

# WALKERANA

THE JOURNAL OF THE FRESHWATER  
MOLLUSK CONSERVATION SOCIETY

**WALKERANA VOLUME 15 NUMBER 1 MARCH 2012**

**Pages 1-10**

How a state-wide stream survey can aid in understanding freshwater mussel (Bivalvia: Unionidae) ecology: examples of utility and limitations from Maryland.

**Matthew J. Ashton**

**Pages 11-16**

Reproductive biology and host fishes of four unionids from the Lake Pontchartrain Basin, Louisiana, U.S.A.

**Wesley M. Daniel & Kenneth M. Brown**

**Pages 17-26**

Recent monitoring of the freshwater mollusks of Kinniconick Creek, Kentucky, with comments on potential threats.

**Ryan Evans**

**Pages 27-44**

Population performance criteria to evaluate reintroduction and recovery of two endangered mussel species, *Epioblasma brevidens* and

*Epioblasma capsaeformis* (Bivalvia, Unionidae.)

**Jess W. Jones, Richard J. Neves  
& Eric M. Hallerman**

**Pages 45-59**

A qualitative freshwater mussel (Bivalvia: Unionidae) survey of the Lamine and Blackwater River Basins, Missouri.

**Stephen E. McMurray, J. Scott Faiman  
& Sue A. Bruenderman**

**Pages 60-68**

Assessing accumulation and sublethal effects of lead in a unionid mussel.

**Shad Mosher, W. Gregory Cope, Frank X. Weber, Thomas J. Kwak & Damian Shea**

**Pages 69-82**

Thermal tolerances of freshwater mussels and their host fishes: species interactions in a changing climate.

**Tamara J. Pandolfo, Thomas J. Kwak & W. Gregory Cope**



# **WALKERANA** The Journal of the Freshwater Mollusk Conservation Society

©2010

## **Editorial Board**

### **CO-EDITORS**

Gregory Cope, North Carolina State University  
Wendell Haag, U.S. Department of Agriculture Forest Service  
Tom Watters, Ohio State University

### **EDITORIAL REVIEW BOARD Conservation**

Jess Jones, U.S. Fish & Wildlife Service /Virginia Tech University  
James Layzer, Tennessee Cooperative Fisheries Research Unit, Tennessee Tech University

### **Ecology**

Ryan Evans, Kentucky Department of Environmental Protection, Division of Water  
Michael Gangloff, Appalachian State University  
Catherine Gatenby, White Sulphur Springs National Fish Hatchery  
Caryn Vaughn, Oklahoma Biological Survey, University of Oklahoma

### **Freshwater Gastropods**

Paul Johnson, Alabama Aquatic Biodiversity Center  
Jeff Powell, U.S. Fish & Wildlife Service, Daphne, Alabama  
Jeremy Tiemann, Illinois Natural History Survey

### **Reproductive Biology**

Jeff Garner, Alabama Division of Wildlife and Freshwater Fisheries  
Mark Hove, Macalester College/University of Minnesota

### **Survey/Methods**

Heidi Dunn, Ecological Specialists, Inc.  
Patty Morrison, U.S. Fish & Wildlife Service Ohio River Islands Refuge  
David Strayer, Cary Institute of Ecosystem Studies  
Greg Zimmerman, Envirosience, Inc.

### **Systematics/Phylogenetics**

Arthur Bogan, North Carolina State Museum of Natural Sciences  
Daniel Graf, University of Alabama  
Randy Hoeh, Kent State University

### **Toxicology**

Thomas Augspurger, U.S. Fish & Wildlife Service, Raleigh, North Carolina  
Robert Bringolf, University of Georgia  
John Van Hassel, American Electric Power  
Teresa Newton, USGS, Upper Midwest Environmental Sciences Center

# HOW A STATEWIDE STREAM SURVEY CAN AID IN UNDERSTANDING FRESHWATER MUSSEL (BIVALVIA: UNIONIDAE) ECOLOGY: EXAMPLES OF UTILITY AND LIMITATIONS FROM MARYLAND

**Matthew J. Ashton**

Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division,  
580 Taylor Ave., C-2, Annapolis, MD 21401 U.S.A.  
phone: (410) 260-8604; email: mashton@dnr.state.md.us

## ABSTRACT

Gaps in our knowledge of freshwater mussel life history, distribution, and ecology remain even though their study has increased considerably over the past few decades. These studies have traditionally taken place within a population, river, or larger drainage unit, but rarely across a broad landscape, such as a state. Given the imperiled status of a majority of unionid species alternative opportunities to collect valuable data cannot be overlooked. We present results from a statewide biological monitoring program (Maryland Biological Stream Survey) that has incorporated a visual survey for mussels, several example analyses using mussel-bioassessment data, and discuss the utility and limitations of incorporating freshwater mussels into stream assessments. Since 2007, we encountered 11 of the 16 mussel species extant in Maryland during assessments of wadeable streams by using an informal visual survey and recording incidental observations. On several occasions, we have discovered new populations of imperiled mussels or extended a species distribution. The biological and physiochemical data collected at sites coincident with freshwater mussels have allowed us to hypothesize factors potentially limiting species distribution, such as fish-host dynamics, habitat quality, nutrient concentration, and catchment land use. We feel that the addition of a survey effort into a biological monitoring program, invaluable data can be collected that can assist resource managers, malacologists, and researchers answer a variety of questions. Further investigation into the cost-benefits of an appropriate level of sampling effort is needed as this could vary markedly among molluscan faunal regions and by objectives.

**KEY WORDS** Freshwater mussels, Unionidae, biological monitoring, Maryland Biological Stream Survey

## INTRODUCTION

The diversity of freshwater mussels (Bivalvia: Unionidae) in North America is unmatched globally, yet they are among the most imperiled aquatic fauna on the continent (Williams et al., 1993; Bogan, 2008). The high rate of imperilment and extinction in mussels has been linked to habitat and flow alteration, invasive species, loss of host fish, increased siltation, and dam construction (Brim Box & Mossa, 1999; Strayer, 1999a; Vaughn & Taylor, 1999; Watters, 2000). Poor land use practices and pollution have further disrupted freshwater ecosystems ultimately leading to the decline of mussels (Bogan, 1993). This decline has likely had major implications on functioning aquatic ecosystems along with the management, conservation, and restoration of aquatic species. Even though the study of freshwater mussels has increased over the past few decades their conservation still faces several challenges. Foremost, basic life history and distributional information of mussels are lacking for many species (Neves, 1993; Strayer, 2006). Potentially exacerbating this problem is that subjective observations about ecological factors

that govern unionid presence typically do not agree with results from quantitative studies (Strayer, 2008). In spite of this, research into the life history and autecology of freshwater invertebrates has declined (Resh & Rosenberg, 2010).

Unionids have long been considered indicators of good water quality (Ortmann, 1909; Neves, 1993), but there is little guidance for resource agencies on ways to utilize them in assessments of stream health (Grabarkewicz & Davis, 2008). The Maryland Biological Stream Survey (MBSS) is a statewide biological monitoring and assessment program administered by the Maryland Department of Natural Resources' Monitoring and Non-Tidal Assessment Division, which has incorporated freshwater mussels into standard operation procedures (Stranko et al., 2007). Objectives of the MBSS are to assess the condition of aquatic resources, identify physiochemical and anthropogenic stressors such as acidification, land alteration, and climate change, and provide an inventory of biodiversity in Maryland's streams (Klauda et al., 1998; Stranko et al., 2005). This is primarily accomplished through a probabilistic design



to make unbiased estimates on the condition of the states' (1st-4th order) Wadeable streams (Heimbuch et al., 1999), but has recently included other sampling designs tailored to meet resource management needs.

Such spatially extensive, readily available data sets may be useful in developing empirical models of multiple stressors that can guide future studies with more detailed and costly methods that test mechanistic hypotheses of mussel conservation and ecology (Strayer, 2008). In this study, we present results from the MBSS and offer simple analytical examples that could be conducted with mussel-bioassessment data that can address gaps in freshwater mussel ecology and conservation (National Native Mussel Conservation Committee, 1998; Strayer, 2006). Additionally, we discuss the utility of incorporating mussels into stream monitoring and assessment programs and the limitations that such an endeavor faces.

## METHODS

Water chemistry grab samples were collected from the upstream extent of 75-m-long sites during spring (March through April) base-flow conditions and analyzed for pH, acid neutralizing capacity ( $\mu\text{eq/L}$ ), specific conductance ( $\mu\text{S/cm}$ ), chloride ( $\text{mg/L}$ ), sulfate ( $\text{mg/L}$ ), total nitrogen ( $\text{mg/L}$ ), ammonia ( $\text{mg/L}$ ), nitrate ( $\text{mg/L}$ ), and total phosphorus ( $\text{mg/L}$ ), using methods described by the U.S. EPA (1986). Water temperature was recorded at 20 minute intervals from June to September with Hobo data-loggers (Onset Corporation) deployed at each site. From these data, we calculated an average of the daily mean temperature ( $N \approx 92$ ). Gradient (% slope) was calculated as the change in water surface height between the up and downstream extent of a site using a surveyor's level and metric stadia. Benthic macroinvertebrate samples were collected with a 540  $\mu\text{m}$  D-net from 20, 0.3  $\text{m}^2$  areas of proportionally available optimal habitat to calculate a benthic macroinvertebrate index of biotic integrity (Stribling et al., 1998).

During summer base-flow conditions, we collected fishes within each site using two-pass depletion with backpack electrofishing units (one anode/3 m of wetted stream width) to calculate a fish index of biotic integrity based on a scale of 1-5 (very poor < 2, poor 2 < 3, fair 3 < 4, and good > 4) (Southerland et al., 2007). From these data, we also calculated the abundance of freshwater mussel host-fishes (Kneeland & Rhymer, 2008; Cummings & Watters, 2010). We visually estimated physical habitat quality using five metrics scored on a 0-20 scale (poor = 0-5, marginal 6-10, suboptimal 11-15, and optimal 16-20): instream habitat, epifaunal substrate, velocity depth diversity, pool-glide quality, and riffle-run quality. Scores of each

metric are meant to characterize aspects of habitat important to stream biota. For example, the instream habitat metric relates to the quality and quantity of fish habitat, while the epifaunal substrate metric rates the suitability of benthic macroinvertebrate habitat. Scores for velocity depth diversity and quality of pool-glide and riffle-run habitats are based on the heterogeneity and extent of those habitats. Riffle embeddedness was determined by estimating the percentage of gravel and larger substrates surrounded by fine sediment (< 2 mm). Average stream width (m) was calculated from the wetted width taken at four equally distant transects within the sample reach. Stream flow was measured with a Marsh McBirney FloMate 2000 on a top-setting metric wading rod. Discharge ( $\text{m}^3/\text{sec}$ ) was then calculated from the cross sectional area of the stream. We hand digitized the catchment upstream from each site based on United States Geological Survey 7.5 minute quarter quad topographic maps using ArcMap 9.3, and calculated drainage area ( $\text{km}^2$ ). We then intersected satellite-derived land cover (2001 NLCD; Homer et al., 2007) to catchments and calculated the percent of major land cover types (urban, agriculture, and forest) within catchments.

While at each MBSS site, we searched suitable unionid habitats for  $\geq 15$  minutes to determine the presence of mussels. Additionally, we searched animal middens when present and noted incidental observations of unionids while sampling other aquatic fauna. When a live mussel was encountered, it was identified and returned to the location of its collection. Representative shells were retained to verify field identifications. A subset of these vouchers were independently verified by the state zoologist and deposited in several museum collections (Delaware Museum of Natural History, Illinois Natural History Survey, and North Carolina Museum of Natural Sciences). The remaining vouchers were housed at MDNR offices in Annapolis, MD and Frostburg, MD for training purposes. Freshwater mussel taxonomy in Maryland follows Turgeon et al. (1998). Annually, field crew managers and leaders receive thorough training in mussel identification along with other taxonomic groups for which data are recorded during MBSS sampling.

We described environmental conditions at sites with *Elliptio fisheriana* (Lea, 1838) to sites where they were apparently absent throughout their range with non-parametric pair-wise comparisons. Continuous variables (water chemistry, habitat, and land use) were compared with Kolmogorov-Smirnov tests and categorical variables (physical habitat metrics and biological multi-metric index scores) with Mann-Whitney U tests. We chose this species as an example as it is restricted to one physiographic region (Coastal Plain); therefore,

conditions should be relatively homogenous (Stribling et al., 1998; Southerland et al., 2007). Absence was presumed if no mussels were detected and present if live or dead specimens were collected. At sites that were sampled on more than one occasion, a species was also assumed present if it was previously encountered. For this study, we defined a species range as the sites within watersheds (Maryland 8-digit) in which we encountered at least one individual of that species. To investigate the role of known and potential fish-hosts on patterns of *E. fisheriana* presence, we calculated the frequency of occurrence for stream fishes collected during MBSS surveys.

## RESULTS

From 2007 to 2009, we encountered unionids at 117 of the 595 MBSS sites sampled (20%). At a minimum, 148.75 person-hours were expended searching for mussels. We made 133 observations of live freshwater mussels or dead shell material representing 11 species (Table 1); however most species were encountered infrequently. *Elliptio complanata* (Lightfoot, 1786) was by far the most widely distributed and frequently encountered unionid during MBSS sampling. *Elliptio fisheriana* was the second most encountered species, followed by *Pyganodon cataracta* (Say, 1817), and *Alasmidonta heterodon* (Lea, 1830). The remaining six species were found at < 5 MBSS sites since 2007. Five species, including the state endangered *Alasmidonta varicosa* (Lamarck, 1819) and *Lasmigona subviridis* (Conrad, 1835), have yet to be found during stream assessments.

Freshwater mussel richness in wadeable streams throughout Maryland's 8-digit watersheds was generally low (Figure 1). The most diverse assemblages were generally found in coastal streams on Maryland's Eastern shore, although two Potomac River watersheds also had relatively diverse assemblages for Maryland streams. We rarely found live mussels or spent valves at sites in central and western Maryland. Some notable distributional records resulting from MBSS surveys include the first records of *Elliptio producta* (Conrad, 1836) in the Upper Patuxent River watershed, the range extension of *Alasmidonta undulata* (Say, 1817) in the Patapsco River, and discovery of a relic population of *A. heterodon* in the Upper Choptank River watershed.

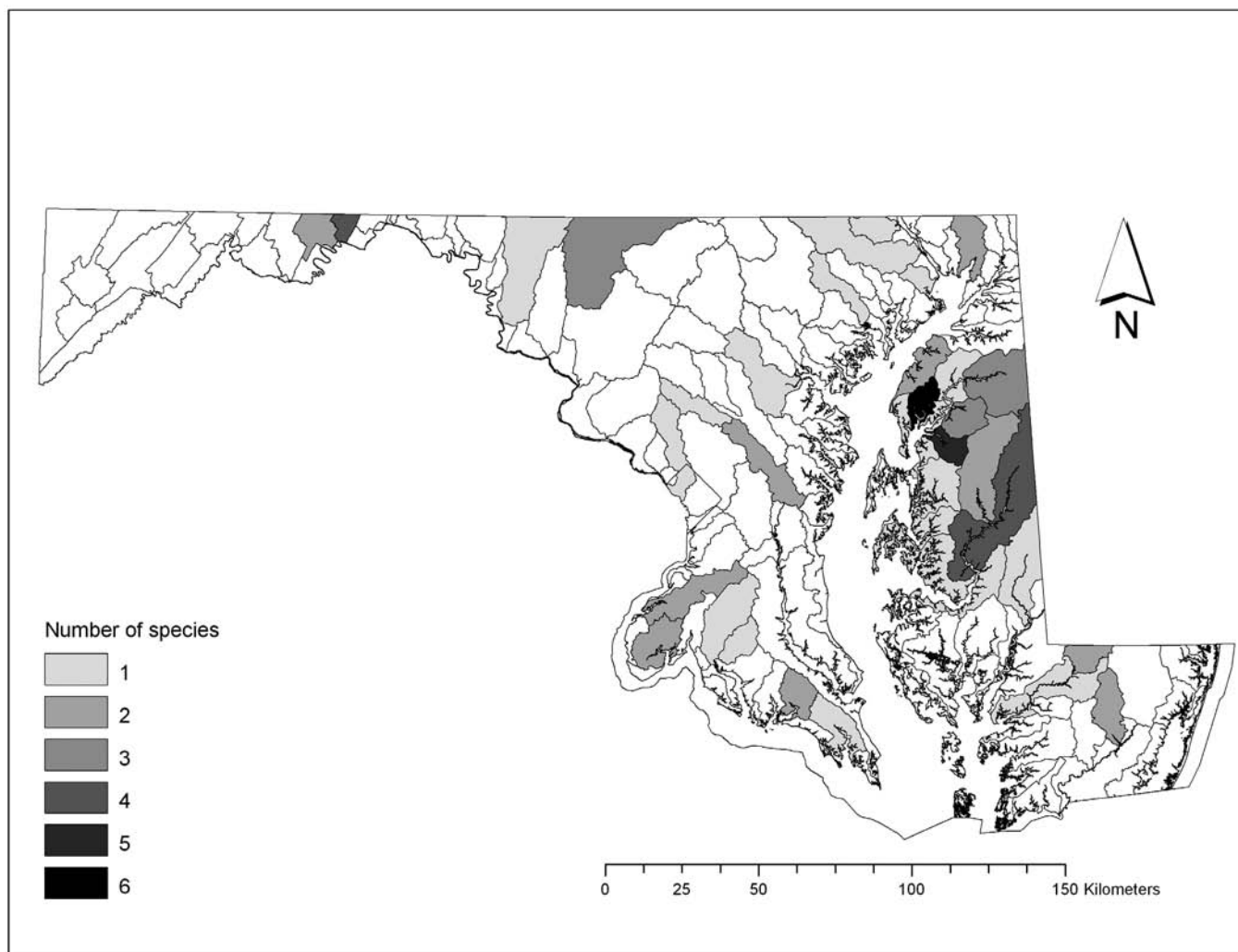
Significant differences were found for most physiochemical and biological variables compared between sites with *E. fisheriana* and sites where they were apparently absent (Table 2). When *E. fisheriana* was encountered at MBSS sites, pH, ANC, and nutrient concentrations were higher. These streams were also on

average several meters wider, had considerably larger upstream catchments, lower gradient, and greater discharge compared to streams where *E. fisheriana* was not found. Physical habitat metrics were consistently several points higher and often in categories that represented better conditions. Fish and benthic macroinvertebrate community indices were also higher at sites with *E. fisheriana* compared to other sites in their range. Differences observed in the amounts and types of catchment land use were likely representative of prevailing land use patterns than a biological response.

Previously confirmed fish-hosts were frequent to absent at sites where *E. fisheriana* was encountered and uncommon to frequent at sites where they were not encountered (Table 3). Two of these species (Bluegill and Largemouth Bass) are not native, while the other (Johnny Darter) is not native to Maryland's Atlantic Slope. While Largemouth Bass were frequently collected at sites with *E. fisheriana*, only a few bass were typically found at a site. Several native fishes (Tessellated Darter, Pumpkinseed, and Redbreast Sunfish) that are congeners of *E. fisheriana* host-fish had rates of occurrence as high to nearly double their respective non-native relative. In addition, these native fishes were infrequently collected at sites where *E. fisheriana* was also not found. Other than American Eel, we rarely collected host-fish of congeneric mussels at sites along with *E. fisheriana*.

## DISCUSSION

By instituting a simple visual survey at all MBSS sites we have been able to readily collect valuable distributional data concurrent with an array of biological and physiochemical data that address several continuing challenges to freshwater mussel conservation (National Native Mussel Conservation Committee, 1998). Our basic analysis illustrates just one example how the information garnered from stream assessments that include measures of freshwater mussels can be used and lays the foundation for more rigorous hypothesis development. The growing data set will be instrumental in addressing aspects of freshwater mussel management and conservation, such as describing species habitat associations and tolerances to anthropogenic stressors, such as nutrients and urbanization (MDNR, 2005). Within the context of streams on Maryland's Coastal Plain, it appears as though *E. fisheriana* cannot tolerate the conditions of naturally acid, blackwater (i.e. low pH and ANC) or headwater streams, and marginal to poor physical habitat. Our pair-wise comparisons also proved useful in describing broad conditions that typify mussel presence; larger streams with flowing water, and relatively low nutrient concentrations (Watters, 1992; Watters, 2000; Morgan & Kline, 2011). However,

**FIGURE 1**

Freshwater mussel richness by Maryland 8-digit watershed as observed during the Maryland Biological Stream Survey, 2007-2009.

we recognize that many of these variables are often correlated with one another and must be accounted for to more rigorously hypothesize determinants of distribution. Variables with considerable overlap between sites of mussel absence and presence further illustrate the confounding nature of mussel-habitat associations as they relate to species distribution (Strayer, 2008).

Our findings also indicate that *E. fisheriana* rarely inhabited biologically degraded streams (IBI's  $\leq 3$ ), yet were frequently collected in high quality streams (IBI's  $\leq 4$ ) (COMAR 26.08.02). This further supports the hypothesis that freshwater mussels are indicators of healthy aquatic ecosystems (Grabarkewicz & Davis, 2008). We feel this highlights a key reason to collect freshwater mussel data as part of a biological monitoring program; regulatory mechanisms (i.e., biocriteria)

are in place that react to IBI scores as thresholds of stream and watershed degradation or health (COMAR 26.08.02). In addition, mussel-bioassessment data would be able to support water quality standard (e.g., ammonia and copper) revisions and could be considered for the development of conductivity standards where impacts associated with natural gas extraction are a concern.

The MBSS data set includes over 3,000 randomly selected sites sampled during three state-wide Rounds and approximately 1,000 non-random sites and has been extensively published on using fish and benthic macroinvertebrate as response organisms (e.g. Pinder & Morgan, 1995; Morgan & Cushman, 2005; Stranko et al., 2005; Stranko et al., 2008; Kilian et al., 2010; Hildebrand et al., 2010). Despite the fact that



freshwater mussels are good response organisms for understanding spatial and temporal environmental patterns (Green et al., 1985), only two publications (Mynsberge et al., 2009; Stranko et al., 2010) have included MBSS-mussel observations. While the pitfalls of using readily available, large environmental data sets are known (Anderson et al., 2001; Strayer, 2008) their potential utility should not be ignored. In fact, we have several ongoing studies proposing hypotheses of mussel distribution and tolerances to environmental and anthropogenic stressors that build upon the basic relationships presented in this study (e.g., Haag & Warren, 1998; Nicklin & Balas, 2007). However, since we have no measure of detection and our data are limited to presence-absence we hesitate to test certain hypotheses without confirming the power of our survey methods. Our data may also not be appropriate for making inference about the cause of a species decline (Strayer, 1999b).

Unfortunately, we have no direct way of evaluating the cost-per-unit-effort (site visit). We suspect actual costs were quite low because assessments would have taken place regardless of our mussel survey and the amount of effort per site was relatively minimal. Therefore, some costs (e.g., travel) were independent of the mussel search. Moreover, the importance of recording freshwater mussel observations was recognized at the inception of the MBSS (1995) and visual surveys were conducted during stream assessments in advance of dedicated funding. Considerable effort was made at the onset of the study period to train crew members in freshwater mussel identification in response to concerns over the quality of identifications (discussed in Shea et al., 2011) from prior MBSS Rounds. Annually, time was required to inspect voucher shells, obtain independent confirmation, maintain voucher collections, attend regional identification workshops, examine institutional holdings, and address potential errors in the data. Further investigation into total costs, the cost-benefits of current versus more traditional mussel surveys, and additional survey effort (e.g., timed snorkel searches) are warranted.

It should be noted our technique may not be appropriate in other parts of the country where unionid distribution, diversity, and richness differ due to differences among faunal regions. The inability to detect certain species (e.g. *A. varicosa* and *Ligumia nasuta* (Say, 1817)) was likely due a variety of factors, including their existence in streams primarily outside of the MBSS scope (> 4th order, tidal influence) or in populations with very low abundance. Although not indicated in this study's data, we have recently encountered these species through stream assessments in large river and tidal-fresh habitats as part of other studies

while using the same informal visual search. Nonetheless, we realize the current methods may be insufficient to detect and characterize the true mussel richness in some habitats where species with cryptic life history traits reside (Metcalf-Smith et al., 2001; Tiemann et al., 2009). However, a cursory comparison of our mussel richness data to that collected by the Maryland Natural Heritage Program using timed-snorkel surveys has shown good agreement between most small to medium sized streams and watersheds.

The need for basic information on freshwater mussels remains and is imperative to develop and implement effective management plans, in addition to guide regulatory agencies in the development water quality standards that are more protective of freshwater mussels (Augspurger et al., 2003; Strayer et al., 2004). While the number of resource agencies that currently employ some form of standardized, state-wide unionid survey is increasing (Howells, 2006; Sietman, 2009; Shasteen et al., 2010; Stagliano, 2010), few pair their effort with assessments of water quality and biological condition even though monitoring programs are ubiquitous. To be clear, we are not by any means discrediting the traditional species or watershed centric approach to conducting mussel research, but there are well documented limitations on applying data collected at small scales to populations outside of those studied (Hamilton et al., 1997). We feel the proper context for mussel-bioassessments such as ours is to 1) support new or strengthen existing regulatory mechanisms to be more protective of freshwater mussels, 2) collect relevant landscape and physiochemical data at large spatial scales, and 3) supplement and guide quantitative surveys of imperiled unionids and specious watersheds.

## ACKNOWLEDGEMENTS

We thank Scott Stranko, Dr. Ron Klauda, and Jim McCann for their review and comments on earlier versions of this manuscript. Additionally, we are indebted to Jay Kilian, Andy Becker, Matt Kline, Matt Sell, and the many MBSS members who were involved in data collection. This study was funded in part by State Wildlife Grants provided to state wildlife agencies by the United States Congress, and administered through the Maryland Department of Natural Resources' Natural Heritage Program.

## LITERATURE CITED

- Anderson, D.R., Burnham, K.P., Gould, W.R. & S. Cherry. 2001. Concerns about finding effects that are actually spurious. *Wildlife Society Bulletin* 39: 351-358.

- Augspurger, T., Keller, A.E., Black, M.C., Cope, W.G. & F.J. Dwyer. 2003. Water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. *Environmental Toxicology and Chemistry* 22: 2569-2575.
- Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. *American Zoologist* 33: 599-609.
- Bogan, A.E. 2008. Global diversity of freshwater mussels (Mollusca, Bivalvia) in freshwater. *Hydrobiologia* 595: 139-147.
- Brim Box, J. & J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. *Journal of the North American Benthological Society* 18: 99-107.
- COMAR 26.08.02. Code of Maryland regulations. <http://www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=26.08.02>. Accessed 10 January 2011.
- Cummings, K.S. & G.T. Watters. Mussel host database. <http://128.146.250.235/MusselHost/>. Accessed 19 October 2010.
- Grabarkewicz, J. & W. Davis. 2008. *An introduction to freshwater mussels as biological indicators*. EPA-260-R-08-15. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC. 140 pp.
- Green, R.H., Singh, S.M. & R.C. Bailey. 1985. Bivalve mollusks as response systems for modeling spatial and temporal environmental patterns. *The Science of the Total Environment* 46: 147-169.
- Haag, W.R. & M.L. Warren. 1998. Role of ecological factors and reproductive strategies in structuring freshwater mussel communities. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 297-306.
- Hamilton, H., Brim Box, J. & R.M. Dorazio. 1997. Effects of habitat suitability on the survival of relocated freshwater mussels. *Regulated Rivers: Research and Management* 13: 537-541.
- Heimbuch, D.G. Seibel, J.C., Wilson, H.T. & P.F. Kazyak. 1999. A multiyear lattice sampling design for Maryland-wide fish abundance estimation. *Journal of Agricultural, Biological, and Environmental Statistics* 4: 443-455.
- Hildebrand, B.H., Utz, R.M., Stranko, S.A. & R.L. Raesly. 2010. Applying thresholds to forecast biodiversity loss from human development. *Journal of the North American Benthological Society* 29: 1009-1016.
- Homer, C.C., Dewitz, J., Fry, J., Coan, M., Hossain, N., Larson, C., Herold, N., McKerrow, A., VanDriel, J.N. & J. Wickham. 2007. Completion of the 2001 National Landcover Database for the Conterminous United States. *Photogrammetric Engineering and Remote Sensing* 73: 337-341.
- Howells, R.G. 2006. Statewide freshwater mussel survey. *Final report as required by State Wildlife Grants Program Texas Federal Aid Project*. Inland Fisheries Division, Texas Parks and Wildlife Department, Austin, TX. 107 pp.
- Kilian, J.V., Becker, A.J., Stranko, S.A., Ashton, M.J., Klauda, R.J., Gerber, J. & M.K. Hurd. 2010. The status and distribution of Maryland crayfishes. *Southeastern Naturalist* 9 Special Issue 3: 11-32.
- Klauda, R.J., Kazyak, P., Stranko, S.A., Southerland, M.T., Roth, N. & J. Chaillou. 1998. Maryland Biological Stream Survey: a state agency program to assess the impact of anthropogenic stress on stream habitat quality and biodiversity. *Environmental Monitoring and Assessment* 51: 299-316.
- Kneeland, S.C. & J.M. Rhymer. 2008. Determination of fish host use by wild populations of rare freshwater mussels using a molecular identification key to identify glochidia. *Journal of the North American Benthological Society* 27: 150-160.
- Maryland Department of Natural Resources. 2005. *Wildlife Diversity Action Plan*. DNR, Wildlife and Heritage Service, Annapolis, MD. 304 pp.
- Metcalfe-Smith, J.F., DiMaio, J., Staton, S.K. & G.L. Mackie. 2000. Effect of sampling effort on the efficiency of the timed search method for sampling freshwater mussel communities. *Journal of the North American Benthological Society* 19: 725-732.
- Morgan, R.P. & S.F. Cushman. 2005. Urbanization effects on stream fish assemblages in Maryland, USA. *Journal of the North American Benthological Society* 24: 632-655.
- Morgan, R.P. & K.M. Kline. 2011. Nutrient concentrations in Maryland non-tidal streams. *Environmental Monitoring and Assessment* 178: 221-235.
- Mynsberge, A.R., Strager, M.P., Strager, J.M. & P.M. Mazik. 2009. Developing predictive models for freshwater mussels (Mollusca: Unionidae) in the Appalachians: Limitations and directions for future research. *Ecoscience* 16: 387-398.
- National Native Mussel Conservation Committee. 1998. National strategy for the conservation of native freshwater mussels. *Journal of Shellfish Research* 17: 1419-1428.



- Neves, R.J. 1993. A state-of-the-unionids address. Pp. 1-10, [In:] Cummings, K.S., Buchanan, A.C. & L.M. Koch (eds.). *Conservation and Management of Freshwater mussels. Proceedings of a UMRCC symposium, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL.* 189 pp.
- Nicklin, L. & M.T. Balas. 2007. Correlation between unionid mussel density and EPA habitat –assessment parameters. *Northeastern Naturalist* 14: 225-234.
- Ortmann, A.E. 1909. The destruction of the fresh-water fauna in western Pennsylvania. *Proceedings of the American Philosophical Society* 48(191): 90-110.
- Pinder, M.J. & R.P. Morgan. 1995. Factors influencing cyprinid presence and distribution in Appalachian streams of Maryland. *Transactions of the American Fisheries Society* 124: 94-102.
- Resh, V.H. & D.M. Rosenberg. 2010. Recent trends in life-history research on benthic macroinvertebrates. *Journal of the North American Benthological Society* 29: 207-219.
- Shasteen, D., Price, A. & S. Bales. 2010. *Muscling (Musseling) across Illinois: The good, the bad and the clammy*. Annual meeting of the Illinois Chapter of the American Fisheries Society, Rend Lake, IL. [unpublished abstract].
- Shea, C.P., Peterson, J.T., Wisniewski, J.M. & N.A. Johnson. 2011. Misidentification of freshwater mussel species (Bivalvia: Unionidae): contributing factors, management implications, and potential solutions. *Journal of the North American Benthological Society* 30: 446-458.
- Sietman, B. 2009. *Minnesota statewide mussel (Bivalvia: Unionidae) survey and long-term monitoring design 2005-2009: Final report*. Minnesota Department of Natural Resources, Ecological Resources Division. 26 pp.
- Southerland, M.T., Rogers, G.M., Kline, M.K., Morgan, R.P., Boward, D.M., Kazyak, P.K., Klauda, R.J. & S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. *Ecological Indicators* 7: 751-767.
- Stagliano, D. 2010. *Freshwater mussels in Montana: Comprehensive results from 3 years of SWG funded surveys*. Montana Natural Heritage Program, Helena, MT. 73 pp.
- Stranko, S.A., Hurd, M.K. & R.J. Klauda. 2005. Applying a large, statewide database to the assessment, stressor diagnosis, and restoration of stream fish communities. *Environmental Monitoring and Assessment* 108: 99-121.
- Stranko, S.A., Boward, D.A., Kilian, J.V., Becker, A.J., Gauza, R., Schenk, A., Roseberry-Lincoln, A. & P. Kayzak. 2007. *Maryland Biological Stream Survey sampling manual*. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. Annapolis, MD. CBWP-MANTA-EA-07-01. 71 pp.
- Stranko, S.A., Hilderbrand, R.H., Morgan, R.P., Staley, M.W., Becker, A.J., Roseberry-Lincoln, A., Perry, E.S. & P.T. Jacobson. 2008. Brook trout declines with land cover and temperature change in Maryland. *North American Journal of Fisheries Management* 28: 1223-1232.
- Stranko, S.A., Gressens, S.E., Klauda, R.J., Kilian, J.V., Ciccotto, P.V., Ashton, M.J. & A.J. Becker. 2010. Differential effects of urbanization and non-natives on imperiled stream species. *Northeastern Naturalist* 17: 593-614.
- Strayer, D.L. 1999a. Effects of alien species on freshwater mollusks in North America. *Journal of the North American Benthological Society* 18: 74-98.
- Strayer, D.L. 1999b. The statistical power of presence-absence data to detect population declines. *Conservation Biology* 12: 1043-1038.
- Strayer, D.L. 2006. Challenges for freshwater invertebrate conservation. *Journal of the North American Benthological Society* 25: 271-287.
- Strayer, D.L. 2008. *Freshwater Mussel Ecology: A Multifactor Approach to Distribution and Abundance*. University of California Press, Berkeley. 204 pp.
- Strayer, D.L., Downing, J.A., Haag, W.R., King, T.L., Layzer, J.B., Newton, T.J. & S.J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. *BioScience* 54: 429-439.
- Stribling, J.B., Jessup, B.K., White, J.S., Boward, D. & M. Hurd. 1998. *Development of a benthic index of biotic integrity for Maryland streams*. Monitoring and Non-Tidal Assessment Division, Annapolis, MD. CBWP-MANTA-EA-98-3. 59 pp.
- Tiemann, J.S., Cummings, K.S. & C.A. Mayer. 2009. Timed search technique to evaluate freshwater mussel (Bivalvia: Unionidae) species richness in headwater streams: Is a single one-hour visit enough? *Journal of Freshwater Ecology* 24: 85-92.
- Turgeon, D.D., Quinn, J.F., Bogan, A.E., Coan, E.V., Hochberg, F.G., Lyons, W.G., Mikkelsen, P.M., Neves, R.J., Roper, C.F.E., Rosenberg, G., Roth,

- B., Scheltema, A., Thompson, F.G., Vecchione, M. & J.D. Williams. 1998. *Common and Scientific Names of Invertebrates from the United States and Canada. Mollusks 2nd Edition*. American Fisheries Society Special Publication 26, Bethesda, MD. 526 pp.
- U.S. Environmental Protection Agency. 1986. *Quality Criteria for Water*. EPA Publication 440/5-86-001. U.S. Gov. Prin. Office, Washington D.C. 477 pp.
- Vaughn, C.C. & C.M. Taylor. 1999. Impoundments and the decline of freshwater mussels: a case study of an extinction gradient. *Conservation Biology* 13: 912-920.
- Watters, G.T. 1992. Unionids, fish, and the species-area curve. *Journal of Biogeography* 19: 481-490.
- Watters, G.T. 2000. Freshwater mussels and water quality: A review of the effects of hydrologic and instream habitat alterations. Pp. 261-274, [In:] Tankersley, R.A., Warmoltz, D.I., Watters, G.T., Armitage, B.J., Johnson, P.D. & R.S. Butler (eds.). *Freshwater Mollusk Symposium Proceedings, Ohio Biological Survey, Columbus, OH*. 274 pp.
- Williams, J.D., Warren, M.L., Cummings, K.S., Harris, J.L. & R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18(9): 6-22.

**TABLE 1**

Number of Maryland Biological Stream Survey sites sampled (N = 595) where live or dead freshwater mussels were encountered, 2007-2009.

Species	Total	Live	Dead	Proportion of sites
<i>Alasmidonta heterodon</i> (Lea, 1830)	10	2	9	0.02
<i>Alasmidonta undulata</i> (Say, 1817)	3	0	3	< 0.01
<i>Anodonta implicata</i> Say, 1829	2	1	1	< 0.01
<i>Elliptio complanata</i> (Lightfoot, 1786)	76	35	55	0.13
<i>Elliptio fisheriana</i> (Lea, 1838)	17	9	11	0.03
<i>Elliptio producta</i> (Conrad, 1836)	3	2	3	< 0.01
<i>Lampsilis radiata radiata</i> (Gmelin, 1791)	2	0	2	< 0.01
<i>Lampsilis</i> sp.	3	0	3	< 0.01
<i>Leptodea ochracea</i> (Say, 1817)	1	1	0	< 0.01
<i>Pyganodon cataracta</i> (Say, 1817)	15	5	11	0.03
<i>Strophitus undulatus</i> (Say, 1817)	1	0	1	< 0.01

\*Due to longstanding problems distinguishing between the non-native *Lampsilis cardium* Rafinesque, 1820, native *L. cariosa* (Say, 1817), and suspected hybrids between the two in the Potomac River basin, *Lampsilis* sp. is recorded when an individual resembling either species is encountered.

**TABLE 2**

Non-parametric comparisons of biological and physiochemical variable medians between Maryland Biological Stream Survey sites where *E. fisheriana* was present (N = 41) and absent (N = 61) in 1st-4th order streams of Maryland, 2007-2009. Sulfate, ammonia, and nitrate concentrations represent the molecules whole weight (e.g., nitrate-nitrogen). Higher physical habitat metric and biological index scores represent superior conditions.

Variable	Present (Median ± SD)	Absent (Median ± SD)	p
pH	7.05 ± 0.46	6.45 ± 0.89	<0.001
Conductivity (µS/cm)	56 ± 79	169 ± 116	0.77
Acid neutralizing capacity (µeq/L)	495 ± 350	239 ± 446	0.002
Average daily temperature °C	21.15 ± 1.53	20.90 ± 1.41	0.42
Total phosphorus (mg/L)	0.07 ± 0.03	0.04 ± 0.05	0.02
Total nitrogen (mg/L)	2.26 ± 1.27	2.00 ± 3.20	0.04
Nitrate (mg/L)	1.96 ± 1.32	1.22 ± 2.85	0.02
Ammonia (mg/L)	0.03 ± 0.04	0.03 ± 0.10	0.77
Chloride (mg/L)	14.80 ± 10.01	16.02 ± 24.97	0.52
Sulfate (mg/L)	15.13 ± 7.17	15.02 ± 8.84	0.66
Discharge (m³/sec)	0.04 ± 0.14	0.01 ± 0.04	<0.001
Average wetted width (m)	4.75 ± 4.15	2.80 ± 1.84	0.001
Fish-IBI	4.33 ± 0.80	3.33 ± 1.23	<0.001
Benthic macroinvertebrate-IBI	4.14 ± 0.82	3.14 ± 1.12	<0.001
Instream habitat quality	14.00 ± 3.17	11.00 ± 4.41	<0.001
Epifaunal substrate quality	13.00 ± 3.78	10.50 ± 4.44	0.001
Velocity-depth diversity	9.00 ± 2.98	7.00 ± 3.61	0.001
Pool-glide score	13.00 ± 3.04	11.00 ± 3.84	0.001
Riffle-run score	11.00 ± 5.85	6.00 ± 5.98	0.009
Embeddedness (%)	100 ± 30.51	100 ± 28.87	0.54
Urban land use (%)	1.60 ± 2.41	0.90 ± 7.73	0.01
Agricultural land use (%)	68.20 ± 14.85	62.00 ± 25.38	0.09
Forested land use (%)	30.10 ± 14.33	31.80 ± 24.72	0.20
Catchment size (km²)	19.42 ± 50.76	6.73 ± 19.99	<0.001
Gradient (% slope)	0.09 ± 0.10	0.18 ± 0.19	0.05



**TABLE 3**

Frequency of occurrence for fishes collected at sites throughout the range of *E. fisheriana* in Maryland. An asterisk (\*) indicates a non-native fish species.

		Frequency of occurrence	
		Present	Absent
Confirmed fish hosts		N = 41	N = 54
<i>Etheostoma nigrum</i>	Johnny Darter	0.00	0.00
<i>Lepomis macrochirus</i> *	Bluegill	0.66	0.57
<i>Micropterus salmoides</i> *	Largemouth Bass	0.49	0.24
Congenerics of confirmed fish hosts			
<i>Etheostoma olmstedii</i>	Tessellated Darter	0.93	0.48
<i>Lepomis cyanellus</i> *	Green Sunfish	0.56	0.31
<i>Lepomis gibbosus</i>	Pumpkinseed	0.78	0.54
<i>Lepomis auritus</i>	Redbreast Sunfish	0.56	0.22
<i>Luxilus cornutus</i>	Common Shiner	0.00	0.00
Confirmed fish hosts of congeneric mussels			
<i>Anguilla rostrata</i>	American Eel	0.98	0.74
<i>Dorosoma cepedianum</i>	Gizzard Shad	0.02	0.00
<i>Fundulus diaphanus</i>	Banded Killifish	0.02	0.04
<i>Gambusia holbrooki</i>	Eastern Mosquitofish	0.22	0.11
<i>Perca flavescens</i>	Yellow Perch	0.15	0.09
<i>Pomoxis nigromaculatus</i> *	Black Crappie	0.17	0.04
<i>Pomoxis annularis</i> *	White Crappie	0.00	0.04

# **WALKERANA** The Journal of the Freshwater Mollusk Conservation Society

©2010

## **OUR PURPOSE**

The Freshwater Mollusk Conservation Society (FMCS) is dedicated to the conservation of and advocacy of freshwater mollusks, North America's most imperiled animals. Membership in the society is open to anyone interested in freshwater mollusks who supports the stated purposes of the Society which are as follows:

- 1) Advocate conservation of freshwater molluscan resources;
- 2) Serve as a conduit for information about freshwater mollusks;
- 3) Promote science-based management of freshwater mollusks;
- 4) Promote and facilitate education and awareness about freshwater mollusks and their function in freshwater ecosystems;
- 5) Assist with the facilitation of the National Strategy for the Conservation of Native Freshwater Mussels (Journal of Shellfish Research, 1999, Volume 17, Number 5), and a similar strategy under development for freshwater gastropods.

## **OUR HISTORY**

The FMCS traces its origins to 1992 when a symposium sponsored by the Upper Mississippi River Conservation Committee, USFWS, Mussel Mitigation Trust, and Tennessee Shell Company brought concerned people to St. Louis, Missouri to discuss the status, conservation, and management of freshwater mussels. This meeting resulted in the formation of a working group to develop the National Strategy for the Conservation of Native Freshwater Mussels and set the ground work for another freshwater mussel symposium. In 1995, the next symposium was also held in St. Louis, and both the 1992 and 1995 symposia had published proceedings. Then in March 1996, the Mississippi Interstate Cooperative Research Association (MICRA) formed a mussel committee. It was this committee (National Native Mussel Conservation Committee) whose function it was to implement the National Strategy for the Conservation of Native Freshwater Mussels by organizing a group of state, federal, and academic biologists, along with individuals from the commercial mussel industry. In March 1998, the NNMCC and attendees of the Conservation, Captive Care and Propagation of Freshwater Mussels Symposium held in Columbus, OH, voted to form the Freshwater Mollusk Conservation Society. In November 1998, the executive board drafted a society constitution and voted to incorporate the FMCS as a not-for-profit society. In March 1999, the FMCS held its first symposium "Musseling in on Biodiversity" in Chattanooga, Tennessee. The symposium attracted 280 attendees; proceedings from that meeting are available for purchase. The second symposium was held in March 2001 in Pittsburgh, Pennsylvania, the third in March 2003 in Raleigh, North Carolina, the fourth in St. Paul, Minnesota in May 2005, the fifth in Little Rock, Arkansas in March 2007, and the sixth in Baltimore, Maryland in April 2009. The society also holds workshops on alternating years, and produces a newsletter three times a year.

## **FMCS SOCIETY COMMITTEES**

Participation in any of the standing committees is open to any FMCS member. Committees include:

- Awards
- Environmental Quality and Affairs
- Gastropod Distribution and Status
- Genetics
- Guidelines and Techniques
- Information Exchange - Walkerana and Ellipsaria
- Mussel Distribution and Status
- Outreach
- Propagation and Restoration

## **TO JOIN FMCS OR SUBMIT A PAPER**

Please visit our website for more information at <http://www.molluskconservation.org>

Or contact any of our board members or editors of WALKERANA to talk to someone of your needs. You'll find contact information on the back cover of this publication.

# WALKERANA

THE JOURNAL OF THE FRESHWATER  
MOLLUSK CONSERVATION SOCIETY

©2010



## FMCS 2011-2013 Officers

*President* **Caryn Vaughn**

Oklahoma Biological Survey  
University of Oklahoma  
111 E Chesapeake  
St. Norman, OK 73019  
**cvaughn@ou.edu**

*President Elect* **Patricia Morrison**

Ohio River Islands NWR  
3982 Waverly Road  
Williamstown, WV 26187  
**patricia\_morrison@fws.gov**

*Secretary* **Greg Zimmerman**

EnviroScience, Inc.  
6751 A-1 Taylor Rd.  
Blacklick, Ohio 43004  
**gzimmerman@enviroscienceinc.com**

*Treasurer* **Heidi L. Dunn**

Ecological Specialists, Inc.  
1417 Hoff Industrial Park  
O'Fallon, MO 63366  
636-281-1982 Fax: 0973  
**Hdunn@ecologicalspecialists.com**

*Past President* **W. Gregory Cope**

North Carolina State University  
Department of Environ. & Molecular Toxicology  
Box 7633  
Raleigh, NC 27695-7633  
**greg\_cope@ncsu.edu**