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FRESHWATER MUSSELS OF MINNESOTA:

A PLAN FOR CONTROLLED PROPAGATION, REINTRODUCTION AND AUGMENTATION WITHIN THE MISSISSIPPI RIVER FROM ST. ANTHONY FALLS TO LAKE PEPIN.

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Cover Illustration: Higgins' eye (*Lampsilis higginsii*), mantle display of brooding female

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PLAN FOR CONTROLLED PROPAGATION, REINTRODUCTION AND AUGMENTATION

INTRODUCTION

Historically the Mississippi River between St Anthony Falls and Lake Pepin (68 river miles) supported over 40 species of native mussels (Sietman 2003). Shortly after 1900 water quality in this reach of the river began declining, by the 1930's fish kills were common (Johnson and Aasen 1989). These degraded conditions continued into the 1970's and all but a few hardy species of native mussels were extirpated (Fuller 1980). Water quality began to improve dramatically during the 1980's and 1990's with the separation of sanitary and storm sewers in the Twin Cities Metropolitan area and the construction of better wastewater treatment facilities. Today, both native fish and mussels are again thriving in this reach of the river. However, nearly 20 species of native mussels have yet to recolonize this improved habitat. In order for this to occur, host fish carrying the glochidia (larvae) of species once present, but now extirpated, must travel from a part of the river still supporting these species to the reach above Lake Pepin. This movement of fish is greatly impeded by locks and dams on the river that many species of fish find it difficult or impossible to pass through. It is only during extended periods of flooding, when control gates at the dams are lifted clear of the water, that significant upstream fish migration can occur.

Zebra mussels were introduced to the Mississippi River about 1990 and have increased dramatically in numbers since that time. Zebra mussel colonization has had a decimating effect on native mussel populations in the Mississippi River including mussel beds in Lake Pepin (Hart,002) and the *Lampsilis higginsii* essential habitat area in Prairie du Chein, WI (Miller, 2002). It now appears that many species may succumb to suffocation caused by zebra mussel colonies that cover the native mussels and river bottom itself. Above Lake Pepin however, zebra mussels have failed to colonize and remain rare despite repeated introduction by barges and recreation vessels. Sustaining high zebra mussel densities in rivers requires an upstream source of larvae (Stoeckel et al, 2004) that are ready to settle and grow to adulthood. Zebra mussel larvae are distributed by water currents, these larvae cannot travel upstream and in rivers are inevitably swept downstream. When a riverine lake like Lake Pepin with its large outflow is colonized, it provides a source of larvae for maintaining zebra mussel colonies downstream. Large reservoirs on rivers can also provide this source of larvae via the reserve of adults that produce them. There are currently two zebra mussel infested lake upstream of Lake Pepin, one of these, Ossawlnnamakee Lake north of Brainerd, does not discharge directly into the Mississippi, is nearly 200 miles upstream of Lake Pepin and while of concern does not pose a threat to the river below St Anthony Falls due to its remote location and small size. The other, Lake St. Croix, does discharge directly into the Mississippi River at Prescott, Wisconsin in Pool 3. While the river upstream of its confluence with the St. Croix is not impacted by the zebra mussels there, the reach from Prescott to Lake Pepin may be in jeopardy of colonization.. Even so, there are no large riverine lakes above Lake Pepin of comparable size or discharge that could

serve in a comparable capacity. While there is still some risk that this reach of the river could become colonized, that it has not is very encouraging.

Because engineering changes to the river prevent natural avenues of immigration and emigration, many of these species will require population management and manipulation to prevent extinction, maintain genetic flow between isolated populations, and to reintroduce species to restored or recovering habitats (UMRCC, 2004; USFWS, 2001).
In 2000 and again in 2001, 470 *Lampsilis higginsii*, a Federally Endangered species, were relocated from areas below Lake Pepin to the reach upstream. They are doing well and remain free of zebra mussels. This project was initiated as one of several Reasonable and Prudent Measures to remove the species from its Jeopardy status. This Jeopardy Decision resulted from zebra mussel colonization of several of this species Essential Habitats as identified in the *Lampsilis higginsii* Recovery Plan. In another phase of this effort, host fish have been inoculated with larvae and are being held in cages in the river in an effort to propagate juvenile mussels. Assessment of this phase is ongoing. Time is believed to be critical to the success of this effort in that the source of adults from downstream may be lost to the zebra mussel invasion in just a few more years, quite likely before their fish hosts may have an opportunity to swim upstream at the right time for recolonization to occur.

Reintroducing *Lampsilis higginsii* to the reach upstream of Lake Pepin presents an opportunity to also reintroduce MN State listed species using identical techniques and many of the same sources of brood stock. While a viable population of *Lampsilis higginsii* and several others of the species listed below still live in the nearby St Croix River, the only source population for several other state listed species is the Mississippi River below Lake Pepin. Evidence for the potential to succeed in this endeavor has been documented with the reappearance of two state Endangered species, *Arcidens confragosus* and *Quadrula nodulata* in recent years, and with the documentation of recruitment occurring now with these and several other species of native mussels.

GOAL AND OBJECTIVES

The goal of this reintroduction program is to restore freshwater mussel biodiversity and their ecological functions (Strayer et al, 1994, Vaughn et al 2004) to appropriate reaches of the Mississippi River through the reestablishment of extirpated populations of mussels.

The objectives of this plan are to:

1) Establish basic protocols for propagating endangered and threatened mussels.

2) Ensure communication and coordination among partners prior to relocation of wild stock, or the release of propagated stock to the wild.

3) Facilitate mussel reintroduction activities in the Mississippi River.

The purposes of propagation and reintroduction are to:

1) Reduce or alleviate risk of species extinctions and loss of genetic complexity.

2) Restore extirpated populations.

3) Restore the ecological functions provided by intact mussel communities.

4) Provide for species recovery and the potential for delisting.

Pistolgrip (*Tritigonia verucosa*), brooding female mantle display

TABLE 1: LISTED FRESHWATER MUSSELS HISTORIC TO THE MISSISSIPPI RIVER IN MN

Common Name	Scientific Name	Federal Status	Minnesota Status
		MUSSELS	
Fat pocketbook	*Potamilus capax*	Endangered	Extirpated
Scaleshell	*Leptodea Ieptodon*	Endangered	Extirpated
Higgin's eye pearly mussel	Lampsilis higginsii	Endangered	Endangered
Winged Mapleleaf	*Quadrula fragosa*	Endangered	Endangered
Rock pocketbook	*Arcidens confragosus*	None	Endangered
Elephant ear	*Elliptio crassidens*	None	Endangered
Yellow sandshell	*Lampsilis teres*	None	Endangered
Wartyback	*Quadrula nodulata*	None	Endangered
Ebonyshell	*Fusconaia ebena*	None	Endangered
Sheepnose	*Plethobasus cyphyus*	Candidate	Threatened
Spectacle case	*Cumberlandia monodonta*	Candidate	Threatened
Mucket	*Actinonaias ligamentina*	None	Threatened
Elktoe	*Alasmidonta marginata*	None	Threatened
Purple wartyback	*Cyclonaias tuberculata*	None	Threatened
Butterfly	*Ellipsaria lineolata*	None	Threatened
Snuffbox	*Epioblasma triquetra*	None	Threatened
Washboard	*Megalonaias nervosa*	None	Threatened
Round pigtoe	*Pleurobema sintoxia*	None	Threatened
Monkeyface	*Quadrula metanevra*	None	Threatened
Salamander mussel	*Simpsonaias ambigua*	None	Threatened
Pistolgrip	*Tritigonia verrucosa*	None	Threatened

Spike	*Elliptio dilatata*	None	Special Concern
Fluted shell	*Lasmigona costata*	None	Special Concern
Hickorynut	*Obovaria olivaria*	None	Special Concern
Black sandshell	*Ligumia recta*	None	Special Concern
NONLISTED, BUT RARE TODAY IN THIS RIVER REACH:			
Fat mucket	Lampsilis siliquoidea	None	None
Fawnsfoot	*Tuncilla donaciformis*	None	None

JUSTIFICATION FOR CONTROLLED PROPAGATION AND REINTRODUCTION

Major obstacles to recovery of state and federally listed mussel species in the Mississippi river are the fragmentation and isolation of the river's habitats by dams and impounded waters, various general and reach-specific water quality and hydrology issues, and the exotic zebra mussel that has colonized extensive regions of the river between Lake Pepin and St Louis. Most listed mussels are now absent from the Mississippi or occur in only a few localized river reaches, in a single tributary (eg. the St. Croix), or in some cases at a single site. Propagation and reintroductions are needed to conserve remaining populations and their genetic integrity (UMRCC, 2004; USFWS, 2001; **National Native Mussel Conservation Committee, 1998)** .

Reintroduction opportunities now exist in the reach of the Mississippi between St. Paul and Lake Pepin where mussels were nearly eliminated due to historical pollution. Water quality conditions there have improved to a degree that is allowing mussels to begin recovering (Kener and Davis, 2002).

However, dams on the river restrict or prevent fish movements in the system that are necessary for mussel re-colonization (Watters 1996, Kelner and Sietman 2000) and natural gene flow through the processes of immigration and emigration. Many species of mussels produce viable larvae during the time of year when dam gates are closed and fish are unable to move between pools. Fish movement must be enabled at the proper time of year if fish are to carry glochidia from existing mussel populations into recovering habitat in Pools 2-4. Navigation dams on the Upper Mississippi River seldom allow this to occur and typically pass fish only briefly, during high flood flows, typically in mid April. Flood flows high enough to require dam gates to be lifted from the water, allowing fish to pass, rarely occur from June-August. An exception was the summer flood of 1993, the only flood ever recorded during that time of year that caused dam gates throughout the system to be raised simultaneously. Unusual fish movements occurred in 1993, even skipjack herring moved up river into Minnesota. This flood event may be the mechanism by which *Quadrula nodulata* and *Arcidens confragosus* arrived in Pools 2 and 3. Although fish may respond to increasing river flows and move upriver during flow events of less magnitude than the 1993 flood, the dam gates block their movement between pools.

In addition to fish passage impairment, some species have been extirpated or become exceedingly rare, with low reproductive and recruitment success. These species often require extensive efforts to locate in the wild for recovery efforts. As with other species, isolated mussel populations may be subject to inbreeding depression and to stochastic events. Other complications include the lack of knowledge of listed mussel host fishes, reproductive timing, and life history requirements of mussels and hosts to their larval stage. Because of these conditions, this plan recognizes that a great deal of human intervention is required to understand, manage, maintain genetic integrity and restore populations of native mussels, including:

- developing technology and facilities for holding endangered and threatened mollusks
- producing individuals through captive propagation for research and technology development
- in some cases, establishing and maintaining captive populations of endangered mussels
- producing individuals for augmenting existing populations, and
- producing individuals for reintroduction of species into restored or recovered habitats.

Since the 1990's, the Minnesota Department of Natural Resources (DNR) has been working with State and Federal partners to locate populations of rare mussels, especially the federally endangered *Lampsilis higginsii* and *Quadrula fragosa*, and to develop appropriate protocols and facilities for propagation of rare mussel species. This work accelerated in May of 2000 following the delivery of a Jeopardy Decision to the US Army Corps of Engineers (COE) and the subsequent creation of a "Mussel Conservation Plan for *Lampsilis higginsii*". As a result of implementing actions identified in the plan, we are at a point where successful propagation of thousands of juvenile mussels has become a reality. U.S. Fish and Wildlife Service policy requires the development of a reintroduction plan prior to the release of propagated endangered and threatened species into the wild (65 FR 56916). A Plan for *Lampsilis higginsii* has been completed and 541 propagated juveniles from the 2001 effort were released at two sites in the Mississippi River in 2003. In 2004 an additional 2,351 juveniles from the 2002 and 2003 efforts were released at three sites.

A similar reintroduction plan for *Quadrula fragosa* was completed in 2004, in time for placing host fish inoculated in September, 2004 into cages in the river in May, 2005.

PARTNERS

The States of Wisconsin, Iowa, and Illinois, and the University of Minnesota Bell Museum of Natural History (Bell), United States Fish and Wildlife Service (FWS), National Park Service (NPS), COE and the U.S. Geological Survey (USGS) have been cooperating in studies of the river's native mussel life histories, and in developing holding and propagation technology for several species.

Live listed mussels are temporarily held and used for life history research and propagation at the University of Minnesota, USGS in Lacrosse, Wisconsin and at the FWS' Genoa National Fish Hatchery in Genoa, Wisconsin. These mussels are returned to their location of collection following propagation, host fish or other life history studies.

DEFINITIONS

Augmentation

Augmentation describes the increase in numbers of a mussel species within a defined area of habitat through the transplantation of adults from other locations, or through the release of hatchery-propagated individuals. Augmentation is appropriate when the population size of a listed species is minimal within an occupied area, and/or the population is experiencing recruitment failure. It is also appropriate where the species may be absent within apparently suitable habitat that is contiguous with and accessible to occupied habitat. Augmentation is part of any reintroduction project utilizing propagated juveniles so that additional year classes and

genetic diversity of the reintroduced species can be established at the reintroduction site.

Augmentation increases the likelihood of population success for spawning, fertilization, host fish infection by mussels, and ultimately recruitment within sparsely occupied habitat. It may be used to expand the range of a species within habitats accessible to existing populations, reducing the likelihood of extirpation due to localized catastrophic events.
The potential for augmentation with endangered or threatened mussels from existing populations is limited, and many species have low numbers of surviving individuals.

Reintroduction
Reintroduction describes the establishment of adult or juvenile mussels into historically occupied river and stream reaches where the species no longer occur, and that are not accessible to natural immigration from extant populations. Reintroductions may be accomplished by transplanting adults from extant populations, or through the release of hatchery-propagated individuals. The reintroduction of mollusks into areas of historical habitat will be considered when it has been established that the conditions that led to the extirpation of the species have been eliminated or improved (e.g., water chemistry, flow, etc.).

Reintroductions are intended to reestablish populations, providing genetic refugia, and reducing the potential of extinction due to random catastrophic events. Successful reintroductions may move a species closer to a recovery threshold and potential delisting.

Low numbers of surviving individuals also complicates the potential for reestablishing endangered or threatened mussels from existing populations. However, the potential of genetic swamping is not an issue in reintroductions since there is no established population to swamp.

CONTROLLED PROPAGATION

Lampsilis higinsii **– two years following host fish Placement in cage. (Hudson Narrows, Lake St. Croix)**

The biology, life history and genetics of the Rivers' mussels are incompletely known. Successful propagation of any mussel species requires this knowledge. Fortunately, we know enough about several species to begin this work. For example, recent attempts to propagate and

raise juvenile *Lampsilis higginsii*, and *Ligumia recta* in cages in Lake St. Croix and Lake Pepin have been very successful and living excysted juveniles of *Quadrula fragosa* have been collected in the fall of 2003 and spring of 2004 from laboratory inoculated and contained blue catfish and channel catfish. To date we have not observed any escape from the propagation cages placed in Lake Pepin.

Ligumia recta juveniles – Lake Pepin, 2003

Methods developed during these efforts present us with a viable protocol guideline for use with other species. However, propagation should still be treated as experimental in nature. Propagation of any of Minnesota's mussel species should abide by the following guidelines:

- Take all necessary precautions to prohibit the potential introduction or spread of diseases and parasites into controlled environments or suitable habitat
- Conduct all activities in a manner that will prevent the escape or accidental introduction of individuals outside of their historical range
- Keep detailed notes and records of life history observations, fecundity, survival and mortality, seasonality, and any other conditions/observations important to successful propagation of these species.
- Naturalize, to the greatest extent possible, selective pressures during propagation efforts to avoid producing "unfit" propagules.

POPULATION REINTRODUCTION

Although the River has been highly modified, opportunities exist to improve mussel status through population propagation and reintroduction (P/R) (Appendix I). P/R activities have been underway since 2000 for *Lampsilis higginsii* and a Conservation Plan written; limited activities have been initiated for several of the other species listed in the table.

Before conducting specific reintroduction actions a Site Reintroduction Plan (Site Plan) will be developed and submitted. It is understood that collection of gravid females, successful

production of progeny, number of progeny produced, etc. is difficult to predict; however, Site Plans should include as much information as possible, including:

- the exact location where animals are to be introduced,
- status of the target species at the site, and why P/R is necessary,
- an Alternatives Analysis (see Alternatives, below),
- relationship of the reintroduction site to other populations of the target species,
- current habitat conditions at the reintroduction site,
- possible limiting factors at the site,
- source of the animals for reintroduction (adults, juveniles, hatchery-produced, cage propagated, or wild),
- source of the P/R stock (location and drainage),
- monitoring plan and responsibilities,
- cooperating and responsible partners,
- a copy of all appropriate permits, and,
- any other pertinent information.

Site Selection

Sites for reintroduction should be selected based on criteria identified above, including historical and current distribution of the species, habitat conditions, and past, present or future threats. Since P/R is experimental in nature, activities for a species or suites of species should be restricted to discrete site areas; for example, all P/R of a species (e.g., *L. higginsii*) should be concentrated at specific sites (e.g., Lake Pepin, Hidden Falls, Sturgeon Lake, etc.). The sites being established for *Lampsilis higginsii* reintroductions will be used and monitored for a period of 10-20 years, or until there is evidence of success or failure. Concentrating efforts at these sites for other species adapted to this habitat type will nearly eliminate any additional monitoring costs. If it is determined that a species requires different habitat, that type of habitat should be sought within the vicinity of other, ongoing monitoring to reduce travel and expense.

Monitoring

Since P/R is experimental in nature, monitoring is critical to determine success and usefulness of such programs. Monitoring of state listed species reintroductions can be accomplished during ongoing monitoring of the *L. higginsii* reintroductions in this reach of the Mississippi. By utilizing the same sites used for federal species, any state listed mussels reintroduced will become a part of the samples collected to monitor *L. higginsii*. MNDNR biologists have been doing this monitoring with funding provided by the federal government since 2002; this funding source is expected to continue for a decade or more. Any future *Q. fragosa* reintroduction sites will offer additional opportunities to dovetail state listed species reintroductions and subsequent monitoring with this effort. Accomplishing monitoring of state listed P/R mussel species simultaneously with federal species is logistically practical and offers great cost and effort savings. If sites for state species reintroductions are needed where no P/R work is proposed for federal species, a similar monitoring plan will be followed and separate funding sought on a case-by-case basis.

Stock

- Transplantations of subadult or adult mollusks should come from locally robust populations.
- Removal of mussels for transplantations should affect less than 5% of the donor population unless that population is threatened with imminent destruction (e.g. zebra mussel population explosion, construction etc.).
- Progeny used for reintroductions should come from parental stock in the nearest connected drainage to the reintroduction site, whenever possible.

Reporting

An annual report of activities will be made, including:

- a brief description of the P/R program, including objectives and status,
- list of cooperators, if any,
- activities conducted, prospects for, or obstacles to achieving their research, propagation, or reintroduction efforts, and,
- a brief description of the status of targeted P/R populations, if any.

GENETIC CONSIDERATIONS

Very little is known of genetic differences between drainage populations of most mussel species of the Mississippi River, as they relate to expressions in morphology, behavior, and other forms of habitat adaptation. As such, it is preferred that stock for P/R should come from the same drainage as the proposed release site. In cases where only a single known population of a once wide ranging species is known to survive, or where a drainage population has been severely reduced or extirpated, this is not an issue.

Juveniles produced by a single female mussel may number in the hundreds to thousands. While, their mortality and survival in the wild is difficult to establish, in order to avoid any potential of inbreeding effects, it is preferred that a specific female mussel will only be used once as a source of juveniles for propagation. Gravid mussels used to produce juveniles for stocking will be uniquely marked and returned to the point of capture. Subsequent releases should come from other appropriate wild mussel stock whenever possible.

DISPOSITION OF EXCESS PROGENY FROM RESEARCH ACTIVITIES

Various partners periodically conduct laboratory host-fish trials with endangered and threatened mussels. Propagation efforts or host fish trials may result in excess juvenile mussels. Larger numbers of research or hatchery-produced offspring should be considered for:

- augmentation or reintroduction releases,
- toxicity testing, or
- other existing experimental needs.

Small numbers of juvenile mollusks, excess individuals, or specimens rendered unfit for population augmentation or reintroduction to historical habitats that result from research activities can be properly preserved for genetic testing (e.g., ethanol or frozen), appropriately labeled, and deposited in the Mussel Tissue Repository at the Upper Midwest Environmental Science Center in LaCrosse, Wisconsin.

ALTERNATIVES ANALYSIS

This plan covers multiple species and there are alternatives to improve the status of each species. The following alternatives should be considered in developing Site Plans.

Controlled Propagation

Controlled propagation requires the temporary removal of reproductively mature individuals from the wild for propagation in captivity, and holding inoculated hosts for periods of time ranging from a few weeks to nearly seven months. Risks include potential mortality during collection and in the lab, premature aborting of larvae, mortality of larvae in the lab, mortality of caged fish, caged or reintroduced juveniles, and lack of knowledge of environmental requirements of the species in the hatchery and at P/R sites. However, controlled propagation is probably the only method to protect many of the Table 1 mussels from eventual extirpation from Minnesota due to acute and chronic threats. In addition, since propagation, translocation, and reintroduction of mussels are experimental activities, the methods that have led to the successful work with *L. higginsii* (caged propagation in lake-like environments) should be replicated with other species unless there is species-specific knowledge that suggests a different approach.

2000 higginsi - Sept 2001
Juvenile from Lake Pepin cage

Direct Translocation

Collection and translocation of adult mussels into recovering or restored habitat, or to augment a declining population requires less intervention than controlled propagation. Risks involve potential mortality during collection and relocation, reduction in size of parental population, and lack of knowledge of precise environmental requirements of the species at reintroduction sites. In some cases, impending mortality of adult mussels from extreme zebra mussel colonization may be a valid reason for translocation to a reintroduction site. In most cases, only a few of the 25 species considered in this plan currently support populations in the Mississippi River

sufficiently robust to consider harvesting for direct translocation. These include the population of *Elliptio dilatata* still extant in Lake Pepin, and localities with abundant *Ligumia recta, Ellipsaria lineolata, Megalonaias nervosa, Pleurobema sintoxia,* and *Obovaria olivaria* populations, mostly from areas of the River below Mississippi River Pool 8. Individuals for translocation of most other species from Table 1 would have to come from tributaries with large populations. These could include *Actinonaias ligamentina, Cyclonaias tuberculata, Quadrula metanevra, Tritigonia verrucosa, Lasmigona costata and Simpsonaias ambigua* from the St. Croix River; *Plethobasus cyphyus* from the Chippewa/Flambeau River in Wisconsin, and *Lampsilis teres* from the Wisconsin River in Wisconsin. Some species are no longer abundant enough anywhere for this method. P/R work for *Quadrula fragosa, Cumberlandia monodonta, Leptodea leptodon,* and *Epioblasma triquetra* will probably depend on successful propagation and placement of juveniles.

Do Nothing

The "do nothing" alternative is likely to lead to the extirpation of the River's rare mussel species due to chronic conditions or stochastic events. Do nothing is a temporary alternative, these mussel species are likely to decline in the foreseeable future due to restricted range and their vulnerability to changes in human demographics, land use activities, and/or water quantity and quality.

CONTROLLED PROPAGATION PLAN REVIEW

This Plan is a working document that is subject to modification based on results of current and future research and recovery activities involving mollusk propagation, augmentation, or reintroduction. Recovery Partners are encouraged to provide comments and suggestions to Mike Davis, MNDNR - Lake City, MN (see Appendix II for contact information). MNDNR will conduct an annual review of the Plan and will incorporate new information, protocols, etc. as they become available.

APPENDIX I: MUSSEL REINTRODUCTION AND AUGMENTATION OPPORTUNITIES IN THE MISSISSIPPI RIVER BELOW ST. ANTHONY FALLS

Species Common and *Scientific Name* and State Status	**Population status in Mississippi River above and below Lake Pepin**	**Opportunities for augmentation of populations already introduced**	**Reintroduction Opportunities**	**Potential P/R source for animals**
Fat pocketbook (EX) *Potamilus copax*	Extirpated	NONE	Mississippi River Pools 2,3,4	Missouri, Arkansas
Scale shell (EX) *Leptodea leptodon*	Extirpated	NONE	Mississippi River Pools 2,3,4	Missouri, Arkansas
Higgins' eye pearly mussel (E) *Lampsilis higginsii*	Present below Pool 6 Reintroduction in progress above Lake Pepin	Mississippi River Pools 2, 3, 4	Mississippi River Pools 2,3,4	St. Croix River, MN Mississippi River Pools 9-14
Winged Mapleleaf (E) *Quadrula fragosa*	Extirpated	St. Croix River below Taylor's Falls	Mississippi River Pools 2,3,4; St. Croix River at Hudson?	St. Croix River, MN
Rock pocketbook (E) *Arcidens confragosus*	Very rare above Pool 14 Recovering in Pools 2 and 3	Monitor recovering populations in Pools 2 and 3	Mississippi River Pool 4	Mississippi River Pools 2 and 3
Elephant ear (E) *Elliptio crassidens*	Extirpated	NONE	Very limited-Host Fish Absent	St Croix River at Prescott
Yellow sandshell (E) *Lampsilis teres*	Extirpated	NONE	Mississippi River Pools 2,3,4	Lower Wisconsin River, WI
Wartyback (E) *Quadrula nodulata*	Rare in Pool 9 and below, recovering in Pools 2 and 3	Monitor recovering populations in Pools 2 and 3	Mississippi River Pool 4	Mississippi River Pools 2 and 3
Ebonyshell (E) *Fusconaia ebena*	Extirpated	NONE	Very limited – Host Fish Absent	St Croix River at Prescott
Sheepnose (E) *Plethobasus cyphyus*	Extremely rare below Lake Pepin, extirpated above.	NONE	Mississippi River Pools 2,3,4	Chippewa River, Flambeau River, WI
Spectacle case (T) *Cumberlandia monodonta*	Extirpated	St. Croix River above and below Taylor's Falls	Mississippi River Pools 2,3,4	St Croix River, MN
Mucket (T) *Actinonaias ligamentina*	Extremely rare	Possibly some Mississippi River tributaries	Mississippi River Pools 2,3,4	St Croix River MN Mississippi River Pools 9-14
Elktoe (T) *Alasmidonta marginata*	Extremely rare, probably never common from Lake Pepin down	Too sporadic and rare for augmentation	Mississippi River Pools 2,3,4	St Croix River, Pomme de Terre River, Zumbro River
Purple wartyback (T) *Cyclonaias tuberculata*	Extremely rare, one individual from Pool 4 in 2003, extirpated above and below that	Too sporadic and rare for augmentation	Mississippi River Pools 2,3,4	St Croix River, MN
Butterfly (T) *Ellipsaria lineolata*	Occasional and rare from Mississippi above Pool 11.	Mississippi River Pools 2,3,	Mississippi River Pool 4	St Croix River, MN; Mississippi River Pools 9-20
Snuffbox (T) *Epioblasma triquetra*	Extirpated	St. Croix River	Mississippi River Pool 2	St Croix River, MN
Washboard (T) *Megalonaias nervosa*	Rare, over harvested from Lake Pepin on downstream. Extremely rare above Lake Pepin	Mississippi River Pools 2,3,4	Lower Minnesota River, Pools 2,3,4	Mississippi River Pools 4 – 11; or from small 2001 reintroduced populations in Pools 2 and 3

APPENDIX I: CONTINUED

Species Common and *Scientific Name* and State Status	**Population status in Mississippi River above and below Lake Pepin**	**Opportunities for augmentation of populations already introduced**	**Reintroduction Opportunities**	**Potential P/R source for animals**
Round pigtoe (T) *Pleurobema sintoxia*	Rare	Mississippi River Pools 2,3,4		St. Croix River, MN
Monkeyface (T) *Quadrula metanevra*	Extremely rare in Pools 2-9	NONE	Mississippi River Pools 2,3,4	St. Croix River, MN
Salamander mussel (T) *Simpsonaias ambigua*	Extirpated	NONE	Mississippi River 2,3,4	St. Croix River, MN
Pistolgrip (T) *Tritigonia verrucosa*	Extremely rare, a single individual from Pool 2, otherwise extirpated on Upper Mississippi River	NONE	Mississippi River 2,3,4	St. Croix River, MN; Wisconsin River, WI
Spike (SC) *Elliptio dilatata*	Extirpated from Pool 2 and probably from Pools 5-8	Mississippi River Pool 4	Mississippi River 2,3,4	Lake Pepin, WI; Mississippi River Pool 9; St. Croix River, MN
Fluted shell (SC) *Lasmigona costata*	Occasional record below Pool 2, probably never abundant below gorge area	Unknown	Mississippi River Pool 2	St. Croix River, MN; Root River, MN
Hickorynut (SC) *Obovaria olivaria*	Rare but present	Mississippi River Pools 2,3,4	Unknown	Mississippi River
Black sandshell (SC) *Ligumia recta*	Rare below Lake Pepin, not abundant in Pools 2-4	Mississippi River Pools 2,3,4	NONE	Mississippi River
NONLISTED, BUT RARE TODAY IN THIS RIVER REACH:				
Fat mucket (no status) *Lampsilis siliquoidea*	Very rare in Mississippi, historically very abundant	Mississippi River Pools 2,3,4	NONE	Mississippi River
Fawnsfoot (no status) *Tuncilla donaciformis*	Historically very abundant, increasingly rare	Mississippi River Pools 2,3,4. St. Croix River below Taylor's Falls	NONE	St. Croix River, MN; Mississippi River

APPENDIX II: Prioritization matrix

MUSSEL PROPAGATION AND REINTRODUCTION – PRIORITIZATION MATRIX													
Species name and State Status	**State of MN status**	**# Reproducing populations in MN (for species not presumed extirpated**	**Population present today in MN Miss River (St. Anthony-Pepin)**	**Extirpated (functionally) from MN Miss River**	**Historically common or abundant**	**Historically rare**	**Historically extra limit al to Miss River**	**Source present**	**Source present in WI, IA Miss River & tribs**	**Source present outside MN and Miss River & tribs**	**Host present**	**Host absent**	**Priority order**
		A gauge of their Susceptibility to extirpation						**In MN-Miss River &trib**					**Total**
Points to Award	E-3; T=2; SC=1	0=5, 1=4, 2 to 3=3, 3 to 6 = 2, >6 = 1	1	4	2	1	-1	4	3	1	1	-2	
Yellow sandshell (E) *Lampsilis teres*	3	5		4	2				3		1		18
Sheepnose (E) *Plethobasus cyphyus*	3	5		4	2				3		1		18
Higgins' eye pearly mussel (E) *Lampsilis higginsii*	3	4		4		1		4			1		17
Winged Mapleleaf (E) *Quadrula fragosa*	3	4		4		1		4			1		17
Spectacle case (T) *Cumberlandia monodonta*	2	4		4	2			4			1		17
Purple wartyback (T) *Cyclonaias tuberculata*	2	4		4	2			4			1		17
Snuffbox (T) *Epioblasma triquetra*	2	4		4	2			4			1		17
Monkeyface (T) *Quadrula metanevra*	2	4		4	2			4			1		17
Salamander mussel (T) *Simpsonaias ambigua*	2	4		4	2			4			1		17
Pistol grip (T) *Tritigonia verrucosa*	2	4		4	2			4			1		17
Butterfly (T) *Ellipsaria lineolata*	2	4		4	2			4			1		17
Washboard (T) *Megalonaias nervosa*	2	4		4	2			4			1		17
Mucket (T) *Actinonaias ligamentina*	2	3		4	2			4			1		16

APPENDIX II: Continued

MUSSEL PROPAGATION AND REINTRODUCTION – PRIORITIZATION MATRIX													
Species name and State Status	**State of MN status**	**# Reproducing populations in MN (for species not presumed extirpated**	**Population present today in MN Miss River (St. Anthony-Pepin)**	**Extirpated (functionally) from MN Miss River**	**Historically common or abundant**	**Historically rare**	**Historically extra limit al to Miss River**	**Source present**	**Source present in WI, IA Miss River & tribs**	**Source present outside MN and Miss River & tribs**	**Host present**	**Host absent**	**Priority order**
		A gauge of their Susceptibility to extirpation						**In MN-Miss River &trib**					**Total**
Elephant ear (E) *Elliptio crassidens*	3	5		4	2			4				-2	16
Ebonyshell (E) Fusconaia ebena	3	5		4	2			4				-2	16
Spike (SC) *Elliptio dilatata*	1	3		4	2			4			1		15
Rock pocketbook (E) *Arcidens confragosus*	3	4	1		2			4			1		15
Wartyback (E) *Quadrula nodulata*	3	4	1		2			4			1		15
Elktoe (T) *Alasmidonta marginata*	2	3		4			-1	4			1		13
Round pigtoe (T) *Pleurobema sintoxia*	2	3	1		2			4			1		13
Hickorynut (SC) *Obovaria olivaria*	1	3	1		2			4			1		12
Fawnsfoot (no status) *Tuncilla donaciformis*		4	1		2			4			1		12
Fluted shell (SC) *Lasmigona costata*	1	2		4			-1	4			1		11
Black sandshell (SC) *Ligumia recta*	1	1	1		2			4			1		10
Fat mucket (no status) *Lampsilis siliquoidea*		Lake Pepin Mucket?	1		2			4			1		8
Fat pocketbook (EX) *Potamilus capax*				4		1				1	1		7
Scale shell (EX) *Leptodea leptodon*				4		1				1	1		7

Explanation of and rationale for matrix fields:

1. State of MN status = Legal listing status in Minnesota; E=Endangered, T=Threatened, SC=Special Concern.
2. # Reproducing populations in MN (for species not presumed extirpated) A gauge of their susceptibility to extirpation = a species with a greater number of known reproducing populations receives fewer points to lessen their priority due to presumed greater resiliency to impacts and lesser vulnerability to extirpation, a species with no reproducing population remaining receives most points to increase their priority for conservation work due to presumed higher vulnerability to extirpation.
3. Population present today in MN Miss River (St Anthony - Pepin) = if still present in the Mississippi River a species is presumed to have a higher potential to recover without intervention than a species that is no longer present and therefore has a lower priority for conservation work than a species that has been extirpated from this area.
4. Extirpated (functionally) from MN Miss River = functionally extirpated means that a species is so rare and individuals so far apart that reproduction has likely stopped and locally derived recruitment no longer possible. When a species' population has declined to this level is it presumed that it cannot recover without intervention and is therefore a higher priority for conservation work than a species with reproductively functional population.
5. Historically common or abundant = a species that was once common and/or abundant is presumed to have been a more critical component of the river ecosystem than a rare species and therefore a higher priority for conservation work.
6. Historically rare = a species that was never common or abundant on the river is presumed to have been a less critical component of the river ecosystem than common or abundant species and therefore a slightly lower priority for conservation work.
7. Historically extralimital to Miss River = an extralimital species is one that has never occurred consistently in the Mississippi River but may be common or abundant in tributaries. It is presumed that the habitat requirements of these species are usually better met outside of the Mississippi River, with the exception of select river reaches that may be better suited to them (e.g. the gorge below L&D1, buffalo slough in Pool 3).
8. Source present in MN-Miss River & tribs = this means that gravid females of this species can be found in Minnesota in the Mississippi River or its tributaries. It is presumed that animals from these locations will most closely match the genome of the mussel species in need of conservation work in some reach of the Mississippi River. It is therefore a higher priority to retain the genetics of animals occupying this river drainage and at similar latitudes than to bring in animals that are adapted to other river systems or areas within the Mississippi drainage but from different latitudes.
9. Source present in WI, IA Miss River & tribs = this represents the next best choice if animals are not available from the Mississippi River and its tributaries within Minnesota.
10. Source present outside MN and Miss River & tribs = this represents a choice that, while it may be the only way to obtain animals for conservation work, is of lower priority due greater presumed genetic risk of introducing less well adapted animal genomes into our waters.

11. Host present = if the host for the mussel species' parasitic larval stage is present here it receives a higher priority for conservation work because it is does not also require the reintroduction of the host.
12. Host absent = if the required host is absent from the historic range of the mussel species conservation work is much more difficult to accomplish and species where this applies receive lower priority as a result.

This matrix is simply a way of ranking/prioritizing listed species that are potential candidates for reintroduction using the best information at hand based on their level of "endangeredness" and feasibility of re-introducing populations.

Using a matrix with "points" awarded for various conditions creates a quantitative process, rather than just saying we should propagate this species or that species because we think it is at greater risk.....Although we would likely use similar criteria in our heads if we were to simply make a list of species to propagate first. The difference between a 17 and 18 may not be significant, but one would probably be more justified in working on a 18 before a 15, and the table shows you why.

There obviously needs to be some additional discretion used though. It could be argued that F. ebena and E. crassidens are high priority because the nearest known population occurs 500 river miles or more from here, and the relict population here might have unique genetic characteristics that are in serious danger of being lost.

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