2007 FMCS SYMPOSIUM
PLENARY SESSION: DIRECTIONS IN MOLLUSC CONSERVATION: MOLECULES TO ECOSYSTEMS
ABSTRACTS

PE 01

FRESHWATER BIVALVE (UNIONIFORMES) DIVERSITY, SYSTEMATICS AND EVOLUTION: STATUS AND FUTURE DIRECTIONS

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Freshwater bivalves of the order Unioniformes represent the largest bivalve radiation in freshwater. This radiation is unique in the class Bivalvia in having an obligate parasitic larval stage on the gills or fins of fish. This diverse assemblage is divided into six families, 180 genera and roughly 800 species. These families are distributed across six of the seven continents and represent the most endangered group of freshwater animals alive today. Unioniform bivalves have been the subject of study and illustration since at least Martin Lister (1675). Over the past 250 years impressive gains have been made in our understanding of the evolutionary history and systematics of these animals. We briefly summarize the current state of unioniform systematics and evolution and suggest research themes for future research. Advancement in the areas of systematics and evolutionary relationships within the Unioniformes will require a resurgence of survey work and re-evaluation of all taxa, especially outside of North America and Western Europe. This will require collection of animals for shell morphology, comparative anatomy and molecular analyses. Along with re-examination of described taxa, we need a renewed emphasis on the natural history, host fish relationships, ecology and physiology of these animals. Traditional conchological and anatomical characters need to be reviewed and new character suites added. New morphometric methods need to be applied to the ontogenetic changes in shape during growth. The fossil record of freshwater bivalves needs to be carefully reviewed and a phylogeny of this group needs to be developed. However, evidence of rampant convergence in shell morphology needs to be factored out of the record. As our understanding of the systematics of these animals improves, it will result in a better understanding of the evolution of this expansive radiation in freshwater. New avenues are being opened in understanding the evolution of the unioniform bivalves. We need to expand our set of tools to include or develop additional markers such as single copy nuclear genes and microsatellites. Examination of double uniparental inheritance of mitochondrial DNA is providing new insights in to the evolution of this order. Gene order has been shown to differ among genera but is still to be explored. Expanding our understanding of the evolutionary relationships and history of unioniform bivalves will provide a solid foundation to study the zoogeography of these rather sessile, obligate freshwater organisms. The unique natural history of unioniform bivalves provides a fertile area for testing and developing evolutionary theories.

PE 02

LIFE HISTORY STRATEGIES OF UNIONOID MUSSELS

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The unique life history strategy of Unionoida is essential to understanding both the evolutionary success of the group and the present conservation crisis. The parasitic larval stage was a key adaptation of the Unionoid ancestor, permitting upstream dispersal in freshwater. Later evolutionary diversification was associated with the origin and exploitation of particular adaptations for parasitizing hosts. Examples of adaptations associated with clades include hooked glochidia (Unioninae), mantle lures and bradyticty (Lampsilini) and host capture behavior (*Epioblasma*). Such adaptations led to varying degrees of host specificity (use of particular host species), which in turn affected other aspects of life history and ecology as diverse as fecundity, reproductive season, habitat, and geographic distribution. Host specialists are more efficient than generalists at contacting particular host species, but are more constrained in host utilization and the related aspects of life history. Unionoids in general are long-lived as adults and many species require several years to reach reproductive maturity. This high somatic investment may allow mussel populations to persist when reproductive success is unpredictable. The age structure of populations is often strongly biased toward adults, suggesting that successful recruitment years are infrequent. These features of life history and population dynamics may reflect fluctuations in host availability. They are also likely to reflect vulnerabilities of the post-parasitic juvenile life stage to environmental factors, which are poorly known. Although recent studies by many workers have greatly improved our understanding of mussel life history, there are tremendous opportunities for future studies. In particular, sustained efforts to propagate endangered species and monitor their populations can provide critical data on the requirements of each life stage and on population dynamics.

PE 03

A STAGE-BASED MODEL TO INVESTIGATE LINKAGES BETWEEN DEMOGRAPHIC AND GENETIC FEATURES OF UNIONID POPULATIONS.

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North American freshwater mussels are continuing to suffer dramatic declines in population size due to a number of anthropogenic stressors such as habitat destruction and commercial harvest. Within populations, neutral genetic variation is lost because of genetic drift. The intensity of drift is negatively correlated with population size. In turn, population size is dependent on demographic parameters such as mortality, migration, and recruitment rates. Thus, demographic and genetic features of populations should be tightly linked. We are developing a stage-based model to investigate the effects of variation in mortality on population size and genetic diversity. Demographic parameters for this model are derived from published data for species of mussels that exhibit considerable variation in population ecology, while our own research has provided measures of population genetic variation using a variety of molecular markers (allozymes, mtDNA sequences, microsatellites) for many species of mussels across a large portion of North America. Using STELLA™ software, our model incorporates a variety of demographic parameters (age-structure, age-specific mortality, recruitment) and population genetic parameters (haplotype frequency, heterozygosity). We will use this model to examine effects of constant and age-specific mortality on populations that have varying levels of genetic diversity. Results of this model will provide insight into interactions of demography and population genetics. For example, we should be able to compare changes in population size and genetic diversity under contrasting scenarios of age-specific mortality due to harvest regulations and constant mortality due to habitat degradation. We will also examine the importance of migration by comparing isolated populations to populations within a tightly linked metapopulation. While changes in population demography are important for estimating extinction risk for populations in the short-term, survival over evolutionary time is dependent on maintenance of genetic variation. Models that incorporate both demographic and genetic features of populations should be of great utility for the development of effective conservation strategies.

PE 04

COMMUNITY AND FOODWEB ECOLOGY OF FRESHWATER MUSSELS

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Freshwater mussels link the water column and bottom sediments through their feeding activities. All species use gill and/or foot cilia to generate water currents that bring in suspended food particles. While there are some species differences in cilia number, spacing, and size, in all species, water enters the shell through the posterior inhalant siphon and also along the anterior shell margin (pedal feeding). Thus, all mussel species can access food particles both suspended in the water column and in the sediment. Particles are sorted by the gill cilia and either ingested or biodeposited as mucus-coated psuedofeces. Research to date shows that mussel diets are remarkably similar regardless of age, size, species, or cilia number and size. Studies using tissue fatty acid profiles, stable isotope ratios, and mussel digestive enzyme production show that all species feed on particles <20 microns in size, particularly micro-algae and bacteria. In addition, direct assimilation of organic molecules such as glucose can occur. Based on these similarities, can we assume that all species perform the same role in foodwebs and communities?

We know that many ecosystem services performed by mussels (clearance of algae from the water column, nutrient excretion, biodeposition of organic matter) are linearly related to community biomass; thus, there is the potential for strong ecosystem effects when mussel biomass is high and hydrologic residence times are long. Multiple studies demonstrate that mussels provide biogenic structure and nutrients to other organisms; algal growth is higher on the shells of living mussels compared to shells alone, and macroinvertebrate richness and densities are higher on shells of living mussels and in mussel patches than in other streambed areas. Effects of mussel community composition vary with spatial and temporal scales and are regulated by factors such as temperature, with significant differences between species' physiological condition (metabolic rate, body condition) and ecological output (respiration and excretion rates) under different environmental conditions. At the scale of a mussel bed, experiments demonstrate potentially strong interactions between mussel species with dominant, driver species regulating factors such as periphyton biomass, but also increasing the body condition of co-occurring rarer mussel species. At the scale of whole rivers, species richness becomes important, with different species driving interactions and ecosystem services under different environmental conditions. Although more research is needed, information to date indicates that mussel feeding activities and community structure can have strong impacts on the entire foodweb, and that interactions between mussel species are important. Thus, efforts to restore mussels should focus on restoring entire communities.

PE 05
USING LANDSCAPE ECOLOGY TO UNDERSTAND FRESHWATER MUSSEL POPULATIONS
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Ecology has been transformed over the past 20 years by the development and application of the landscape ecology subdiscipline, i.e., the influence of spatial pattern on ecological processes. Mussel populations and the environments they inhabit are heterogeneous, raising the question: "To what extent can landscape ecology principles be applied to the scientific understanding and management of freshwater mussels?" We review three areas in which landscape ecology might be applied to freshwater mussels.

First, mussel ecologists are grappling with how to define and conceptualize patches of suitable mussel habitat. Recent progress with models and empirical data shows that hydraulics can be successfully used to delineate patches of mussel habitat. It is not yet clear whether hydraulics alone will ultimately provide a satisfactory definition of mussel habitat, or whether we will need to consider additional variables such as host fish, food, or predators. As in other applications of landscape ecology, we do not know whether mussel ecology will be best served by simple binary patch/matrix models, or if habitat quality should be viewed as a continuous variable, nor if we will need to model within-patch dynamics. Special problems associated with mussel populations include distinguishing "fossil" patches in which conditions were suitable for mussel recruitment in the past from "active" patches in which recruitment still occurs, and the possibility of strong source-sink dynamics resulting from Allee effects in sparse populations.

Second, mussel ecologists have begun to think about the importance of connectivity among habitat patches. We would like to know the conditions under which connectivity among patches is important, and which attributes of the environment, the mussel species, and its host, determine connectivity among mussel beds. Major challenges are determining whether connectivity can be estimated in the field, whether human activities that reduce connectivity (e.g., dams) have produced large extinction debts in mussel populations, and whether connectivity is strongly directional in running waters.

Third, recent studies have shown that characteristics of the watershed (especially land use) affect mussel populations. This work is still in an early stage, and needs to be critically tested. We also need to better understand the links between events on the watershed (e.g., timing and amounts of water, nutrient, and sediment inputs, condition of the riparian zone) and the quality, extent, location, and connections among patches of mussel habitat. In addition, it is critical to identify the locations on the watershed that have the strongest links to mussel populations.

Landscape ecology has the potential to improve scientific understanding and management of mussel populations, and in particular help define the best spatial scales for scientific studies and management activities. However, terrestrial paradigms will need to be used carefully.

PE 06

FRESHWATER MUSSEL ECOSYTEM ECOLOGY: THE INTEGRATED FUNCTIONAL ROLES OF WATER QUALITY, POLLUTION, AND PHYSICAL HABITAT IN SUPPORTING ADULT AND EARLY LIFE STAGES OF FRESHWATER MUSSELS AND THEIR ROLE IN NUTREINT RECYCLING

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A recent assessment of the published literature on the topics of water quality, pollution, and physical habitat and their roles in supporting adult and early life stages of freshwater mussels revealed two types of informational sources contributing to our current understanding of environmental health. Descriptive field-based studies showed that mussels have been adversely affected by poor water quality and associated pollutants, and loss and degradation of physical habitat. Noted site-specific effects, contaminant accumulation, as well as global declines were documented by these studies. Based on these observations and the development of ASTM International standard methods for conducting laboratory toxicity tests with early life stages of freshwater mussels, recent experimental-based studies have attempted to determine links, causal mechanisms, and establish rigorous testing and assessment methods. We evaluated the routes and pathways of exposure for all life stages (glochidia, encysted, juveniles, adults) of native freshwater mussels to environmental pollutants, in a life history and ecosystem ecology context, and found that each life stage has both common and unique characteristics that contribute to observed differences in sensitivity and exposure. For example, glochidia may be exposed only briefly (e.g., 1-12 days) through the water column, whereas juveniles and adults have sustained exposure through the water column, pore water, sediment and dietary routes. Juveniles and adults differ in their primary habitat and feeding mechanisms; thereby altering the importance of these routes in exposure, depending on life stage. This synthesis has shown that a combination of life history and ecosystem-level ecological information is needed to properly assess the risks of environmental exposure. Knowledge of differing habitat-based exposure routes on mussel life stages is critical to understanding the relation and applicability of recently developed ASTM International standard acute and chronic laboratory toxicity test methods for predicting toxicological risk and the ultimate protection and conservation of the mussel fauna. In terms of the role of freshwater mussels in ecosystem processes, a review of the literature has shown that mussels play an important role in nutrient recycling. Mussels feed on materials variable in C:N:P, use these nutrients for growth, and egest materials variable in C:N:P. Nutrients used for growth can be sequestered for long periods of time, whereas egested material may become

readily available for subsequent trophic interactions. Freshwater mussels perform vital functional roles in ecosystem processing.

PE 07
DIRECTIONS AND INFORMATION NEEDS FOR FRESHWATER MUSSEL CONSERVATION

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Conservation of freshwater biodiversity should be the highest priority in the U.S., based on global significance of our resident taxonomic groups and number of species susceptible to extinction over the next decade. Trends in demand for land, water, and energy indicate that means for conserving mussel resources while allowing for economic growth must be determined. Developing long-term plausible solutions will require coordination with other scientific disciplines, engineers, resource managers, developers, and higher levels of government. Current mussel conservation and management ranges from basic life history research to improvement of habitat conditions to facilitate mussel community maintenance and enhancement. In addition to actions presented as goals and strategies in the National Strategy for the Conservation of Native Freshwater Mussels about 10 years ago, information is needed to catapult our taxon-specific discipline to a more quantitative, scientifically defensible, and user friendly level. Our knowledge of mussel biology would increase greatly if sister disciplines include mussels as study animals in their areas of expertise, such as toxicology, population biology, veterinary medicine, physiology, biochemistry, biological engineering, and other such complementary sciences. We need field-level tools to determine baseline physical, cellular, and population-level conditions, and detect responses to physical and chemical stress on both the cellular and population level. Development of appropriate biomarkers would fill this gap. Greater knowledge of mussel habitat requirements and the effects of change on mussels are also needed in mussel conservation. Coordinating with personnel such as hydrologists, geomorphologists, and civil engineers can provide suitable techniques for measuring key habitat parameters. However, sustainable development and mussel conservation must have the support of governmental agencies, as field biologists often are inhibited by archaic policies and procedures. Higher levels of government must be educated on the importance of mussel conservation, and the need for policy changes to allow this effort to go forward. Additionally, engineers, developers, and resource managers must coordinate with mussel biologists on the front-end of private projects or government programs, such that mussel conservation needs are accommodated in the planning process rather than as an afterthought. Techniques such as mussel propagation for enhancing and restoring mussel populations, stream restoration to improve habitat, mussel toxicology to test water quality standards, and mussel sampling and monitoring to detect changes in mussel communities are being conducted. However, effectiveness of implementing these techniques in mussel conservation and management depends on our ability to better understand mussel biology and coordinate with outside disciplines. Although we have progressed in the last 10 years, mussel conservation needs are more acute, as most endangered populations continue to decline. A combination of mussel expertise, other biological expertise, regulatory agencies, and engineering disciplines will provide the toolbox of actions required to allay the currently projected extinction rate.

PE 08

FRESHWATER GASTROPOD ECOLOGY AND CONSERVATION DIRECTIONS

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North American freshwater snails remain an understudied yet critically imperiled fauna. As part of a larger discussion on freshwater mollusks in general, we highlight five specific areas of concern regarding freshwater snails, and discuss how best to address those concerns in the context of conservation: ecology, taxonomy and systematics, the impact of invasives and other future threats, the needs of state and federal agencies for prioritization and implementation of management plans, and the role of the non-governmental groups and outreach for preservation of these natural treasures. We illustrate the how each of these topics relate to conservation efforts and present synthetic and prioritized research goals to improve our baseline knowledge of freshwater snail biology. For ecology, we review the literature on freshwater gastropods, identifying important trends and highlighting the importance of ecological data in studying these groups. A necessary precursor to conservation efforts is an adequate assessment of biological diversity. We present the current state of freshwater snail taxonomy, and show how modern methods such as population and molecular genetics have affected our understanding of natural evolutionary units and the identification of species. Invasive species have affected freshwater taxa across North America, through competition, habitat modification and parasitism to name a few. These alien species originate not only in other countries, but also in neighboring drainages and systems as native taxa become exotic through human-mediated introductions. We outline currently recognized and potential threats to native species and the impacts they are having and may have in the future. Finally, effective conservation strategies require the participation of people at all levels, from local communities to governmental agencies, for implementation and management. We summarize the status and efficacy of freshwater snail captive propagation, as well as partnerships with non-governmental organizations, federal agencies, and other stakeholders. Suggestions for the future direction of multi-partner cooperation in freshwater snail conservation are discussed.

PE 09

A NEW NATIONAL FRESHWATER MOLLUSK CONERVATION SOCIETY STRATEGY FOR CONSERVATION OF NATIVE FRESHWATER MOLLUSKS

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The National Strategy for the Conservation of Native Freshwater Mollusks (Strategy) was developed a decade ago, prior to the establishment of the FMCS. Since the Strategy was published there have been significant changes in the conservation status of freshwater mollusks, the kind and degree of threats to aquatic ecosystems and mollusks, and in the state of our

knowledge of freshwater mollusks. A revised and current National Strategy can serve as a guidance document for the FMCS in its support of mollusk conservation, research and monitoring as well as FMCS policy and activities. The purpose of the session is to present a draft strategy to the Society and provide an opportunity for the exchange of ideas between the FMCS National Strategy subcommittee and the FMCS membership. The format will be a panel, with subcommittee members presenting specific recommendations for revision. These will include the topics addressed in the current National Strategy and new issues such as conservation genetics, propagation, adaptive management, expanded outreach, and coordination with other organizations and conservation efforts such as the National Fish Habitat Initiative. The resulting input will be incorporated into a document for FMSC board approval by June, 2007.