgins' eye preferred. However, there are also observations which indicate fewer species of mussels were found after the project was constructed compared to pre-project conditions; also, it is difficult to determine a direct link between the distribution and abundance of Higgins' eye due to habitat alteration since it apparently has always been a relatively minor component of the mussel community (Hornbach 1999).

Impoundment accelerated sedimentation rates throughout the UMR, especially in overbank and backwater areas. Since substrate type and stability is important to most freshwater mussel species, high sedimentation rates or changes in substrate composition likely impacted mussels in these areas.

Several fish species have been identified as suitable hosts for Higgins' eye glochidia, including walleye and largemouth bass (Waller and Holland-Bartels 1988). Although fish movement was restricted by the locks and dams, the abundance of these host fish increased upon completion of the project (Fremling and Claflin 1984).

Wilcox *et al.* (1998) examined various factors to determine the likelihood a particular fish species could pass through the locks and dams of the UMR, such as hydraulic conditions, dam design, migration behavior, and seasonal timing. They found two UMR dams which completely restricted upstream fish movement: Lock and Dam 1 in St. Paul, Minnesota, and Lock and Dam 19 in Keokuk, Iowa. The exchange of gene flow within a mussel species may be inhibited by restricted inter- and intra-pool movements of fish serving as the glochidial host (Romano *et al.* 1991); however, there are no supporting data for Higgins' eye. Also, restriction of fish movement may limit or prevent the dispersal of parasitic mussel glochidia; likewise there are no supporting data for Higgins' eye. However, Coker (1930) discussed the historical movement of skipjack herring (*Alosa chrysochloris*), blue sucker (*Cycleptus elongatus*), and blue catfish (*Ictalurus furcatus*) where these species moved upstream in the spring, followed by downstream migrations to overwinter in warmer waters. The extirpation of the ebony shell (*Fusconaia ebena*) and the elephant ear (*Elliptio crassidens*) in the upstream portion of the UMR was attributed to the inability of the mussels' host fish, skipjack herring, to navigate past lock and dam 19 (Fuller 1980).

As stated previously, there are no data which quantify the abundance of Higgins' eye on the UMR pre- and post project. It is therefore questionable whether impoundment had positive or negative effects on Higgins' eye; there simply are no conclusive data. However, we do know that impoundment of the UMR created more lentic (lake-like) habitat, favoring conditions for certain aquatic species. Lentic habitat also proved favorable to the proliferation of the exotic zebra mussel (Refer to Section 5.2.5, Exotic Species).

5.2.2 Channel Maintenance

5.2.2.1 Dredging

Following impoundment by the locks and dams, periodic dredging was necessary to maintain the 9-Foot Channel Project. Maintenance dredging primarily affected the main channel of the river. However, dredging may have also affected side channels, sloughs and backwater lakes and ponds through increased suspended sediment levels during dredging events.

Channel maintenance dredging was normally conducted in areas of shifting/shoaling bedload; any mussels within the dredge cut were killed by either the dredging operation or from placement of dredged materials at the disposal site. Mussel shells are often found at historic disposal sites. Bottom substrates in dredge cuts were often unstable or shifting for some time following dredging and thus provided poor habitat for recolonization by mussels (Burky 1983); consequently, frequent dredging of these cuts for maintenance of the project likely had little effect on freshwater mussels.

However, if maintenance dredging did not occur frequently (every 5 to 10 years), recolonization of dredge cuts by native freshwater mussels was possible. Miller and Payne (1992) collected Higgins' eye from a location in the East Channel of the UMR at Prairie du Chien, Wisconsin, which had been dredged 8 years earlier, indicating some recolonization of dredge cut areas does occur. Eckblad (1999) reported nearly half of 38 historic dredge cuts studied contained 14 mussel species within 5 years. Fuller (1980) reported a live Higgins' eye in the mussel community located at Hudson, Wisconsin, in the St. Croix River adjacent to a frequently dredged channel. Mussels which recolonized historic dredge cuts were likely killed through the dredging/disposal process.

Suspended solids and sedimentation from dredging operations may cause clogging and abrasion of gills and other respiratory surfaces in mussels, however there are no data documenting this for Higgins' eye. Miller and Payne (1998) found that mussels tolerated discrete disturbances (*i.e.*, commercial vessel passage, dredging, and extreme high water), but no determination of the long-term effects to mussels could be made from a data set spanning approximately 10 years. Since contaminants have an affinity for smaller-sized particles, not the coarse-grained material of most dredge cuts, maintenance dredging activities in the main channel likely had only minor impacts on contaminant movement in these areas.

5.2.2.2 Disposal of Dredged Material

As previously stated, there are no data quantifying the impacts of the 9-Foot Channel Project on freshwater mussels in general and Higgins' eye in particular. However, some inference to possible impacts from channel maintenance activities can be made. Historic dredged material placement sites were either upland or aquatic habitats located adjacent to the main navigation channel. Dredging was conducted using hydraulic or mechanical equipment. In early years, it was routine practice by the Corps of Engineers to dispose of dredged material as close to the dredge as possible, often filling aquatic habitats (in-water disposal) adjacent to the main channel. Permanent in-water disposal also included thalweg disposal, placing dredged material in the deeper water area of the main channel where it could be assimilated into the river's natural sediment transport system. Mussels located within in-water disposal sites were presumed killed by burial due to the large quantities of material involved.

Current placement of dredged material focuses on using historic disposal sites, temporary transfer sites, and upland sites. Use of upland disposal sites likely had only minor effects on freshwater mussels, including Higgins' eye from activities such as equipment access to the site, and subsequent wind and water erosion of dredged materials into the river. Hydraulic placement of dredged material on upland sites normally required a settling basin from which effluent was discharged to the river. The quality of this effluent depended on the composition of the sediment dredged, including contaminants.

5.2.2.3 Modern Dredging and Disposal Activities

Since the mid 1970's, there have been many improvements in channel maintenance dredging and disposal activities in the St. Paul, Rock Island and St. Louis Corps Districts. The majority of these improvements came as a result of the interagency Great River Environmental Action Team (GREAT) studies. Channel maintenance activities are now routinely coordinated with the Service and State natural resource agencies with the objective of avoiding/minimizing riverine habitat impacts which often occurred in the past. An example of this interagency planning and coordination effort is the recent completion of the Channel Maintenance Management Plan (CMMP) in the St. Paul District which addresses dredging and disposal activities (Corps 1996). Today, channel maintenance activities associated with the 9-Foot Channel Project are routinely coordinated with such interagency groups as the On-Site Inspection Teams, River Resources Forum and River Resources Coordinating Team to avoid/minimize project impacts to fish and wildlife resources of the UMR, including freshwater mussels.

Of the 10 existing/proposed Essential Habitat Areas, only the Harper's Slough and Prairie du Chien Essential Habitat Areas are located within the 9-foot navigation channel. Historically, channel maintenance dredging has not occurred and is not proposed at the Harper's Slough area.

The Prairie du Chien Essential Habitat Area includes both the main navigation channel and the East Channel. Historically, channel maintenance dredging has not occurred and is not proposed in the main navigation channel. However, the St. Paul District is responsible for commercial navigation in the East Channel which is approximately 18,480 feet long and passes by the City of Prairie du Chien, Wisconsin. The Corps of Engineers proposed a 449-foot dredge cut (2,500 cubic yards, Dredge Cut 1) at the north end of the channel, and a 351-foot dredge cut (1,900 cubic yards, Dredge Cut 2) at the City Dock to maintain commercial navigation; frequency of dredging for Cuts 1 and 2 were once in forty years and twice in forty years, respectively. A Biological

Opinion was prepared for this activity on June 28, 1993, concluding jeopardy for Higgins' eye (FWS 1993). The project has since been deferred by the St. Paul District (Corps 1996).

5.2.2.4 Channel Control Structures

Thousands of channel control structures (wing dams, closing dams, shoreline protection) were constructed on the UMR as part of the 4.5 and 6-Foot Channel Projects (USGS 1999); new or rehabilitated structures have also been constructed as part of the 9-Foot Channel Project. Channel control structures were constructed by the Corps of Engineers to maintain the channel alignment or constrict flows to improve the sediment transport efficiency through a reach of the river (Corps 1996). As such, channel control structures reduce maintenance dredging by concentrating flows in the main channel to scour (deepen) it for navigation. Construction of channel control structures likely covered benthic habitat and buried mussels.

Wing dams were constructed/rehabilitated in main channel and channel border habitats, areas which may have contained Higgins' eye. Wing dams increased current velocities and thereby increased scouring of main channel areas near the wing dams, producing the desired increased channel depths and/or widths for commercial navigation.

Closing dams were constructed to reduce flows into side-channel areas and force flows to the main channel. In addition to burial impacts from the footprint of these projects, impacts such as reduced volume of flow, reduced current velocities, reduced sediment input, and increased water residence time in backwaters probably occurred in the closed side channels and affected mussels. The increased flows in the main channel resulting from side channel closure affects main channel and channel border habitats as well. Resulting impacts to mussels depended on the amount of change in the rates of sedimentation and erosion.

Sedimentation patterns changed in these areas, with sediment transported through wing dam fields to downstream areas of lower velocity likely burying freshwater mussels located in these areas. However, since areas of velocity change attract fish species, high mussel densities were subsequently found on or in the vicinity of wing dams near suitable substrate; Higgins's eye mussels have been collected between and on wingdams in Pools 7 and 10 of the UMR. Placement of riprap for bank stabilization also attracted host fish and some of these areas were also likely to have rich mussel assemblages.

In summary, while construction of channel control structures and subsequent changes to sedimentation and erosion rates likely adversely affected some freshwater mussels, wing dams, closing dams and other rock structures also provided habitat for fish (some of which were hosts for glochidia) and freshwater mussels, including Higgins' eye.

5.2.3 Commercial Navigation

Commercial navigation resulting from the 9-Foot Channel Project affected mussels by increasing suspended solids through propeller wash over a mussel bed, by striking or dislodging mussels from the sediment by propeller wash, or by burying or crushing mussels during barge groundings or fleeting in shallow water conditions. In a study in lower pool 10, Miller and Payne (1997, 1998) found no significant difference in shell morphometrics of common to abundant species in areas where barge passage occurred and in two nearby reference sites where barges did not pass. However, at this same location mussel densities ranged from 6.36-13.85 mussels/ft^2 in the reference area, while mussels in the turning basin ranged from 2.04-4.52 mussels/ft^2 (Miller and Payne 1992). Miller and Payne (1996) and Miller and Payne (1998) reported velocity change from barge passage did not damage benthic organisms or their habitat in reasonably straight reaches having more than 2 feet of water below the vessels.

Substantial erosion can result from propeller wash as tows negotiate tight turns in the channel, enter and exit lock chambers, and while awaiting lockage along shorelines. These areas may have been subjected to severe propeller wash creating an environment too hostile for mussel colonization. Barges sometimes ground for a number of reasons including running into unknown shoals in the navigation channel, operating outside of the navigation channel in shallow water, or by being loaded past the nine-foot draft. Barge grounding in newly formed shoals is unlikely to impact mussels because the new, unstable substrate is unlikely to be colonized by mussels. Substantial local mussel damage is likely if a barge grounded on an off-channel mussel bed. Mussels, including Higgins' eye, would be buried, crushed, and/or scoured by propeller wash and the weight of the barge(s).

There are approximately 120 commercial port facilities in the range of Higgins' eye (UMR upstream of lock and dam 19; Minnesota River; Black River; and St. Croix River). Port facilities likely impacted native mussels through habitat loss during construction or subsequent maintenance of facilities.

Spills of contaminants and cargo from commercial tows may have impacted Higgins' eye and other freshwater mussels by direct mortality and by chronic effects. Benthic organisms are sensitive to a wide range of contaminants including ammonium, pesticides, and petroleum products, all of which are commonly transported on the UMR. Weirs, locks and dams, and mooring sites made navigation safer on the UMR and have reduced the potential for hazardous spills, but accidents and spills have occurred on the UMR. To date, there are no data which conclude that these spills had an adverse impact on Higgins' eye populations.

5.2.4 Recreation

Some recreational facilities likely degraded habitat for freshwater mussels. Construction activities, such as sand fill for beach or swimming areas, placement of fill or dredging to create marinas/harbors, or riprap for shoreline protection likely covered or otherwise permanently changed mussel habitat. Large recreational boats also likely impacted mussels by inducing abortion, by physically damaging mussels, or by other factors similar to those noted for commercial navigation. Swimmers have been observed collecting mussels at some beach sites; indiscriminate collections may have included Higgins' eye at some locations.

5.2.5 Exotic Species

Of major concern to the well being of mussels in general, and Higgins' eye in particular, was the introduction of zebra mussels to the UMR. Zebra mussels have been found throughout the UMR and have the potential to kill or otherwise eliminate native mussels, including Higgins' eye.

Adult zebra mussels attach to natural substrates, such as rocks, native mussels, wood, aquatic plants, and other zebra mussels. They also attach to man-made materials, such as fiberglass, iron, plastic, and concrete [U.S. Army Corps of Engineers (Corps) 1992]. Male zebra mussels release sperm directly to the water to fertilize eggs released to the water by the females. Large females release up to one million eggs per season (Corps 1992). Eggs are released when water temperatures reach 52-54° F. Immature zebra mussels (veligers) spread via passive drift on water currents. Adults and veligers attach to boat hulls, or to wet compartments, containers, and equipment in boats.

Zebra mussels affect other mussels by competing for food and by attaching to mussels in such numbers that infested mussels cannot travel or burrow. When infested by approximately 100 or more zebra mussels, native mussels cannot open their shells to respire, feed, burrow, or move, nor can they close their shells for protection. Zebra mussels can build up on native mussels in such numbers that waves and currents can dislodge native mussels from the substrate. Recent observations suggest infested native mussels may remove themselves from the substrate to escape zebra mussels (Miller 1995). Any of these impacts or combination of impacts can lead to the death of the infested mussel. Commercial and recreational boats are the main vectors carrying this species upstream and between water bodies, while currents carry veligers and juveniles downstream for further dispersal.

Zebra mussels attach themselves by byssal threads to nearly any hard surface. Zebra mussels reach a maximum length of about two inches, and hundreds of thousands can colonize a square meter. Up to 10,000 zebra mussels have been counted on a single mussel (Corps 1992). In Michigan's Lakes Erie and St. Clair, where zebra mussels have existed for several years, native mussel populations have been devastated, and in some areas eradicated (Masteller and Schloesser 1991, Gillis and Mackie 1991). Gillis and Mackie (1991) found a positive correlation between large increases in the average number of zebra mussels attached to native mussel shells and a decline in live native mussel numbers in Lake St. Clair. They also found that approximately 2,000 zebra mussels on a native mussel occluded the native mussel's siphon region completely, affecting its ability to filter. Colonization rates of approximately 0.4 to 1.0 g of zebra mussels per g of native mussel (dry mass) were recorded in native mussels immediately before extirpation from the Canadian side of the Detroit River (Ohnesorg *et al.* 1993).

Zebra mussels may have greater impact on some native mussel species than others although this is not conclusive. Haag *et al.* (1993), in a test of six species, found species in the Anodontinae subfamily to be the most sensitive to zebra mussels, followed by Lampsilinae and Ambleminae. Higgins' eye is a member of the subfamily Lampsilinae. Hunter *et al.* (1997 and references within) also found some species to be more sensitive to infestation than others. Giant floater (*Anodonta grandis*) was the most sensitive, followed by fragile papershell (*Leptodea fragilis*), fatmucket (*Lampsilis siliquoidea*), pink heelsplitter (*Potamilus alatus*), and black sandshell (*Ligumia recta*). Zebra mussel data collected by the Corps of Engineers at the Prairie du Chien Essential Habitat Area did not find a similar trend in sensitivity to zebra mussel infestation among species (Whiting 2000).

Zebra mussels were first discovered in Lake St. Clair in 1988 and in all the Great Lakes in 1989. They were found in the Chicago Sanitary and Ship Canal in 1989 and in the main stem of the Illinois river in 1991. The first zebra mussel collected from the UMR was taken in 1991, south of La Crosse, Wisconsin (Corps 1999). Miller (1995) sampled mussels of the lower East Channel at Prairie du Chien, Wisconsin. He found a maximum density of 14,000 zebra mussels/m^2 affecting up to 100 percent of the native mussels in some of his samples. He found the 1995 level of zebra mussels to be an order of magnitude greater than 1994 levels. An animated map of the spread of zebra mussels on the UMR produced by the U.S. Geological Survey (USGS) can be viewed on the Internet at www.nationalatlas.gov/zmussels1.html.

Unlike the Illinois River (via Lake Michigan and the Chicago Sanitary and Ship Canal), the UMR did not have an upriver source of veligers to spread downriver with the currents. Based on the zebra mussel's current distribution within the UMR, it appears tow traffic is the main transportation vector of upstream spread in the UMR upstream of the Illinois River (Carlton 1993, Keevin *et al.* 1992), while river currents are responsible for its downstream spread from the UMR/Illinois River confluence. With a less abundant upriver source, UMR zebra mussel populations grew at a slower pace than those in the Illinois River. Despite slower population growth rate, recent reports from Lake Pepin (Pool 4) and Pools 8-10 indicate high adult zebra mussel numbers and densities (>20,000/m^2) (Corps 1999, p. 71). Studies conducted by Minnesota and Wisconsin resource agencies since 1996 indicate Lake Pepin is the likely source population for the increasing zebra mussels in Pools 7 and 8 (Corps 1999, p. 71). Lake Pepin may be a substantial and long-term source of zebra mussels to the downstream UMR. Cope *et al.* (1997) found zebra mussel densities higher in the UMR downstream of Lake Pepin compared to densities upstream of Lake Pepin.

Based on current zebra mussel densities at dewatered lock chambers, it is likely that they harbor reproducing zebra mussels. Yager *et al.* (1994) estimated zebra mussel densities in lock chambers up to 68.4/m^2. Recent examination of Lock and Dam 5A revealed a much higher present density than was found in Yager *et al*'s earlier examination (Corps 1999, p. 72). Yager *et al.* (1999) report zebra mussel densities exceeding 7,000/m^2 at locks and dams downstream of Lake Pepin.

Hornbach *et al.* (1995b) stated the recent invasion of the UMR and probable future invasion of the St. Croix River with zebra mussels has cast the survival of Higgins' eye in doubt. With the continuing expansion of the zebra mussel and the limited locations of Higgins' eye populations, it is clear that Higgins' eye is under threat from the zebra mussel. Recent information from the East Channel Essential Habitat Area at Prairie du Chien, Wisconsin, supports this conclusion; the following discussion on zebra mussel impacts is from Corps unpublished 1999 data. Quantitative and qualitative samples for freshwater bivalves have been collected in the East Channel Essential Habitat Area of the UMR by personnel of the U.S. Army Engineer Waterways Experiment Station since 1984 (Table 1; Miller and Payne 1993). Samples have been collected at multiple sites where the river splits into an east and main channel near river mile 635. However, only data from a reference site, located downriver and away from a barge turning basin in the north section of the east channel, are presented in Table 1. These data provide a baseline for native mussel densities and recruitment rates prior to introduction and spread of zebra mussels. In addition, the data set illustrates effects of introduction and spread of zebra mussels on the native fauna.

All samples for mussels were collected by divers equipped with surface supplied air. Quantitative samples were obtained by having a diver excavate all substratum, which consisted of shells, live mussels, sand and gravel, from the confines of a 0.25 sq m aluminum quadrant. Substratum was washed through screens, live bivalves were removed, identified, and total shell length (SL) measured with digital calipers. From 10 to 60 quadrant were processed in any year. Qualitative samples were obtained by either having divers search an area for a specific period of time (15-30 min), or until a certain number of mussels were obtained. All searching was done by feel since visibility is extremely low.

Table 1 contains a measure of recent recruitment, as indicated by both the percentage of individual mussels less than 30 mm total SL, and the percentage of species with at least one individual less than 30 mm SL. Mussels less than 30 mm total shell length are typically 1-3years old; therefore a mussel in this size range could be evidence of recruitment that took place several years previously. In addition, Table 1 contains data on zebra mussel and native mussel density; the former were first collected in quantitative samples in 1993. Zebra mussel density increased to over 10,000 individuals/sq m in 1996. In 1998 density had dropped to approximately 1700 individuals/sq m and consisted mainly of older individuals and there were few new recruits in the population. In 1999, zebra mussel density increased to 56,507 individuals/sq m; it was observed that the older cohort present in 1998 had recruited and many juvenile zebra mussels were present. The substratum was virtually covered with a thick mat (up to 10 cm thick) of dead and living zebra mussels.

Table 1. Summary Data on Evidence of Recent Recruitment (Percent Individuals and Species Less than 30 mm Total Shell Length) and Unionid and Zebra Mussel Density in the East Channel of the Upper Mississippi River. Information from Corps 1999 unpublished data.

Year	No. of Quadrants	Unionid Recruitment		Mean Density Individuals/sq m	
		% Ind. < 30mm	% Species < 30mm	Unionids	Zebra Mussels
1984	20	10.7	45.8	113.6	
1985	30	15.2	66.7	149.1	
1987	30	34.4	75.0	68.5	
1988	30	24.5	52.0	79.5	
1989	10	16.3	44.4	83.6	
1990	30	14.8	42.1	80.0	
1992	30	17.6	36.8	44.7	
1993	30	41.5	44.4	28.3	2.0
1994	40	20.7	52.0	63.4	36.5
1996	60	32.4	66.7	59.2	10,853.0
1998	60	25.8	45.0	10.1	1,762.0
1999	60	0.0	0.0	1.7	56,507.0

For the first 10 years (from 1984 to 1994), evidence of recent recruitment for native mussels was highly variable and obviously unaffected by zebra mussels. For example, the percentage of live unionids less than 30 mm total shell length during this period varied from 10.7 percent in 1984 to a maximum of 41.5 percent in 1993. The percentage of species showing at least some evidence of recent recruitment ranged from a low of 36.8 percent in 1992 to a high of 75 percent in 1987. In 1996, when zebra mussel density was at its maximum, there were still juvenile native mussels present. However, the percentage of recent native mussel recruits, both species and individuals, dropped to 0.0 in 1999. This was certainly the result of the high zebra mussel densities in 1996 and 1997 that virtually eliminated recruitment of native species.

Mean density of all unionids varied from a maximum of 149 individuals/sq m to a minimum of 28.3 individuals/sq m in the first 10 years (1984-1994; Figure 1). Year- to-year variation could have been caused by slight differences in sample site locations, mortality of older age classes, and variation in recruitment. However, the rapid decline in native mussel density after 1996, first noted in 1998 (10.1 individuals/sq m) and continuing in 1999 (1.7 individuals/sq m) is certainly related to the presence of zebra mussels.

Live specimens of *L. higginsi* were not collected at the east channel location in 1999. In all previous study years this species was collected in the east channel, typically representing approximately one percent or less of the total native mussel fauna. It should be noted that this species is often collected alive where zebra mussels are present. In 1999 quantitative and qualitative samples were also collected in the main channel of the UMR, at a location approximately 1 mile from where samples were taken in the east channel. In a qualitative sample obtained in the main channel, consisting of 198 native mussels, 5, or approximately 2.5 percent, were live *L. higginsi*. Zebra mussel densities have always been less in the main channel than the east channel; hence, the impacts to native species is greater in the latter location.

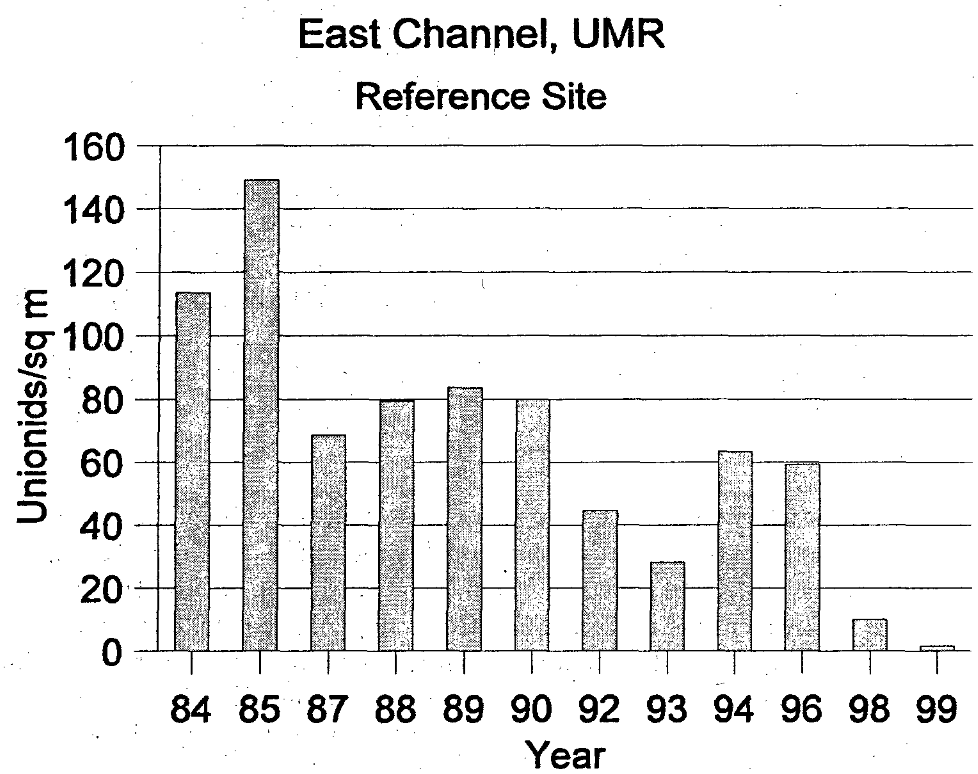

Figure 1. Density of native mussels collected at a reference site in the East Channel Essential Habitat Area, Upper Mississippi River, at Prairie du Chien, Wisconsin. (Corps, unpublished 1999 data).

5.2.6 Commercial Harvest

The commercial harvest of native freshwater mussels in the UMR peaked during the pearl button period of the 1920's and later during the cultured pearl era in the late-1980's and early 1990's. There are few documented reports of commercial clammers taking Higgins' eye. Other than harvest activities such as brailing that may have influenced the entire mussel community, little is known regarding the direct impacts of commercial harvest on Higgins' eye. Mathiak (1979), based on observations he made at a commercial clamming operation, concluded that hundreds of Higgins' eye had probably been harvested in 1975 before the species was placed on the endangered species list (paragraph from Hornbach 1999).

5.2.7 Summary

Since construction of the 9-Foot Channel Project approximately 60 years ago, the UMR continues to adjust from a riverine to a reservoir system. Because of the general lack of pre-project mussel data, it is impossible to assess with any certainty the impacts of the original 9-Foot Channel Project on Higgins' eye for use in establishing the environmental baseline for the Biological Opinion. In general, most adverse impacts to Higgins' eye were associated with the construction, operation and maintenance of the original 9-Foot Channel Project, and thousands of channel structures preceding it, for commercial navigation; these impacts are largely unknown and occurred nearly a century ago.

Studies before 1993 found no significant declines in the distribution and abundance of Higgins' eye on the UMR; since completion of the original Recovery Plan in 1983, its known range has been extended by 180 river miles and the Higgins' eye Recovery Team tentatively proposed an additional three Essential Habitat Areas (Hornbach 1999). For the species, the outlook was cautiously optimistic; it seemed plausible to consider that Higgins' eye populations were stable and perhaps recovering. Following the Flood of 1993, the Higgins' eye Recovery Team reassembled and began updating the original recovery plan.

Unfortunately, the recent invasion of the exotic zebra mussel has significantly changed this scenario. Due to upstream transport by commercial barge traffic, zebra mussels are now found throughout the UMR and have had a significant adverse impact on Higgins' eye and other native freshwater mussels. Based on Corps unpublished 1999 data on freshwater mussels from the Prairie du Chien Essential Habitat Area, and observations and recommendations of the Higgins' Eye Pearlymussel Recovery Team (Hornbach 1999), it is evident that zebra mussels are a significant threat to native freshwater mussels on the UMR, including Higgins' eye.

The environmental baseline for this Biological Opinion includes approximately 60 years of operation and maintenance of the original 9-Foot Channel Project. The environmental baseline also includes significant adverse impacts to Higgins' eye from the exotic zebra mussel at the Prairie du Chien Essential Habitat Area; it is probable that similar impacts have occurred to the other Essential Habitat Areas on the mainstem UMR. Fortunately, at this time, the existing/proposed Essential Habitat Areas on the Lower St. Croix (Karns 2000) and Lower Wisconsin Rivers are not infested with zebra mussels. The Proposed Action by the Corps of Engineers is to continue existing operation and maintenance activities for another 50 years. The effects of this action on Higgins' eye are described below.

5.3 Effects of the Proposed Action

5.3.1 Direct Effects

Direct effects in Biological Opinions are the direct or immediate effects on listed species caused by the proposed Federal agency action (including action to be permitted or authorized by the Federal agency). Direct effects of the proposed action include the effects of interrelated actions and interdependent actions. In this Biological Opinion, direct effects are effects likely to result to Higgins' eye from continued operation and maintenance of the 9-Foot Channel Project for the next 50 years.

The Biological Assessment (Corps 1999) was used in our assessment of project effects on Higgins' eye. As noted in the Biological Assessment, the Corps will consult with the Service on future operation and maintenance projects which may affect Higgins' eye to avoid and minimize adverse effects to the species. We also used information and observations of the Higgins' Eye Pearlymussel Recovery Team in determining effects of the Proposed Action on the species (Hornbach 1999). Our assessment of direct effects to Higgins' eye from continuing operation and maintenance of the 9-Foot Channel Project for an additional 50 years included the following parameters.

5.3.1.1 Operation of the 9-Foot Channel Project

5.3.1.1.1 Water Level Regulation

Refer to Section 5.3.1.1.2, Impoundment

5.3.1.1.2 Impoundment

The major adverse effects of water level regulation and impoundment of the UMR for an additional 50 years are associated with continuing the upstream transport of exotic zebra mussels by commercial barge navigation as discussed in Section 5.3.2.1.4, Exotic Species. Other impacts to Higgins' eye from continuing existing water regulation and impoundment activities by the Corps of Engineers for an additional 50 years are considered to be minor in comparison to zebra mussel impacts and any major physical changes to Higgins' eye habitat which occurred in the years following construction of the 9-Foot Channel Project approximately 60 years ago.

Water level management projects are being proposed on the UMR by the Corps of Engineers in cooperation with natural resource agencies as a tool to restore aquatic vegetation in the navigation pools. These projects will likely involve partial drawdowns of 1-3 feet at the dam in selected pools. Impacts to freshwater mussels including Higgins' eye will be assessed separately, including Section 7 consultation, as each project is developed. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.1.2 Maintenance of the 9-Foot Channel Project

5.3.1.2.1 Dredging

Refer to Section 5.3.1.2.1, Disposal

5.3.1.2.1 Disposal

Adverse impacts may occur to individual Higgins' eye on a site-specific basis from continuing modern dredging and disposal activities for another 50 years on the UMR. Unless relocated, any Higgins' eye located within the boundaries of a new/historic dredge cut will be killed as a result of the project.

No impacts are anticipated for upland disposal sites having 100 percent containment of dredged materials and effluent. Unless relocated, all Higgins' eye located within the boundaries of a new/historic dredged material placement site will be killed. Higgins' eye may also be killed as a result of dredging necessary to reach the disposal site, and placement of pipeline(s).

Use of temporary dredged material transfer sites may affect mussels through direct coverage, but the likelihood of Higgins' eye mussels colonizing open water areas of the transfer sites is quite low. The shifting sand substrates in these areas are typically poor habitat for freshwater mussels and are secluded from the UMR flow and these areas are frequently disturbed either through placement of dredged materials, or excavation of materials during transfer operations.

In-water placement of dredged material including thalweg disposal may affect freshwater mussels through direct burial. Depending on the thickness of the material, mussels buried by in-water placement of dredged material may perish as a result of asphyxiation and/or starvation. Although no permanent in-water placement of dredged material is proposed in the upstream pools, it is a common practice in lower reaches of the UMR (Corps 1999); it could also be considered in the future for other reaches (Corps 1996). In addition to the potential for burial, mussels inhabiting re-handling sites could be re-dredged and deposited on upland locations, leading imminently to death.

Today, channel maintenance activities associated with the 9-Foot Channel Project are routinely coordinated with such interagency groups as the On-Site Inspection Teams, River Resources Forum and River Resources Coordinating Team to avoid/minimize project impacts to fish and wildlife resources of the UMR, including freshwater mussels. The Corps of Engineers will continue to conduct individual Section 7 consultation on all projects which are likely to affect Higgins' eye (Corps 1999). Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized. Based on the above, we do not anticipate major adverse impacts to Higgins' eye from continued maintenance dredging and disposal activities on the UMR for an additional 50 years.

5.3.1.2.3 Clearing and Snagging

Removal of trees or other obstructions from the navigation channel could affect Higgins' eye through disturbance of bottom substrates. Most snagging, however, occurs on the Minnesota River, outside the current known range of Higgins' eye.

Higgins' eye does occur in the Lower St. Croix River, but any snag removal is conducted only upon request of the National Park Service. Snag removal has not been requested for the past 20 years and in that time the National Scenic Riverway was established. The Corps does not anticipate snagging on the St. Croix River during the next 50 years (Corps 1999); we therefore do not anticipate major adverse impacts to Higgins' eye from clearing and snagging operations. In addition, the Corps of Engineers will enter into Section 7 consultation with the Service for any clearing and snagging project which is likely to affect Higgins' eye. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.1.2.4 Channel Structures/Revetment

5.3.1.2.4.1 Wingdams

Refer to Section 5.3.1.2.4.5, Closing Structures

5.3.1.2.4.2 Bendway Weirs - Not applicable

5.3.1.2.4.3 Bank Revetment/Off-Bank Revetment - Not applicable

5.3.1.2.4.4 Chevron Dikes - Not applicable

5.3.1.2.4.5 Closing Structures

Unless relocated, all Higgins' eye located within the boundary of proposed modifications to existing rock structures, or new closing dams, wing dams or rip rap will be killed. The Corps of Engineers will continue to conduct individual Section 7 consultation on all projects which are likely to affect Higgins' eye (Corps 1999). Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized. Based on the above, we do not anticipate major adverse impacts to Higgins' eye from maintenance activities or new channel structures during the next 50 years.

5.3.1.2.5 Lock and Dam Rehabilitation

A programmatic Environmental Impact Statement on major rehabilitation of locks and dams 2-22 (Corps 1989) exists and is incorporated by reference. The Service's biological opinion on the project found the rehabilitation action was likely to incidentally take Higgins' eye. Rehabilitation of lock and dam structures would not cause permanent loss or disturbance of aquatic habitat. The work would entail repair or replacement of existing structures with very little intrusion into aquatic habitat during future rehabilitation. Petroleum or other hazardous materials can spill during construction, so contractors working on rehabilitation would have approved Environmental Protection Plans with spill prevention measures and spill response plans to minimize the likelihood of a spill. Once the structures are rehabilitated, their operation would be more efficient and safer for traffic, thereby reducing the spill potential. Riprapping is occasionally performed in downstream portions of spillways. Many of these areas attract high fish concentrations, hence some have rich mussel assemblages. Unless relocated, any Higgins' eye present in the riprap placement area(s) would be killed by the construction activities.

5.3.1.3 Summary of Direct Effects

Although the major direct effects to Higgins' eye from the 9-Foot Channel Project and preceding navigation projects occurred nearly a century ago, continued channel maintenance activities (dredging, disposal, clearing and snagging, channel structures/revetment) for an additional 50 years may affect individuals or populations of Higgins' eye at a local scale. As noted in the Biological Assessment (Corps 1999), the Corps will consult with the Service on future operation and maintenance projects which may affect Higgins' eye. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.2 Indirect Effects

Indirect effects in Biological Opinions are project impacts produced after the action has been completed or after the permitted activity terminates. Indirect effects are caused by or result from the proposed action, are later in time, and are reasonable certain to occur. They may occur outside the area directly affected by the proposed action.

5.3.2.1 Navigation Related Indirect Effects

5.3.2.1.1 Tow Traffic

Since most commercial navigation occurs in the main navigation channel and has been on-going since the project was completed early this century, impacts to Higgins' eye from individual tows (e.g., prop wash, increase in suspended sediments, physical impacts from grounding) are considered to be minor in nature and of a local scale. Any major physical changes to Higgins' eye from commercial navigation traffic in the main navigation channel occurred in the years following construction of the 9-Foot Channel Project.

Continued commercial barge transportation on the UMR for an additional 50 years will continue to transport zebra mussels on the UMR upstream from the Illinois River within the range of Higgins' eye to the detriment of freshwater mussels in general, and Higgins' eye in particular. Continued upstream transport of zebra mussels is a significant adverse impact to the species (Refer to Section 5.3.2.1.4, Exotic Species).

5.3.2.1.2 Fleeting

Continued use of existing barge fleeting areas, or development of new fleeting areas may adversely affect freshwater mussels including Higgins' eye. Under Section 10 of the Rivers and Harbors Act of March 3, 1899, the placement of permanent structures below ordinary high water on navigable waterways require a Department of Army permit. Where installation involves discharge of dredge or fill materials, permits under Sections 401 and 404 of the Clean Water Act of 1977 are required. Future expansion of fleeting areas or terminals will be subject to regulation and environmental review including Section 7 consultation with the Service. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.2.1.3 Port Facilities

Continued use of existing port facilities, or development of new port facilities may adversely affect freshwater mussels including Higgins' eye. Under Section 10 of the Rivers and Harbors Act of March 3, 1899, the placement of permanent structures below ordinary high water on navigable waterways require a Department of Army permit. Where installation involves discharge of dredge or fill materials, permits under Sections 401 and 404 of the Clean Water Act of 1977 are required. Any future expansion or new construction projects, or maintenance of existing facilities, would follow Section 404 permitting guidelines; Section 7 consultation with the Service would occur through the application process. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.2.1.4 Exotic Species

The major adverse effect of the Proposed Action on Higgins' eye is from indirect effects of zebra mussels, an exotic species which is transported upstream from the Illinois River by commercial barge traffic dependent on the 9-Foot Channel Project. Zebra mussels are considered to be a significant threat to Higgins' eye populations on the UMR (Hornbach 1999). Continued operation and maintenance of the 9-Foot Channel Project for an additional 50 years will facilitate the continued upstream transport of zebra mussels by commercial barge traffic if they are infested with zebra mussels. The upstream transport of zebra mussels will continue to replenish zebra mussels in the UMR, encompassing all UMR mainstem Higgins' eye Essential Habitat Areas, and potentially the existing/proposed Essential Habitat Areas on the Lower St. Croix and Lower Wisconsin Rivers which are not currently infested with zebra mussels.

Unfortunately, the likelihood of another exotic species invading the UMR is high; one exotic mussel that could impact Higgins' eye in the same fashion as the zebra mussel over the next 50 years is the quagga mussel (*Dreissena bugensis*). In 1997, it was well established in the lower Great Lakes and the St. Lawrence Seaway and has been found at one location in the UMR near St. Louis, Missouri (see Internet site www.entryway.com/seagrant/feb97q.jpg).

5.3.2.1.5 Contaminants

A large spill of salt, fertilizer, ammonia or petroleum products from a tow(s) could kill all freshwater mussels in its path. The overall consequence however, can not be predicted, but would depend on the amount and type of substance spilled, the effectiveness of spill containment and cleanup, river stage, and other factors (USFWS 1993). The same conditions apply to contaminants hauled by rail; in most cases railroad facilities are located on both sides of the UMR floodplain. We would anticipate that a spill(s) may adversely affect Higgins' eye on a local scale.

5.3.2.2 Recreation Related Indirect Effects

5.3.2.2.1 Facilities

Any future expansion or new construction projects, or maintenance of existing facilities, would follow Section 10/404 permitting guidelines. Section 7 endangered species consultation with the Service would occur through the permit application process. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.2.2.2 Large Vessels

Large recreational vessels will also continue to transport zebra mussels on the UMR within the range of Higgins' eye to the detriment of freshwater mussels in general, and Higgins' eye in particular referenced in Section 5.3.2.1.4, Exotic Species. However, while recreational boats may transport zebra mussels on the UMR, commercial barge transportation is the predominant upstream carrier. Barges have larger submerged surface areas than recreational craft for mussel attachment; they remain for long periods in the water (exposure and attachment time); they travel long distances within the UMR, from below lock and dam 26 to the head of navigation in Minneapolis, Minnesota; and they travel within and downstream of the Illinois River, a constant source of zebra mussels from Lake Michigan to the UMR.

5.3.2.2.3 Beach Use – Not applicable

5.3.2.2.4 Exotic Species

Refer to Section 5.3.2.1.4, Exotic Species

5.3.2.2.5 Contaminants

The risk to Higgins' eye and other freshwater mussels from small contaminant spills from recreational craft are considered to be minor in comparison to the potential for a large spill from commercial navigation or rail traffic. Refer to Section 5.3.2.1.5, Contaminants.

5.3.2.3 Summary of Indirect Effects

The indirect effects to Higgins' eye from continued zebra mussel persistence in the UMR are significant. As long as commercial barges, towboats and other equipment are infested with zebra mussels, continued operation of the 9-Foot Channel Project will facilitate the upstream transport of zebra mussels to the detriment of Higgins' eye and other native freshwater mussels on the UMR. Based on Corps unpublished 1999 data on freshwater mussels from the Prairie du Chien Essential Habitat Area, and observations and recommendations of the Higgins' Eye Pearlymussel Recovery Team (Hornbach 1999), it is evident that zebra mussels are a significant threat to native freshwater mussels on the UMR, including Higgins' eye. Due to upstream transportation by commercial barge traffic, zebra mussels are now found throughout the UMR. The indirect effect of continued operation and maintenance of the 9-Foot Channel Project for another 50 years will continue to facilitate this upstream transportation vector, and increase the risk of establishing zebra mussels at currently uninfested mussel beds containing Higgins' eye in the Lower St. Croix and Lower Wisconsin Rivers.

5.3.3 Interrelated Effects

An interrelated activity is an activity that is part of the proposed action and depends on the proposed action for its justification.

5.3.3.1 Timber Management – Not applicable

5.3.3.2 Cabin Leases - Not applicable

5.3.3.3 General Plan Lands - Not applicable

5.3.3.4 Public Use Sites - Not applicable

5.3.3.5 Corps Port Facilities

Two Corps-operated port facilities exist within the range of Higgins' eye: one in the St. Paul District (Fountain City, Wisconsin) and one in the Rock Island District (LeClaire, Iowa). No live Higgins' eye have been found recently near the Fountain City Base. The LeClaire Service Base is located immediately downstream of a high quality mussel bed. Any future maintenance or construction activities at these locations will be coordinated with the Service under Section 7 of the Endangered Species Act. Through the Section 7 process, impacts to Higgins' eye will be avoided/minimized.

5.3.4 Interdependent Effects

An interdependent activity is an activity, not part of the proposed project, that has no independent utility apart from the proposed action under consultation.

5.3.4.1 Missouri River Navigation - Not applicable

5.3.4.2 U.S. Coast Guard (USCG) Buoy Tending

A potential impact of buoy placement and maintenance by USCG is the transport of zebra mussels into previously unoccupied habitat; USCG buoy tending vessels entering the St. Croix River from the Mississippi River would very likely carry zebra mussels from the Mississippi into the St. Croix. This could lead to establishment of a zebra mussel population in the St. Croix River. However, on September 27, 1999, a Service representative met with representatives of the U.S. Coast Guard and other Federal, State, and local stakeholders regarding the maintenance of navigation aids in the St. Croix River. It was agreed that the USCG would replace the existing heavy metal buoys with lighter easy-to-service buoys and with on-shore daymarkers. This action will preclude the USCG having to bring zebra mussel-infested cutters and work barges into the St. Croix River.

5.3.5 Cumulative Effects

Cumulative effects in biological opinions are effects of future state, local, or private actions, not involving Federal action, reasonably certain to occur in the action area [50 CFR 402.14 (g)(3) & (4)]. Cumulative effects include the effect of future State, Tribal, local or private actions that are reasonably certain to occur in the action area considered in this Biological Opinion. Future Federal actions unrelated to the proposed action are not considered in this section because they will undergo separate consultation pursuant to Section 7 of the Act.

Cumulative effects will not be subject to future Section 7 review because no Federal action is associated with them. The Service knows of no projects reasonably certain to occur in the action area that will produce cumulative effects. Residential, industrial, and recreational uses will likely continue to increase on the UMR and may change habitat conditions for Higgins' eye.

5.4 Conclusion

5.4.1 Jeopardy Analysis

After reviewing the current status of Higgins' eye pearlymussel, the environmental baseline for the action area, the effects of the proposed action, the cumulative effects, and effects of exotic zebra mussels, it is the Service's biological opinion that the action, as proposed, is likely to jeopardize the continued existence of Higgins' eye pearlymussel. No critical habitat has been designated for this species, therefore, none will be affected.

The problem is not commercial barge transportation, per se. The ongoing problem is commercial barge transportation on the UMR with vessels and equipment infested with zebra mussels. The major adverse effect of the project on Higgins' eye is from the indirect effects of zebra mussels, an exotic species which is maintained by the conditions created from the operation and maintenance of the 9-Foot Channel Project and is transported upstream from the Illinois River by commercial barge transportation dependent on the navigation project. This jeopardy opinion is based on the Service's assessment of the project in light of information on Higgins' eye's range wide population size, distribution, and status and on reasonably likely zebra mussel impacts. Continued operation and maintenance of the 9-Foot Channel Project will facilitate upstream transport of zebra mussels by large vessels using navigation locks, thereby continuing to replenish zebra mussels in the UMR and encompassing all UMR mainstem Higgins' eye Essential Habitat Areas. Continued operation and maintenance of the 9-Foot Channel Project also facilitates maintenance of existing populations of zebra mussels in navigation pools and lock chambers, which are more hospitable for zebra mussels than unimpounded riverine conditions.

The proposed project makes possible large-scale commercial barge transportation on the UMR. But for the project, there would be no commercial barge navigation. But for the commercial barge traffic, there would be no continuous, large-scale transport and replenishment of zebra mussels in the UMR upstream of the Illinois River. While recreational boats may transport zebra mussels on the UMR, commercial barge transportation is the predominant upstream carrier. Barges have larger submerged surface areas than recreational craft for mussel attachment; they remain for long periods in the water (exposure and attachment time); they travel long distances within the UMR, from below Lock and Dam 26 to the head of navigation in Minneapolis, Minnesota; and they travel within and downstream of the Illinois River, a constant source of zebra mussels from Lake Michigan to the UMR. Furthermore, the proposed project provides ideal habitat for zebra mussel colonization (Corps 1999). Zebra mussel colonization is restricted by water velocity. Colonization is most successful in slow-moving water. The operation and maintenance of the 9-Foot Channel Project provides these ideal slow-moving water conditions.

Zebra mussels affect native freshwater mussels like Higgins' eye by competing for food and by attaching to native mussels in such large numbers that infested mussels cannot travel or burrow. When infested by many zebra mussels, native mussels cannot open their shells to respire, feed, burrow, or move, nor can they close their shells for protection. Zebra mussels can build up on native mussels in such numbers that waves and currents can dislodge native mussels from the substrate. Any of these impacts or combination of impacts can lead to the death of the infested mussel; if enough adults die, reproduction and recruitment may be limited to the point that the mussel population and community cannot be maintained.

Thus, the Service believes it is reasonably certain that operation and maintenance of the navigation pools and project-dependent commercial barge transportation will facilitate zebra mussel persistence in the UMR to the extent that the likelihood of recovery and survival of Higgins' eye is appreciably reduced.

5.4.2 Reasonable and Prudent Alternative

Regulations (50 CFR 402.02) implementing Section 7 of the Act define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that: (1)

can be implemented in a manner consistent with the intended purpose of the action; (2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; (3) are economically and technologically feasible; and (4) would, the Service believes, avoid the likelihood of jeopardizing the continued existence of the listed species or resulting in the destruction or adverse modification of critical habitat.

The continued operation and maintenance of the 9-Foot Channel Project facilitates a continued and maintained source of zebra mussels in the UMR, and thus, appreciably reduces the likelihood of survival and recovery of Higgins' eye. To avoid jeopardizing the continued existence of the species, while continuing operation and maintenance of the 9-Foot Channel Project, guarding against further Higgins' eye population loss due to zebra mussel infestation is imperative. To achieve this, it is necessary to (1) establish, reestablish, or augment Higgins' eye populations in areas currently uninfested by zebra mussels, (2) prevent zebra mussel infestation above Lock and Dam 3 and into the Lower Wisconsin River, and (3) reverse current zebra mussel population trends in the UMR, especially downstream of Lock and Dam 3 to the confluence of the Illinois River.

Continued operation and maintenance of the 9-Foot Channel Project will facilitate zebra mussel persistence in the UMR, and is likely to decimate all Higgins' eye Essential Habitat Areas on the UMR. To insure against the eventual loss of these essential populations, Higgins' eye populations need to be relocated into areas unaffected by zebra mussels. The Wisconsin Department of Natural Resources (WIDNR) and Illinois Natural History Survey surveyed zebra mussel veligers from Lock and Dam 2 to Lock and Dam 11, and at the mouth of the St. Croix River (WI DNR unpublished 1998 data). No veligers were found coming from the St. Croix River, indicating it did not support a reproducing population of zebra mussels in 1998. During August 1999, the WIDNR conducted another veliger survey in the St. Croix River and found 17 veligers in a sample taken from the mouth of the river just downstream of the railroad bridge at the City of Prescott, Wisconsin. The veliger density was 0.18 veligers per liter with a bimodal size distribution (Benjamin per comm 1999). Veligers were found at all UMR locks and dams sampled in 1998 (Locks and Dams 2 through 11). Very few veligers, however, were found in the tailwater of Lock and Dam 3 (0.1 veligers per liter) compared to the tailwater of the downstream dams (range 18 to 487 veligers per liter; WIDNR unpublished 1998 data).

Zebra mussel densities at Corps locks and dams in the St. Paul District are substantially lower upstream of Lock and Dam 3 than downstream. Corps personnel have routinely monitored zebra mussels at locks and dams in the St. Paul District (Upper St. Anthony Falls to Lock and Dam 10) since 1992. Combined zebra mussel densities for 1993 and 1994 averaged 0.9 individuals/ sq m at upstream locks (Upper St. Anthony Falls to and including Lock and Dam 3), and 18.4 individuals/ sq m at downstream locks (Locks and Dams 4 - 10). By 1995, zebra mussel densities were so large at downstream locks that they were described as being "in layers and too numerous to count by divers;" in comparison, zebra mussel densities at upstream sites were only 3.8 and 6.6 individuals/ sq m in 1995 and 1999, respectively (Yaeger 1999).

Based on these data, we conclude that there is limited to absent zebra mussel reproduction occurring upstream of Lock and Dam 3, in the St. Croix River, Lower Wisconsin River, and in other tributaries. Thus, in protecting these currently uninfested areas from zebra mussel impacts, and mussel relocation sites per implementation of the Reasonable and Prudent Alternative (Section 5.4.2), it is also necessary to minimize the probability of zebra mussel transport upstream from Lock and Dam 3.

A Reasonable and Prudent Alternative (RPA) is for the Corps to (1) develop a Higgins' eye Pearlymussel Relocation Action Plan and (2) to conduct a reconnaissance study to control zebra mussels in the UMR. This RPA will involve the following:

1. Conduct a Higgins' eye relocation feasibility analysis and prepare a Higgins' eye Pearlymussel Relocation Plan to address the feasibility of the Reasonable and Prudent Alternative in avoiding jeopardy and reducing incidental take. This will be an interdisciplinary/interagency effort designed to determine the most efficient and cost effective combination of methods and measures to provide for relocation of Higgins' eye. The effort will follow the Corps' traditional six-step planning process and include the utilization of pilot field studies if necessary. A report on the findings of this effort will be provided to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665, by April 30, 2001, for approval. If the feasibility study concludes that relocation of Higgins' eye is not feasible, the Corps will immediately reinitiate consultation with the Service under Section 7 of the Endangered Species Act to develop an alternative RPA to avoid jeopardy. If relocation is feasible, implementation of the Higgins' eye Pearlymussel Relocation Plan is to commence by June 1, 2001. The feasibility analysis will include, but not be limited to, the following:

   Development of milestones or success criteria and time frames for achieving such goals,

   Development of a relocation site criteria plan based on political, institutional and biological parameters,

   Development of a search plan for candidate relocation sites,

   Implementation of the search plan, including pilot projects necessary to develop site suitability criteria and to evaluate candidate relocation sites,

   Preparation of a prioritized list of candidate relocation sites, with narrative evaluation,

   Evaluation of relocation methods including relocation of adult and juvenile Higgins' eye from existing populations, hatchery (*in situ*) propagation and rearing where juveniles would be used in relocation, and release of glochidia-laden host fish,

   Funding the relocation of Higgins' eye at selected site(s) and evaluating success at the site(s). The relocation plan will include a monitoring component to determine the effectiveness of the relocation program in re-establishing viable populations of *L.*

higginsi. Annual status reports of the relocation and monitoring program will be submitted for approval to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665,

Support and continuation of pilot projects to evaluate relocation techniques. Biologists from the Wisconsin and Minnesota Departments of Natural Resources and Service are planning to conduct emergency relocation efforts for Higgins' eye in fiscal year 2000, perhaps before this formal Section 7 consultation is completed. The Corps will continue to support these actions when Section 7 consultation is completed, including post-relocation monitoring of pilot projects.

2. Conduct a zebra mussel reconnaissance study to determine the necessary measures, projected costs, and likelihood of success in controlling zebra mussels in the UMR. This will be an interdisciplinary/interagency effort designed to determine the most efficient and cost effective combination of measures necessary to control zebra mussels. Based on these findings, the Corps will pursue, for those actions that fall within their perview, the appropriate project planning and other steps to implement the necessary measures. Also, the Corps and the Service will seek the assistance of other agencies in pursuing those additional actions, which are within the authorities of those agencies and deemed necessary to control zebra mussel infestation. The reconnaissance report will be provided to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665, by April 30, 2002, for approval. If the zebra mussel control program is feasible, it will include a monitoring component to determine the effectiveness of the program in controlling zebra mussel abundance and distribution. Annual status reports of the zebra mussel control and monitoring program will be submitted for approval to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665.

   If the reconnaissance report or a subsequent feasibility report concludes that zebra mussel control in the UMR is not feasible, or feasible actions under the perview of the Corps are not implemented within two years of their identification, the Corps will immediately reinitiate consultation with the Service under Section 7 of the Endangered Species Act to develop an alternative RPA to avoid jeopardy.

   Because this Biological Opinion has found jeopardy to Higgins' eye pearlymussel, the Corps is required to notify the Service of its final decision on the implementation of the reasonable and prudent alternative.

5.5 Incidental Take Statement

Section 9 of the Act and Federal regulation pursuant to Section 4(d) of the Act prohibits the take of endangered and threatened species without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such activity. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, and sheltering. Incidental take is defined as take incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of Section 7(b)(4) and Section 7(o)(2), take incidental to and not an intended part of the agency action is not considered prohibited taking under the Act, provided such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the Corps for the exemption in Section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps fails to assume and implement the terms and conditions, the protective coverage of Section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement (50 CFR, 402.14(I)(3)).

5.5.1 Level of Take

The Service has developed the following incidental take statement based on the premise that the RPA will be implemented. The Service anticipates that incidental take of Higgins' eye will occur between issuance of this biological opinion and complete implementation of the RPA, as well as, for a short period following implementation of the RPA (perhaps a 5 to 10-year period). During this period, zebra mussels will continue to adversely affect Higgins' eye in the UMR mainstem, and, to a lesser extent, in the St. Croix River as well. Incidental take will occur in the form of harassment (e.g., competition for food, locomotion impairment) and harm (e.g., suffocation, starvation). Based on current zebra mussel densities, we anticipate all UMR Higgins' eye essential populations, except the Orion population, could be harassed or harmed during this interim period. In a few of these areas, adverse impacts could lead to complete loss of recruitment and substantial mortality.

Incidental take will be difficult to detect and monitor, however. The reasons for this are as follows. First, changes to fitness parameters (e.g., decreased recruitment) often are not manifested in a year or two but rather over several years (e.g., 5 to 10 years). This is especially true for species that occur at low densities. Second, detection of impaired or recently morbid specimens is unlikely given the low abundance of Higgins' eye. Third, the normal variance in Higgins' eye population trend is great, a consequence of low densities, and thus, identifying a declining trend over such a short time-frame is problematic. We believe, however, the level of take can be monitored by observing the population trends of other native freshwater mussels and zebra mussel densities. At high infestations, the differences in mussel susceptibility to mortality and stress from zebra mussels are likely minor (Corps 1999). If other native co-habitant species are reduced by zebra mussels, it is also likely true for Higgins' eye. Thus, the general level of Higgins' eye take can be determined by monitoring the trend of the co-existing mussel community and the concurrent trend of zebra mussels.

Although we suspect that nearly all reproductive potential will be lost and that mortality could be substantial in some Essential Habitat Areas during this interim period, we do not anticipate that recruitment will be impaired or that mortality will be significant in the following four Essential Habitat Areas: Interstate Park, Hudson, Prescott, and Orion. Based on population monitoring at Prairie du Chien (at Prairie du Chien, natural density fluctuations in the native mussel community were typically less than 50 percent of mean values), we anticipate that the native mussel diversity and density should not decline by more than 40 percent and that zebra mussel density in these four areas will not exceed $6000/m^2$, a density at which native mussel impacts have been observed (Cope *et al* 1997), within the next 8 to 10 years in any of the four Essential Habitat Areas identified above.

We believe that this anticipated interim level of take due to zebra mussel infestation is unlikely to jeopardize the continued existence of Higgins' eye. Zebra mussels obtain greater abundance in areas of high native mussel densities. Thus, zebra mussel occurrence (and consequently, adverse impacts) is likely to be greater in areas supporting high density mussel beds, i.e., Essential Habitat Areas. It is, therefore, unlikely that residual populations occurring outside these Essential Habitat Areas will be substantially impacted during this 8 to 10-year period. Although the majority of take will be concentrated in Essential Habitat Areas in the UMR and this take is likely to include a substantial reduction in recruitment, it is unlikely that all individuals within these areas will be lost during this interim period. Hence, throughout the implementation phase of the RPA, Higgins' eye populations in the UMR are likely to persist and future reproductive potential will likely be maintained. Furthermore, based on recent surveys, zebra mussel densities are much lower in the upper pools (above Lock and Dam 3) and are unlikely to have significant adverse impacts to Higgins' eye populations in such areas during this time-frame. Thus, an upstream source for re-colonization and augmentation will persist. Lastly, following implementation of the RPA, relocated populations will provide additional sources of specimens to replenish once infested Essential Habitat Areas. In short, the impact of the anticipated take will be marked but the effects will be short-term and mitigated following implementation of the RPA.

In addition to impacts associated with zebra mussels, continued operation and maintenance of the project may result in the take of Higgins' eye from specific channel maintenance activities such as dredging and modification of channel control structures. However, this programmatic biological opinion does not authorize any incidental take associated with such channel maintenance activities that may occur. These actions will require further Section 7 review. Although the level of anticipated incidental take from these actions is currently unknown, we believe such take will not rise to the level of jeopardy. The reasons for this are (1) in most instances, such projects will occur in the main navigation channel, and thus, will not affect Essential Habitat Areas, (2) such projects will have localized effects affecting only a few individuals, and (3) as the specific locations and project descriptions are developed and undergo Section 7 review, measures further minimizing the impacts of any such incidental take will be required and implemented.

5.5.2 Reasonable and Prudent Measures

The measures described below are non-discretionary, and must be implemented by the agency for the exemption in Section 7(o)(2) to apply. The Corps has a continuing duty to implement the activity covered by this incidental take statement. If the Corps fails to adhere to the terms and conditions of the incidental take statement, the protective coverage of Section 7(o)(2) may lapse.

The Service believes the following Reasonable and Prudent Measures (RPM) are necessary and appropriate to minimize take of Higgins' eye:

1. Implement a monitoring program for Higgins' eye and other unionids in the UMR,

2. Investigate and implement opportunities to protect live Higgins' eye individuals within Essential Habitat Areas in the UMR during the interim period between issuance of the biological opinion and implementation of the RPA,

3. Develop and implement an action plan to monitor abundance and distribution of zebra mussels on the Upper Mississippi River System (UMRS; navigable portions of the UMR, Illinois, Black, Lower Minnesota and Lower St. Croix Rivers, Lower Wisconsin River, and the Upper St. Croix River upstream of Taylors Falls, Minnesota). This should include continuing the monitoring of zebra mussel impacts to Higgins' eye at the Prairie du Chien Essential Habitat Area. These studies are currently being conducted by personnel from the Corps of Engineers Waterways Experiment Station (WES) and are critical to understanding zebra mussel impacts to native species.

5.5.3 Terms and Conditions

To be exempt from the prohibitions of Section 9 of the Act, the Corps must comply with the following terms and conditions which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. In monitoring Higgins' eye and other native mussel populations, assessments will include estimates of density, recruitment and genetic variability among populations in Essential Habitat Areas as well as secondary habitats identified in the Higgins' Eye Pearlymussel Recovery Plan (Hornbach 1999). Annual reports on the findings of this effort will be provided for approval to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665.

2. In developing and implementing the feasible provisions of a plan to protect live Higgins' eye individuals within Essential Habitat Areas, the Corps may involve an interdisciplinary/interagency effort designed to determine the most efficient and cost effective combination of methods and measures to protect Higgins' eye individuals at Essential Habitat Areas downstream of the St. Croix River and Wisconsin River (Hornbach 1999). Annual reports on the findings of this effort shall be provided for approval to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665.

3. The zebra mussel monitoring effort will also include assessing the ongoing effects of zebra mussel densities on Higgins' eye and other native mussels in the 10 Essential Habitat Areas and secondary habitats (Hornbach 1999). The plan will also evaluate dispersal of zebra mussel veligers, and develop models to determine source populations and population dynamics of zebra mussels on the UMRS. The action plan will include a specific plan for the Lower St. Croix River and Lower Wisconsin River that would avoid or minimize colonization by zebra mussels. Annual reports on the findings of this effort shall be provided for approval to the Field Supervisor, U.S. Fish and Wildlife Service, 4101 East 80th Street, Bloomington, Minnesota, 55425-1665.

4. The Service believes that all Higgins' eye essential populations may experience some incidental take as a result of the proposed action. However, this incidental take will be difficult to detect and monitor. As an indicator of Higgins' eye take, we believe that no more than a 40 percent decline in the native mussel densities will occur and that zebra mussel densities will not exceed 6000/m^2 in any of the four currently uninfested Essential Habitat Areas during the interim period. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable an prudent measures provided. The Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

5.6 Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. Conduct a feasibility analysis using the traditional Corps planning process to enhance the opportunity for fish passage at locks and dams for species of fish that are hosts of the *L. higginsi* glochidia. Implement feasible measure(s). Existing locks and dams are semi-permeable barriers to fish movement between navigation pools on the UMR. Water control gates at Lock and Dam 5 are raised out of the water less frequently than other navigation dams on the UMR in the St. Paul District. There has been only one live *L. higginsi* found in the UMR upstream of Lock and Dam 6 (Pool 1 in 1993; Cawley 1996). Since upstream expansion of *L. higginsi* is dependent on transport of glochidia by host fish species, existing locks and dams are restricting the upstream distribution of *L. higginsi*. Priority should be given to locks and dams in the St. Paul District. Existing data indicate the majority of the population of *L. higginsi* in the UMR occurs in Pool 10 and downstream areas (Cawley 1996). Enhancing fish passage at Locks and Dams 9, 10 and upstream sites may increase the number of host fish

carrying glochidia to the upper navigation pools.

2. Implement a public outreach effort, in coordination with the Service and other resource agencies, as a means to disseminate information on life history and distribution of zebra mussels, ecological importance of native mussels to include Higgins' eye, control measures to limit the spread of zebra mussels on the UMR and tributaries, and status of mussel relocation efforts.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

5.7 Literature Cited

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6.0 Winged mapleleaf mussel

6.1 Status of the Species

The winged mapleleaf was listed in 1991 as endangered because (1) the species has been eliminated from nearly all of its original 11-state range and at listing was known from only one population along a 13-mile segment of the St. Croix River, (2) its population was small and therefore vulnerable to catastrophic stochastic events, such as toxic spills or low water levels, (3) its reproductive success was threatened by its low population, and (4) changes in land use practices in the watershed were anticipated because the watershed is close to a growing metropolitan area (USFWS 1997). The plan recognized zebra mussels as a grave potential threat. Zebra mussels are repeatedly found on recreational boats entering the St. Croix River from the Mississippi River and the reduction of the threat of zebra mussel invasion is a priority to the Winged Mapleleaf Recovery Team (USFWS 1997); for these reasons zebra mussels is a major concern to the well-being of the winged mapleleaf.

Little is known of the details of winged mapleleaf reproduction, feeding ecology, and specific habitat requirements (USFWS 1997). The brooding period for winged mapleleaf was presumed to be late May to the middle of July (Baker 1928). Recent investigation, however, revealed the brooding period of winged mapleleaf extended from about mid-September to mid-October in the St. Croix River (Heath *et al.* 1999). Hove *et al.* 1999 have begun laboratory studies to determine the host fish species for winged mapleleaf. In 38 trials on 29 fish species and on one species of mudpuppy, no species were found to provide complete winged mapleleaf glochidial metamorphosis. Recently, two glochidia successfully were released from a channel catfish in the laboratory (Hove 2000). However, the host glochidial species for winged mapleleaf remains unknown.

Much research on habitat requirements of the remnant St. Croix River population has been done during the last decade. Winged mapleleaf occurs in riffles with clean gravel, sand, and

A New Distributional Checklist of Minnesota Fishes, With Comments on Historical Occurrence

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Abstract

Historical documents, Minnesota Department of Natural Resources stream surveys, and the 66,000 record distributional database of the James Ford Bell Museum of Natural History (1879-2002) were used to produce a field-usable checklist of the 160 fish species known from Minnesota waters and waters shared with its boundary states and Canadian provinces. The checklist includes distribution by eight major drainages, the conservation status for each species, and reference to nomenclatural changes over the past 20 years. Fishes are arranged according to the latest interpretations of phylogenetic relationships among species and supraspecific taxa. New distributional information is presented for six species introduced since 1986 and for 70 species with previously established occurrence.

Introduction

Minnesota has a rich heritage of ichthyological study dating back to the late 1700s. The earliest reports (1799-1846) of fishes from Minnesota waters come from myriad notes and journals of explorers and early settlers of the region (see Keating, 1823; Lanman, 1847; Coues, 1897). The first scientific contribution regarding Minnesota fishes was that of Louis Agassiz (1850), who reported on 30 species from Lake Superior. Charles Girard (1858) reported four species (*Amia calva*, *Ameiurus nebulosus*, *Ambloplites rupestris* and *Lepomis macrochirus*) from the vicinity of Fort Snelling and two other species (*Ichthyomyzon castaneus* and *Hiodon tergisus*) from two other Minnesota localities. Seth Meek (1892) collected 12 species from the Cedar River near Austin, Minnesota, and professors U. O. Cox and A. J. Woolman surveyed the lakes and streams of southwestern Minnesota, including the upper Minnesota River and Big Stone Lake, in 1882 and 1889 (Cox, 1894; Woolman, 1895).

Cox (1897) published a preliminary survey of the fishes of Minnesota based in part on collections made by members of the Minnesota Geological and Natural History Survey under the direction of State Zoologist, Henry F. Nachtrieb. In effect, this publication provided the first ichthyofaunal list for the state. In 1920, Thaddeus "Doc" Surber published a preliminary catalogue of fishes and fish-like vertebrates, which included 119 species—15 more than reported by Cox (Surber, 1920). Collections made by CCC (Civilian Conservation Corps), WPA (Works Progress Administration), and Soil Erosion Service crews from 1935 to 1942 culminated in the publication of the first edition of *Northern Fishes* (Eddy and Surber, 1943). Since then, thousands of fish collections have been made and more than 100 papers have been written about fish distributions and abundance by researchers associated with various state and federal agencies and the University of Minnesota (e.g., Eddy and Surber, 1947; Underhill, 1957, 1986; Eddy and Underhill, 1959, 1974; Nordlie et al., 1961; Eddy et al., 1963, 1972; Moore and Braem, 1965; Phillips and Underhill, 1967, 1971; Underhill and Moyle, 1968; Peterson, 1971; Anderson et al., 1977; Bailey et al., 1993; Fago and Hatch, 1993; Goldstein et al., 1996, 1999; Koel and Peterka, 1998).

Since the publication of the most recent checklist (Underhill, 1989), fish species in Minnesota have undergone numerous faunistic, distributional, phylogenetic, nomenclatural, and conservation status changes. Several historical inaccuracies also have been discovered. With the increasing use of regional, state, and local species lists to guide resource management decisions, it is vitally important to have historically accurate and reliable floral and faunal lists. The purpose of this paper is to provide in one concise reference: 1) a field-usable, comprehensive distributional and phylogenetic checklist of all fish species known historically from Minnesota waters and waters shared with its boundary states and Canadian provinces, 2) brief accounts of six recent non-indigenous species introductions, and 3) brief accounts of new distributional records and corrections to historical occurrences for 70 additional species.

Methods

Phylogeny and Nomenclature—World-wide diversity estimates and evolutionary divergence times were derived from Nelson (1994). We followed the phylogeny of Janvier (1997) in recognizing basal groups of fishes. Within the teleosts, we followed the phylogeny of Nelson (1994). Species were listed alphabetically following Mayden et al. (1992) with these exceptions. We retained *Notropis dorsalis* in place of *Hybopsis dorsalis* as bigmouth shiner, *Notropis topeka* in place of *N. tristis* as Topeka shiner (Opinion 1821, 1995), *Lepomis gulosus* in place of *Chaenobryttus gulosus* (Mabee 1993), and *Ammocrypta clara* in place of *Etheostoma clarum* as western sand darter (Near et al 2000). We also replaced the genus *Stizostedion* with the genus *Sander* as recognized by Kottelat (1997).

Distribution and Historic Occurrence—We included in the checklist all species determined to have been collected since the late 1700s in Minnesota and its boundary waters with the exceptions noted below. To determine historic occurrence, we reviewed documents referenced in the Introduction and examined fish survey records of the Minnesota Department of Natural Resources and Fish Collection records (N = 65,958) of the James Ford Bell Museum of Natural History (JFBM). We also consulted fish biologists from the Minnesota Department of Natural Resources (MDNR), the Minnesota Sea Grant Program, the Ontario Ministry of Natural Resources (OMNR), the U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (USFWS), and the Wisconsin Department of Natural Resources (WDNR). Fish collection records were accepted if we had originally identified a specimen, found an extant voucher specimen or photograph that we could identify, or found an ichthyologist who could attest to the validity of a specimen. We included species collected in other states or

Canadian provinces if they were collected in waters contiguous with those of Minnesota. Such species were clearly indicated in the checklist. We did not include introduced species that have not persisted (but see *Ictalurus furcatus* below), nor did we include non-indigenous species on the sole basis of angling records. Conservation status was determined by the Minnesota Department of Natural Resources in accordance with state statutes (Minnesota Rules, Chapter 6134).

Comprehensive Checklist

We intended the checklist to stand alone so that it could be used in the laboratory as a data tally sheet, in the field (in laminated form) as a quick reference for watershed distribution, and in the classroom as a general reference for ichthyology students. Therefore, we designed it as a single-page (back-to-back), information-rich reference to the phylogenetic position, nomenclature, present distribution, and conservation status of Minnesota fishes (Figure 1). The symbols and codes used on the checklist are either self-explanatory or explained on the second page of the list.

At present, we recognize 158 species that occur within the boundaries of Minnesota, plus two others that occur in boundary waters. Of these 160 total species, we consider 139 to be native to Minnesota waters, plus one native in contiguous boundary waters. We have added four species collected in Minnesota waters since 1989 (*Coregonus nipigon*, *Gasterosteus aculeatus*, *Neogobius melanostomus*, and *Proterorhinus marmoratus*), two species collected in Minnesota boundary waters (*Apeltes quadracus* and *Fundulus dispar*), and one species of dubious historical occurrénce (*Ictalurus furcatus*).

Historically, ichthyologists have recognized eight major drainages within the state, which are shown at the bottom of the last column in the checklist (Figure 1). The boundary between the Upper Mississippi River drainage and the Lower Mississippi River drainage is St. Anthony Falls, which acted historically as a barrier to upstream fish migration (Eddy et al., 1963). The greatest number of species occurs in the Lower Mississippi River drainage (80% of the 158 species), followed by the St. Croix River (67%), Minnesota River (60%), Lake Superior (53%), Red River of the North (52%), Upper Mississippi River (47%), Rainy/Lake of the Woods (46%), and Missouri River (27%)

drainages. The number of genera and families shows the same drainage sequence (Table 1). The Lake Superior and Upper Mississippi River drainages have the greatest number of species introductions and the highest introduced to native species ratios. The Missouri River drainage has the fewest species introductions, but the Lower Mississippi River drainage has the lowest introduced to native species ratio. The latter drainage also harbors 76% of Minnesota's endangered, threatened, and special concern species (Table 1).

Recent Non-Indigenous Species Introductions

Between 1986 and 2001, six species of non-indigenous fishes were discovered in Lake Superior and its estuaries. Five of the species were found in Minnesota waters. We do not have unequivocal evidence in each case, but we believe that all six introductions occurred when ballast waters were bilged from commercial transport vessels.

1. *Gasterosteus aculeatus*—The threespine stickleback was first collected in the Lake Superior drainage in March, 1987. Three specimens were taken from south Neebing Marsh in Thunder Bay Harbor, Ontario (Hartviksen and Momot, 1989). Additional specimens were collected in 1994 in Minnesota waters of Lake Superior. One was taken from the Poplar River near Lutsen and many were removed from Taconite Harbor cooling tanks on 8 June. Another specimen was seined from the Duluth-Superior Harbor at Connor Point, Wisconsin, on 6 July (S. A. Stephenson, OMNR, pers. comm.). Many specimens have been collected in Wisconsin waters of the Harbor and further east at the mouth of Saxine Creek since 1994 (Lyons et al., 2000; D. Pratt, WDNR, pers. comm.). From 1998 to 2000, over 100 specimens were taken from Grand Marais Harbor, Baptism River, Split Rock River, and Skunk Creek, indicating that this species has become established along the North Shore of Lake Superior.

2. *Apeltes quadracus*—The fourspine stickleback was collected from the mouth of the Neebing-McIntyre River in Thunder Bay, Ontario, in 1986 and 1987 and later from two other locations in bays of Lake Superior (Hartviksen and Momot, 1989; Momot and Stephenson, 1996). No specimens have been taken from Minnesota waters. We are unable to predict the likelihood of population establishment in Minnesota.

3. *Morone americana*—Nine specimens of white perch were collected from the St. Louis River Estuary in 1986 and 1987. Although this species has invaded other Great Lakes through migration, it most likely reached the St. Louis Estuary via ballast water. An analysis by Johnson and Evans (1990) suggested that a viable population should be difficult to establish in the St. Louis River system or in western Lake Superior since cold winter water temperatures produce high mortality in young-of-the-year white perch. However, Lyons et al. (2000) pointed out that the St. Louis Estuary lies outside winter air isotherm delimiting the species' range elsewhere in the Great Lakes. The continued collection of this species throughout the 1990s indicates that a winter-hardy population has been established in the estuary.

4. *Gymnocephalus cernuus*—The European ruffe was first collected from the St. Louis River below the Fond du Lac dam in 1986 by EA Engineering, Science and Technology, Inc. biologists and in three additional locations the following year by WDNR and USFWS biologists (Pratt et al., 1992). It has been collected in the St. Louis estuary every year since. It was taken from Sand Point and Two Harbors in Lake Superior in 1996 and from Keene Creek in Duluth in 1998. The ruffe has established a robust population in the estuary and perhaps western Lake Superior and is competing with native yellow perch (*Perca flavescens*) and trout-perch (*Percopsis omiscomaycus*) (Ogle et al., 1995). It also may be drastically reducing the forage base of emerald shiners (*Notropis atherinoides*) and spotfin shiners (*Notropis hudsonius*) (Evrard , 2000). It is unlikely that natural predation will control ruffe population growth and expansion (Ogle et al., 1996).

5. *Neogobius melanostomus*—Another ballast arrival is the round goby, which was collected in the Duluth-Superior Harbor twice in 1995. Both specimens were adults. No new specimens were found in 1996, but many were collected from the St. Louis Estuary in 1998 and subsequently, indicating that a population has been established (Minnesota Sea Grant, 1998; Lyons et al., 2000). Populations have been established in other parts of the Great Lakes as well (Marsden and Jude, 1995; Jude, 2001).

6. *Proterorhinus marmoratus*—The most recent Lake Superior ballast water arrival is the tubenose goby. Two specimens were collected from the Duluth-Superior Harbor in 2001, one on the Minnesota side by USGS biologists and one on the Wisconsin side by WDNR biologists in September 2001. One specimen was less than one year old and may have originated from natural reproduction. In 2002, ten more specimens were collected in the St. Louis River estuary from Dwight's Point to Hog Island (D. Pratt, WDNR, pers. comm.). This

species is established but not common in Lake St. Clair, which occurs between Lake Erie and Lake Huron (Jude 2001.).

Recent Distributional Records and Corrections to Historical Records

Since 1989, many stream surveys have produced an unprecedented number of new distributional records. In addition, the construction of the JFBM Fish Collection electronic database has given us the ability to quickly track new distributional records and to systematically discover errors made in the past. Below we report on changes to the published distributions of 70 species.

Among the 70 species are eight whose ranges have extended beyond St. Anthony Falls. For approximately 10,000 years, since the Mankato ice sheet receded, St. Anthony Falls acted as an effective barrier to upstream fish dispersal in the Mississippi River (Eddy et al., 1963). After the opening of the upper lock at the Falls in 1963, it became possible for fish to move beyond this barrier at least 20 km upstream to the Coon Rapids Dam, which was built in 1914. However, we had no evidence of any dispersal until 1976 when *Hypentilium nigricans* (northern hogsucker) was reported without voucher from the Mississippi River near Monticello (above the Coon Rapids dam). In 1995, *Ictalurus punctatus* (channel catfish) and *Lepomis humilis* (orangespotted sunfish) were collected just below the dam near Dunn Island, and *Percina maculata* (blackside darter) was collected in two locations above the dam. Since then, *Noturus flavus* (stonecat), *Pylodictis olivaris* (flathead catfish), *Pimephales vigilax* (bullhead minnow), and *Dorosoma cepedianum* (gizzard shad) also have been discovered at or above the Coon Rapids Dam (see individual accounts).

1. *Lampetra appendix*—The American brook lamprey was designated a species of special concern in 1984 because of its apparent extirpation from the Credit River near Savage, Minnesota, its only historic occurrence in the Minnesota River drainage (Coffin and Pfannmuller, 1988). At that time, other records indicated its distribution was restricted to a few sites in southeastern Minnesota and one site in Valley Creek, a tributary of the St. Croix River. Although the species still appears to be absent from the Credit River, it has been found recently in three other Minnesota River tributaries—Eagle Creek (JFBM 27717) and an unnamed tributary to the Minnesota River (JFBM

36607) in Scott County and Assumption Creek (JFBM 31057) in Carver County. Additionally, the American brook lamprey is now known from 48 sites in the St. Croix and Lower Mississippi drainages, which here includes the Upper Iowa River system (and see Mundahl, 1994, 1995).

Underhill (1989) reported this species mistakenly from Lake Superior drainage. Fago (1992) accepted a single record from the Bois Brule River in Wisconsin, but we have no specimens from the Lake Superior drainage.

2. *Ichthyomyzon fossor*—The northern brook lamprey was unknown from Minnesota until 1986, when it was taken from the Blackhoof River in the Lake Superior drainage (JFBM 23793). Based on its presence in western Wisconsin and southern Manitoba, Cochran and Pettinelli (1988) predicted the discovery of additional populations in Minnesota. Since 1986, northern brook lampreys have been taken from an additional six sites in the Lake Superior drainage, 25 sites in the Rainy/Lake of the Woods drainage (e.g., JFBM 31401), one site in the Zumbro River system (JFBM 24040), and one site in the Upper Iowa River (JFBM 31289). Clearly, this is a native species that has been overlooked and misidentified for a long time.

3. *Ichthyomyzon gagei*—The southern brook lamprey was unknown from Minnesota waters until 1985 (Cochran, 1987), when it was taken from a small tributary of the St. Croix River (JFBM 22867). Currently, it is known from a total of 36 sites in the St. Croix River and 13 of its tributaries in Carlton, Chisago, Kanabec, Pine, and Washington counties. This St. Croix population (which extends into Wisconsin) is over 900 km away from the next northernmost southern brook lamprey population (Cochran, 1987). Cochran favored the hypothesis that the St. Croix population is a relict of *I. gagei* (i.e., left over from when the continuous range included Minnesota), but he recognized the possibility that it may represent an independently evolved satellite species of the chestnut lamprey (*Ichthyomyzon castaneus*). A recent molecular genetic study (Mundahl et al., 1997) and a morphological study (Lyons et al., 1997) strongly suggest that this population is *I. gagei*.

4. *Acipenser fulvescens*—Lake sturgeon have not been reported from the Minnesota River drainage in any checklist or fish compendium, and we have no specimens in the Bell Museum Collection. However, we have accepted two recent angling records from the

Minnesota River based upon published photographs. Both photographs permit accurate identification. The first specimen was caught below the dam in Granite Falls in 1991, and the second was caught at Riverside Park in New Ulm in 1993.

5. *Scaphirhynchus platorynchus*—Eddy and Underhill (1974) reported this species from the lower St. Croix River and indicated that it was "common years ago." Fago and Hatch (1993) listed it as "pre-1975." On 4 April 2001, Mark Hove of the University of Minnesota collected a single specimen from the Dalles area (river kilometer 81.9) during a scuba diving excursion. To our knowledge, this is the first documented specimen from the entire drainage (JFBM 35086).

6. *Lepisosteus osseus*—There are only two records for longnose gar within the Lake Superior drainage, one from Nipigon Bay in Ontario (a 1961 record reported by Hartviksen and Momot 1989) and one in the lower reach of the Brule River, WI (reported by Moore and Braem, 1965). On the basis of these records, Underhill (1986, 1989) considered longnose gar as native to the Lake Superior drainage. Momot and Stephenson (1996) and Fago (1992) were not able to verify either record, and numerous subsequent surveys in these and other areas of the drainage have failed to collect the species. Thus, we no longer include this species in the Lake Superior drainage ichthyofauna.

We still include this species in the Red River of the North drainage list, but it has not been documented there since 1893 (Woolman, 1895). Koel (1997) considered it extirpated.

7. *Hiodon alosoides*—Underhill (1989) indicated that there were no verifiable Minnesota records of goldeye from the Lower Mississippi drainage below the St. Croix River confluence, and Fago (1992) reported no Wisconsin records for this reach after 1972. Pitlo et al. (1995) regarded goldeye as rare to uncommon in this reach of the Mississippi. We now have 13 specimens from 8 sites between Pools 2 and 9; ten of these specimens were collected in 1994 and 1995 and one in 2001 (e.g., JFRBM 28110). Despite the recent records, we still consider goldeye to be rare in the lower Mississippi River, and Wisconsin lists it as endangered (Wisconsin Department of Natural Resources 2000).

8. *Anguilla rostrata*—Underhill (1989) reported the American eel from the Upper Mississippi River drainage (above St. Anthony Falls) based on the single sight record acknowledged by Eddy et al (1963). Occasional unsubstantiated reports of this species have been made

from the vicinity of St. Cloud and Coon Rapids Dam. It may be that eels sometimes circumvent the dam, but we have no specimens from above St. Anthony Falls. We follow Eddy et al. (1963) in not considering this catadromous species to be part of the Upper Mississippi River fish community.

Our only Lake Superior drainage specimens are from the Blackhoof River (JFBM 22158), but Lyons et al. (2000) reported specimens from Lake Superior proper. We have added this species to the Lake Superior list.

9. *Alosa chrysochloris*—In 1986, skipjack herring were collected in Lake Pepin for the first time since 1928. Additional specimens were taken from Lake Pepin in 1993 (JFBM 27248) and again in 2001 (JFBM 37733). Water levels in the Mississippi River were exceptionally high in all three of these years, which may have allowed skipjacks to negotiate the dams and reach Lake Pepin. Young-of-the-year were found in 1986 and 1993 but were not collected in subsequent years, suggesting that reproduction is not on-going.

Underhill (1989) did not report skipjack herring from the Minnesota River, having overlooked a specimen captured near Savage in 1899 (JFBM 7335). We also recognize this species historically in the lower St. Croix River based on old records reported and examined by Greene (1935) and accepted by Fago (1992) and by Fago and Hatch (1993).

10. *Dorosoma cepedianum*—The gizzard shad is the most recent of eight species to extend its range from the Lower to Upper Mississippi River drainage. It was collected from an unnamed tributary to the Mississippi River downstream of the Coon Rapids Dam, Anoka County, in August 2000 (JFBM 35357).

11. *Campostoma oligolepis*—The largescale stoneroller was first verified from Minnesota by Burr and Smith (1976), who reported it from four sites in the Zumbro and Root river systems. Subsequent re-analysis of JFBM collections revealed its presence in the Forest River of North Dakota (1952), and in the Redwood (1955) and Yellow Medicine rivers (1973) of Minnesota. We since have verified it from 18 sites in the Zumbro and Root river systems of the Lower Mississippi River drainage. It also has been taken from Sand Creek, Snake and Knife rivers, Rush Creek, and the St. Croix River in the upper St. Croix River system and from Otter Creek in the Cedar River system (e.g., JFBM 27541). It is likely that the unusually disjunct distribution in Minnesota is a result of continued misidentifications of this species.

12. *Couesius plumbeus*—Underhill (1989) reported the lake chub from the Rainy River/Lake of the Woods drainage based on a single specimen (JFBM 10477). We have been unable to locate the specimen and the locality data in the catalogue are incomplete. Thus, we no longer recognize the lake chub as occurring in this drainage, although Scott and Crossman (1973) reported it within this drainage in Ontario.

13. *Cyprinella spiloptera*—Underhill (1989) reported the spotfin shiner from the Missouri River drainage in Minnesota. Two of the authors believe that they encountered this species somewhere in the drainage in recent years, but we can find no specimens. Thus, we no longer recognize the spotfin shiner as occurring in this drainage.

14. & 15. *Nocomis biguttatus* and *Notemigonus crysoleucas*—Underhill (1989) reported the hornyhead chub and the golden shiner from the Missouri River drainage, but we have been unable to find specimens. Thus, we no longer include them in the list from that drainage.

16. *Notropis anogenus*—The status of the pugnose shiner in Minnesota is unclear. Prior to 1970, it was known from 40 sites across a wide portion of central Minnesota, where it inhabited vegetated areas in clear glacial lakes and streams. Post-1970 surveys have located pugnose shiners at 39 sites, but only four of these coincide with historical sites (e.g., Cass Lake, JFBM 26660; Fish Lake, JFBM 29365). Removal of littoral vegetation from lakes and an increase in lake and stream siltation have been linked to this species' demise in other states (Smith, 1979; Trautman 1981; Lyons et al., 2000), and many pre-1970 Minnesota sites now exhibit these types of degradation. However, it is now clear that this species is more widespread than once thought.

Until recently, the only record of pugnose shiner from the Lake Superior drainage was in the Floodwood River, collected by John Moyle in 1941 (uncatalogued). With no vouchered specimen, Eddy and Underhill (1974) excluded it from the species list for that drainage. In May 2002, one specimen was collected from Long Lake (Itasca and St. Louis counties, JFBM 39064), about 7.1 km northwest of the Moyle collection site.

17. *Notropis atherinoides*—Eddy and Underhill (1974) stated that the emerald shiner had been collected from all drainages in the state, but Underhill (1989) did not include it in the Missouri River drainage. The first vouchered specimen in this drainage was collected in 1996 from the Ocheyedan River in Nobles County (JFBM 28738). Further sampling in this river system needs to be undertaken. Emerald

shiners have not been collected in the Iowa portion of this drainage for several decades.

18. *Notropis blennius*—The river shiner has been reported from the Upper Mississippi River drainage of Minnesota based on the report of Hubbs and White (1923). We have not located the specimen but believe that it was misidentified because no additional individuals of this species have been taken above St. Anthony Falls. A previously reported river shiner from Leech Lake was actually *Notropis volucellus*. Thus, we no longer recognize this species as occurring in the Upper Mississippi River drainage.

19. *Notropis heterodon*—The only extant specimens of blackchin shiner from the Lake Superior drainage were collected in Pequaywan Lake, St. Louis County, in 1922 (JFBM 10447). Smith and Moyle (1944) also reported their occurrence in Two Island River, but we do not have the specimens. This species is present in the Lake Superior drainage in Wisconsin and further east, but it has not been reported along the North Shore in Ontario (Stephenson and Momot, 1994).

20. *Notropis heterolepis*—Underhill (1989) reported the blacknose shiner from the Missouri River drainage, but we been unable to verify this record.

21. *Notropis hudsonius*—The spottail shiner was taken for the first time in the Missouri River drainage of Minnesota in 1997 (JFBM 38075). It was collected in the Ocheyedan River in Nobles County, which is also the only stream in the Missouri River drainage to harbor emerald shiners.

22. *Notropis ludibundus*—The sand shiner was previously reported from the Upper Mississippi River drainage (Underhill, 1989), but we could not verify its occurrence there.

23. *Notropis texanus*—A survey in 1984 revealed the weed shiner in three locations in the Shell River (e.g., JFBM 23738). These are the only records of this species from the Upper Mississippi River drainage. They were overlooked in the 1989 checklist (Underhill, 1989). The weed shiner is not very common in Minnesota and it exhibits a highly disjunct distribution. Thus, the Shell River population may represent an overlooked native population, or it may be the result of an inadvertent "bait bucket" introduction.

24. *Notropis topeka*—Recent surveys have proven this species to be common and widespread in small prairie streams tributary to the

Missouri River in Lincoln, Murray, Nobles, Pipestone, and Rock counties (Hatch, 2001). From 1997 through 2001, it was collected from a total of 107 sites in 17 streams. An additional 85 intensively sampled sites in the Des Moines River system yielded no Topeka shiners (Dahle 2001). There are only two historic records outside the area of these surveys. One is from Okabena Lake in Nobles County, 1947, but remains unverified. Intensive sampling of the watershed from the lake to the headwaters of Okabena Creek in 1998 produced no Topeka shiners (Hatch, 1998). The other record is from an unnamed tributary about 26 km east of Austin in Mower County, most likely in the Cedar River system (UMMZ 127672). Underhill (1957) and Eddy and Underhill (1974) mistakenly reported that these specimens were collected by Seth Meek in 1890. However, they were collected by George Myer and William Gosline in 1939. Thus, there should be only one site in Mower County shown on the map of Bailey and Allum (1962). Intensive sampling in the Cedar River watershed from 1953 through the present have produced no further specimens of this species.

The Topeka shiner was listed as a species of special concern in 1996. The U.S. Fish and Wildlife Service listed it as endangered in January 1999.

25. *Opsopoeodus emiliae*—The pugnose minnow reaches its northern-most distribution in Minnesota. It was listed as special concern in 1984 because of its unknown and possibly rare abundance in the state (Coffin and Pfannmuller, 1988). Recent surveys have shown it to be common to abundant, but sporadically distributed, in many backwater areas of the Mississippi River from Dakota County to Houston County and in three sites in the Root and Zumbro rivers. Population size appears to fluctuate widely across years.

26. *Phoxinus erythrogaster*—Underhill (1989) reported the southern redbelly dace in the Minnesota River drainage based on three collections. We have identified the specimens from two of these collections (the third is not extant) as northern redbelly dace (*P. eos*). Thus, we no longer recognize this species as occurring in the Minnesota River drainage.

27. *Phoxinus neogaeus*—The finescale dace was recently collected from a small, direct tributary of the Mississippi River in Dakota County (JFBM 29262). The tributary is known locally as Valley Creek and is labeled as Colonial Creek on some older road maps. This is the first record of this species in the Lower Mississippi River drainage.

28. *Pimephales vigilax*—Thirteen specimens collected from the Blue Earth River in 1945 and 1948 were identified as bullhead minnows by ichthyologist Raymond E. Johnson. Eddy and Underhill (1974) subsequently reported that intensive sampling in the Minnesota River drainage produced no further specimens, which led Underhill (1989) to regard the species as restricted to the Lower Mississippi River drainage. We have not been able to verify the 1940s records. However, we now have a single record from the Minnesota River in Fort Snelling State Park, collected by Konrad Schmidt in 1989 and verified by James Underhill. Unfortunately this specimen is not extant. We also have a single specimen collected in 2000 from the upper Mississippi River at the Coon Rapids Dam (JFBM 35491), which is the only record above St. Anthony Falls.

29. *Platygobio gracilis*—The flathead chub has been collected only once (1984) from Minnesota waters in the Red River of the North drainage near Climax in Polk County (JFBM 22917). However, the species also has been reported from the lower Red River of the North upstream of Lake Winnipeg in Manitoba. We believe that this single occurrence in Minnesota may be the result of introductions into a North Dakota reservoir of the Sheyene River. This species was not found in the extensive surveys of 1993-1995 (Goldstein et al., 1996; Koel, 1997).

30. *Rhinichthys cataractae*—The longnose dace has been reported from the Minnesota drainage based on the records of Woolman and Cox from Dougherty Creek at Brown's Valley and the Pomme de Terre River at Appleton (Cox, 1897). However, we have not collected this species anywhere in the drainage despite considerable sampling in the 1970s, 1990s, and in 2001. We no longer recognize this species as occurring in the Minnesota River drainage. Its reported occurrence in the Missouri River drainage in Underhill (1989) was a clerical error.

31. *Cycleptus elongatus*—Underhill (1989) regarded the blue sucker as occurring in the Lower Mississippi River drainage, Wisconsin portion of the St. Croix River drainage, and the South Dakota portion of the Missouri River drainage. We now have verified records from the St. Croix River (uncatalogued) and the Minnesota River (Carver Co., JFBM 24441; Nicollet Co., JFBM 30374). We also have additional records from the Mississippi River in Hennepin, Ramsey, Washington, Wabasha, Winona, and Houston counties (e.g., JFBM 28832).

32. *Hypentelium nigricans*—In August 1996, Ecological Services biologists (MDNR) captured northern hogsuckers (JFBM 28723) in

the Mississippi River at Anoka. These are the first vouchered specimens from upstream of St. Anthony Falls, but biologists from Xcel Energy Co. have reported this species in the river near Monticello (further upstream) every year since 1976. We now have specimens from there (JFBM 36735, 36855), from the North Fork of the Crow River in Meeker County (JFBM 35235), and from the Mississippi River at St. Cloud (JFBM 38105). It appears that the northern hogsucker managed to circumvent Coon Rapids Dam at least 25 years ago, quite possibly during the flood water of 1965. Its population is now well established in the Upper Mississippi River drainage.

33. *Ictiobus bubalus*—In September 1995, members of the MDNR captured two smallmouth buffalo (JFBM 28391), one below the Breckenridge Dam in the Otter Tail River and one below the Kidder Dam in the Red River of the North drainage. Formerly, this species was known only from the Minnesota and Lower Mississippi River drainages and from Lake St. Croix (Underhill, 1989).

34. *Ictiobus cyprinellus*—On 29 July 2001, a 6.8 kg bigmouth buffalo was taken by an angler just below the Blanchard Dam in Morrison County. This is the first verified record (JFBM 38101) from the Upper Mississippi River drainage since the early 1900s (Eddy and Underhill, 1974). A second specimen was taken at the mouth of Elm Creek near Anoka in October 2002 by MPCA biologists. Eddy and Surber (1947) acknowledged the presence of a "landlocked" population in the vicinity of Brainerd at the turn of the last century, and they considered this population the source for a specimen from Grand Rapids captured in 1894 and reported by Cox (1897). Until recently, we had considered this species extirpated from the Upper Mississippi River drainage. It is unclear whether the recent specimens are descendants of the Brainerd population or recent ascendants from the lower Mississippi River.

We now also have a second record of this species within the Missouri River drainage. It was collected from the Ocheyedan River in Nobles County in 1997 (JFBM 38073).

35. *Ictiobus niger*—Although this species was known historically from the Mississippi River as far north as Lake Pepin (Phillips and Underhill, 1971; Becker, 1983), there were no verified records from Minnesota waters before 1983. Since that time, several specimens have been taken from Minnesota and Wisconsin waters of Navigation Pools 4, 7, and 8 in the Mississippi River (JFBM 30336) (Pitlo et al., 1995). We also have two recent specimens from the Minnesota River, one captured in 1998 near St. Peter (JFBM 30337) and the other captured and

photographed (uncatalogued) in 2002 near the Black Dog Power Plant, Dakota County. In addition, one specimen was caught by an angler in 1990 in the lower portion of the Cottonwood River, tributary to the Minnesota River (we have not seen this specimen, which was identified by Huon Newberg, MDNR). These records, along with 12 historical Wisconsin records in the Mississippi River from Lake Pepin through pool 9 (Becker, 1983), clearly establish the black buffalo as part of Minnesota's fish fauna.

36. *Moxostoma carinatum*—The river redhorse was first collected from state waters in the Minnesota River in 1899 (e.g., JFBM 7297); however, no additional specimens have since been taken from that drainage. This species is also known from the Kettle River (1996, JFBM 28589), the St. Croix River (1979-1997, e.g., JFBM 29466), and Lake St. Croix (1966, JFBM 29174) in the St. Croix River drainage, and from Navigation Pools 2 and 4-9 (1993-2001, e.g., JFBM 28025) in the lower Mississippi River system.

37. *Moxostoma duquesnei*—In 1984, the black redhorse was known from only six sites in the Zumbro and Root River systems (Coffin and Pfannmuller, 1988). It is now known from 17 sites in the above river systems and four sites in the Upper Iowa River system, although it appears to occur in low numbers at all sites (see Schmidt, 1993). There is an unsubstantiated report of a black redhorse from Pool 4 in the Mississippi River. It may have been a stray from the Zumbro River, but Lyons et al. (2002) considered it more likely an erroneous report.

38. *Moxostoma valenciennesi*—Based on a detailed analysis of specimens collected from Minnesota and neighboring states carried out by Phillips and Underhill (1971), Eddy and Underhill (1974:290) stated that the "presence of the greater redhorse in Minnesota is doubtful." Historically, this species was included on the faunal list (*M. rubreques* in Eddy and Surber 1943) on the basis of a single adult specimen collected in 1948 from the Mississippi River at LaCrosse, Wisconsin (UMMZ 156836) and a single juvenile also collected from the Mississippi, but at Minneapolis in 1926 (UMMZ 71967). We now know that the greater redhorse, although apparently not abundant, is widely distributed in five major watersheds of Minnesota (Figure 1). The JFBM collection now has a total of 33 specimens from the Otter Tail River in the Red River of the North drainage (e.g., JFBM 25189); Lake Andrusia, Inguadona Lake, Ossawinamakee Lake, Sauk River, Long Prairie River, and the Mississippi River in the Upper Mississippi River drainage (e.g., JFBM 36305); the Snake, Sunrise, and St. Croix rivers in the St. Croix River drainage (e.g., JFBM 28598); Elm Creek, the Yellow Bank, Redwood, and Minnesota rivers of the Minnesota

River drainage (e.g., JFBM 25995); and the Straight, Root, and Mississippi rivers of the Lower Mississippi River drainage (e.g., JFBM 31765). It also is possible that this species is present in the Rainy/Lake of the Woods drainage. An early juvenile specimen (48 mm SL) collected in 1894 from Lake of the Woods (USNM 61510) has been identified by Dr. Robert E. Jenkins, Roanoke College, Virginia, as *M. valenciennesi*.

39. *Ameiurus natalis*—Eddy and Underhill (1974) considered the yellow bullhead rare in Minnesota and not present in the Red River of the North, Lake Superior, and Missouri River drainages. We now have numerous collections of this species from the Red River of the North drainage, two collections from the Missouri River drainage (JFBM 38078, 38088), and one collection from the St. Louis River in the Lake Superior drainage (JFBM 29117).

40. *Ictalurus furcatus*—We are unable to ascertain whether or not the blue catfish is native to Minnesota. The species occurs in the Mississippi and Missouri rivers to the south of Minnesota, but there are no authenticated records from anywhere in Minnesota or Wisconsin. However, Eddy and Surber (1943:154) state that blue catfish were "frequently taken during the warmer months from Lake Pepin southward in the Mississippi River." They also conjectured that a very large catfish (almost 2m long and over 70 kg) taken from the Minnesota River near Hanley Falls might have been a blue catfish. Eddy et al (1963) did not accept an unsubstantiated report of a blue catfish (16.8 kg) from the Mississippi River near Fort Ripley in 1959. Phillips et al. (1982) suggested that this species at one time may have been present in Minnesota as a result of northward summer migrations during the years prior to extensive lock and dam construction on the Mississippi River. The few authenticated records of this species north of the Missouri River confluence are from late summer months, which is consistent with this suggestion.

In 1977, the Minnesota Department of Natural Resources stocked 6,335 yearling blue catfish into Lake St. Croix. Two specimens, presumably from this stocking, were collected the following year in Lake Pepin by DNR personnel. In recent years, numerous anglers have claimed to have caught large blue catfish from the lower St. Croix, but none has been authenticated. Fago and Hatch (1993) reported it as an introduced species in the St. Croix River drainage, and Lyons et al. (2000) considered the species a failed introduction in Wisconsin. Because we have no physical evidence of their occurrence in Minnesota prior to the 1977 stocking effort, we have chosen to recognize the blue catfish as an introduced species.

41. *Ictalurus punctatus*—The channel catfish is another species that now occurs in the Upper Mississippi River drainage. In this case, the species was intentionally released above Coon Rapids Dam by Minnesota Department of Natural Resources in 1963 and 1974 (Enblom, 1977). In 1995 and 1996, we received two vouchered records from the Mississippi River at Coon Rapids Dam and at Anoka (JFBM 28725), two from the Crow River at the mouth (JFBM 28312) and at Delano, and two from Rice Creek in Ramsey County (e.g., JFBM 35575). Since then, channel catfish have been collected as far north as the Blanchard Dam near Royalton (JFBM 38250). This species also was stocked in Boom Lake in Brainerd in the mid-1990s. Clearly, the channel catfish has become a part of the Upper Mississippi River fish community.

42. *Noturus flavus*—In 1998 and 2000, stonecats were taken in the vicinity of the Coons Rapids Dam, but no specimens were deposited in the Museum. We now have a specimen from that area that was collected on 30 August 2001 (JFBM 38116). This is one of eight species whose range extension to the Upper Mississippi River has been documented in the past six years.

Recently, we discovered that Raymond Johnson identified this species from the St. Louis River in 1942, but we were unable to locate the specimens. MDNR reported it in the estuary in 1981, 1986, and 1990. In 1997, MPCA collected it from the North Fork of the Nemadji River in Carlton County (JFBM 29397). Apparently this species has been present in the Lake Superior drainage for some time, but it is rare.

43. *Pylodictis olivaris*—In 1999, this species was collected in the Mississippi River in the vicinity of Monticello (JFBM 31905). It became the sixth new species whose range was extended beyond St. Anthony Falls (Upper Mississippi River).

44. *Umbra limi*—The central mudminnow was collected for the first time from the Missouri River drainage in 1997. It was found in an unnamed tributary to Kanaranzi Creek in Nobles County (JFBM 29375).

45. *Esox masquinongy*—The first specimens of muskellunge in Minnesota waters of the St. Croix River drainage were captured in July 1996. They were taken from the St. Croix River in Pine County downstream of Wisconsin's Clam River by members of the Minnesota Pollution Control Agency. Becker (1983) considered this species common in the St. Croix River north to the Trego Dam. Fago (1992)

considered the early St. Croix records uncertain, and Fago and Hatch (1993) listed this species as introduced in the St. Croix River drainage. Lyons et al (2000) implied an historical occurrence in the drainage citing the work of LeBeau (1992) but did identify it as native there. No Minnesota authors recognize this species from the St. Croix River drainage and no authenticated Wisconsin records exist prior to stocking efforts. We consider the present St. Croix population to be the result of introductions. This species also has been introduced into the Otter Tail River system of Red River of the North drainage.

46. *Osmerus mordax*—The rainbow smelt is an introduced species that was first verified in Minnesota waters of Lake Superior in 1946 (Phillips et al., 1982). The species has since been introduced or migrated to 26 inland lakes in 5 Minnesota counties (Franzin et al., 1994; MDNR records). These lakes include (years of collection in parentheses): Chester (1979-1994), Devilfish (1971-1984), Gneiss (1979), Gunflint (1983-1994), Hungry Jack (1971-1994), Kimball (1972-1974), Magnetic (1978-79), Rose (1987-1992), Saganaga (1982-1992), Trout (1984-1987), and West Bearskin (1982-1993) in Cook County; Buckeye (1995), Kennedy (1977), and Pokegama (1990) in Itasca County; Lake of the Woods (1991) in Lake of the Woods County; Bass (1995), Burntside (1989), Eagles Nest 1&2 (1989), Hanson (1989), Lac La Croix (1989), Little Long (1989), Namakan (1990), Rainy (1990), and Shagawa (1979) in St. Louis County; and Grindstone (1984) in Pine County. In addition, rainbow smelt have been found in Lake St. Croix (1976) and in navigation Pool 8 of the Mississippi River (1993, JFBM 35887) but are not established in either locality.

47. *Coregonus clupeaformis*—In 1967, several specimens of lake whitefish were taken in commercial seines from Lake St. Croix. The captures were reported but the specimens were not saved. Recently, Mr. Howard Krosch, formerly of the Minnesota Department of Natural Resources, provided us with a definitive photograph of one of the specimens, which he had identified on site. We are uncertain about how these fish reached Lake St. Croix; and, to our knowledge, no other specimens have been reported from the St. Croix River drainage. We do not consider this species part of the St. Croix River drainage fish community.

48. *Coregonus nigripinnis*—The blackfin cisco has been incorrectly recognized as part of the Minnesota ichthyofauna since Evermann and Smith (1894) reported it from Lake Miltona in Douglas County. Cox (1897) and Surber (1920) agreed with Evermann and Smith (1894)

and speculated that it was probably the common species in other deep lakes of the state, especially in the north. Eddy and Surber (1943) correctly indicated that the cisco species found in inland lakes was *Coregonus artedi*, not *C. nigripinnis*. However, based on the work of Koelz (1929), Eddy and Surber recognized *C. nigripinnis* (cf., *Leucichthys nigripinnis cyanopterus*) as a common species along the north shore of Lake Superior. Eddy and Underhill (1974) continued to recognize this taxon in Lake Superior. Based on the work of Todd and Smith (1980), Underhill (1986, 1989) no longer recognized this taxon as part of the Lake Superior fauna. While *C. nigripinnis* is still considered a valid species that once occurred in lakes Michigan and Huron, Todd and Smith persuasively demonstrated that *C. nigripinnis cyanopterus* from Lake Superior was not distinguishable from *C. zenithicus*. We, therefore, now recognize Lake Superior specimens originally identified as *C. nigripinnis* to be *C. zenithicus*.

49. *Coregonus nipigon*—The Nipigon cisco was identified in 1991 from Lake Saganaga, Cook County, by David A. Etnier (JFBM 25376). Although Robins et al. (1991) and Mayden et al. (1992) do not recognize this particular species, recent studies of coregonine populations in Lake Saganaga by D. A. Etnier (University of Tennessee) and B. A. Shields (Oregon State University) indicate that *C. nipigon* is a distinct and recognizable species. Arguments for the validity of this species will be forthcoming (D. Etnier, University of Tennessee, pers. comm.). This species should be searched for in large, deep lakes of the Boundary Waters Canoe Area.

50. *Coregonus reighardi*—The shortnose cisco is another example representing confusion with the identification of deepwater ciscoes. Koelz (1924) described this species from Lake Michigan and later recognized a subspecific form, *C. reighardi dymondi,* from Minnesota waters of Lake Superior (Koelz, 1929). This taxon was recognized by all Minnesota authorities until Todd and Smith (1980) showed it to be a variant of *C. zenithicus*. Underhill (1986, 1989) did not include *Coregonus reighardi* in his lists, and we now recognize Lake Superior specimens originally identified as *C. reighardi* to be *C. zenithicus*. *Coregonus reighardi* is a valid but extinct species that occurred in lakes Huron and Michigan.

51. *Coregonus zenithicus*—In 1991, Dr. David Etnier identified the shortjaw cisco from Lake Saganaga in the Rainy River/Lake of the Woods drainage (JFBM 25370). This is the only Minnesota record from this drainage, but Crossman (1976) noted that four specimens of this

species had been identified from the Canadian waters of Basswood Lake. This is another species that may be present in other deep lakes of the Boundary Waters Canoe Area.

52. *Aphredoderus sayanus*—Prior to 1989, the pirate perch was known from only 5 sites in southeastern Minnesota. It is now known from 12 sites, all of which are in the lower Mississippi River and the mouths of its tributaries in Wabasha, Winona, and Houston counties (e.g., JFBM 30203). Despite the increase in records, this species remains rare in Minnesota.

53. *Fundulus diaphanus*—The banded killifish was recently documented from Lake of the Woods (JFBM 38110). This is the first verified record from the Rainy River/Lake of the Woods drainage. This species is relatively common in the St. Croix River drainage of Wisconsin (Fago, 1992; Lyons et al., 2000), but it was not collected in upper St. Croix River system of Minnesota until 2000 and 2001 (JFBM 38098, Aitkin County; JFBM 38112, Pine County).

54. *Fundulus dispar*—The starhead topminnow has never been reported from Minnesota waters, but one specimen were collected in 1996 from the lower Black River in Wisconsin near its confluence with the Mississippi River in Navigation Pool 7 (JFBM 28393), which reaches Minnesota shores. This species has been collected previously from the lower reaches of the Black River in Wisconsin (Fago 1992).

55. *Fundulus sciadicus*—The plains topminnow was unknown in the state before 1973 (Anderson et al., 1977). By 1989, it had been found in 9 sites in the Rock River system of Rock and Pipestone counties. Surveys in the 1990s increased the known sites to 16 and the number of tributaries from 4 to 8, all still within the Rock River system (e.g., JFBM 30011). This species remains one of the rarest inhabitants of our southwestern prairie streams.

56. *Cottus cognatus*—Underhill (1989) inadvertently indicated that within the St. Croix River drainage, the slimy sculpin was restricted to Wisconsin waters. While this is true for the upper St. Croix River system, it is not so for the lower St. Croix River system. Slimy sculpins historically were abundant in Valley Creek, Washington County (Eddy and Underhill, 1974), where they still occur (JFBM 30728).

57. *Cottus ricei*—Until 1998, this species was known only from Lake Superior in Minnesota. In 1998, two specimens were collected from the Baptism River (JFBM 30117). In 2000, Dr. David Etnier (University of Tennessee) retrieved a specimen from the stomach of a lake trout caught in Saganaga Lake (UT 129.669). He collected a second specimen there in 2002. We suspect that this species, as well as the deepwater sculpin (next account), occur in a number of the deep boundary water lakes in Minnesota.

58. *Myoxocephalus thompsoni*—The deepwater sculpin was formerly known only from Lake Superior, where a somewhat recent collection was made off Beaver Bay in 183 m of water (1982). The species now has been collected from Saganaga Lake in Cook County. Dr. David Etnier (University of Tennessee) collected it there for the first time in 1985 and on several occasions thereafter (JFBM 24402, 22866, 25373). It may well occur in other deep lakes of the Boundary Waters.

Recently, a single specimen of deepwater sculpin was found in a 1969 collection of fishes from Lake St. Croix (JFBM 38097). We have no doubt that this is a legitimate record, but we do not believe there is an established population of deepwater sculpins in Lake St. Croix.

59. *Morone mississippiensis*—The yellow bass has been reported sporadically in the Mississippi River from Navigation Pool 8 up to Lake Pepin, but we have no specimens in the Bell Museum Collection, nor have we examined any from Minnesota waters. Wisconsin specimens verified by Becker (1983) and accepted by Fago (1992) are from below Navigation Pool 9. We deem the yellow bass another of Minnesota's rare species.

60. *Lepomis gulosus*—The warmouth is native to the Lower Mississippi River drainage and possibly the lower St. Croix River system. Reports from the past 20 years include Lake Winona (1983-1989, e.g., JFBM 34787), the old channel of Root River (1995), and Mississippi River Navigation Pools 5 through 9 (1982-1995, e.g., JFBM 29244). Additional specimens have been collected from the St. Croix River drainage of Wisconsin (Fago, 1992).

For the past 40 years, the Minnesota Department of Natural Resources (MDNR) and various anglers have sporadically reported this species from Big Ole Lake and, in one instance, East Lake near Marcell, MN, which lie in the Big Fork River system of the Rainy River/Lake of the Woods drainage. We have recently verified the identification of three specimens from Big Ole Lake (JFBM 38114). MDNR personnel indicate that this species was stocked in a few lakes in that area prior to 1960.

61. *Lepomis humilis*—The orangespotted sunfish was historically present in the Minnesota River, Missouri River, and Lower Mississippi River drainages. However, in 1995 specimens were collected from the Upper Mississippi River drainage in the Mississippi River at the Coon Rapids Dam (JFBM 28389), the mouths of Elm Creek (JFBM 28316) and Crow River (e.g., JFBM 28313), lower Elk River (JFBM 28288), and an outlet on Swartout Lake in the Clearwater River system (JFBM 28289). In 2000, specimens were taken at three sites in the headwater regions of the Crow River in Renville County (e.g., JFBM 35305). This species may have gained access to the Upper Mississippi River drainage while the dam at Coon Rapids was being replaced in the early 1990s, or it may have been introduced.

Underhill (1989) did not report this species from the Red River of the North drainage in Minnesota, but it has been taken at the mouth of the Otter Tail River in 1991 and in Lake Traverse in 1985 (Koel, 1997).

62. *Lepomis megalotis*—The longear sunfish has a very spotty, but wide distribution in Minnesota. Recent reports establish it in numerous lakes in the Upper Mississippi River drainage (e.g., JFBM 24010), in at least three lakes in the Rainy River/Lake of the Woods drainage (e.g., JFBM 21881), and McCarrons Lake (Ramsey County, no extant specimens) in the Lower Mississippi River drainage. Specimens have also been collected from Wisconsin's Yellow River in the upper St. Croix River system (JFBM 24235). Both the Minnesota and Wisconsin specimens are assignable to *L. m. peltastes*, the northern longear sunfish (Trautman 1981).

63. *Crystallaria asprella*—Studies of the crystal darter carried out in the 1990s increased the number of Minnesota records from 5 to 14 (Schmidt, 1995; Hatch, 1997). This species occurs in small numbers at three sites in the lower St. Croix River (JFBM 30068), eight sites in the Mississippi River from just north of Redwing to the state's southern border (e.g., JFBM 30341), and four sites in the Zumbro River between Millville and Kellogg (e.g., JFBM 30315). The crystal darter's habit of burrowing in sand and pebble bottoms makes it harder to collect than most darter species, but we still believe that they are relatively rare in Minnesota, as they appear to be elsewhere (George et al., 1996).

64. *Etheostoma asprigene*—The mud darter is restricted to the lower St. Croix River system and the Lower Mississippi River

drainage. Recent collections are from the St. Croix River in 1989 and 1998 (e.g., JFBM 30283); Mississippi River Navigation Pools 4-9 from 1987 to 1999 (e.g., JFBM 31885); eleven small, direct tributaries to the lower Mississippi River from 1984 to 1999 (e.g., JFBM 30236); the lower Root River in 1995 (JFBM 28186); the lower Whitewater River in 1994 (JFBM 27574); and Wisconsin's lower Black River in 1996 (JFBM 29310).

65. *Etheostoma caeruleum*—The rainbow darter was taken on two occasions in 1996 from Lake Phalen in Ramsey County and on several occasions through 2001 (e.g., JFBM 29298). This is the only occurrence of this species from a lake environment in Minnesota. Typically, rainbow darters inhabit gravel and rubble riffles of small to moderate sized streams (Kuehne and Barbour, 1983; Page, 1983), although Cahn (1927) reported them exclusively from ten "larger gravel lakes" in southern Wisconsin and Winn (1958) found then in the outlet to a lake in Michigan. We do not know how these darters reached Lake Phalen; it is possible they represent an aquarium release. The population appears to be well-established there.

Historically, this species was common and abundant in the Cannon River (Lower Mississippi River drainage) from the Byllsby Dam to riffles below the mouth of Belle Creek. Numerous attempts to collect them in the 1990s in this reach of the river failed. The last documented collections are from the late 1970s. We do not know what caused their disappearance, but the timing of this loss coincides with several fish kills that the MDNR has associated with operation of the Byllsby Dam.

66. *Etheostoma chlorosoma*—Four specimens of bluntnose darter were collected in Navigation Pool 9 near the Iowa border in 1944, and two were collected from an overflow pool near the mouth of the Root River in 1945 (not catalogued). Intensive sampling for this species in the 1980s and 1990s produced no new individuals and in 1996 the bluntnose darter was considered extirpated (Schmidt, 1991; Lyons et al 2000). In 1997, one of the authors (KPS) and Ray Katula, found a single young-of-the-year specimen in Pine Creek (JFBM 29263). Katula collected a second specimen from the Mississippi River near Winona in 2001 (JFBM 38690). The bluntnose darter is Minnesota's rarest fish species and undoubtedly will be added to the list of protected species.

67. *Etheostoma microperca*—Prior to 1990, the least darter was known from 31 sites—16 of which were mapped by Burr (1978)—in

10 streams and nine lakes scattered across the southern three-fourths of the state. Surveys from 1990 through 2002 added 47 sites in nine new streams and 41 new lakes, mostly in the Otter Tail River system and the Upper Mississippi River drainage. A collection from Long Lake on the border of Itasca and St. Louis counties was the first record of the least darter in the Lake Superior drainage (JFBM 39065). Minnesota populations represent the northwestern limit of the species' range, are disjunct from those of the Ozark and eastern Great Lakes regions, and exhibit life history parameters different from those of populations near the center of the range (Johnson and Hatch, 1991).

68. *Percina maculata*—The blackside darter is one of eight species whose range has extended into the Upper Mississippi River drainage. Since 1995, it has been collected from the Sauk River (JFBM 36596), North Fork of the Crow River (JFBM 35608), the Mississippi River at Monticello and Anoka (JFBM 36167, 36730), an unnamed tributary to the Mississippi River in Anoka County (JFBM 35359), County Ditch 2 (Stearns, Co.; JFBM 37511), Elk River (JFBM 30616), Coon Creek (JFBM 36489), and the Crow River (JFBM 36817). We expect this species to continue to spread within the Upper Mississippi River drainage.

69. *Percina shumardi*—The river darter was collected twice in 1998 from the lower Minnesota River in the vicinity of Fort Snelling State Park (JFBM 29818, 29828), and there is a single unverified record from Fort Snelling State Park in 1975. Whether or not there is an established population in this area is not known at this time. A large population of river darters occurs at the first riffle downstream of Lock and Dam No. 1 on the Mississippi River, which is only 4 km from the mouth of the Minnesota River.

70. *Aplodinotus grunniens*— The freshwater drum was recently documented from Lake of the Woods (JFBM 38109). This is the first verified record from the Rainy River/Lake of the Woods drainage. This species also appears to have been introduced into the St. Louis River estuary where it was first collected by WDNR biologists in 1981 and has been collected by them frequently since that time (D. Pratt, WDNR, pers. comm.). MDNR reported it in their catches in 1986, 1987, 1991, 1992 and 2000.

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This paper is dedicated to the memory of the late Professor James Campbell Underhill, who studied the distribution and natural history of Minnesota fishes for more than 50 years. His contributions to the state of Minnesota, to its decades of ichthyology students, and to each of the remaining authors are beyond enumeration.

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Table 1. Number of fish families, genera, introduced species, native species and endangered-threatened-special concern (ETS) species in 8 ma drainage in Minnesota, excluding *Fundulus dispar* and *Apeltes quadracus*. 1 = Red River of the North, 2 = Rainy River/Lake of the Woods, 3 Upper Mississippi River, 4 = Lake Superior, 5 = St. Croix River, 6 = Minnesota River, 7 = Missouri River, 8 = Lower Mississippi River.

	1	2	3	4	5	6	7	8	All
Number of families	20	17	18	21	25	21	10	26	27
Number of genera	49	41	47	51	63	56	29	69	80
Number of introduced species	9	6	10	16	7	4	3	7	19
Number of native species	73	67	65	67	99	91	39	119	139
Total number of species	82	73	75	83	106	95	42	126	158
Number of ETS species	3	3	2	6	8	7	2	16	21