

NATIONAL STRATEGY FOR THE CONSERVATION OF NATIVE FRESHWATER MUSSELS

Prepared by
The National Native Mussel Conservation Committee, June 1, 1997

HISTORY OF THIS DOCUMENT

On April 1995, representatives from several federal and state natural resource agencies, the commercial mussel industry (Shell Exporters of America), academia, and The Nature Conservancy met to discuss freshwater mussel declines and gather information on freshwater mussel trends, research, and recovery activities (Appendix I). As a result of the magnitude and immediacy of the nationwide threats to the freshwater mussel fauna, the group agreed that a coordinated effort of national scope was needed to prevent further mussel extinctions and population declines.

To address this need, the group decided to (1) draft a National Strategy for the Conservation of Native Freshwater Mussels (National Strategy) and (2) establish a national ad hoc committee with broad-based representation from state, tribal, and federal agencies, the mussel industry, private conservation groups, and the academic community to help implement mussel conservation at the national level. A draft National Strategy was presented at the second Symposium on the Conservation and Management of Freshwater Mussels organized by the Upper Mississippi River Conservation Committee, in St. Louis, Missouri in October 1995. Comments received at and subsequent to the symposium were incorporated into another draft dated September 16, 1996. The September 1996 draft was presented at a February 1997 meeting of the newly formed National Native Mussel Conservation Committee in St. Louis, Missouri. Comments from the February 1997 meeting have been incorporated into this current document.

STATUS AND ROLE OF NATIVE FRESHWATER MUSSELS

The world's greatest diversity of freshwater pearly mussels, nearly 300 species, reside in the continental United States (Turgeon et al., 1988). However, within the last 50 years this rich fauna has been decimated by impoundments, sedimentation, channelization and dredging, water pollution, and, more recently, the nonindigenous zebra mussel (*Dreissena polymorpha*) (Neves, 1997). Approximately 67% of freshwater mussel species in the United States are vulnerable to extinction or are already extinct; more than 1 in 10 mussels may have become extinct during this century (Williams et al., 1993; Master et al., 1998).

Freshwater mussels are a renewable resource, providing significant ecological and economic benefits to the nation. They are ecologically important as a food source for many aquatic and terrestrial animals; they improve water quality by filtering contaminants, sediments, and nutrients from our rivers; and because they are sensitive to toxic chemicals, they serve as an early-warning system to alert us of water quality problems. In recent years the annual value of shells to the mussel shell industry has been estimated at \$40-\$50 million dollars. The mussel shells are used in the cultured pearl and jewelry industries, and the shell harvest provides employment to about 10,000 residents, primarily in the Mississippi River basin.

CONSERVATION STRATEGY GOALS

The goal of this National Strategy is to conserve our nation's freshwater mussel fauna and ensure that the ecological and economic values to society are maintained at a sustainable level. Specifically, the purposes of this document 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 for species and habitat protection programs; and (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.

Identification of Specific Problems, Goals, and Strategies

In order to conserve and restore native freshwater mussels, the National Strategy has identified a number of conservation needs or problems. Tasks or strategies designed to address the problems are subsequently enumerated, and when implemented, will direct the successful conservation of freshwater mussels.

The following problems, goals, and strategies have not been prioritized. The intent is to provide a list of strategies and allow each agency or organization to prioritize and choose the strategy(s) that best fits its own mission, funding, and expertise. However, Appendix II provides a list of ranking criteria to assist in ranking specific projects.

PROBLEM 1: There is no coordinated national strategy for the conservation of freshwater mussel resources.

GOAL: Increase coordination and information exchange among entities that study, manage, harvest, conserve, or recover native freshwater mussels.

STRATEGIES

- 1.1 Establish a National Freshwater Mussel Ad Hoc Committee to coordinate national mussel conservation activities¹. This ad hoc committee (Committee) should be comprised of one individual appointed by each of the following entities: the Service, Tennessee Valley Authority (TVA), U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (Corps), U.S. Forest Service (USFS), National Park Service (NPS), Environmental Protection Agency (EPA), each state and tribe with significant mussel resources, the commercial mussel industry, the conservation community, and academia. The Committee will perform the following tasks:
 - 1.1.1 Identify entities that study, manage, harvest, conserve, or recover mussel populations; solicit their support; and foster partnerships in mussel conservation. The Service, NBS, TVA, Corps, and several state natural resources agencies, the Great Lakes Indian Fish & Wildlife Commission, and the commercial mussel industry assisted with the development of this National Strategy (see Appendix I). However, there are numerous other individuals and agencies that are currently conducting research and management on freshwater mussels. Potential partners in the mussel conservation effort should be informed of the National Strategy and encouraged to join in its implementation (see strategies under Problem 2 and 10).
 - 1.1.2 Develop and implement effective mechanisms to disseminate information on the progress of the mussel conservation effort to cooperators and interested parties. It is important that information on the conservation effort be readily available to all interested parties. This prevents duplication of effort and allows for better coordination of conservation activities. For example, the Tri-annual Unionid Report, compiled and circulated by Richard Biggins of the U.S. Fish and Wildlife Service, Asheville Field Office, Asheville, North Carolina, provides an existing mechanism to disseminate current information on mussel conservation. Copies may be obtained by calling 704/258-3939 or over the internet (<http://www.inhs.uiuc.edu/cbd/collections/mollusk.html/TUR>). Information exchange is also being facilitated by the development of Internet sites, including a unionid listserv (UNIO) to subscribe send an e-mail message to: Maioresimo@lists.umbc.edu as well as numerous web pages including the Illinois Natural History Survey Mollusk Collection (<http://www.inhs.uiuc.edu/cbd/collections/mollusk.html>). The Committee should review currently available information exchange mechanisms and develop additional options as needed.
 - 1.1.3 Provide guidance for the mussel conservation effort. As representatives of the national mussel conservation community, the Committee will meet on an annual basis to review the current status of the collective mussel conservation effort. Each Committee member should submit an annual report to the Committee outlining his group's projects. Based on their discussions, the Committee should develop and circulate an annual appendix to this National Strategy. This report would (1) provide a brief overview of the status of the conservation effort; (2) summarize important research and management results; (3) identify any new problems and strategies; and (4) suggest direction for future research and management initiatives.
 - 1.1.4 Coordinate a thorough search and summary of the current knowledge of basic biology, population characteristics, and habitat requirements of mussels. Much of the information that exists on freshwater mussels is scattered throughout various professional journals, government publications, unpublished research projects, museum records, and observation records of numerous individuals. If this information could be consolidated into a computerized annotated bibliography, the mussel conservation community and other interested individuals would have ready access to current knowledge to help expedite the conservation effort.
 - 1.1.5 Serve as the primary advocate for the implementation of the National Strategy. Members of the Committee should act as primary advocates within their agency/organization for educating the conservation community, their respective agencies, and the general public about this mussel conservation effort.
 - 1.1.6 Appoint a technical committee (four to six members) of mussel researchers. These individuals would have specific mussel research or related expertise and would be available to review research proposals and reports, provide technical assistance, develop draft national standards for conservation techniques such as sampling, population augmentation, introductions, propagation and quarantine facilities/management, and make technical recommendations to the Committee.
 - 1.1.6.1 Develop a standardized mussel sampling regime that can be used throughout the country. Mussel sampling techniques must be adapted to each situation based on available funding, the expertise of collectors, and environmental conditions. Therefore, it is difficult to standardize a sampling protocol. However, by standardizing some aspects of the sampling protocol, mussel biologists would be better able to compare data among sites and among collections at the same site (see Strategy 4.1).
 - 1.1.6.2 Develop a standardized mussel die-off response procedure. Many mussel populations have experienced die-offs, and the cause(s) of most events has not been determined. It is unlikely that the cause(s) of all future die-offs can be ascertained, but a standardized die-off response procedure would help resource managers and commercial mussel fishermen respond in a more timely manner and collect the critical information and samples needed by researchers.
- 1.2 Foster and create new partnerships and facilitate the development of formal agreements (e.g., memorandums of agreement) among government agencies and private entities to help implement this National Strategy. 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

¹The National Native Mussel Conservation Committee was established in February 1997 including an executive subcommittee to direct activities.

conservation program, and these partnerships should be actively pursued (see strategies listed under Problems 2 and 10).

- 1.3 Foster and create cooperative ventures with academic institutions and the private sector to address specific research, information, and conservation needs (see strategies listed under Problems 2-10).

PROBLEM 2: Quality mussel habitat continues to be degraded and lost.

GOAL: Protect and reverse the decline of quality mussel habitat.

STRATEGIES

- 2.1 Use information gathered under Strategies 4.1, 4.2, and 4.3 to identify important mussel resource areas and develop programs to conserve and recover these key areas. The magnitude of the mussel conservation challenge is great, but the resources available for mussel conservation are 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. Those few stream 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 degraded habitat.
 - 2.1.1 Identify and inform potential partners of important mussel sites and develop cooperative agreements to conserve and recover mussel communities. It is essential for the success of this National Strategy that potential partners understand the importance of the resource at risk, how the conservation program will benefit mussels and other biota, and how ecosystem recovery will benefit other user groups.
 - 2.1.2 Use existing federal, state, tribal, and local laws and regulations to protect mussel resources. There are many environmental laws and regulations that, if fully implemented, could provide better protection for mussel resources. Use existing information and information generated under Strategies 3.1.3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 5.4, and 5.5 to help ensure that mussel populations receive the full protection provided under existing laws.
 - 2.1.3 Encourage federal, state, tribal, and local government entities to use their authority to review their activities for actions and alternatives that protect and recover key mussel habitats and communities. Many agencies, although not bound by law, have modified their projects and programs and even initiated distinct programs that benefit aquatic resources, including mussels. Some agencies have specific programs and funding targeted for use on projects to protect and recover aquatic resources. These agencies should be recognized for their efforts and encouraged to review their activities for potential adverse impacts to mussel habitats and to communities and avoid or minimize these impacts.
 - 2.1.4 Encourage industry to review their activities for actions and alternatives that could protect and recover key mussel habitats and communities. Many environmentally conscientious industries implement habitat protection and enhancement programs on their land. Contact the appropriate industries, increase their awareness of the mussel resources subject to their activities, and assist them with improving their stewardship efforts, which will benefit both them and the downstream riverine habitat.
 - 2.1.5 Encourage local landowners to review their activities and, when feasible, provide financial (e.g., Service "Partners for Wildlife" funds) or other incentives to the landowners to protect and recover key mussel habitats and communities. Many environmentally conscientious landowners implement habitat protection and enhancement programs on their land. Other landowners might be willing to conserve habitat if they had the necessary information or were provided with incentives. Investigate and implement new and innovative approaches to encourage landowners to protect aquatic resources. Develop a means to recognize the efforts of cooperating landowners.
 - 2.1.6 Encourage conservation organizations, universities, schools, civic groups, and other organizations to assist in the protection and recovery of key mussel habitats. Substantial support and assistance for restoration efforts is available from many environmental groups and other organizations. Their support should be encouraged and formally recognized.
 - 2.1.7 Encourage conservation organizations (e.g., TNC, land trusts or other land protection organizations) and agencies to acquire key habitats to protect freshwater mussels.
- 2.2 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. Several habitat restoration projects are underway to protect significant mussel resources. A list and description of these projects and the addresses of project managers would be helpful in the initiation of new projects.

PROBLEM 3: The basic life history, reproductive biology, ecology, and habitat requirements of most mussels are unknown.

GOAL: Increase fundamental knowledge of basic biology and habitat requirements of mussels so that managers can more effectively conserve and manage our mussel fauna.

STRATEGIES

- 3.1 Initiate studies on life histories, population dynamics, and environmental requirements to obtain information necessary to effectively manage mussels. Unlike many other animal species, little is known about the basic biology and habitat requirements of most mussel species. The lack of basic knowledge hampers conservation efforts. The following list identifies some specific research needs.
 - 3.1.1 Fish host identification.

- 3.1.1.1 Determine the specific fish hosts for mussel species in need of management.
- 3.1.1.2 Determine the host fishes' biological needs and their population sizes necessary to support mussel reproduction and population viability.
- 3.1.1.3 Determine the extent and mechanism of the immune response of host fish to glochidia.
- 3.1.2 Mussel reproductive biology.
 - 3.1.2.1 Determine age and size at earliest maturity, peak reproductive years, fecundity, and reproductive longevity.
 - 3.1.2.2 Determine the period of spawning and gravidity as well as spawning and settling sites.
 - 3.1.2.3 Determine the level of recruitment needed for species survival and long-term viability.
 - 3.1.2.4 Determine the frequency of successful recruitment in native habitats.
- 3.1.3 Mussel habitat requirements.
 - 3.1.3.1 Determine species-specific physical and chemical habitat requirements (e.g., substrate, flow, temperature, dissolved oxygen, hardness, pH, and alkalinity) for adults and juveniles.
- 3.1.4 Mussel population dynamics.
 - 3.1.4.1 Conduct studies to determine the impacts of diseases, parasites, predation, and harvest on mussels and how these factors affect mussel population demographics.
 - 3.1.4.2 Determine population size and age class structure necessary to maintain a long-term viable population.
 - 3.1.4.3 Determine the demographics of representative mussel populations and the extent of natural variations in recruitment; attempt to define what constitutes a healthy mussel population.
 - 3.1.4.4 Evaluate the effectiveness of current harvest regulations in sustaining viable populations of both sensitive and commercial species.

PROBLEM 4: Knowledge of the current distribution and health of mussel populations is lacking, and much of the historic distributional data are not readily available.

GOAL: Increase knowledge of the status and trends of native mussel populations so that resource managers and administrators can better determine the species and populations most at risk and which populations could be managed for sustained commercial harvest.

STRATEGIES

- 4.1 Increase sampling effort to determine location, density, species composition, and status of existing mussel communities. Many rivers 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. The use of the standardized sampling regime to be developed under Strategy 1.1.6.1 is encouraged.
- 4.2 Gather historic mussel distribution data and make it more readily available. 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.
- 4.3 Gather information on the occurrence and abundance of mussel stocks that have value for the commercial mussel industry and tribal subsistence. Some mussel populations, if properly managed, can provide a sustainable harvest with little or no impact on sensitive mussel species. Populations that could sustain a managed harvest should be identified and evaluated. Information gathered under Strategy 3.1.4.4 should be used to develop harvest management guidelines.
- 4.4 Develop a central database on the status and location of native mussel populations. Information should be categorized based on USGS hydrologic unit maps and mapped using GIS. The database can be used to track mussel populations and should include absence data.
- 4.5 Develop a mussel distributional atlas. In the early 1980s the 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.
- 4.6 Encourage the use of 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. However, molecular genetic analysis has shown that some species are comprised of complexes of distinct species (Kat, 1983a; Kat, 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 genetic research should help clarify the taxonomic relationships within these complexes.

PROBLEM 5: Habitat alterations, water quality degradation, and other anthropogenic factors continue to negatively affect mussels, but poor documentation exists as to how and at what levels such perturbations are realized.

GOAL: Determine how various perturbations impact mussels and their habitat, and provide managers with the information needed to minimize or eliminate threats and protect quality mussel habitat.

STRATEGIES

- 5.1 Determine how and to what extent various habitat alterations affect mussel species and populations. The impacts to mussels from habitat alterations, such as the impounding 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 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) increased siltation; (2) pesticides, herbicides, and fungicides; (3) stream-flow modifications; (4) wastewater discharge of various pollutants and subsequent sediment loading; and (5) modifications in water temperature, dissolved oxygen levels, nutrients, and pH. A better understanding of how environmental factors affect mussels will enable resource agencies to better manage and conserve mussel communities.
- 5.2 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 mussels 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.
- 5.3 Determine if current "Best Management Practices" (BMP) 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 benefitted 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.
- 5.4 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.
- 5.5 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 a river's present lack of mussels. If the original cause of the loss has been eliminated or minimized, mussel reintroduction may be feasible.
- 5.6 Develop biomonitoring protocols using freshwater mussels to complement fish and other macroinvertebrate biomonitoring protocols presently used to evaluate the integrity of a stream. Fish and macroinvertebrate biomonitoring protocols have been developed to score and rank lotic systems 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.

PROBLEM 6: The invasion of zebra mussels poses a new and significant threat to the continued existence of many native mussel species.

GOAL: Develop management options to eliminate or reduce the threat of zebra mussels to native mussels.

STRATEGIES

Note: Any new zebra mussel initiatives should be coordinated with other organizations (e.g., Sea Grant) that are already significantly involved with this species.

- 6.1 Develop predictive models on the spread of zebra mussels and their likely impact on native mussels. Zebra mussels have devastated native mussel populations in the Great Lakes (O'Neill and MacNeill, 1991; Kelch, 1994; Taylor and Kerschner, 1995), and they have now invaded inland rivers where they are likely to affect important commercial mussel resources and protected species. Information is needed to predict the rate of zebra mussel movement into inland waters, the types of habitats they will invade, and the impacts they will have on native mussels in these habitats.
- 6.2 Track the spread of zebra mussels and develop and maintain a GIS system to monitor their spread relative to the location of native mussel populations. The spread of zebra mussels should be monitored and the data reported in a readily available format. The USGS's Southeastern Biological Science Center, Gainesville, Florida, currently tracks the spread of zebra mussels. That database should be reviewed to determine whether modifications are necessary to meet the needs of native mussel conservation and aquatic resource managers.
- 6.3 Develop guidelines and thresholds (triggers) to assist managers in determining when, which species, and how many individuals of a species should be brought into captivity or relocated when it is determined they are at risk from zebra mussel infestations (see Strategy 9.5). Zebra mussels have decimated native mussel populations in the Great Lakes, and this non-indigenous species is now infesting native mussel beds in the Inland Basin. The continued existence of rare large-river mussels is now threatened by this invasion. Guidance is needed on when, which species, and how many individuals of a species should be brought into captivity or relocated when it is determined they are at risk from zebra mussels. Information also will be needed on the relationship between zebra mussel infestation rates and the survival of native mussels. It should be determined if portions, or an entire population, of rare mussels need to be rescued before infestation is observed or if native mussels can survive relocation after some degree of infestation.

- 6.4 Move native mussel species at risk into hatchery facilities or to locations within their historic ranges where zebra mussel infestations will be inconsequential or unlikely (see strategies under Problem 9). It appears that the greatest threat to native mussels from zebra mussel infestations will occur in large rivers and in rivers with upstream reservoirs. Consideration should be given to moving species at risk of extinction into suitable refugia.
- 6.5 Develop protocols to ensure that zebra mussels are not inadvertently introduced into new waters when native mussels are relocated. Because of the dire threat posed by zebra mussels, some mussel species will be moved into hatchery facilities or to locations where zebra mussels do not exist. Protocols should be developed and complied with to ensure that zebra mussels are not incidentally introduced when relocating native mussels.
- 6.6 Determine how zebra mussels 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 smaller rivers and lakes. Definitive information on the zebra mussel's mode of transport could be useful in developing control procedures.
- 6.7 Investigate the feasibility of controlling the spread of zebra mussels through technological means. Research on the physical, chemical, and biological control of zebra mussels is urgently needed. Biological control of zebra mussels may offer the best option for conserving native mussels. However, extreme care must be taken to ensure that zebra mussel control methods do not jeopardize native mussels.
- 6.8 Inform the public about the threat zebra mussels 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 zebra mussels into other waters. The public should be informed of the economic and ecological threat posed by zebra mussels and provided with information as to what they can do to reduce the species' dispersal rate (see strategies under Problem 7). If the spread of zebra mussels can be slowed, increased opportunities will be available to develop native mussel protection strategies.

PROBLEM 7: There is a general lack of concern, awareness, and understanding by government agencies, legislators, academia, and the general public about the ecological and economic value of our native mussels, other aquatic resources, and the anthropogenic impacts that threaten their continued existence.

GOAL: Enhance public and government agency understanding and support for federal, state, local, tribal, and private programs that protect and enhance natural stream ecosystems for the benefit of freshwater mussels and other aquatic and aquatic-dependent resources.

STRATEGIES

Note: Outreach is critical to the success of this National Strategy, and it is especially important to the successful implementation of strategies listed under Problems 2 and 10.

- 7.1 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.
- 7.2 Identify target audiences, evaluate the need for outreach material for these audiences, 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 perceive they could be, impacted by the program. Where needed, develop specific outreach material for these target groups.
 - 7.2.1 Develop and implement an educational program that increases public awareness of the plight of mussels and the benefits of maintaining the ecological integrity of aquatic ecosystems. The future of our nation's freshwater mussel fauna and other aquatic and aquatic-dependent biota (e.g., nongame and sport fish, neotropical migrants, amphibians, reptiles, small mammals, and wetland-dependent plants) will depend on the degree of public support for aquatic ecosystem protection and recovery programs. However, the public generally places little value on aquatic species (with the exception of some game species). Many people perceive the conservation of mussels and other invertebrates as unnecessary and wasteful of government funds. The public should be provided information on the following: (1) the plight of freshwater mussels; (2) their aesthetic, commercial, scientific, and ecological value; (3) the benefits other aquatic resources derive from maintaining mussels as a component of natural stream ecosystems; and (4) what they can do to help in this recovery effort. With this information, the public will be better informed when judging the benefits and costs of preserving mussel resources.
 - 7.2.2 Develop and implement an educational program that increases government agency awareness of the plight of mussels and the benefits of maintaining healthy, intact aquatic ecosystems. The support of natural resources agencies and other agencies with programs that impact aquatic resources is critical to a successful mussel conservation effort. In order for administrators and other employees of these agencies to consider mussels within their program, they must be provided information as to the many ecological and social values of maintaining the biological integrity of freshwater ecosystems.
 - 7.2.3 Develop and implement an educational program that increases the awareness of nongovernment organizations about the plight of mussels and the benefits of maintaining healthy, intact aquatic ecosystems. Many nongovernment organizations (e.g., TNC, American Fisheries Society, American Sports Association, Izaak Walton League, Science Educators of America, American Rivers, Association of Southeastern Biologists, and various universities, zoos, and museums) actively support aquatic resource conservation. These organizations should be (1) kept informed of this conservation initiative; (2) provided with educational materials related to the goals, strategies, and progress of this effort; and (3) encouraged to join in this conservation program.

7.2.4 Develop and implement an educational program that increases awareness within the commercial mussel shell industry and among pearl producers about the plight of mussels and the benefits of working jointly to maintain healthy, intact aquatic ecosystems. The commercial mussel industry and pearl producers view the value of mussel resources from a different perspective than most natural resource managers, and they sometimes disagree on management issues. However, the commercial mussel industry, mussel resource managers, and mussel researchers are all interested in conserving the benefits obtained from sustainable native mussel resources. Cooperative efforts should be pursued that benefit the industry and the mussel resource managers' ability to conserve mussel abundance and diversity. There will be times when the desires of the industry and those of resource managers will conflict, but both groups need to understand that significant benefits can be derived by working together on common issues. The industry can assist researchers and managers by providing field expertise, assistance, and historical knowledge, by soliciting funds and providing facilities for research, by conducting outreach to the general public, and through support and actions to prevent further habitat degradation. Mussel researchers and managers can help to preserve mussel habitat and community structure for commercially valuable species, provide technical assistance on mussel propagation and holding technology, and set and enforce size and harvest regulations that ensure a sustainable mussel harvest.

7.3 Identify and develop specific educational/informational material and mechanisms to assist field biologists with implementing this National Strategy. This includes items such as an annotated bibliography of existing freshwater mussel literature (see Strategy 1.1.4), a database on the historic and current distribution of mussels (see Strategies 4.4 and 4.5), and an effective information transfer system on current mussel research, management, and conservation issues (see Strategies 1.1.2 and 2.2). In addition, the following strategies should also be implemented:

7.3.1 Develop a mussel key. The only available comprehensive mussel key was produced by EPA in 1973 (Burch 1973). This key has been a valuable resource, especially to people new to the field. However, it does not cover all species, taxonomic revisions have occurred since 1973, and the key is difficult to use. A new or revised version of the existing mussel key, making ample use of color photographs, would help increase the identification abilities of new mussel workers.

7.3.2 Develop training courses and seminars on mussel identification, basic biology, culture techniques, sampling methods, and habitat restoration/protection. As more individuals and agencies become involved in this mussel conservation effort, training sessions and seminars will be useful.

PROBLEM 8: The survival and recovery of many mussel species will require the development of artificial propagation and juvenile mussel reintroduction techniques, but these methods have not been perfected.

GOAL: Develop, evaluate, and use the technology necessary to propagate and reintroduce juvenile mussels on a large scale.

STRATEGIES

8.1 Develop glochidia transformation technology for native mussels. Artificially propagated juvenile mussels are needed for four primary purposes: to (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; and (4) for bioassay research. Once developed, the propagation technology must be adapted to larger-scale operations in order to produce sufficient young mussels for these activities.

8.1.1 Perfect an artificial culture medium. Juvenile mussels have been propagated using artificial media, but results have not been consistent with all species. Additional research is needed to improve applicability and usefulness of this technique.

8.1.2 Perfect artificial culture using host fish. The use of fish hosts for glochidia transformation has been developed and is used by many researchers. However, because of fish host specificity and the need to maintain large numbers of a variety of fish species, this method is labor intensive. Suppression of host fish immunity, identification of alternative host species, and the use of non-indigenous fish should be evaluated to determine if healthy juvenile mussels can be produced.

8.1.3 Determine the feasibility of propagating and rearing juvenile mussels in hatchery raceways, ponds, or tanks. Other propagation techniques currently under development include (1) artificially infesting fish with glochidia and releasing the fish into a hatchery raceway, and (2) holding gravid adult mussels in a raceway with their fish hosts and allowing the fish to be infested naturally. In both cases the juvenile mussels can drop off the fish, be reared in a raceway, pond, or tank and be removed when they are large enough for stocking. If successful, these methods would require less manpower than other artificial propagation techniques that are under development.

8.2 Develop diets for artificially propagated juvenile mussels. Once juvenile mussels are produced, they must be fed and reared to a size suitable for release. The technology to feed juvenile mussels is not fully developed, and has been tested on only a few species. The food and feeding regimes must also be adapted to large-scale operations in order to make propagation a feasible management tool.

8.3 Determine the viability of artificially propagated juveniles. The survival and growth of medium-produced and artificially reared juveniles should be compared to those of naturally produced juveniles to evaluate their suitability for release in restoration and recovery programs.

- 8.4 Conduct a comprehensive review of foreign and related literature that could have application in mussel propagation research. As Asian countries have a wealth of experience in freshwater mussel culture, their literature should be translated so techniques can be tested and implemented here.
- 8.5 Conduct a review of mussel culture activities outside the United States (e.g., China, Japan, Australia, and Indonesia) and organize an international symposium on artificial propagation. Foreign researchers are working on propagation technology. An international symposium on the subject would bring these various groups together to share research results and explore new research directions.
- 8.6 Identify criteria for selecting federal, state, tribal, and private hatchery facilities that could be used for large-scale mussel propagation. Although propagation technology is not fully developed, existing hatchery facilities will eventually 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. (Appendix III contains draft criteria modified from the Service's facility criteria.)
- 8.7 Determine the risks associated with mussels, their fish hosts, and associated diseases escaping from the facility 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>) 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.
- 8.8 Develop the technology to reintroduce juvenile mussels into historic habitat. The reintroduction/relocation of adult mussels has met with limited success, and 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.
- 8.9 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.

PROBLEM 9: The survival of rare mussels will require the ability to hold them in captivity or in refugia and to translocate adult mussels to reestablish populations. However, these techniques are not adequately developed for implementation by resource managers.

GOAL: Develop, evaluate, and use the techniques necessary to hold and translocate large numbers of adult mussels.

STRATEGIES

- 9.1 Develop protocols to relocate adult mussels. Adult mussels are generally relocated for two reasons: to (1) remove them from an area when a development project or other factors threaten their survival and (2) release them back into restored historic habitat. 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 (see Problem 6). To save some of these native species, it will be necessary to move some rare and commercially valuable species to areas that will not be threatened by the zebra mussel (see Strategies 6.3 and 6.4). Also, adult mussels can be relocated in order to reestablish extirpated populations when sufficient specimens are available in a donor population.
- 9.2 Develop criteria for mussel relocation. Develop a checklist of the physical, chemical, and biological parameters (e.g., habitat type, pH, oxygen requirement, 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 introductions into nonhistoric habitat. The guidance should also stress the need to monitor and fully report project results.
- 9.3 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. For example, research was conducted in the early 1980s on the feasibility of tagging mussels with magnets and radio tags, but did not provide any reliable technology. Since radio telemetry has improved in recent years, another mussel tagging study may be warranted. Other avenues of relocating and monitoring transplanted mussels should be investigated as well.
- 9.4 Develop technology to maintain adult mussels in captivity. Many species are so rare or so threatened by habitat destruction or other factors 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.
- 9.5 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. Guidelines are needed to assist managers in determining when a species is so threatened by these factors that it should be brought into captivity or relocated to a more secure location (see Strategy 6.3).
- 9.6 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 (see Strategy 8.6).

- 9.7 Determine risks associated with species escaping from the facility into nonhistoric habitat. (See narrative under Strategy 8.7).
- 9.8 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 effects of mussel diseases on fish and fish diseases on mussels should be assessed.
- 9.9 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 were 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.

PROBLEM 10: Current funding levels are not sufficient to address identified information needs or to implement this National Strategy.

The outreach strategies identified under Problem 7 are critical to the success of the following strategies.

GOAL: Increase available funding levels and develop other means to increase mussel conservation efforts.

STRATEGIES

- 10.1 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 our nation's 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 benefits of mussel conservation must be linked to other aquatic resource benefits.
 - 10.1.1 Seek funding assistance from federal, state, and tribal agencies that have direct involvement with aquatic resources management. Many natural resources agencies, such as the Service, BRD, USGS, Corps, TV A, EPA, USPS, NPS, and state and tribal natural resources agencies, are already funding projects directly related to mussel conservation. Develop specific proposals and solicit their help in the conservation effort. These agencies should be encouraged to examine their existing authorities to determine how they could expand into mussel conservation.
 - 10.1.2 Seek funding for mussel conservation from agencies or organizations that have activities which impact mussel communities. Many regulatory agencies oversee programs that secondarily benefit mussels; they might be willing to 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 fund 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).
 - 10.1.3 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.
 - 10.1.4 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.

This National Strategy presents an outline of suggested goals and strategies for a national mussel conservation program. These strategies do not encompass all the conservation activities that are currently under way nor do they identify all activities that will be needed for the long-term conservation of mussels. They are offered as guidance to provide a national mussel conservation perspective and to help various organizations identify the types of conservation tasks that could be implemented to assist in the greater conservation effort. Furthermore, the National Strategy is intended to be a dynamic document that will be revised periodically as new information becomes available and new strategies are developed. The authors welcome any comments and suggestions that would help enhance short- and long-term mussel conservation goals.

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Appendix I

Participants at the April 1995, mussel meeting in Roanoke, Virginia, and other individuals who were involved in drafting the document, or provided written comments.

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Appendix II

Criteria for Prioritizing Projects and Activities Identified in this National Strategy

- Project has partners or has the potential to create partnerships.
- Project work is related to priorities for geographical distribution and species diversity and considers the degree of threat.
- Project addresses both the status and trends of the mussel populations.
- Project focuses on the aquatic system within the watershed (USGS quadrants).
- Project fulfills the objectives of existing management or recovery plans.
- The project is feasible and achievable (i.e., cost-effective; uses the best choice of methods).
- Project does not unnecessarily duplicate existing studies.
- Project provides a short-term solution until a long-term plan is developed, or itself offers a long-term solution.
- Project has a monitoring component.
- Projects that prevent extinction are of a higher priority than projects that maintain existing populations, and maintenance projects are of a higher priority than recovery projects.
- All other options have been explored (e.g., habitat restoration or translocation).
- Applicability of research to multiple species (national research receives a higher priority than local research).

Appendix III

U.S. Fish and Wildlife Service Facility Criteria

- The activity must be considered essential and must be justified in management, conservation, or recovery plans, etc. For Service facilities, the work needs to meet the goals of the ecosystem plan.
- The water quality and supply must be known and must be compatible with species to be held.
- Facilities should ONLY work with mussels from the same basin or watershed. Mussels will only be allowed to be cultured or held outside of their native basin or watershed under a special permit or in cases of emergency (i.e., the threat of extinction) and with

approval from state natural resources agencies and the support of the conservation community. Culture of non-native mussels shall go forward only in well-confined facilities with detailed operations management plans.

- Facilities must have a water source free of zebra mussels.
- Facilities must have a wet lab or have ready access to one.
- If the facility staff DOES NOT have the technical expertise required, the facility's project leader must procure the necessary training or secure the necessary expertise through cooperative arrangements with appropriate experts.
- Facilities must have an available and suitable food source. If a natural source is not available, a facility must have the space and expertise needed to produce food.
- Projects should be cooperative ventures involving federal, state, tribal, or private organizations. For example, projects designed by the Service should involve hatcheries, Fish Health Labs, and Fish Technology Centers. If federally listed species are concerned, involve Ecological Services.
- The project must comply with all federal and state permit requirements.
- The introduction of mussels into a facility should not significantly affect the existing fish production program.
- A contingency plan should be prepared that addresses how listed mussels will be rescued in case of flooding or other disaster.

Note: Criteria should be a function of the project objectives (e.g., refugia, propagation, and research). If particular criteria are not applicable to the project, compliance with that particular criterion is not necessary. If this is the case, justification for not complying with the criterion must accompany a proposal. For example, the need for raceways or ponds is dependent on the species and project.