

**Status Report on Implementing the  
Upper Mississippi River Conservation Committee  
Conservation Plan for Freshwater Mussels of the  
Upper Mississippi River System**

**Compiled by:**

**Gary J. Wege  
Chair, UMRCC Mussel Ad Hoc Committee  
U.S. Fish & Wildlife Service  
4101 American Boulevard East  
Bloomington, MN 55425-1665  
gary\_wege@fws.gov**



**November, 2008**

# **Status Report on Implementing the Upper Mississippi River Conservation Committee Conservation Plan for Freshwater Mussels of the Upper Mississippi River System**

November, 2008

## Introduction

The Upper Mississippi River Conservation Committee (UMRCC) *Conservation Plan for Freshwater Mussels of the Upper Mississippi River System* was completed by the Mussel Ad Hoc Committee in November, 2003 (Upper Mississippi River Conservation Committee 2003). The goal of the plan is to return a healthy, self-sustaining native freshwater mussel fauna to the UMRS. Specifically, the purposes of the plan are to (1) identify the research, management, and conservation actions necessary to maintain and recover the mussel fauna; (2) increase government and public awareness of the plight of these animals and their essential ecosystems, and garner support, including adequate funding for species and habitat protection programs; (3) foster creative partnerships (working and funding) among federal, state, tribal, and local governments and the private sector to restore the mussel fauna and environmental quality to our rivers; (4) document the many problems which are barriers to effective mussel resource management efforts and; (5) prescribe a strategic plan of action, which if implemented, will restore the valuable freshwater mussel resources of the UMRS.

This status report summarizes activities and accomplishments by river biologists from the UMRCC Mussel Ad Hoc Committee, Mussel Coordination Team, federal and state agencies, universities and private sector. These activities and accomplishments are shown in bold type. It also includes revisions to the original plan and reference sections.

Given the bleak economic times we now face, it is critical that we prioritize information needs for the next decade so we can focus our efforts and limited funds. Section 2 contains a list of priority mussel conservation activities for the next ten years to facilitate this process.

## **Table of Contents**

	<u>Page</u>
Section 1. Revisions and Accomplishments .....	3
1. Implement a long-term survey and monitoring program to assess the distribution, abundance, recruitment and health of native mussels .....	3
2. Describe the life history, taxonomy and population dynamics of native mussels .	4
3. Determine how changes (man-made and natural) to the ecological health of the Upper Mississippi River System affect native mussels .....	6
4. Implement measures to restore and sustain populations of native mussels on the Upper Mississippi River System .....	9
5. Educate people (private, public and political) on the ecological and economic value of native mussels, threats to their continued existence, and restoration opportunities .....	15
6. Develop strategies to implement the Conservation Plan for Freshwater Mussels of the Upper Mississippi River System .....	16
Section 2. Priority Mussel Conservation Activities for the Next 10 Years .....	18
Section 3. References Cited Above .....	19
Section 4. Additional References from the Mussel Coordination Team, UMRCC Mussel Ad Hoc Committee, Federal/State Agencies, Universities and Private Sector....	22

## Section 1. Revisions and Accomplishments

**Revised Goal = Restore and sustain a diverse, multi-species native mussel community in the Upper Mississippi River System**

### **Revised Objectives**

**1. Implement a long-term monitoring program to assess the distribution, abundance and relative health of native mussels.**

### **Strategies**

#### **1.1 Status of Mussels**

1.1.1 Include native mussel monitoring as a component of the Environmental Management Program, Long Term Resources Monitoring Program (LTRMP).

**Not Accomplished**

1.1.2 Increase sampling effort to determine the location, density, species composition, and status of existing mussel communities in the Upper Mississippi River System (UMRS). Many reaches and tributaries need basic or current survey information. Knowledge of the condition and location of mussel resources is critical to understand a species' status and develop proper management actions. Basic sampling guidelines should be developed and implemented. **Pool-wide population estimated for Pools 5, 6 and 18 (Corps of Engineers, U.S. Geological Survey, and States). Shallow-water mussel surveys conducted in Pools 5 and 6 (U.S. Geological Survey) and planned in Pool 18 (U.S. Geological Survey, Corps of Engineers). Higgins eye Essential Habitat Areas and other important mussel beds sampled by Corps of Engineers and Mussel Coordination Team. Higgins eye found in Pool 6 in 2007, and in Pools 5A and 5 in 2008 (Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, U.S. Geological Survey). Sheepnose (*Plethobasus cyphus*) found in Pools 4 and 5 in 2008 (Minnesota Department of Natural Resources). Additional project-specific sampling for Environmental Management Program (EMP) habitat projects, drawdowns and private projects conducted by agencies and contractors. Sampling designs developed for mussel surveys at large and small-spatial scales (U.S. Geological Survey). A mussel survey of the St. Croix River was conducted between 2001-3 (Hove and Hornbach 2004). Since 1992 there has been a decline in mussel density in the St. Croix River at Interstate State Park, one of the most diverse communities in the river. Over this same time period mean riverbed particle size at Interstate has decreased (Hornbach and Hove 2007).**

1.1.3 Compile historic mussel distribution data to facilitate its use. Many historic collections exist in museums, universities, and private collections. However, some

specimens have been misidentified, and many of the collections have not been catalogued or the data are not readily available. This historic information is critical to understanding the current status of many mussel populations. The information also may be useful for identifying potential reintroduction sites and locating unknown populations. **Table of mussel distribution completed for Upper Mississippi River System pools and tributary reaches (Corps of Engineers).**

- 1.1.4 Develop a central database on the status and location of native mussel populations. Information should be categorized based on U.S. Geological Survey hydrologic unit maps and mapped using a geographic information system (GIS). The database can be used by resource managers to track mussel populations and should include absence data. **Mussel data from Corps of Engineers-sponsored surveys are contained within a new central database (Corps of Engineers).**
- 1.1.5 Continue development of protocols for evaluating the relative health of mussels and establish a central database for mussel health data. The U.S. Fish and Wildlife Service Fish Health Center, La Crosse, Wisconsin, should provide leadership in developing these protocols on the Upper Mississippi River System. River managers need standard techniques to assess the health of individual mussels and populations, and major mortality events (die-offs). Baseline conditions for mussel health should be described and diseases noted as endemic to native mussels, or new to the Upper Mississippi River ecosystem. **Not Accomplished.**
- 1.1.6 Develop a mussel distributional atlas. In the early 1980s, the U.S. Fish and Wildlife Service funded the production of an Atlas of North American Freshwater Fishes (Lee et al. 1980). This document provides a distribution map for all North American freshwater fishes and includes information on the species' habitat and biology. The fish atlas has been a valuable tool for fisheries managers and biologists; a similar atlas on native mussels would benefit mussel conservation efforts. **Not Accomplished.**

## **2. Describe the life history, taxonomy, genetics and population dynamics of native mussels.**

### **Strategies**

#### **2.1 Life History**

- 2.1.1 Conduct life history studies. Unlike many other animal species, little is known about the basic biology and habitat requirements of most species of mussels. A basic knowledge of life history and ecological requirements is critical to the conservation of mussels in the Upper Mississippi River System. **Hydrophysical model quantifies ranges of several hydrophysical variables that are associated with areas of dense mussel assemblages (U.S. Geological Survey).**

**In the St. Croix River Higgins eye and winged mapleleaf were only found at 'high density' sites and in areas with coarser substrate. Also, Higgins eye were found in areas with higher shear stress and shear velocity, and winged mapleleaf at locations with higher shear stress, shear velocity, Roughness Reynolds and Froude numbers (Hornbach and Hove 2007).**

- 2.1.2 Conduct studies on reproductive biology. River managers need to know more specifics about how native mussels reproduce, when and where reproduction occurs and what environmental conditions are critical for reproduction and recruitment. Certain species of fish and amphibians are an important link in the reproductive cycle of freshwater mussels; they serve as intermediate hosts in the transformation of glochidia into juvenile mussels. Studies to identify glochidial hosts are critical for future propagation and restoration of mussel species and populations. Host information is available for some mussels (available on the Internet at Ohio State University website <http://www.biosci.ohio-state.edu/~molluscs/main/databases.html>) and needs to be completed and validated for UMRS species. **Host fish for many mussel species, including T&E species, are now known (University of Minnesota, Minnesota Department of Natural Resources, U.S. Fish & Wildlife Service, U.S. Geological Survey). During 2007, host suitability trials were conducted using spectaclecase, monkeyface, butterfly and elktoe glochidia (Hove et al. 2007).**
- 2.1.3 In addition to native species, river managers need to better understand the reproductive biology of non-indigenous species like zebra and quagga mussels, and black carp (*Mylopharyngodon piceus*) to develop management strategies. **Not Accomplished.**
- 2.1.3 Conduct studies on habitat requirements. What habitat conditions (biotic and abiotic) are needed by mussels to sustain their populations and communities? This information is needed by river managers to maintain, restore or create mussel habitats on the Upper Mississippi River System. Likewise, it is important for river managers to understand the habitat requirements of non-indigenous species like zebra and quagga mussels to develop effective management strategies favoring native mussels. **Studies conducted on Hydrophysical modeling and diet (U.S. Geological Survey).**

## **2.2 Taxonomy**

- 2.2.1 Develop and implement molecular genetics techniques to help identify mussel species. Historically, mussels have been described primarily on the basis of shell characteristics. This method has been very reliable, and there is little question regarding the taxonomic distinctiveness of most mussel species in the Upper Mississippi River System. However, molecular genetic analysis has shown that some species are comprised of complexes of distinct species (Kat 1983a, 1983b, Lydeard et al. 1996, Mulvey et al. 1997). Thus some species believed to be widespread may be unknowingly lumped with species that are rare and in need of

protection. Molecular genetics research should help clarify the taxonomic relationships within these complexes. **Not Accomplished.**

### **2.3 Genetics and Population Dynamics**

- 2.3.1 Conduct studies on genetics. Information is needed by river managers to evaluate genetic variability between individuals and populations. This information is important in developing mussel propagation and relocation activities. **Genetic work conducted on Higgins eye (Bowen 2004) and winged mapleleaf (Iowa State University). Population genetics of *Lampsilis cardium* compared within and among UMR pools (Miami University, U.S. Geological Survey).**
- 2.3.2 Conduct studies on population dynamics. Information is needed on the dynamics of mussel populations and communities in the Upper Mississippi River System. What environmental and population factors affect growth, mortality and recruitment? How do different species interact within mussel beds? How many adults and juveniles are needed to establish a new population or restore a former one? How close should they be placed to each other to optimize reproduction and recruitment? How do non-indigenous species like zebra mussels affect the diversity and abundance of native mussels? This information is important in restoring mussel populations and monitoring their long-term viability on the Upper Mississippi River System. **Juvenile recruitment estimated in Pools 5, 6 and 13 (U.S. Geological Survey). Preliminary estimates of natural mortality in Pools 5, 6 and 18 (U.S. Geological Survey).**

### **3. Determine how changes (man-made and natural) to the ecological health of the Upper Mississippi River System affect native mussels.**

#### **Strategies**

#### **3.1 Environmental Changes**

- 3.1.1 Determine how and to what extent various habitat alterations affect mussel species and populations. The impacts to mussels from habitat alterations, such as impoundment and dredging of mussel beds, are fairly well understood. However, the links between the decline or loss of many mussel populations and the causative agent(s) are generally unknown. Research is needed to determine how and to what extent the following factors affect mussels (this list is not intended to include all of the potential mussel perturbation agents that need research): (1) pesticides, herbicides, and fungicides; (2) wastewater discharge of various pollutants; (3) siltation; (4) stream-flow modifications; and (5) modifications in water temperature, dissolved oxygen levels, nutrients, and pH; water level management activities associated with operation of the 9-foot channel project. A better understanding of how environmental factors affect mussel will enable

resource agencies to better manage and conserve mussel communities.

**Evaluated effects of waterlevel drawdowns on unionid populations (Corps of Engineers, U.S. Fish & Wildlife Service, U.S. Geological Survey, Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources). Developed conceptual model of the effects of habitat fragmentation on mussel populations (U.S. Geological Survey).**

- 3.1.2 Review early literature to determine what historic factors may have caused the decline or extirpation of mussel populations. The loss or decline of some mussel populations in specific rivers is the result of historic rather than current conditions. A review of historic literature may reveal the reasons for the current depressed status of mussel communities. If the original cause of the loss has been eliminated or minimized, mussel reintroduction may be feasible. An example of historical documentation is a report by Pritchard (2001) “An Historical Analysis of Mussel Propagation and Culture: Research Performed at the Fairport Biological Station”. **Not Accomplished.**
- 3.1.3 Develop and implement biomonitoring protocols using freshwater mussels. These monitoring activities should complement fish and other macrionvertebrate biomonitoring protocols presently used to evaluate the integrity of a stream. Fish and macrionvertebrate biomonitoring protocols have been developed to score and ranks lotic system for their health based on numbers and presence of sensitive species. Freshwater mussels are a very logical monitoring component for the biotic health of a system since they are generally long-lived and sedentary. This would provide valuable information for linking environmental threats to presence or absence of specific species, more adequately assess the integrity of streams, and provide a valuable tool to biologists and resource managers. **See 3.1.4 below.**
- 3.1.4 Encourage the U.S. Environmental Protection Agency to set standard bioassay protocols as a basis to set water quality standards that would protect mussel populations. **Developed ASTM standard guide for conducting toxicity tests with freshwater mussels (U.S. Geological Survey). Evaluated sedimentary ammonia toxicity to freshwater mussels (U.S. Geological Survey). Evaluated sensitivity of mussels to contaminants across life stages, exposure routes and exposure durations (North Carolina State University, U.S. Geological Survey, U.S. Fish & Wildlife Service).**
- 3.1.5 Encourage state agencies to adopt water quality standards that protect native mussels. **Not Accomplished.**

## **3.2 Non-Indigenous Species**

- 3.2.1 Continue development of predictive models on the spread of zebra mussels, black carp and other non-indigenous species and their likely impact on native mussels. Zebra mussels and other non-indigenous species have devastated native mussel



populations in the Great Lakes (O'Neill and MacNeill 1991, Kelch 1994, Taylor and Kerschner 1995) and the Upper Mississippi River System, and they have now invaded inland rivers where they are likely to affect important mussel resources and protected species. Information is needed to predict the rate of movement of zebra mussels, black carp and other non-indigenous species into inland waters, the types of habitats they will invade, and the impacts they will have on native mussels in these habitats. **Initiated Zebra Mussel Risk Assessment for St. Croix River (Corps of Engineers).**

- 3.2.2 Develop and maintain a geographic information system (GIS) to monitor the spread of non-indigenous species relative to the location of native mussel populations. The spread of non-indigenous species should be monitored and the data reported in a readily available format. The U.S. Geological Survey Florida Caribbean Science Center at Gainesville, Florida, currently tracks the spread of zebra mussels and other non-indigenous species. That database should be reviewed to determine whether modifications are necessary to meet the needs of native mussel conservation and aquatic resource management. **Conducted zebra mussel veliger surveys (Corps of Engineers & Mussel Coordination Team); adult zebra mussel collections during native mussel sampling (Corps of Engineers, Mussel Coordination Team, States, contractors); adult zebra mussel surveys of lower St. Croix River (NPS and interagency dive team); new UMRS Mussel Database (Corps of Engineers). While zebra mussels have remained at very low densities in the Twin Cities Metro Reach (UMR Pools 1-3), they have increased in the lower St. Croix River (now a source population to the UMR (National Park Service 2008), and also at the Frontenac cage propagation site in Pool 4 which was abandoned and moved upstream to Pool 3 in 2008. At other locations on the Upper Mississippi River System, zebra mussel densities appear cyclic (annually and seasonally). Quagga mussels (*Dreissena bugensis*) were recently found in low numbers in Pools 4, 5, 7 and 10 (Grigorovich 2008 draft report).**
- 3.2.3 Determine how non-indigenous species spread to new waters. Barge traffic has been the primary zebra mussel transport mechanism in large navigable rivers, and recreational boats are the likely vector into small rivers and lakes. Definitive information on non-indigenous species mode of transport could be useful in developing control procedures. **Initiated Zebra Mussel Risk Assessment for St. Croix River (Corps of Engineers).**
- 3.2.4 Investigate the feasibility of controlling the spread of non-indigenous species through technological means. The feasibility of a barrier between the Illinois Waterway and the Great Lakes should be investigated. Research on the physical, chemical and biological control of non-indigenous species is urgently needed. However, extreme care must be taken to ensure that biological control methods for non-indigenous species do not jeopardize native mussels. **Installation of first electrical barrier in Illinois Waterway and authorization of second barrier**

**(Corps of Engineers); bubble barrier authorized at LD 11 under WRDA 2007; bio-bullet studies by U.S. Geological Survey.**

- 3.2.5 Develop measures to control the spread of black carp. Black carp are an Asian species whose primary foods are mollusks and crustaceans. Specimens have been found in the wild in the Upper Mississippi and Red River (Louisiana) Basins. **Black carp listed as injurious (U.S. Fish & Wildlife Service); no action on control measures except for authorization of bubble barrier at LD 11 per WRDA 2007.**

#### **4. Implement measures to restore and sustain viable populations of native mussels on the Upper Mississippi River System.**

##### Strategies

#### **4.1 Propagation**

- 4.1.1 Conduct a comprehensive review of foreign and related literature that could have application in mussel propagation research. Asian countries have a wealth of experience in freshwater mussel culture and their literature should be translated so techniques can be tested and implemented here. **Not Accomplished.**
- 4.1.2 Continue development of artificial propagation technology for native mussels. Artificially propagated juvenile mussels are needed for four primary purposes: (1) augment populations when population size of a rare species is too small, young, or old to support reproduction; (2) establish new populations when the translocation of adults is not possible; (3) maintain a captive population when the species' natural habitat is deemed unsuitable because of zebra mussels and other impacts; and (4) for bioassay research. **See Item 4.2.1 below. Higgins eye Relocation Plan implemented by Corps of Engineers with assistance from Mussel Coordination Team to establish 5 new and viable populations (Mussel Coordination Team 2007). Host fish for winged mapleleaf (*Quadrula fragosa*) were found to be channel and blue catfish (Steingraeber et al. 2005). Host fish and propagation studies were conducted by Minnesota Department of Natural Resources, University of Minnesota, U.S. Fish & Wildlife Service, U.S. Geological Survey on a variety of species. Cage propagation has been successful for black sandshell (*Ligumia recta*), mucket (*Actinonaias ligamentina*), fatmucket (*Lampsilis siliquoidea*), plain pocketbook (*Lampsilis cardium*) and snuffbox (*Epioblasma triquetra*).**
- 4.1.3 Determine the risk associated with mussels, their fish hosts, and associated disease escaping from the facility or propagation cages into non-historic habitat. Whenever species are moved into areas outside their historic range there is always a risk that they will escape and become established. If mussels and their associated fish hosts are to be propagated and held outside their historic range, an

assessment should be made of the risk of escape and potential consequences. The Performance Standards for Safely Conducting Research with Genetically Modified Fish and Shellfish (available on the Internet at <http://www.nbiap.vt.edu>), and U.S. Fish and Wildlife Service and Department of Commerce Policy on Controlled Propagation of Species Listed Under the Endangered Species Act (U.S. Fish and Wildlife Service 2000) will be considered in the course of propagation and containment activities. Mussel containment activities will not continue where the consequences of escape are likely and severe. **Winged mapleleaf controlled propagation plan completed (U.S. Fish and Wildlife Service 2004a).**

- 4.1.4 Develop a health strategy for captive mussel populations. This would include the development of techniques for disease diagnosis, determination of disease vectors, and disease control. If adult mussels are to be brought into active fish hatchery facilities, the effect of mussel disease on fish and fish diseases on mussels should be assessed. **Not Accomplished.**
- 4.1.5 Identify criteria for selecting federal, state, tribal, and private hatchery facilities that could be used for large-scale mussel propagation. Once artificial propagation technology is developed, existing hatchery facilities will be needed to produce juveniles for reintroduction. If the facility managers know that they might be requested to propagate mussels, they could consider these criteria when planning modifications at their facility. **Not Accomplished. Continued use of Genoa National Fish Hatchery for propagation (U.S. Fish & Wildlife Service).**

## **4.2 Reintroduction/Relocation**

- 4.2.1 Develop protocols and techniques to relocate juvenile and adult mussels. Mussels are generally relocated for two reasons: to (1) remove them from an area when a development project or other factors threaten their survival; or (2) release them back into restored historic habitat or to non-zebra mussel impacted areas. Efforts to relocate adult mussels have met with varied success; nevertheless, this tool is essential to mussel conservation. For example, zebra mussels are currently threatening rare mussels in the Ohio and Mississippi River systems. To save some of these native species, it will be necessary to move some rare species to areas that will not be threatened by zebra mussels. Also, adult mussels can be relocated in order to reestablish extirpated populations when sufficient specimens are available in a donor population. The feasibility for releasing juvenile mussels into the wild and artificially infesting and releasing fish hosts needs to be tested. Additional research on such factors as habitat suitability, size and number of juveniles to release, method of release, and time of release are needed. **Higgins eye Relocation Plan implemented to establish 5 new and viable populations by Corps of Engineers with assistance from Mussel Coordination Team (Mussel Coordination Team 2007). Accomplishments through 2007 include: 1) relocating 472 adults; 2) stocking 28,385 subadults produced in closed**

propagation cages; 3) stocking 2,834,649 potential juveniles from open-bottom cages and free release of host fish. Predation was observed on stocked subadults probably by large fish such as common carp and drum. Post-release surveys found 20 juvenile Higgins eye in the Wapsipinicon River, Iowa, from free fish releases since 2002. In 2005, four juveniles were found in the lower Wisconsin River, Wisconsin, downstream of open propagation cages. Many subadults stocked since 2001 are now adults; gravid females have been observed. Since 2001, zebra mussels infested the Frontenac Propagation Site in Pool 4 resulting in high mortality of subadult mussels inside propagation cages. They also essentially eliminated the 2007 cohort resulting in the extension of the propagation effort into 2009 to make up for the lost year class. In 2008, all propagation activities were moved upstream to Sturgeon Lake in Pool 3 and the lower St. Croix River near Stillwater, MN.

Propagation of winged mapleleaf (*Quadrula fragosa*) has limited success with only 24 juveniles produced from channel catfish infested with glochidia in 2004 (Mussel Coordination Team 2007). No juveniles were collected from subsequent inoculations. A study will be conducted in 2008-2009 to better assess infestation of glochidia on host channel catfish in the fall of 2008 and subsequent transformation in the spring of 2009.

A Twin Cities Reach Plan was completed in 2005 by Minnesota Department of Natural Resources (Davis 2005). In 2008, a reintroduction plan for mucket (*Actinonaias ligamentina*) and snuffbox (*Epioblasma triquetra*) was completed for Hidden Falls in upper Pool 2 (Davis 2008); propagated subadults from St. Croix River stock were released in September, 2008. The Twin Cities Reach (Pools 1 through 3) continues to be refuge from zebra mussels; they are present but at a very low density and not harmful to native mussels. Four of the ten Population Establishment Sites for Higgins eye are located in the Twin Cities Reach due to the low density of zebra mussels compared to downstream Pools (Mussel Coordination Team 2007). In addition to Higgins eye, over 2000 state-listed mussels have been relocated to this reach.

In 2007, a study was initiated on Developing a Propagation Technique for Native Illinois River CWCP Mussels (Illinois Department of Natural Resources). To date, 167 butterfly (*Ellipsaria lineolata*) were placed in stockpiles for use as donor females. Glochidia infested host fish will be placed in a floating cage system in 2009.

- 4.2.2 Develop criteria for mussel relocation. Develop a checklist of the physical, chemical, and biological parameters (e.g., habitat type, presence of other mussel species, and number of individuals needed for a self-sustaining population) to be considered before attempting to translocate mussels or hold them in refugia. This guidance should address moving species between watersheds and introduction

into nonhistoric habitat. The guidance should also stress the need to monitor and fully report project results. **See Item 4.2.1 above. Higgins eye Relocation Plan implemented (Corps of Engineers, Mussel Coordination Team); Twin Cities Reach Plan completed by Minnesota Department of Natural Resources (Davis 2005).**

4.2.3 Develop protocols to ensure that zebra mussels and other non-indigenous species are not inadvertently introduced into new waters when native mussels are relocated. Because of the dire threat posed by zebra mussels and other non-indigenous species, some mussel species will be moved into hatchery facilities or to locations where these non-indigenous species do not exist. **Relocation and quarantine of native mussels in the UMR and Genoa National Fish Hatchery (U.S. Geological Survey, U.S. Fish & Wildlife Service).**

4.2.4 Identify streams for reintroduction and augmentation of mussel populations. Federal and state natural resources agencies should form partnerships to develop a prioritized list of streams that can be used for reintroduction and augmentation of mussel populations. **See Item 4.2.1 above. Higgins eye Relocation Plan implemented (Corps of Engineers, Mussel Coordination Team); Twin Cities Reach Plan completed by Minnesota Department of Natural Resources (Davis 2005).**

4.2.5 Develop mechanisms for the long-term monitoring of transplanted mussels. Once released into the wild, individual mussels are difficult to relocate, complicating the assessment of release success. Use of radio telemetry should be explored along with other tagging methods (Lemarie et al. 2000). Other avenues of relocating and monitoring transplanted mussels should be investigated as well. **See Item 4.2.1 above. Higgins eye Relocation Plan implemented (Corps of Engineers, Mussel Coordination Team); Twin Cities Reach Plan completed by Minnesota Department of Natural Resources (Davis 2005).**

### **4.3 Refugia and Cryopreservation**

4.3.1 Continue development of protocols and technology to maintain adult mussels in captivity. Many species are so rare or so threatened by habitat destruction or other factors like non-indigenous zebra mussels that they are likely to become extinct in the wild in the foreseeable future. As mussels are long-lived, it may be possible to maintain some species in captivity for extended periods. When habitat is restored or suitable habitat is located, these individuals or their propagated offspring could be returned to the wild. The technology for the long-term maintenance of captive mussel populations is not fully developed. Research on the feeding and habitat requirements of captive-held adults is crucial. **Not Accomplished.**

- 4.3.2 Develop guidelines with thresholds (triggers) to assist managers in determining when individuals of a mussel species should be brought into captivity. Many factors threaten the continued existence of native mussels. **Not Accomplished.**
- 4.3.3 Develop criteria for selecting an appropriate facility to be used for captive mussel holding and identify specific facilities that could be used in this effort. These criteria will assist managers in determining if their facilities are suitable for captive holding. If the facility managers know they might be requested to hold mussels, they could consider these criteria when planning modifications to their facilities. Secure appropriate commitments from agencies or organizations for facility space in areas where there is an imminent need for captive holding. **Not Accomplished; Genoa National Fish Hatchery currently used for propagation activities (U.S. Fish & Wildlife Service).**
- 4.3.4 Develop mussel cryopreservation technology. Cryogenic preservation could maintain mussel genetic material (much like seed banks for endangered plants) until such time that the habitat is suitable for reestablishing the species. Additionally, if a mussel population was lost to a catastrophic event, such as a toxic chemical spill, cryogenic preservation could allow for the eventual reestablishment of that population using preserved genetic material. As cryopreservation techniques for other faunal groups are developed, the technology should be adapted and tested on native mussels. **Not Accomplished.**

#### **4.4 Habitat Restoration**

- 4.4.1 Develop and implement projects to restore mussel habitats. The magnitude of the mussel conservation challenge is great, but staff and funding resources available for mussel conservation is small. Managers should concentrate their efforts, within their area of responsibility, on those key habitats, research programs, and protection / enhancement activities that will achieve the greatest benefit to mussel conservation. **Mussel channel constructed for Bertom/McCartney EMP project in Pool 11 (Corps of Engineers, Wisconsin Department of Natural Resources); no monitoring to date. Hydrophysical thresholds are serving as design criteria in EMP projects (U.S. Geological Survey).**
- 4.4.2 Develop a list of case studies that identify and summarize successful habitat restoration and protection projects and make the information available to the mussel conservation community. **Not Accomplished.**
- 4.4.3 Construct habitat projects that provide flow and substrate conditions more favorable to native mussels than non-indigenous zebra mussels. **Not Accomplished**

#### **4.5 Species and Habitat Protection**

- 4.5.1 Encourage state and federal agencies to use their regulatory authority to strengthen their enforcement capabilities to reduce or abate pollution and habitat loss on the Upper Mississippi River System, establish effective harvest restrictions and violation penalties, and optimize enforcement activities. Those few reaches that still harbor diverse mussel populations should be protected from further habitat degradation to the extent possible. It is much more cost-effective to protect existing quality habitat than to restore. **Not Accomplished.**
- 4.5.2 Determine if current laws and regulations protect freshwater mussels. Many existing laws and regulations are aimed at protecting aquatic resources. However, information is needed to determine if they provide sufficient protection for rare mussels. **Regulations for commercial and/or sport harvest of mussels revised in Minnesota, Wisconsin, Iowa and Missouri.**
- 4.5.3 Determine if current water quality criteria protect all life stages of freshwater mussels. Bioassays should be conducted to evaluate the sensitivity of all life stages of mussel relative to the sensitivities of standard bioassay organisms. Surrogate species should be selected to be protective of most sensitive mussel species or appropriate buffers should be built into protective criteria models. **Developed ASTM standard guide for conducting toxicity tests with freshwater mussels (U.S. Geological Survey). Evaluated sedimentary ammonia toxicity to freshwater mussels (U.S. Geological Survey). Observed sensitivity of mussels to contaminants across life stages, exposure routes and exposure durations (North Carolina State University, U.S. Geological Survey, U.S. Fish & Wildlife Service).**
- 4.5.4 Determine if current Best Management Practices (BMPs) protect mussel populations and their habitat. Great strides have been made in the development and implementation of BMPs for agriculture, silviculture, road and bridge construction, and other activities, and these practices have benefited aquatic resources. Research is needed to determine if these practices adequately protect mussel populations and how they might be modified to be more effective. Information is also needed about the degree of voluntary compliance with BMPs. **Not Accomplished.**
- 4.5.5 Use federal and state legislation such as the Endangered Species Act (ESA) to formally list mussels as endangered, threatened or other appropriate designation. **Sheepnose (*Plethobasus cyphus*) and Spectaclecase (*Cumberlandia monodonta*) as candidate species; ESA listing packages for threatened/endangered status completed for sheepnose, spectaclecase and snuffbox (U.S. Fish & Wildlife Service).**

## 4.6 Endangered Species Act Recovery Plans

- 4.6.1 Implement recovery plans for federally endangered mussels of the Upper Mississippi River System. Four mussel species that reside in the Upper Mississippi River System receive federal protection under the Endangered Species Act. They are listed as endangered species and include the winged mapleleaf (*Quadrula fragosa*), Higgins eye pearlymussel, fat pockbook (*Potamilus capax*) and scaleshell (*Leptodea leptodon*).  
**Propagation/reintroduction of Higgins eye and winged mapleleaf initiated under the April 2000 biological opinion (Corps of Engineers, Mussel Coordination Team). Discussions initiated by U.S. Fish & Wildlife Service and Minnesota Department of Natural Resources on reintroduction of *P. capax* into Pool 2. Discussions initiated by U.S. Fish & Wildlife Service on propagation/reintroduction of Higgins eye in 2009 for recovery purposes. Because of zebra mussel infestation in the Upper Mississippi River, the Recovery Plan for the Higgins eye Pearlymussel was revised in 2004 (U.S. Fish and Wildlife Service 2004a). Essential Habitat Areas (EHA's) for Higgins eye were reviewed and updated in 2008 (Delphey 2008).**

**5. Educate people (private, public and political) on the ecological and economic value of native mussels, threats to their continued existence, and restoration opportunities.**

### **Strategies**

#### **5.1 Public Education**

- 5.1.1 Compile an annotated list of existing freshwater mussel-related outreach material. Considerable educational material relating to freshwater mussels and the value of protecting natural stream ecosystems already exists. **See 5.1.3 below.**
- 5.1.2 Identify target audiences, evaluate the need for outreach material for these audiences, and develop appropriate media to strategically convey focused mussel conservation messages to specific audiences. Identify target groups that can assist with mussel conservation and those that could be, or perceived they could be, impacted by the program. Where needed, develop specific outreach material for these target groups. **See 5.1.3 below.**
- 5.1.3 Identify and develop specific educational/informational material and mechanisms to assist field biologists with implementing this plan. This includes items such as an annotated bibliography of existing freshwater mussel literature, a database on the historic and current distribution of mussels, videos and other materials, and an effective information transfer system on current mussel research, management, and conservation issues. **Freshwater Mussels of the Upper Mississippi River System website contains outreach and educational materials, videos and literature (<http://midwest.fws.gov/mussel>) (U.S. Fish & Wildlife Service, U.S. Geological Survey, Mussel Coordination Team). Mussel data from Corps of Engineers -sponsored surveys are contained within a new central database**



**(Corps of Engineers). Mussel identification guides completed for Upper Mississippi River (Wisconsin Department of Natural Resources 2003), Minnesota (Sietman 2003) and Missouri (Bruenderman et al 2002) waters.**

- 5.1.4 Inform the public about the threat zebra mussels and other non-indigenous species pose to native aquatic species and other resources (e.g., sport fisheries, water supply facilities, and power plants). Public support will be needed to stem the invasion of these species into other waters. The public should be informed of the economic and ecological threat posed by non-indigenous species and provided with information as to what they can do to reduce the species' dispersal rate. If the spread of non-indigenous species can be slowed, increased opportunities will be available to develop native mussel protection strategies. **Not Accomplished.**
- 5.1.5 Request the U.S. Fish and Wildlife Service National Conservation Training Center develop training and educational coursework on freshwater mussel conservation. **Not Accomplished.**
- 5.1.6 The U.S. Fish and Wildlife Service and U.S. Geological Survey should continue to operate and maintain the Internet mussel web site "Freshwater Mussels of the Upper Mississippi River System" (<http://midwest.fws.gov/mussel>) to assist with implementation and outreach strategies. **Ongoing operation and maintenance of website (U.S. Fish & Wildlife Service, U.S. Geological Survey, Mussel Coordination Team).**
- 5.1.7 Revise and reprint the 1985 identification booklet "Freshwater Mussels of the Upper Mississippi River" on waterproof paper (Wisconsin Department of Natural Resources 1985). **Completed in 2003 (Wisconsin Department of Natural Resources 2003).**

## **6. Develop strategies to implement the Conservation Plan for Freshwater Mussels of the Upper Mississippi River System.**

### **Strategies**

#### **6.1 Plan Implementation**

- 6.1.1 Ensure that new federal programs on the Upper Mississippi River System include conservation of native mussels as a project objective and implement appropriate portions of this plan. Recommend that this Conservation Plan for Freshwater Mussels on the Upper Mississippi River System be included as a project feature of the Upper Mississippi River – Illinois Waterway System Navigation Study. **Recommended by Upper Mississippi River Conservation Committee and Mussel Coordination Team but not implemented by Corps of Engineers.**

- 6.1.2 Encourage federal, state and tribal natural resource agencies to establish new mussel conservation positions on the Upper Mississippi River System. **Ongoing; mussel conservation position established at Genoa National Fish Hatchery.**
- 6.1.3 Use the interagency Mussel Coordination Team (**Mussel Coordination Team**) to coordinate mussel conservation activities under this Plan. The role of the **Mussel Coordination Team** may include, but not be limited to, such activities as establishment of priority mussel research and management needs; collection and publication of mussel statistics; review of critical environmental issues; providing professional consultation services to the Corps and other agencies; development of uniform mussel investigation, propagation and relocation procedures, and public education programs and materials. **Ongoing.**
- 6.1.4 Foster and create new partnerships that facilitate the development of formal agreements (e.g., memorandums of agreement) among government agencies and private entities to help implement this plan. The mussel conservation community is small and, by itself, cannot significantly alter the factors that threaten this faunal group. However, most of the strategies that benefit mussels and their habitat quality also significantly benefit other aquatic fauna and resource user groups (commercial mussel industry, sport fisheries, water supply industry, canoeists, birders, etc.). Partnerships with other entities are essential to the success of this mussel conservation program, and these partnerships should be actively pursued. **Not Accomplished.**
- 6.1.5 Develop partnerships and seek funding from government agencies, private organizations, foundations, industries, and individuals. No one agency or organization has sufficient funds or expertise to conserve and recover the Upper Mississippi River System mussel fauna. Partnerships, cooperative ventures, and funding from within and outside government are essential to program success. Additionally, mussel conservation will not succeed unless it is integrated with other aquatic ecosystem conservation efforts. The benefit of mussel conservation must be linked to other aquatic resource benefits. **Not Accomplished.**
- 6.1.6 Seek funding for mussel conservation from agencies or organizations that have activities that impact mussel communities. Many regulatory agencies oversee programs that secondarily benefit mussels; they should strengthen their programs to improve the protection of mussel resources. Pursue cooperative funding that satisfies an agency's needs and promotes mussel conservation. Consider establishing mitigation trust funds to help compensate for the loss of mussel resources caused by development projects. A trust was established to mitigate for the loss of a mussel bed on the Ohio River. This trust now provides funds for mussel conservation projects that benefit Ohio River mussels (Marshall et al. 1993). **Not Accomplished.**
- 6.1.7 Evaluate funding alternatives, such as a tax on exported shells, commercial mussel harvest fees, or a tax on the import of products made from native shells.

Some states already impose a tax on harvested shells, and the funds are used for mussel conservation efforts. A federal tax on domestic shell exports or the foreign import of mussel-derived products should be considered. **Not Accomplished.**

- 6.1.8 Seek funding assistance from non-government agencies and organizations, businesses, and foundations. Many organizations fund conservation projects or provide in-kind support. If one organization provides funding, other organizations are often more willing to match the original funds. Solicit the support of such organizations and build cooperative efforts among these groups. **Not Accomplished.**

## **Section 2. Priority Mussel Conservation Activities for the Next 10 Years**

As noted above, a significant amount of effort has taken place since 2003 to begin implementing the Upper Mississippi River Conservation Committee Mussel Conservation Plan. However, given the facts of limited budgets and staffing, it is critical that future activities be focused on the most critical conservation issues and information needs over the next 10 years. On June 27, 2008, a small group of river biologists<sup>1</sup> met and developed the following list of questions. These questions are presented here as a draft for further refinement/prioritization by the Mussel Coordination Team and Upper Mississippi River Conservation Committee Mussel Ad Hoc Committee:

- 1. What is the current distribution/status of mussels across UMR pools/reaches?**
  - a. How does species composition and mussel distributions change over the length of the system?
    - i. Why are some species present in some pools and tributaries and not others?
  - b. What is the relative health of the Upper Mississippi River System mussel community (% juveniles, age/length structure)?
  - c. What are the criteria used to define important mussel areas—where are they and what are their extents?
  - d. What is the minimum information needed to conduct mussel surveys?
  
- 2. What are the trends in mussel populations in UMR pools over time?**
  - a. Are populations stable, increasing or decreasing?
  - b. What are the trends in recruitment over time—across a group of species?
  - c. What are trends in total mortality over time?

---

<sup>1</sup> Biologists at meeting or providing information and assistance: Teresa Newton, Steve Zigler, U.S. Geological Survey; Dennis Anderson, Dan Kelner, Corps of Engineers; Dave Heath, Wisconsin Department of Natural Resources; Mike Davis, Minnesota Department of Natural Resources; Tony Brady, Jim Luoma, Doug Aloisi, Pam Thiel, Jon Duyvejonck, Gary Wege, U.S. Fish & Wildlife Service.

- 3. What population-level variables (i.e., mortality, recruitment, reproduction, movement) are most likely constraining mussel populations in the Upper Mississippi River System?**
  - a. What are the effects of zebra mussels on unionids?
  - b. How much does predation (i.e., carp, drum) affect unionid populations?
  - c. What are the effects of climate change on unionids?
  - d. What is the minimum population size needed for rare species (population viability analysis)?
  - e. How does hydrology/geomorphology influence population vital rates?
  - f. How do host fish populations influence unionid populations?
  
- 4. What are the restoration targets for mussels at both the species and community level?**
  - a. What is the historical species composition/richness in each pool/reach?
  - b. Would a “mussel IBI” be useful to assess mussel health and the success of restoration projects?
  
- 5. What are the effects of ecosystem restoration activities on mussels?**
  - a. What is the significance of stranding/killing mussels during drawdowns or island construction on the UMR?
  - b. Which ecosystem activities are most beneficial to mussels?
  - c. How do altered flow regimes affect mussel populations?
  - d. What is the balance between short-term impacts and long-term benefits in river restoration activities?
  
- 6. What management activities can we undertake to enhance mussel populations?**
  - a. Can we reestablish a viable, self-sustaining mussel assemblage through propagation and reintroduction?
  - b. Can we use results from hydrophysical models to design and construct mussel habitat projects in the field?
  - c. Would installation of fish passage facilities enhance populations or reintroduce mussel species?
  - d. How can we successfully propagate T&E species?
  - e. What are the host fish for rare species?
  
- 7. In educating people, what roles do mussels play in the Upper Mississippi River ecosystem?**
  - a. How important are mussels in stabilizing river sediment?
  - b. How important are mussels in processing nutrients?
  - c. How important are mussels in providing habitat to other biota?

### **Section 3. References Cited Above**

- Bowen, B. 2004. Genetic variability and geographic structure of *Lampsilis higginsii* mussels in the upper Mississippi River and tributaries. Department of Animal Ecology, Iowa State University, Ames, Iowa.
- Bruenderman, S., J. Sternburg and C. Barnhart. 2002. Missouri's freshwater mussels. Missouri Department of Conservation, P.O. Box 180, Jefferson City, MO. 16pp.
- Davis, M. 2005. Freshwater mussels of Minnesota: a plan for controlled propagation, reintroduction and augmentation in the Mississippi River from St. Anthony Falls to Lake Pepin. March, 2005. Minnesota Department of Natural Resources, Lake City, MN.
- Davis, M. 2008. Site reintroduction plan for mucket (*Actinonaias ligamentina*) and snuffbox (*Epioblasma triquetra*) at Hidden Falls in St. Paul, Minnesota. Minnesota Department of Natural Resources, Lake City, MN.
- Delphey, P. 2008. Higgins eye (*Lampsilis higginsii*) Essential Habitat Areas: 2008 review and addition of new EHA's. U.S. Fish and Wildlife Service, Twin Cities ES Field Office, Bloomington, Minnesota. 9 pp.
- Grigorovich, I.A., T.R. Angradi and C.A. Stepien. 2008. Occurrence of the quagga mussel (*Dreissena bugensis*) and the zebra mussel (*Dreissena polymorpha*) in the Upper Mississippi River System. Draft Report, U.S. Environmental Protection Agency, Duluth, MN. 13 pp.
- Hornbach, D. J. and M. C. Hove. 2007. Habitat requirements of the winged mapleleaf mussel: potential habitat degradation and decline in the St. Croix River. Final report to the National Park Service, St. Croix National Scenic Riverway, St. Croix Falls, WI. 65 pp.
- Hove, M. N. Rudh, A. Morantes, and J. Stevenson. 2007. Host fish requirements of select upper Mississippi River mussel species. Annual report to the Minnesota Department of Natural Resources, St. Paul, MN. 19 pp.
- Hove, M. and D. Hornbach. 2004. Mussel communities in the St. Croix National Scenic Riverway: an outstanding natural resource - final report. Final report to St. Croix National Scenic Riverway, St. Croix Falls, WI. 48 pp. + app.'s
- Kat, P.W. 1983a. Genetic and morphological divergence among nominal species of North America Anodonta (Bivalvia: Unionidae). *Malacologia* 23:361-374.
- Kat, P.W. 1983b. Genetics, morphological divergence, and speciation among *Lampsilis*. *Journal of Molluscan Studies* 49:133-145.

- Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister and J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. Publication #1980-12 of the North Carolina Biological Survey. 854pp.
- Lydeard, C., M. Mulvey and G.M. Davis. 1996. Molecular systematics and evolution of reproductive traits of North American freshwater unionacean mussels (Mollusca Bivalvia) as inferred from 16S rRNA DNA sequences. Proceedings of the Royal Society (London) Series B:351:1593-1603
- Mulvey, M., C. Lydeard, D.L. Pyer, K.M. Hicks, J. Brian-Box, J.D. Williams and R.S. Butler. 1997. Conservation genetics of North American freshwater mussels *Amblema* and *Megaloniais*. Conservation Biology 11:868-878.
- Mussel Coordination Team. 2007. 2006 Status report on the accomplishments of the Mussel Coordination Team (MCT). September, 2007, St. Paul District Corps of Engineers, Minnesota. 133 pp.
- National Park Service. 2008. Annual report: quantitative assessment of zebra mussels associated with native mussel beds in the lower St. Croix River, 2007. National Park Service, St. Croix National Scenic Riverway, St. Croix Falls, WI. 7 pp.
- O'Neill, C. Jr. and D.B. MacNeill. 1991. The zebra mussel (*Dreissena polymorpha*): an unwelcome North American invader. New York Sea Grant, FACT SHEET November 1991, SUNY College at Brockport, Brockport, NY. 12pp.
- Pritchard, J. 2001. An historical analysis of mussel propagation and culture: research performed at the Fairport Biological Station. December 2001. Clear Creek Historical Research, Ames, IA. 76pp.
- Sietman, B.E. 2003. Field guide to the freshwater mussels of Minnesota. Minnesota Department of Natural Resources, 500 Lafayette Road, St. Paul, MN. 144 pp.
- Steingraeber, M., Bartsch, M., Kalas, J. and T. Newton. 2005. Winged mapleleaf early life history investigations conducted by the Department of Interior in FY 2004. U.S. Fish and wildlife Service, Fishery Resources Office, Onalaska, Wisconsin. 23 pp.
- Taylor, R.M. and Kelly Kershner (eds.). 1995. Sea Grant zebra mussel report: an update of research and outreach. Ohio Sea Grant College Program, The Ohio State University, Columbus, OH. 54 pp.

- Upper Mississippi River Conservation Committee 2003. Conservation plan for freshwater mussels of the Upper Mississippi River System. 555 Lester Avenue, Onalaska, WI, 54650. 28 pp.
- U.S. Fish and Wildlife Service. 2000. Controlled propagation of species listed under the Endangered Species Act. U.S. Fish and Wildlife Service and Department of Commerce, Federal Register, September, 2000.
- U.S. Fish and Wildlife Service. 2004a. Winged mapleleaf (*Quadrula fragosa*): plan for controlled propagation, augmentation and reintroduction. Twin Cities Ecological Services Field Office, Bloomington, Minnesota. 13 pp.
- U.S. Fish and Wildlife Service. 2004b. Higgins eye pearlymussel (*Lampsilis higginsii*) recovery plan: first revision. Ft. Snelling, Minnesota. 126 pp.
- Wisconsin Department of Natural Resources. 1985. Freshwater mussels of the Upper Mississippi River. Wisconsin Department of Natural Resources, Madison, WI. 63pp.
- Wisconsin Department of Natural Resources. 2003. Freshwater mussels of the upper Mississippi River. Wisconsin Department of Natural Resources, Madison, WI. 62 pp.

#### **Section 4. Additional References from the Mussel Coordination Team, UMRCC Mussel Ad Hoc Committee, Federal/State Agencies, Universities and Private Sector**

##### **Peer-reviewed manuscripts:**

- Bartsch, M.R., T.J. Newton, J.W. Allran, J.A. O'Donnell, and W.B. Richardson. 2003. Effects of pore water ammonia on in situ survival and growth of juvenile mussels (*Lampsilis cardium*) in the St. Croix Riverway. *Environmental Toxicology and Chemistry* 22:2561-2568.
- Cope, W.G., T.J. Newton, and C.M. Gatenby. 2003. Review of techniques to prevent introduction of zebra mussels (*Dreissena polymorpha*) during native mussel (Unionoidea) conservation activities. *Journal of Shellfish Research* 22:177-184.
- Cope, W.G., R.B. Bringolf, D.B. Buchwalter, T.J. Newton, C.G. Ingersoll, N. Wang, T. Augspurger, F.J. Dwyer, M.C. Barnhart, R.J. Neves, and E. Hammer. 2008. Differential exposure, duration, and sensitivity of Unionoidean bivalve life stages to environmental contaminants. *Journal of the North American Benthological Society* 27:451-462.

- Gooding, M.P., T.J. Newton, M.R. Bartsch, and K.C. Hornbuckle. 2006. Toxicity of synthetic musks to glochidia and juvenile life stages in the freshwater mussel *Lampsilis cardium*. *Archives of Environmental Contamination and Toxicology* 51:549-558.
- Morales, Y., L.J. Weber, A.E. Mynett, and T.J. Newton. 2006. Mussel dynamics model: a hydroinformatics tool for analyzing the effects of different stressors on the dynamics of freshwater mussel communities. *Ecological Modeling* 197:448-460.
- Morales, Y., L.J. Weber, A.E. Mynett, and T.J. Newton. 2006. Effects of substrate and hydrodynamic conditions on the formation of mussel beds in a large river. *Journal of the North American Benthological Society* 25:664-676.
- Morales, Y., L.J. Weber, A.E. Mynett, and T.J. Newton. 2007. Simulating the effect of invasive species on native freshwater mussel communities. *International Journal of River Basin Management* 5:267-277.
- Newton, T.J. 2003. The effects of ammonia on freshwater unionid mussels. *Environmental Toxicology and Chemistry* 22:2543-2544.
- Newton, T.J., J.W. Allran, J.A. O'Donnell, M.R. Bartsch, and W.B. Richardson. 2003. Effects of ammonia on juvenile unionid mussels (*Lampsilis cardium*) in laboratory sediment toxicity tests. *Environmental Toxicology and Chemistry* 22:2554-2560.
- Newton, T.J. and M.R. Bartsch. 2007. Assessing contaminant sensitivity of early life stages of freshwater mussels (Unionidae): lethal and sublethal effects of ammonia to juvenile *Lampsilis* mussels in sediment and water-only exposures. *Environmental Toxicology and Chemistry* 26:2057-2065.
- Newton T.J. and W.G. Cope. 2007. Biomarker responses of unionid mussels to environmental contaminants. Pages 257 to 284 in *Freshwater Bivalve Ecotoxicology*, J.L. Farris and J.H. Van Hassel, eds., SETAC Press, Pensacola, FL and Taylor & Francis, Boca Raton, FL.
- Newton, T.J., D.A. Woolnough, and D.L. Strayer. 2008. Using landscape ecology to understand freshwater mussel populations. *Journal of the North American Benthological Society* 27:424-439.
- Steingraeber, M.T., M.R. Bartsch, J.E. Kalas, and T.J. Newton. 2007. Thermal criteria for early life stage development of the Winged Mapleleaf mussel (*Quadrula fragosa*). *American Midland Naturalist* 157:297-311.
- Steuer, J.J., T.J. Newton, and S.J. Zigler. 2008. Use of complex hydraulic variables to predict the distribution and density of unionids in the Upper Mississippi River. *Hydrobiologia* 610:67-82.



- Strayer, D.L., J.A. Downing, W.R. Haag, T.L. King, J.B. Layzer, T.J. Newton, and S.J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. *BioScience* 54:429-439.
- Wang, N., T. Augspurger, M.C. Barnhart, J.R. Bidwell, W.G. Cope, F.J. Dwyer, S. Geis, I.E. Greer, C.G. Ingersoll, C.M. Kane, T.W. May, R.J. Neves, T.J. Newton, A.D. Roberts, and D.W. Whites. 2007. Assessing contaminant sensitivity of early life stages of freshwater mussels (Unionidae): intra- and inter-laboratory variability in acute toxicity tests with glochidia and juvenile mussels. *Environmental Toxicology and Chemistry* 26:2029-2035.
- Zigler, S., T. Newton, J. Steuer, M. Bartsch, and J. Sauer. 2008. Importance of physical and hydraulic characteristics to unionid mussels: a retrospective analysis in a reach of large river. *Hydrobiologia* 598:343-360.

#### **Reports and Publications:**

- Anderson, D.D. and M. Farr. 2003. Report of 2002 collecting, cleaning, and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in pool 11 near Cassville, Wisconsin. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Bowen, B. 2002. Progress report on genetic study of *Lampsilis higginsii*. Department of Animal Ecology, Iowa State University, Ames, Iowa.
- Bowen, B. 2004. Genetic variability and geographic structure of *Lampsilis higginsii* mussels in the upper Mississippi River and tributaries. Department of Animal Ecology, Iowa State University, Ames, Iowa.
- Bowen, B. January 2006. Genetic identification of juvenile freshwater mussels from Iowa Rivers. Department of Animal Ecology, Evolution, and Organismal Biology, Iowa State University, Ames, Iowa. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.
- Bowen, B. and T.J. Kelley. 2003. Progress report on population genetics of *Lampsilis higginsii* using microsatellite DNA. Department of Animal Ecology, Iowa State University, Ames, Iowa.
- Bowen, B. and T.J. Kelley. 2004. Assessment of nuclear DNA microsatellites for genetic studies of *Lampsilis higginsii* mussels. Department of Animal Ecology, Iowa State University, Ames, Iowa.
- Brady, T., M. Hove, C. Nelson, R. Gordon, D. Hornbach, and A. Kapuscinski. 2004. Suitable host fish species determined for hickorynut and pink heelsplitter. *Ellipsaria* 6(1): 14-15.

- Corgiat, D., B. Schanzle, B. Atwood, and T. Kelley. 2002. Report on 2002 placement and monitoring of *Lampsilis higginsii* inoculated fish in cages into pool 24, Illinois
- Crownhart, A. B. Sietman, M. Hove, and N. Rudh. 2007. *Quadrula metanevra* glochidia metamorphose on select minnow species. *Ellipsaria* 8(3): 6-7.
- Davis, M. 2001. Emergency conservation relocation and reintroduction of Higgins eye pearlymussel (*Lampsilis higginsii*) and other mussel species from zebra mussel infested areas in the upper Mississippi River. Section 6 Grant Project Final Report, 2001. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2002. Clam chronicles: an account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – 2002 Field Season. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2003. Clam chronicles: an account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – 2003 Field Season. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2004. Clam chronicles: an account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – 2004 Field Season. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2005. Clam chronicles: an account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – 2005 Field Season. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2005. Freshwater mussels of Minnesota: a plan for controlled propagation, reintroduction and augmentation in the Mississippi River from St. Anthony Falls to Lake Pepin. March, 2005. Minnesota Department of Natural Resources, Lake City, MN.
- Davis, M. 2006. Clam chronicles: an account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – 2006 Field Season. Minnesota Department of Natural Resources, Lake City, Minnesota.
- Davis, M. 2008. Site reintroduction plan for mucket (*Actinonaias ligamentina*) and snuffbox (*Epioblasma triquetra*) at Hidden Falls in St. Paul, Minnesota. Minnesota Department of Natural Resources, Lake City, MN.

- Delphey, P., D.D. Anderson, D. Sallee, and M. Davis. 2002. Report of 2001 relocation of adult *Lampsilis higginsii* from the Mississippi River in pool 14 near Cordova, Illinois to Pool 2, Minnesota. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota; U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota; Illinois Department of Natural Resources, Sterling, Illinois; and Minnesota Department of Natural Resources, Lake City, Minnesota.
- Delphey, P. and D.D. Anderson. 2002. Report of 2001 collecting, cleaning, and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in pool 11 near Cassville, Wisconsin. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota; U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Delphey, P. 2008. Higgins eye (*Lampsilis higginsii*) Essential Habitat Areas: 2008 review and addition of new EHA's. U.S. Fish and Wildlife Service, Twin Cities ES Field Office, Bloomington, Minnesota. 9 pp.
- Ecological Specialists, Inc. 2001. Zebra mussel monitoring in the inland waterways: synthesis of current research and recommendations for the development of population dynamics models. St. Peters, Missouri.
- Ecological Specialists, Inc. 2007. 2006 Monitoring of native and non-indigenous mussel species in the upper Mississippi River. O'Fallon, Missouri.
- Farr, M.D., A.C. Miller, and B.S Payne. Draft – 2002. Ecological aspects of native and non-native bivalves at selected sites in the upper Mississippi River, 2001 Studies. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Farr, M.D., A.C. Miller, and B.S Payne. Draft – 2003. Ecological aspects of native and non-native bivalves at selected sites in the upper Mississippi River, 2002 Studies. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Farr, M.D., A.C. Miller, and B.S Payne. 2005. Ecological aspects of native and non-native bivalves at selected sites in the upper Mississippi River, 2003 Studies. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Farr, M.D., A.C. Miller, and B.S Payne. 2005. Ecological aspects of native and non-native bivalves at selected sites in the upper Mississippi River, 2004 Studies. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Farr, M.D., A.C. Miller, and B.S Payne. 2005. Ecological aspects of native and non-native bivalves at selected sites in the upper Mississippi River, 2005 Studies. U.S.

Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and V.E. Alley. 2003. Distribution and abundance of zebra mussel veligers in the upper Mississippi River and its major tributaries, 2002. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and V.E. Alley. March 2004. Distribution and abundance of zebra mussel veligers in the upper Mississippi River and its major tributaries, 2003. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and M. Antwine . 2005. Distribution and abundance of zebra mussel veligers in the upper Mississippi River and its major tributaries, 2004. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and M. Antwine . 2007. Distribution and abundance of zebra mussel veligers at sites in the upper Mississippi River and its major tributaries, 2006. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D., V.E. Alley, and N.M. McVay. Draft March 2004. Distinguishing between live and recently dead zebra mussel veligers associated with the Chicago Sanitary and Ship Canal electrical barrier, 2003. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and V.E. Alley. 2005. Summary of ERDC UMR 2005 mussel survey at Winters Landing, McMillan Island, and Cordova Essential Habitat Areas. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Farr, M.D. and B.S. Payne. September 2006. Environmental habitat conditions associated with freshwater Dreissenids. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Gordon, R. 2001. Zebra mussel (*Dreissena polymorpha*) control protocol associated with culture of freshwater mussels. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI.

Gordon, R. 2001. Operational procedures and techniques for the artificial infestation of *Lampsilis higginsii*. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI.

Gordon, R. 2001. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2001. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.

- Gordon, R. 2002. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2002. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Gordon, R. and T. Brady. 2003. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2003. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Gordon, R. and T. Brady. 2004. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2004. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Gordon, R. and T. Brady. 2005. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2005. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Gordon, R. and T. Brady. 2006. *Lampsilis higginsii* recovery project Genoa National Fish Hatchery, 2006. U.S. Fish and Wildlife Service. Genoa National Fish Hatchery, Genoa, WI. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Gritters, S. 2001. Letter report on Iowa River inoculations in 2001. Iowa Department of Natural Resources, Guttenberg, Iowa.
- Gritters, Scott A. and R. Gordon. 2006. Summary of freshwater mussel surveys in Iowa inland streams by the Mussel Coordination Team in 2005 and 2006. Iowa Department of Natural Resources, Guttenberg, Iowa.
- Havlik, M. E. 2002. A mussel survey in the vicinity of a proposed outfall pipe, Mississippi River Mile 823.0-823.4, Rosemount, Dakota County, Minnesota. Report to the Metropolitan Council, St. Paul, Minnesota. 15 pages.
- Havlik, M. E. 2002. Revisited: effects of a low-head dam replacement on a unionid population, Steel Dam, Rock River, at Milan, Illinois. *Ellipsaria*. The Newsletter of the Freshwater Mollusk Conservation Society 4(1):10-11.
- Havlik, M. E. 2002. A comparative study of Mississippi River unionid surveys, St. Paul, Minnesota, to Cairo, Illinois. Proceedings of the 34th Mississippi River Research Consortium, 25-26 April 2002. Vol. 34:26.
- Havlik, M. E. 2002. R9 Conservation assessments for creek heelsplitter, *Lasmigona compressa* (Lea, 1829), flutedshell, *Lasmigona costata* (Rafinesque, 1820), black sandshell, *Ligumia recta* (Lamarck, 1819), and ellipse shell, *Venustaconcha*

- ellipsiformis* (Conrad, 1836). Report to U.S. Forest Service, Cass Lake, Minnesota. 195 pages plus list of verified museum specimens.
- Havlik, M. E. January 2002. Unionids rescued in Pool 8, Mississippi River, La Crosse, Wisconsin, USA. Tentacle. The Newsletter of the IUCN-SSC Mollusk Specialist Group, Species Survival Commission -IUCN-The World Conservation Union. No. 10:10. Download at: <http://www2.hawaii.edu/~cowie/tenta>
- Havlik, M. E. 2003. Follow-up on a 2002 Wisconsin River mussel translocation from U.S. Hwy 12 bridge, Sauk and Dane Counties, Wisconsin, May and June 2003. Report to Strand Associates, Inc., Madison, Wisconsin. 15 pages.
- Havlik, M. E. 2003. 2003 follow-up on a mussel translocation from Mississippi River Mile 818.9, Cottage Grove, Minnesota. Report to Knutson Construction, Minneapolis, Minnesota, and Metropolitan Council, St. Paul, Minnesota. 29 pages.
- Havlik, M.E. August 2003. Measured and aged 200 *Amblema plicata*, Mississippi River Mile 646, Harpers Ferry, Iowa. 5 pages; 1 table, 1 figure. (self-funded).
- Havlik, M. E. 2003. Mussels and fish resources technical memo (Pool 14, Mississippi River, Clinton, Iowa). Prepared for H. R. Green, Cedar Rapids, Iowa, and Iowa Department of Transportation, Ames, Iowa. 19 pages.
- Havlik, M. E. 2003. Mussel surveys at two U.S. Hwy 52 bridge sites, Rochester, Minnesota, April 2003. Report to Zumbro River Constructors, Rochester, Minnesota. 9 pages.
- Havlik, M. E. 2003. A mussel translocation in the vicinity of a new disposal pipe, Mississippi River Mile 818.9, Cottage Grove, Washington County, Minnesota. Report to Knutson Construction, Minneapolis, and Metropolitan Council, St. Paul, MN. 49 pages.
- Havlik, M. E. 2003. U.S. Hwy 12 Wisconsin River mussel survey and translocation, Sauk and Dane Counties, Wisconsin, May 2002. Report to Strand Associates, Inc., Madison, Wisconsin. 24 pages.
- Havlik, M. E. 2004. 2004 follow-up on a 2002 mussel translocation from the Eagle Point Wastewater Treatment Plant Area, Mississippi River Mile 818.9, Cottage Grove, Minnesota. Report to Metropolitan Council, St. Paul, MN 55101. 36 pages.
- Havlik, M. E. 2004. Unionid mussels at a proposed dock site, St. Paul Yacht Club, Mississippi River Mile 839.3-839.5, Right Descending Bank, St. Paul, Ramsey County, Minnesota, 3-4 May 2004. Report to Hard Hat Divers, Inc., White Bear Lake, MN 55110, and St. Paul Yacht Club, St. Paul, MN 55107. 13 pages.

- Havlik, M. E. 2004. Mussel translocations from three U.S. Hwy 14 bridge areas, Mississippi River Mile 697.4, La Crosse, WI, June 2003. Report to Lunda Construction Co., Black River Falls, Wisconsin, and the Wisconsin Department of Transportation, La Crosse, Wisconsin. 16 pages.
- Havlik, M. E. 2005. A 2004 follow-up of mussel translocations from three U.S. Hwy 14 Bridge areas, Mississippi River Mile 697.4, La Crosse, WI. Prepared for Wisconsin Department of Transportation, La Crosse, WI, and Lunda Construction, Black River Falls, WI. 13 pages.
- Havlik, M. E. 2005. Mussel surveys at three sites on the South Fork of the Zumbro River, Rochester, MN. Report to the Department of Public Works, Rochester, Minnesota. 17 pages.
- Havlik, M. E., and T. Balding. 2006. *Ligumia subrostrata* (Say 1831) records from the upper Mississippi River. *Ellipsaria*. The Newsletter of the Freshwater Mollusk Conservation Society. 8(2):8-9.
- Havlik, M. E. 2006. A preliminary survey of mussels in the vicinity of a potassium chloride spill, Mississippi River Mile 818.7, Cottage Grove, Washington County, Minnesota. Report to Pinnacle Engineering, Inc., Maple Grove, Minnesota 55369. 16 pages.
- Havlik, M. E. 2006. Mussel surveys at three additional sites on the South Fork of the Zumbro River, Rochester, MN, 26 September 2005. Report to the Department of Public Works, Rochester, Minnesota. 11 pages.
- Havlik, M. E. 2007. Mussel translocations at four sites on the South Fork of the Zumbro River, Rochester, Minnesota, June–September 2006. Report to the Department of Public Works, Rochester, Minnesota. 24 pages.
- Havlik, M. E. 2007. A mussel survey at a test pit site for a proposed forcemain, Mississippi River Mile 834.2, South St. Paul, MN. Report to H. R. Green, Minneapolis, MN. 10 pages.
- Havlik, M. E. 2007. Mussel surveys in the vicinity of the proposed site of the McCollister Boulevard Bridge on the Iowa River, Iowa City, IA, September 2006. Report to H. R. Green, Inc., St. Louis, MO. 15 pages.
- Havlik, M. E. 2008. 2007 follow-up of mussel translocations on the South Fork of the Zumbro River, Rochester, Minnesota. Report to the Department of Public Works, Rochester, Minnesota. 17 pages.

- Havlik, M. E. 2008. A mussel translocation at the McCollister Boulevard Bridge, Iowa River, Iowa City, Johnson County, Iowa, 9-14 September 2007. Report to H. R. Green, St. Louis, MO. 17 pages.
- Havlik, M. E. 2008. A mussel survey at Mississippi River Mile 701.7 at the I-90 bridge crossing, Dresbach, MN, October 2997. Report to the URS Corporation, Minneapolis, MN. 11 pages.
- Heath, D.J. December 2001. Letter report on May 2001 collection of *Lampsilis higginsii* from the St. Croix R., Minnesota for use as brood stock for mussel propagation at the Genoa National Fish Hatchery. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. January 2001. Letter report on placement of juveniles of *Lampsilis higginsii* into the lower Black River, Jackson County, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2001. Report on placement of *L. higginsii* inoculated fish in cages and free-ranging fish, lower Wisconsin R., 2001. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. January 2002. Progress report on mussel surveys to identify potential relocation sites for the Endangered Higgins eye pearl mussel (*Lampsilis higginsii*) Black and Chippewa Rivers, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2003. Results of 2002 monitoring of freshwater mussel communities of the Wisconsin River near Orion, Richland County, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2003. Report on July 2002 monitoring of *Lampsilis higginsii* placed in cages in the Wisconsin River near Orion in 2001. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2003. Report on May 2002 collection of *Lampsilis higginsii* from the St. Croix R., Minnesota for use as brood stock for mussel propagation at the Genoa National Fish Hatchery. Wisconsin Department of Natural Resources, Minnesota Department of Natural Resources and the U. S. Fish and Wildlife Service.
- Heath, D.J. 2003. Report on 2002 *Lampsilis higginsii* brood stock collection and stockpiling in the Wisconsin River near Prairie du Sac, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2003. Report on May 2002 collection of *Lampsilis higginsii* from the Mississippi R. near Cassville, Wisconsin for use as brood stock for mussel



- propagation at the Genoa National Fish Hatchery. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2004. Report on April 2003 collection of *Lampsilis higginsii* from the St. Croix R., Minnesota for use as brood stock for mussel propagation at the Genoa National Fish Hatchery. Wisconsin Department of Natural Resources, Minnesota Department of Natural Resources and the U. S. Fish and Wildlife Service.
- Heath, D.J. 2004. Report on March 2003 collection of *Lampsilis higginsii* from the Mississippi River, near Cassville, Wisconsin for use as brood stock for mussel propagation at the Genoa National Fish Hatchery. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J. 2004. Report on 2003 monitoring of the *Lampsilis higginsii* relocation site on the Wisconsin River near Prairie du Sac, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J., R. Benjamin, and M. Endris. 2001. Results of monitoring of freshwater mussel communities of the Saint Croix National Scenic Riverway, Minnesota and Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Heath, D.J., R. Benjamin, K. Von Ruden, and J. Janvrin. Draft March 2004. A survey of freshwater mussel aggregations on the lower Black River, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin. 25 pp and appendices.
- Heath, D.J., R. Benjamin, K. Von Ruden, and J. Janvrin. 2004. A survey of freshwater mussel aggregations on the lower Chippewa River, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Hove, M. 2004. Recovery information needed to prevent extinction of the federally endangered winged mapleleaf: early life history of select upper Mississippi River mussels. Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, Saint Paul, Minnesota
- Hove, M., M. Berg, K. Dietrich, C. Gonzalez, D. Hornbach, K. Juleen, M. Ledford, M. Marzec, M. McGill, C. Nelson, B. J. Ritger, J. Selander, and A. Kapuscinski. 2003. High school students participate in snuffbox host suitability trials. *Ellipsaria* 5(3): 19-20.
- Hove, M., M. Berg, S. Schieffers, G. Widiker, V. Kanodia, K. Yngve, C. Nelson, M. Marzec, D. Hornbach, A. Kapuscinski. 2004. High school and university researchers verify flathead catfish as host for pistolgrip (*Tritogonia verrucosa*). *Ellipsaria* 6(3): 16-18.

- Hove, M. 2005. Host fishes for the federally endangered winged mapleleaf (*Quadrula fragosa*). Final report to the St. Croix National Scenic Riverway, National Park Service. St. Croix Falls, Wisconsin. 18 pp.
- Hove, M., D. Hornbach, M. Cox, B. Dickinson, E. Evans, E. Kushner, K. MacGregor. 2005. Habitat requirements of the winged mapleleaf mussel: potential habitat degradation and decline in the St. Croix River. Annual report to the St. Croix National Scenic Riverway. St. Croix Falls, WI. 30 pp.
- Hove, M., N. Ruhd, A. Morantes, J. Stevenson, B. Sietman, A. Crownhart and B. Dickinson. 2008. Host fish requirements of select upper Mississippi River mussel species. 2007 research report to the Minnesota Department of Natural Resources, Ecological Services, St. Paul, Minnesota. 18 pp.
- Howard, C.S. and H.L. Dunn. 2003. Final report: qualitative surveys of unionid mussels and associated habitat in four Mississippi River tributaries of Iowa to identify potential relocation areas for the endangered Higgins eye pearl mussel (*Lampsilis higginsii*). Harding ESE, Inc. St. Louis, MO and Ecological Specialists, Inc., O'Fallon, MO. Prepared for U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois
- Kelner, D.E. and M. Davis. 2002. Final report: mussel (Bivalvia: Unionidae) survey of the Mississippi National River and Recreation Area Corridor, 2000-01. Minnesota Department of Natural Resources, Ecological Services Division, St. Paul, Minnesota.
- Kelner, D.E. and S. Gritters. 2003. Report of 2003 collecting and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in pool 10 near Harpers Ferry, Iowa. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota and Iowa Department of Natural Resources, Guttenberg, Iowa.
- Kelner, D.E. 2005. Report of 2004 collecting and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in Pool 14 near Cordova, Illinois and in Pool 11 near Cassville, Wisconsin. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Kelner, D.E. 2006. Report of 2005 collecting and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in Pool 14 near Cordova, Illinois and in Pool 11 near Cassville, Wisconsin. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Kelner, D.E. February 2004. Preliminary report - phase 1 - Higgins eye relocation site monitoring plan for Biological Opinion for the endangered Higgins eye pearl mussel (*Lampsilis higginsii*) Upper Mississippi River and tributaries, Minnesota, Wisconsin, Iowa, Illinois, and Missouri. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.

- Kelner, D.E., M. Davis, G. Wege. 2004. Report of 2003 relocation of sub-adult *Lampsilis higginsii* reared in cages from the Mississippi and St. Croix rivers. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota; Minnesota Department of Natural Resources, Ecological Services Division, St. Paul, Minnesota; and U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota.
- Kusilek, L. I., M. C. Hove, B. E. Sietman, D. J. Hornbach, D. C. Allen, J. M. Davis, A. K. Crownhart and A. R. Kapuscinski. 2007. Identification of juvenile mussels collected from a naturally infested white sucker using scanning electron microscopy. *Ellipsaria* 9(1): 12-13.
- Lance, R.F. and E. P. Perkins, Ph.D. January 2002. Population genetic diversity within *Lampsilis higginsii* as determined by amplified fragment length polymorphisms. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Lee, J., H. Dunn, and W.J. Elzinga. December 2003. Draft report: qualitative surveys of unionids and associated habitats within the Rock, Illinois, and Kankakee Rivers, Illinois to identify potential relocation areas for the endangered Higgins' eye pearly mussel (*Lampsilis higginsii*). MACTEC, Inc. St. Louis, Missouri and Ecological Specialists, Inc., O'Fallon, MO. Prepared for U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois.
- Miller, A.C., B.S. Payne and J. Miller. February 2001. A preliminary evaluation of possible strategies to reduce or eliminate zebra mussels and their associated impacts to *Lampsilis higginsii*, from the Upper Mississippi River Navigation System. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Miller, A.C. and B.S. Payne. Draft March 2001. Effects of zebra mussels (*Dreissena polymorpha*) at essential habitat areas for *Lampsilis higginsii* in the upper Mississippi River System, 2000. Technical Report EL-200- , U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Minnesota Department of Natural Resources. February 2002. Final report: mussel (Bivalvia: Unionidae) surveys 2001: lower St. Croix River from Stillwater, Minnesota (RM 23.7) to Prescott, Wisconsin (RM 1.7), Mississippi River Pool 7, Mississippi River Lock and Dam 3 tailwaters mussel bed mapping, and Higgins eye gravid female collection. Minnesota Department of Natural Resources, Ecological Services Division, St. Paul, Minnesota.
- Mussel Coordination Team. March 2001. Draft Higgins eye pearly mussel conservation plan. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota and U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Mussel Coordination Team. 2002. Report of 2001 Mussel Coordination Team activities,

- endangered species permit TE 023308-1. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota and U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Mussel Coordination Team. 2003. Saving the Higgins eye pearl mussel (*Lampsilis higginsii*) from extinction: 2002 status report on the accomplishments of the Mussel Coordination Team. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota and U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.
- Mussel Coordination Team. Preliminary report - long-term monitoring protocol for native mussels, including the endangered Higgins eye (*Lampsilis higginsii*), upper Mississippi River and tributaries; Minnesota, Wisconsin, Iowa, Illinois, and Missouri. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota, U.S. Army Corps of Engineers, St. Paul District, and U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
- Mussel Coordination Team. Mussel Coordination Team 2005 mussel surveys Harpers and Prairie du Chien *Lampsilis higginsii* Essential Habitat Areas, Pool 10, Upper Mississippi River. U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.
- Mussel Coordination Team. December 2006. Mussel Coordination Team 2006 mussel survey *Lampsilis higginsii* East Channel Prairie du Chien Essential Habitat Area, Pool 10, Upper Mississippi River. U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.
- Mussel Coordination Team. 2007. 2006 Status report on the accomplishments of the Mussel Coordination Team (MCT). September, 2007, St. Paul District Corps of Engineers, Minnesota. 133 pp.
- National Park Service. 2004. Annual report: quantitative assessment of zebra mussels (*Dreissena polymorpha*, Pallas, 1771) in the lower St. Croix River at native mussel beds. National Park Service, St. Croix National Scenic Riverway, St. Croix Falls, WI.
- Pritchard, J. 2001. An historical analysis of mussel propagation and culture: research performed at the Fairport Biological Station. Clear Creek Research Center, Ames, Iowa. Prepared for U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois. 151 pp.
- Roe, Kevin J. Genetic identification of freshwater mussels from Iowa Rivers and Lake Pepin propagation cages. Department of Natural Resource Ecology and Management, Iowa State University. Prepared for U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.

- Rogala, J.T. and T.J. Newton. 2008. Shallow water surveys of native freshwater mussels in Pool 6 of the Upper Mississippi River: Population estimates and sampling design evaluation. Final report to the U.S. Fish and Wildlife Service, Winona, MN. 8 pp.
- Rogala, J.T. and T.J. Newton. 2008. Poolwide population estimates of native mussels in Pool 18, Upper Mississippi River. Final report to the U.S. Army Corps of Engineers, Rock Island, IL. 2 pp.
- Rogala, J.T., T.J. Newton, and B.R. Gray. 2007. Documentation of mussel survey methodology deployed in Pool 5 with applications for future pool-wide estimates in the Upper Mississippi River. Final report to the U.S. Army Corps of Engineers, Rock Island, IL. 12 pp.
- Sallee, D. 2003. Mussel surveys to identify potential relocation sites for the endangered Higgins eye (*Lampsilis higginsii*) on the Rock River, Illinois. Illinois Department of Natural Resources, Sterling, Illinois.
- Sallee, D. and B. Schanzle. 2004. Report on 2004 propagation efforts of *Lampsilis higginsii* (inoculated fish in closed bottoms cages) in pool 12 of upper Mississippi River. Illinois Department of Natural Resources, Sterling, Illinois.
- St. Paul District, U.S. Army Corps of Engineers. August 2000. Letter report - determination of federal interest in conducting a reconnaissance study of measures for controlling zebra mussels in the 9-foot navigation channel of the upper Mississippi River. U.S. Army Corps of Engineers, St. Paul, Minnesota.
- St. Paul District, U.S. Army Corps of Engineers. August 2003. Final reconnaissance study. Mississippi River between the Missouri River and Minneapolis, 9-foot channel project measures to manage zebra mussels. U.S. Army Corps of Engineers, St. Paul, Minnesota.
- St. Paul District, U.S. Army Corps of Engineers. July 2002. Final definite project report and environmental assessment for relocation plan for the endangered Higgins eye pearl mussel (*Lampsilis higginsii*), upper Mississippi River and tributaries; Minnesota, Wisconsin, Iowa, and Illinois. U.S. Army Corps of Engineers, St. Paul District, in cooperation with the interagency Mussel Coordination Team.
- Smith, D., J. Rogala, B. Gray, S. Zigler, and T. Newton. 2008. Evaluation of single and two-stage adaptive sampling designs for estimation of density and abundance of freshwater mussels in the Upper Mississippi River. Final report submitted to the U.S. Geological Survey's Long Term Resource Monitoring Program. 17 pp.
- Stefanik, E.L. 2004. Summary of zebra mussel monitoring efforts for the upper Mississippi River, 2000 through 2003. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.

- Steingrabber, M. 2004. Laboratory study jump-starts winged mapleleaf recovery efforts. LaCrosse Fisheries Resource Office, U.S. Fish and Wildlife Service, Onalaska, Wisconsin.
- Steingraeber, M., M. Bartsch, J. Kalas, and T. Newton. 2005. Winged mapleleaf mussel early life history investigation conducted by the U.S. Department of the Interior in FY 2004. U.S. Fish and Wildlife Service, Fishery Resources Office, Onalaska, WI and U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, WI. 14 pages plus figures.
- Steingraeber, M., M. Bartsch, J. Kalas, and T. Newton. 2007. Thermal criteria for early life stage development of the winged mapleleaf mussel (*Quadrula fragosa*). American Midland Naturalist, 157:297-311.
- Stoekel, J. 2002. Evaluation of zebra mussel veliger abundances in the upper Mississippi River, 2001. Illinois River Biological Station, Illinois Natural History Survey, Havana, Illinois.
- U.S. Fish and Wildlife Service. June 2002. Propagation and restoration of Higgins eye pearl mussels in the upper Mississippi River Basin – partnership efforts and achievements in 2000-2001, Fish and Wildlife Service, La Crosse Fishery Resource Office, Onalaska, Wisconsin.
- Wege, G., D. Anderson, E. Stefanik, and D. Sallee. 2002. Report of 2002 collecting and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in pool 14 near Cordova, Illinois. U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota; U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota; and Illinois Department of Natural Resources, Sterling, Illinois.
- Welke, K., T. Turner, R. Gordon, V. Hyde, and P. Thiel. 2000. Propagation of the federally endangered Higgins eye pearl mussel (*Lampsilis higginsii*) at the Genoa National Fish Hatchery as a Survival Strategy. Interim Report. October 25, 2000. 5 pp.
- Wisconsin Department of Natural Resources. 2004. Report on 2004 placement of cages containing *Lampsilis higginsii* in the Wisconsin River near Orion. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Wisconsin Department of Natural Resources. 2004. Results of 2004 monitoring of freshwater mussel communities of the Saint Croix National Scenic Riverway, Minnesota and Wisconsin. National Park Service, U. S. Fish and Wildlife Service and Wisconsin Department of Natural Resources, La Crosse, Wisconsin.
- Wisconsin Department of Natural Resources. 2005. Report on 2004 monitoring of *Lampsilis higginsii* released into the Wisconsin River near Orion and Prairie du Sac, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Wisconsin Department of Natural Resources. 2005. Report on 2005 monitoring of *Lampsilis higginsii* released into the Wisconsin River near Orion and Prairie du Sac, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Wisconsin Department of Natural Resources. 2005. Report on 2004 placement of cages containing *Lampsilis higginsii* in the Wisconsin River near Orion and in Woodman Lake. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Wisconsin Department of Natural Resources. 2005. Report on 2005 placement of cages containing *Lampsilis higginsii* in the Wisconsin River near Orion, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin.