# Keynote Address: A National Strategy for the Conservation of Native Freshwater Mussels

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**Abstract.** The molluscan garden of Eden in North America has been plundered of productivity and diversity, and is now sown with exotic seeds of destruction in the form of zebra mussels (*Dreissena polymorpha*). The decline of freshwater mussels in the 20th century has accelerated in the last decade, resulting in a prognosis for widespread extirpations and extinctions in the next decade. Although numerous agencies, organizations, and individuals are working feverishly to reverse the downward trend in mussel populations, there has been no document of national scope to focus research, technology, and facilities on conservation management through protection and propagation of species at risk. That document is now drafted and available to all interested parties. The current euphoria for the noble but elusive goals of ecosystem management must be implemented through habitat protection and artificial propagation for those mussel species with greatest potential for recovery. Big river mussel communities are at greatest risk from the zebra mussel, and stream mussel communities are jeopardized by habitat degradation and genetic isolation. Luminary biologists must decide on the allocation of limited resources, targeting those species most amenable to salvation, and those that must fend for themselves. Partnerships involving managers of hatcheries, water supply reservoirs, private lakes and ponds, and protected riverine environments offer the greatest hope to adaptable mussel species. Conversely, benign neglect will fall on the highly specialized, endemic species for a gloomy hereafter in the 21st century. The planning and use of natural and artificial refugia and multiple use of fish hatcheries provide options presently under evaluation in several states. The role of some federal hatcheries could be expanded to accommodate the needs of aquatic fauna of national significance and mandated for conservation by federal law. As biologists and resource managers, our mission must be to create partnerships, protection plans, propagation options, and public awareness for the conservation of mussels and associated aquatic species on the path to extinction.

## Historical Perspective

The decline of freshwater mussels (Margaritiferidae and Unionidae: superfamily Unionoidea) in the United States has been most readily evident and documented over the last half century, long before passage of the Endangered Species Act (ESA) of 1973. At the turn of the century, the problem of water pollution and its effects on mussel beds was already evident (Smith 1899). During the first half of this century, the construction of large dams on mainstem rivers created voluminous impoundments that eliminated literally thousands of miles of riverine habitat and associated fauna. The silent crisis of ecosystem destruction and biodiversity losses was most evident in the southern U.S. (Noss et al. 1995). Because most indigenous mussel species were incapable of survival or reproduction in these reservoirs, healthy populations died out and were replaced in some cases with an assemblage of non-indigenous unionids or exotic bivalves that blossomed in abundance (Fuller 1974; Williams et al. 1993). Many of these invasive unionid species were of commercial value and provided new populations capable of sustaining commercial harvest, as did riverine mussel beds during the era of the pearl button industry. The long-term costs to biodiversity from anthropogenic actions to create more electricity, recreational opportunities, flood control, and other benefits to society began to be evident in the 1960s when mussel populations not immediately depleted or destroyed by impoundments, water pollution, and general habitat destruction began a

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steady decline. The great longevity and high number of cohorts in riverine populations are such that the lag time between reproductive impairment and measurable population declines may extend for more than a decade. Thus, the ruination of mussel resources may be documented years after the causative problem began. In my opinion, species declines in the 1970s stemmed from, in most cases, earlier catastrophic events (excessive pesticide usage, toxic spills, illegal discharges, coal waste releases, etc.) and cumulative changes to environmental suitability (e.g., impoundment, dredging, water quality, riparian development).

Passage of the ESA in 1973 and the federal listing of 23 freshwater mussel species in 1976 by the U.S. Fish and Wildlife Service began formal conservation and recovery actions for these species. The presence of a malacologist in the Office of Endangered Species at this time was a key factor to their listing and to evaluations of other freshwater molluscs known or assumed to be in trouble. From 1976 to 1995, only 35 other mussel species have been listed as endangered or threatened, in spite of the fact that a much larger contingent of unionid species are viable candidates for federal protection (Williams et al. 1993). The distribution of these 58 federally listed species is highly skewed to the southeastern U.S., with the states of Tennessee and Alabama assuming the lion's share of responsibility for their protection (Figure 1).

## National Strategy Document

In the face of declining mussel populations, the invasive zebra mussel, and likely revisions to the ESA, the overture of a national conservation plan could be viewed by cynics as analogous to reassigning staterooms on the Titanic. In spite of these uncertain times and the prospect of a political bottleneck to mussel conservation, a national strategy has been prepared to address the woeful state of freshwater mussels in the U.S. (Biggins et al. 1995).

The goal of the national plan is to conserve native freshwater mussels, to ensure their continued survival, and to maintain their ecological, economic, and scientific values to our society. To achieve this goal and to assimilate the combined wisdom of biologists, administrators, conservation groups, the shell industry, and other interested parties, a document was prepared to identify the problems contributing directly or indirectly to the fauna's demise and to recommend actions or management strategies to reverse the downward trends in populations and decelerate extinctions of highly endemic species (Biggins et al. 1995).

The strategy document identifies 10 problem areas in need of attention by a cadre of agencies, professionals, and local citizenry. Problems that can be addressed within the mission, authority, or responsibility of particular agencies or organizations

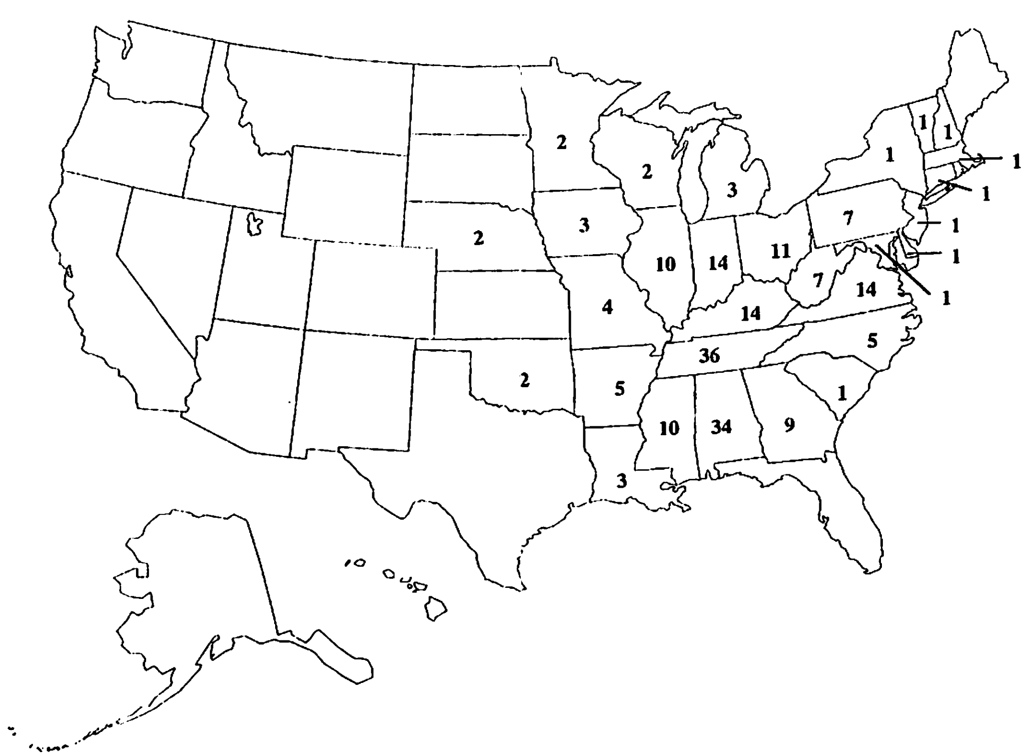


**Figure 1.** Occurrence of federally listed mussel species by state.

can be prioritized and acted upon through the suggested strategies. The following problems have been cited as key issues to be addressed to achieve a national conservation program:

1. A coordinated national conservation strategy for mussels does not exist.
2. Quality mussel habitat continues to be lost.
3. Insufficient information is available on basic mussel biology.
4. Insufficient information is available on current and historic mussel populations.
5. Insufficient information is available as to how habitat alterations affect mussels.
6. Invasion of zebra mussels threatens native mussel species and populations.
7. The public has a lack of understanding of the plight and value of mussels.
8. Mussel propagation technology is not fully developed.
9. Mussel captive holding and reintroduction technology is not fully developed.
10. Insufficient funds are available for mussel conservation and recovery.

This outline of issues and the corrective strategies discussed in the document do not include all conservation efforts currently under way, nor do they define all actions needed for the long-term success of a national conservation program. The intent of the document is to provide guidance to interested participants and to serve as a lightning rod to effect change and improve coordination at the state and national levels. Acceptance of this document by natural resource and regulatory agencies at all political levels would resolve the stumbling block identified as problem 1 and lead to much greater participation and concern for the fate of native freshwater mussels and the ecosystems upon which they depend. Freshwater mussels can serve as the umbrella taxon, being the indicator of environmental change in streams and rivers and focusing corrective actions on water quality, physical habitat degradation, and exotic species expansion by the appropriate resource agencies. It is hoped that the national strategy will serve as a call-to-arms to attack the molluscan crisis before a spasm of extinctions is inevitable.

## Unionoid Conservation on a Global Scale

We are currently experiencing a temporally compressed repetition of the geologic record for molluscs, with a spasm of extinctions similar to that recorded in the Permian and Cretaceous periods. However, the present time scale is measured in decades rather than geologic eras. This most ancient of extant animal groups, dating back more than 500 million years, has been among the most successful and diverse, radiating to occupy most terrestrial and aquatic habitats worldwide. From a global perspective, the molluscan taxa reported to be threatened and endangered by the International Union for the Conservation of Nature (IUCN) reflect an obvious geographic and scientific bias (Groombridge 1993). In a recent review of 1,130 species and subspecies of molluscs identified as at risk or recently extinct, Kay (1995) noted the bias toward (1) adequately sampled countries, (2) nonmarine molluscs, and (3) families well-studied with sufficient historic and recent records of distribution. She noted common characteristics of jeopardy-prone groups of molluscs to include actively evolving taxa, relatively large body size, restricted distributions, habitat and food specialists, and specialized reproductive traits. As with most other animal phyla, degree of specialization is directly correlated to probability of extinction in today's altered ecosystems.

Although the IUCN assessment is a very limited and admittedly biased overview of molluscan taxa at risk (Kay 1995), the status of Unionoidea is globally dismal. The precipitous decline of freshwater mussels in the U.S. also is being documented in many other countries. Groombridge (1993) recognized *Margaritifera margaritifera*, *M. auricularia*, *Pseudanodonta complanata*, and *Unio crassus* as threatened throughout much of Europe, the United Kingdom, and Russia, with two other species threatened in more localized areas. Many species of the family Margaritiferidae have declined markedly in range and abundance. In central Europe, the eastern pearlshell or pearl mussel (*M. margaritifera*) is now on the verge of extirpation, with greater than a 75% reduction in range (Bauer 1979). The decline of pearl mussel populations in southern Europe is comparable to that in central Europe (Bauer 1986). In Scandinavia, habitat degradation and acid deposition effects threaten the pearl mussel. The species has been protected in Finland since 1955 because 75% of resident populations have been lost during this century (Valovirta 1995). Domestic and industrial wastes, intensive agriculture, and habitat degradation jeopardize the continued existence of this and other species throughout much of Europe. Large populations of pearl mussels reside in northwest Russia, but periodic poaching of host fish (salmon) and of the mussels by pearl seekers has reduced many populations. Regrettably, most countries with unionoid species have poor survey and range records to evaluate the status of their populations. Thus, the status of freshwater mussel species throughout much of their total range is undetermined and grossly underrepresented in the periodic IUCN Red Lists that identify species at risk. The primary actions required to conserve molluscan diversity worldwide were identified by Kay (1995), and are generic analogs of the document prepared for freshwater mussel conservation in the U.S. She identifies five action items for mollusc conservation:

1. Acquire and manage threatened habitats on islands, in aquatic ecosystems, on continents, and on coral reefs for the conservation and protection of the native molluscan biota.
2. Develop the database necessary for knowledge of molluscan diversity.
3. Prevent the introduction of alien species that have negative impacts on native mollusc species and control and eradicate these exotic species where such introductions have already occurred.
4. Establish self-sustaining captive populations of endangered mollusc species and support their eventual reintroduction into their native habitats.
5. Promote public awareness and concern for molluscan conservation programs.

An independent evaluation of commercial shellfish resources stressed the need for genetic resource management as well (Thorpe et al. 1995). The commonality of global needs for all molluscan taxa with those of national needs for our unionoid fauna is readily apparent. Perhaps our national strategy for the conservation of native freshwater mussels will serve as a model for similar nationalistic documents, to be prepared by other countries also experiencing precipitous declines and a potpourri of threats to their native unionoid fauna.

## Captive Propagation

Although each of the 10 problems specified for freshwater mussels is deserving of a lengthy exposition, I would like to comment on aspects of problems 3, 8, and 9 in light of current paradigms and research efforts. The value and priority of captive breeding as a means of recovering rare species or preventing the extinction of critically endangered species will remain contentious within the conservation community (Norton et al. 1995). There is no challenge to the claim that the protection and restoration of natural habitats is the keystone action to achieve the long-term survival of species at risk of extirpation or extinction. The symptom (isolated, declining populations) cannot be treated unless the causative agent (habitat degradation) is identified and corrected. However, captive breeding can play a significant role in the conservation of freshwater mussels. The locations of eastern national fish hatcheries and fish health and technology centers (Figure 2), and the distributions of federally listed mussel species (Figure 1) exhibit considerable overlap. Mussel conservation projects could be conducted at suitable hatcheries with surplus space (ponds, raceways) not used in fish production. The most suitable facilities for unionoid holding and culture occur at older hatcheries with earthen ponds and raceway channels marginally useful to high-density fish production. Similarly, the more numerous state fish hatcheries in the eastern U.S. provide suitable locations and facilities where supportive breeding of juvenile mussels of federal- or state-listed species could occur.

The debate over captive breeding of rare species has been effectively summarized and rationalized for fishes in a recent document by the Aquatic Conservation Network (Huntley and Langton 1994). Eight of the most common statements of opposition to propagation were examined and debated, justifying the benefits to be gained by captive breeding programs. Those same arguments apply to all aquatic species capable of being propagated under low-technology conditions. The success of captive breeding programs for charismatic mammals and birds provides optimism that the same degree of success can be achieved for lowly aquatic species and at a fraction of the cost.

The best options for endangered mussel recovery occur when natural populations still reside in portions of their original range, even if those populations are small and disjunct. Occurrence in native albeit degraded habitats provides opportunities for habitat and population manipulations to allow the species to expand its range, and for mussels to be relocated to suitable historic habitats after the cause(s) of extirpation has been ameliorated. Remnant wild populations, such as in headwater streams or in tailwaters below dams, may not be self-sustaining, and it may not be possible to reverse population declines before their projected extinction. Under these circumstances, the last hope for recovery lies in the collection and sequestering of a captive population for propagation and release of progeny to suitable wild habitats. Ideally, captive populations for propagation should be established in hatcheries or other refugia before wild populations begin their terminal decline, but such proactive management is typically untenable for species of

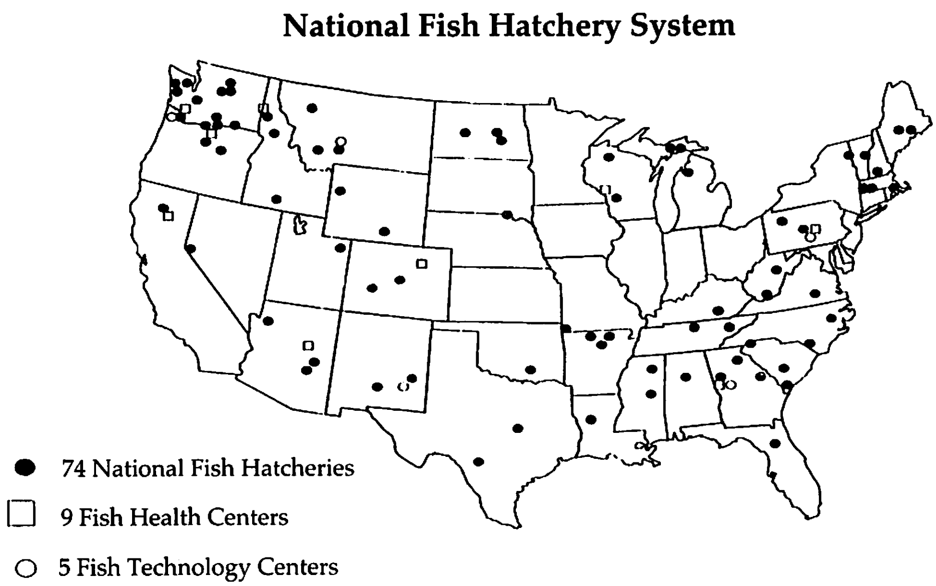


**Figure 2.** Distribution of federal fish hatcheries and associated health and technology centers in the United States.

low priority and without the charisma to justify such actions by a natural resource agency.

Captive propagation and reintroduction are effective means to recover endangered mussels, but they are far less efficient and inherently more expensive than the maintenance of natural habitats. In captivity, species can undergo shifts in genetic, physiological, or behavioral traits that could be detrimental to their readaptation to the wild. In my opinion, this is of much lesser concern for unionoids with simple, instinctive behaviors, high fecundity, great longevity, and poikilothermic physiology. Regardless of theoretical consequences, captive propagation may provide the only option for recovery of species on a collision course with extinction, and numerous "guinea pigtoe" species have been selected to begin the testing and development of various protocols for captive breeding (Gatenby 1994; Yeager et al. 1994; Burress 1995). The prodigious fecundity and output of glochidia by individual females provide the opportunity to produce more juveniles from a small captive population than what is normally produced in natural populations, orders of magnitude larger but inherently less efficient reproductively. Induced infestations on host fishes, although labor and space intensive, can provide the juveniles for recruitment in populations not effectively reproducing or for the reestablishment of species in vacant but suitable habitats.

## Genetic Considerations

To preserve the genetic integrity of species or populations held in captivity for eventual release, captive breeding must minimize adaptive and nonadaptive genetic changes; that is, altering the natural evolutionary process. Fortunately, a random sample of only 20-25 animals contains roughly 98% of the expected heterozygosity of a wild population (Lacy 1994), so the collection of genetic variation is tenable even for rare unionoids. The concept of genetically effective population size ($N_e$) is now well entrenched in the management of captive vertebrates, and is being assimilated into invertebrate conservation programs. Because captive propagation and supportive breeding are likely recovery actions for rare mussels (Ryman and Laikre 1991), concerns for both inbreeding and variance effective numbers must be addressed (Ryman 1994). Target numbers can range from a minimum of 50 animals to avoid inbreeding depression to 500 animals to allow mutations and random mating to restore heterozygosity lost through genetic drift (Lande and Barrowclough 1987). However, the effective population size is usually much smaller than the mean census size, so sizes of captive mussel populations for long-term management should be several-fold larger than the theoretical $N_e$ due to unequal sex ratios, nonrandom fertilization processes and production of young, and fluctuations in population size. Guidelines for determining minimum acceptable $N_e$ and genetic risks in hatcheries are available in the literature (Ryman and Stahl 1980; Allendorf and Ryman 1988; Busack and Currens 1995). Because our knowledge of the unionoid fertilization process, natural sex ratios, and other reproductive traits is incomplete, captive population sizes should be maintained at large but manageable levels, such as a minimum of 1,000 adults as a founder population for brood stock in captive propagation efforts.

For most unionoid species threatened by the zebra mussel, founder populations at the maximum size supportable in holding facilities are readily available, but the collection of these mussels for captivity must occur prior to a population or species crisis. Once in captivity, all mussels produced beyond this captive carrying capacity are available for release to historic or protected habitats. Soule et al. (1986) proposed a goal of 90% retention of genetic variation over 200 years in the source population, with the assumption that habitat suitability for wild populations would improve in two centuries. This 90% value has been widely adopted in Species Survival Plans of the American Association of Zoological Parks and Aquariums and is a laudable target for inclusion in freshwater mussel conservation plans.

If we let conservation genetics become the goal rather than the guidelines for restoring and recovering mussel populations, then we will be doomed to failure with rare species. While examples of inbreeding depression and genetic maladies have been documented (Leberg 1990), the long-term ecological consequences of lower genetic variance are indeterminate. Numerous small founder populations of native and exotic species have burgeoned in new habitats, with few examples of failure due to inbreeding, low heterozygosity, or other bottleneck effects (Brown 1994). The destruction and degradation of habitat for declining mussel species and the reduction in population sizes are the driving forces to extinction, not the loss of genetic variability and its possible deleterious effects. When mussels are brought into captivity for propagation, maintenance of genetic variability should be of major concern. However, reality dictates that the high cost in effort and dollars to maximize heterozygosity through controlled breeding in noncharismatic invertebrates is untenable, and support for other conservation measures to sustain the species is of higher priority. Therefore, maintaining captive populations at several locations, such as in hatcheries and ponds with controlled access, is the preferred demographic alternative to genetic management of one large population. Similarly, treating all disjunct populations of a once widespread species as a functional evolutionary unit (i.e., metapopulation) would greatly simplify management and increase the number of recovery and restoration options for the relocation of adults or propagation of juveniles to establish self-sustaining populations. Each remnant population, with suitable habitat to expand, may not survive without the infusion of adults or juveniles reared from a sister population, and political boundaries should have no relevance in the management of evolutionary units. Although the concept of supportive breeding without the introduction of exogenous genes into the recipient population is scientifically sound and a worthy goal, this option may not be realistic. The general public views most invertebrates with attitudes of aversion, antipathy, or fear, and these sentiments will not change without long-term educational programs (Kellert 1993). We cannot expect minor genetic differences among populations of invertebrates to be sufficient justification for nonscientists to accept biological conservation at the population level. This distinction was made clear even by a conservation-minded Congress in the language of the ESA, limiting protection of invertebrates to species and subspecies, not populations. With so many species and subspecies of freshwater mussels at risk, we must be pragmatic and realistic in our approach to preventing extinction.

The concern for retaining genetic variation in critically endangered unionoids also could be addressed through cryogenic methods for preserving genetic diversity, as practiced with vertebrate species (Pursel and Johnson 1989). Cryopreservation of eggs, sperm, and early embryos of vertebrates and some invertebrates has become routine and widely practiced (Leopold and Rojas 1989); however, its utility to unionoids is limited by practical considerations and undeveloped protocols (Chang 1993). Techniques for the extraction of mature sex products or early embryos are untested, and the culture of early embryos *in vivo* to the glochidial stage has not been attempted to my knowledge. Thus, our knowledge of *in vivo* culture is too rudimentary at present to consider the cryopreservation option as more than a novel but unproven approach. We must await the development of this technology, likely in bivalve mariculture (Renard 1991), to assess the applicability to unionoid conservation.

## Reintroduction and Natural Reproduction

Relocation and reintroduction of unionoids has been used as a conservation and management tool, mostly to prevent the destruction of animals from project impacts. Such short-term salvage activities provide no opportunity or requirement to assess the success or failure of relocations conducted for convenience rather than for conservation. Cope and Waller (1995) provide a thorough synopsis of the relocation projects that have been conducted, most of them buried in unpublished reports not readily available to mussel biologists. Nearly half of the cited studies were conducted to comply with the federal ESA. Because our knowledge of mussel ecology is more cerebral than empirical, there is no manual for inexperienced field biologists to consult when faced with the opportunity or requirement to relocate for purely conservation purposes. Most of the literature, principally unpublished, describes salvage efforts conducted with such limited time and funds that science was compromised in lieu of expediency. Therefore, there are insufficient case studies to provide defendable recommendations that ensure a high probability of success. Of the 33 papers reviewed by Cope and Waller (1995), only 3 occurred in the peer-reviewed literature. There are undoubtedly many more mussel relocations that have occurred in the last 20 years, but unpublished reports and the unwritten word are inaccessible without an effective communication network of mussel biologists, fish biologists, and field biologists of agencies and consulting firms who participate in the occasional relocation of mussels. A query of attendees at this national symposium would likely add many more projects that have involved the collection and relocation of mussels.

Mussel reintroductions will remain more of an art than a science until such time as statistically designed research studies are conducted to assess the effects of variables (e.g, species, time of year, transport time and distance, substratum type) on survival and establishment of relocated mussels (Waller et al. 1995). Of critical importance to mussel restoration is the documentation of spawning and fertilization success at the relocation site. The true measure of a successful relocation is reproductive success *in situ*, leading to the establishment of viable populations no longer in need of human intervention. This "acid test" of relocation as a conservation strategy is noticeably absent from previous studies.

The evaluation of reproductive success at relocation sites is a long-term commitment of monitoring, requiring roughly 5 years to complete. Survival of mussels is only the first step in the establishment of species at new locations. The reproductive cycle of mussels is such that fertilization success depends on the proximity of males and females in the population. Is there a minimum density and optimal sex ratio needed for reproductive success? This question of basic reproductive ecology is not answerable at this time. Downing et al. (1993) sampled a population of eastern elliptios (*Elliptio complanata*) in a Canadian lake and presented conclusions on minimum densities for reproductive success that have been erroneously assumed valid for other species and habitat types. Many riverine mussel species exist as viable populations of $<10/m^2$ the reported threshold for usually complete reproductive failure of *E. complanata* (Downing et al. 1993).

Personal observations in field studies over the last 15 years, particularly with endangered species at extremely low densities, lead me to believe that particular sex ratios and densities are not critical to spawning success or to the reestablishment of populations. This somewhat heretical view stems from anecdotal evidence gained in the laboratory and field, examining multiple species at various densities. My experience has been that females of many species, whether at population densities of $10/m^2$ or $1/m^2$, are usually gravid at the expected time of year (bradytictic vs. tachytictic). Not only are they gravid, but the degree of fertilization success is nearly always high (>95 % embryos or glochidia). The current paradigm of the fertilization process requires upstream males to release sperm into the water column, those sperm to drift downstream, be withdrawn through the incurrent aperture of a reproductively receptive female, and to fertilize the thousands to millions of eggs recently ovulated and awaiting transport to the marsupial gills. Consider the credence of this reproductive process in a river with numerous mussel species of various densities and sex ratios, armies of filter feeders capable of ingesting or at least affecting sperm transport, and the numbers of sperm that would be available after dilution and dispersal in the water column. The credibility of internal fertilization from externally derived sperm becomes suspect when absolute densities and distances between males and females of rare species are factored into the equation. Densities of some rare species are typically $<1/m^2$ and often much lower than this abundance level. How is it that females collected at such densities are usually gravid and with high fertilization success? Our current paradigm of reproductive biology is inadequate, in my opinion, to explain the fertilization success of rare species or other mussels at low densities.

Hermaphroditism is commonplace in the Mollusca, and the benefits of such a reproductive strategy are well known (Coe 1943; Ghiselin 1969). van der Schalie (1966) reported an array of species with an apparent low incidence of hermaphrodites in populations and a few species that are typically monoecious. Although Downing et al. (1993) did not census endobenthic mussels, they noted that about 80% of their sampled population of

*E. complanata* was hermaphroditic and that most mussels had either very low or nearly 100% fertilization success. Does their explanation of differences in spatial aggregation likely explain this virtually "all-or-none fertilized" phenomenon in their population or in other populations and species? Results of Downing et al. (1993) disagree with Kat (1983), who sampled 560 specimens of *E. complanata* from 28 widely disparate populations of varying densities and found no evidence of hermaphroditism. Similarly, Heard (1979) reported <2% hermaphroditism in 1,178 specimens of *Elliptio* spp. from various locations. As judged by these studies, there can be a basic difference in mode of fertilization among populations or seemingly among localized aggregations of unionids within a population. If the eastern elliptio, one of the most abundant and widespread unionids in North America, can exhibit such high and low incidences of hermaphroditism, could other unionids contain the same labile sex determination, perhaps triggered at low abundance during range expansions or to survive population bottlenecks emanating from stochastic events? To further challenge the presumed typical reproductive cycle, I have brought nongravid female *Villosa iris* into a laboratory tank in mid-summer, prior to the spawning period in their natal river, and have had all of them become gravid 2 months later. Although sperm storage, sex reversal from digenean trematodes, or other biological anomalies are possible explanations for fertilization of females in isolation (Kat 1983), these observations and others lead me to hypothesize that many (most?) females of the Unionidae are facultative hermaphrodites, capable of cross- or perhaps self-fertilization under situations of low density, highly skewed sex ratio, or other extrinsic conditions that induce hermaphroditism. Females may retain this lability throughout their reproductive life and implement this option at times when insufficient sperm or lack of male pheromones in the water trigger spermatogenesis in a portion of the female gonad.

Ghiselin (1969) noted that monoecious reproduction has evolved convergently in many phyla as an adaptation to special conditions, and that it is often facultative. The widespread hermaphroditism of opisthobranch and pulmonate gastropods, marine bivalves, and documented hermaphroditism in *M. margaritifera* indicates that this mode of reproduction in unionoids is more prevalent than what previous studies have inferred (van der Schalie 1966; Kat 1983; Bauer 1987). If the occurrence of hermaphrodites is density dependent, is it any wonder that the incidence of hermaphroditism was low in most previous reproductive studies conducted with relatively healthy (abundant) mussel populations? A test of the hypothesis of facultative hermaphroditism in the Unionidae would require prescribed experiments with females in isolation and manipulated population densities of several species, preferably in natural and artificial habitats. Histological examination of gonads must be extensive, because the ratio of male:female gonadal tissue is frequently low and easily overlooked in cursory gonadal sampling (Kat 1983). Documentation and explanations to solve the "reproductive paradox of Unionidae" would open a new frontier for resource managers and provide new options in the restoration and conservation of rare species.

## Unionoid Conservation to 2000

The flurry of progressive optimism and activity for implementing species conservation and habitat protection came to a screeching halt in 1995. Reauthorization of the ESA became a political hot potato and the scapegoat for many of the ills of economic growth and development in the U.S. In spite of strong public support for a healthy environment, a vocal minority threatens to undue legislatively what has taken nearly 25 years to nurture, perfect, and implement for the public good. Concurrently, with a congressional moratorium on new federal listings of threatened or endangered species until reauthorization is completed, policy changes within the U.S. Fish and Wildlife Service (USFWS) were announced purportedly to eliminate false perceptions of candidate species and to focus internal attention on high-priority Category 1 species (Beattie 1995). Skeptics contend that the changes were made to lower the visibility of conflict between the laundry list of species awaiting attention via the ESA, private property rights, and the oxymoronic "sustainable growth." The policy change in 1995 dramatically reduced the recognition of candidate molluscs, literally by the stroke of a pen. The most recent Animal Candidate Review List, published on November 15, 1994, in the Federal Register, recognized 13 unionid species already proposed to be listed, 1 species of taxonomic uncertainty, and 54 species as Category 2. Category 2 species are defined as those for which the USFWS has information indicating that a proposal to list as endangered or threatened is possibly appropriate, but they lack persuasive data on vulnerability and threats to proceed with listing. Although several of these species are in definite trouble and deserving of Category 1 status, sufficient information on biological vulnerability and threats to support their listing has not been collected. Regardless of their deserving designation, the policy change redefined candidate species to mean only those species for which sufficient data exist to indicate that listing may be appropriate (i.e., only Category 1 candidates). Thus, all Category 2 mussel species were summarily eliminated from recognition as candidates in trouble and in need of prescribed survey efforts and data acquisition. Their new designation as "species of concern" took them out of the candidate limelight.

Changes in the environmental attitudes of many public officials also have been felt within many states. State lists of rare species have been attacked as inappropriate, and the implementation of federal and state environmental laws on water quality and habitat protection has been compromised through budget and personnel reductions. Paranoia over property rights and the boundaries between individual rights and the safety, health, and welfare of society have been called into question. The result of this economic hedonism has made it much more difficult to identify threats, reduce negative impacts, and effect restoration activities to recover habitats and species (Barbier et al. 1994).

In spite of this ambivalent political climate, the continuing decline of federally listed mussel species and others now officially unrecognized, and the imminent threat posed by the exotic and unpredictable zebra mussel, our mission as biologists has not changed. The unionoid fauna in North America is of world-class significance and should not be compromised by the short-term and shortsighted ideology that reveres the national pocketbook and denigrates the speckled pocketbook. We assemble here today as guardians of this resource, unable to control the forces that threaten the mussel fauna, but unwilling to relinquish its future to a covetous minority or to misguided officials, who would spurn ecological integrity and diminish a bountiful earth. While their fate awaits divine retribution (Revelation 11:18), the fate of the unionoid fauna rests principally with us and the agencies we represent. A national plan to conserve freshwater mussels and their ecosystems would benefit all freshwater fauna and provide a suite of economic and ecological values to humans, codependent on clean water and a healthy environment to sustain our well-being and presupposed standard of living.

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