Mussel Diversity as a Function of Drainage Area and Fish Diversity: Management Implications

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Abstract. Forty-seven riverine systems in the Ohio River drainage were included in a study of the relationships between mussel diversity, fish diversity, and drainage area. Fish data were shown to follow a species-area curve, with diversity highly correlated with area. A similar relationship was found for mussels and area. Lines for fish and mussel diversity, versus area, were parallel. However, the greatest correlation occurred between fish and mussel diversity ($r^2 = 0.92$). At any drainage size, numbers of fish species outnumber mussel species by a factor of approximately 2.25. The diversity of mussels for a given river depends on the diversity of fishes in that river, and the approximate number of mussel species for an area can be estimated if the fish diversity is known. Because of the high degree of correlation between these data, estimates may even be made without knowledge of the fish diversity. The relationships also help to define statistically "high" and "low" diversity systems.

Introduction

Most workers in the field of freshwater malacology have felt that there may be a relationship between the numbers of species of unionids and fishes in a river, although this phenomenon has not previously been quantified or tested. Most, if not all, unionids require a host in the glochidial stage of their life cycle, and the majority of those hosts are fishes. Therefore, the greater the diversity of fishes in any given river, the higher the potential for that drainage to include unionid hosts and, hence, to support a greater unionid diversity. Unfortunately, the hosts for many unionids are unknown, and the reported host lists for others may be fragmentary or spurious (for review, see Hoggarth 1992, Watters 1992a).

Watters (1992b) has shown that in the Ohio River drainage, the diversity of fishes and unionids are correlated, *regardless of known host-parasite relationships.* Fish diversity in turn is correlated with the drainage area of the riverine system. Theoretical and strictly biological discussions of these relationships may be found in the original study. Efforts now are under way to model this relationship and determine its implications for unionid host specificity. The current study examines some management and conservation potentials for these results.

Methods and Materials

The diversities of unionids and fishes were taken from the literature for 47 riverine systems—37 systems in the Ohio River drainage and 10 in the Maumee River system (Watters, 1992b). The Maumee River was included because it was once a glacial outlet into the Wabash River, and its unionid fauna bears more resemblance to the Ohio River fauna than it does to the Laurentian (Clark and Wilson 1912, Walker 1913). The data included extinct, extirpated, and introduced species of mussels and fishes. Several systems had data for unionids, but not fishes.

Species numbers of fishes and unionids were plotted against each other and against drainage area. Regression lines were best fit to either linear or power functions. Slopes of lines were compared with a t-test.

Results and Discussion

The plot of number of species of fishes on the species-area curve (Watters 1993; Figure 1) has the power function:

$\# \text{ sp. fishes} = 4.686 \text{ sq. km}^{0.322}; r^2 = 0.81; p(r^2) < 0.0000.$

Unionids show a similar species-area curve relationship (Figure 1):

$\# \text{ sp. unionids} = 1.738 \text{ sq. km}^{0.343}; r^2 = 0.84; p(r^2) < 0.0000.$

The two lines are nearly parallel, with the probability of $b_{1[0.322]} = b_{2[0.343]} > 0.3$ using a t-test for different slopes.

The diversities of unionids and fishes also are correlated on a linear plot (Figure 2):

$\#$ sp. unionids = 0.046 + 0.445 $\#$ sp fishes; $r^2 = 0.92$; $p(r^2) < 0.0000$.

Since Jaccard's (1908) observation that larger areas contain predictably greater numbers of species than smaller areas, the concept of the species-area curve has been applied to many scenarios. Fish diversity has been shown to be related to drainage area or drainage volume (Angermeier and Schlosser 1989, Swift et al. 1986), and the diversities of the 47 systems studied here follow a well-defined species-area curve (Figure 1). Unionids also show a species-area curve relationship, and the lines of fish and unionid diversity are nearly parallel (Figure 1). It is unlikely that two groups of organisms as different as fishes and mussels would show the same species-area curve.

The data also may be represented as a cumulative curve, showing the cumulative numbers of systems having *x* number of species (Figure 3). Because fish diversity data were not available for some systems, not all 47 drainages were used. Again, the lines for fish and unionid diversity track each other.

Apparently, unionid diversity is not a consequence of drainage area, but of the established relationship between fishes and drainage area, and the host-parasite relationship between fishes and mussels. Thus, if fish diversity is covariant with drainage area and unionid diversity is covariant with fish diversity, then unionid diversity also is related to drainage area, but in a *nonbiological* way. This has important implications for management and conservation. The expected number of unionid species for this data is given by the best fit line either between fish and unionid diversity (Figure 2), or between unionid diversity and drainage area (Figure 1).

The ratio of fish diversity to expected unionid diversity is essentially a constant. The ratio only varies from approximately 2.21 for a 10 km² drainage to 2.25 for a 100,000 km² system (Figure 4). This ratio may be used to represent the average unionid diversity expected for a known fish diversity. For example, a system having 100 species of fishes would be expected to have 44 species of mussels, *on average*, and a fish diversity of 250 would yield a unionid diversity of 111 species (Figure 5).

The number of fish species in a drainage is not always known, and no reasonable estimate of unionid diversity can be made by the above method in these

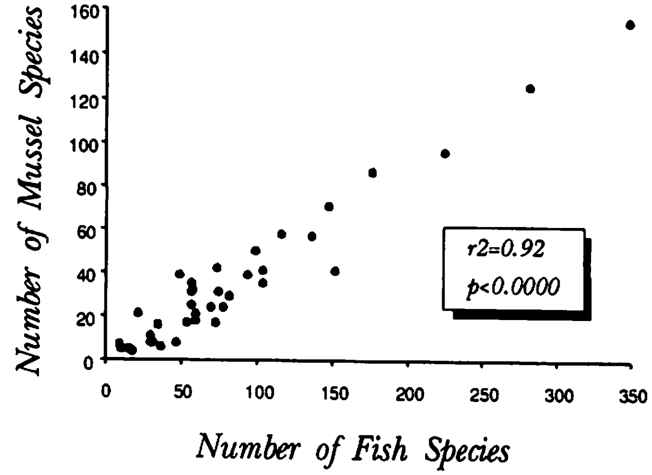

Figure 2. Plot of numbers of species of unionids vs. fishes. p = probability for r^2.

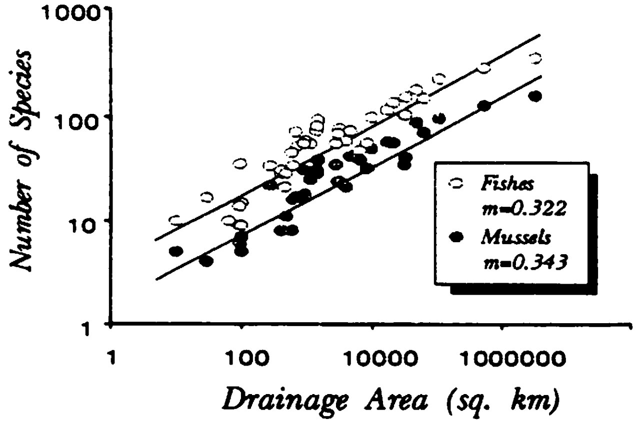

Figure 1. Log-log plot of numbers of species of unionids and fishes vs. system drainage areas. Lines represent best fit power functions for each regression. m = slope.

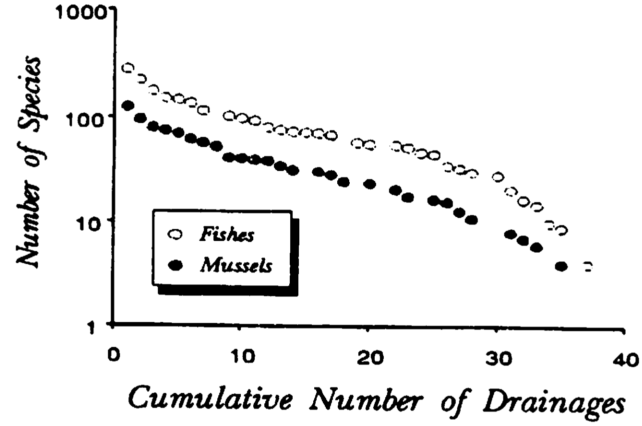

Figure 3. Semilog plot of numbers of species of unionids and fishes by cumulative number of drainages. The graph should be read as the *x* number of drainages that contain at least *y* number of species.

situations. However, because of the relationship between unionid diversity and drainage area, an estimate may be made based solely on the size of the system. A drainage of 1000 km^2 has an expected unionid diversity of 19 species, and a 100,000 km^2 drainage area, an expected diversity of 90 species (Figure 6).

Because the estimates are based on regression analysis, it is possible to assign systems to different levels of diversity corresponding to normal, high, and low with statistical confidence limits. In Figure 7, a 95% confidence interval is shown around the best fit line. Systems within that limit are not different from the expected diversities for a drainage area. Systems above the limit may be considered high-diversity drainages, and those below as low-diversity drainages. Notice that Ohio Brush Creek and Big Darby Creek are high-diversity creeks, whereas the Allegheny River is a low-diversity river. The Tennessee River, despite its apparent high diversity of mussels, is shown to contain the expected number of species. Low-diversity systems may be singled out for inspection for impacts, and high-diversity drainages marked for conservation. Other confidence limits could be chosen to restrict or broaden the concept of high- and low-diversity systems.

There are several caveats associated with the use of these calculations. First, some systems are natu-

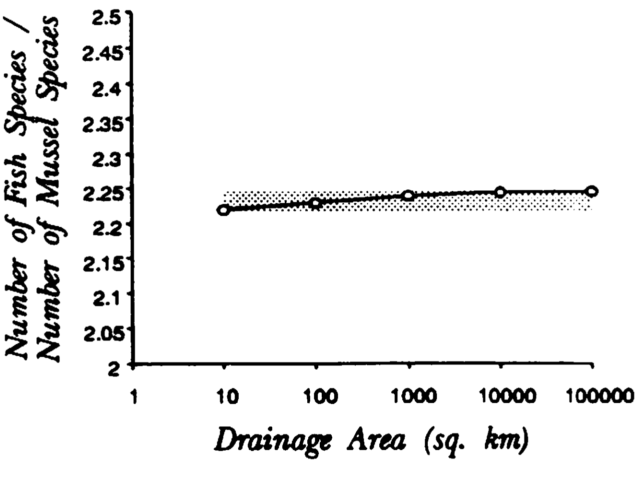

Figure 4. Semilog plot of ratio of numbers of species of fishes/unionids vs. drainage areas based on relation between numbers of fish species and numbers of unionid species. Shaded area represents possible range of ratio values for drainage areas studied.

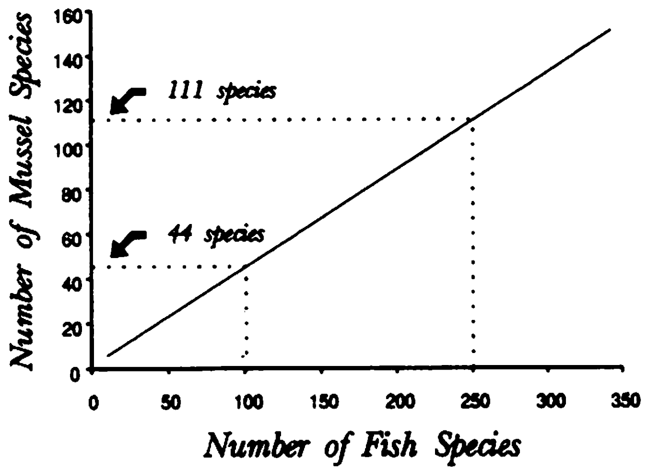

Figure 5. Estimates of unionid diversity for a given fish diversity as calculated by regression line.

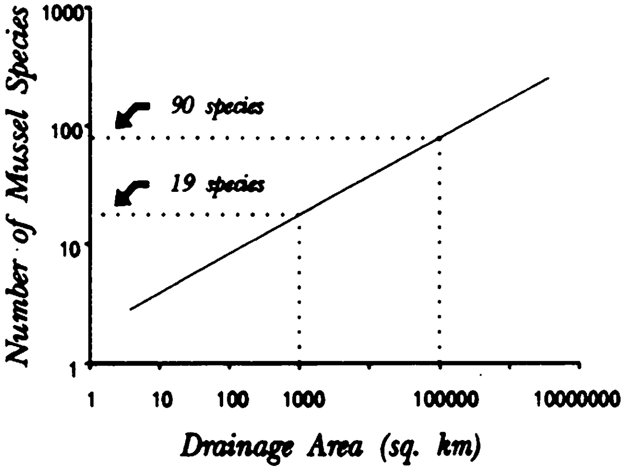

Figure 6. Estimates of unionid diversity for a given drainage area as calculated by regression line.

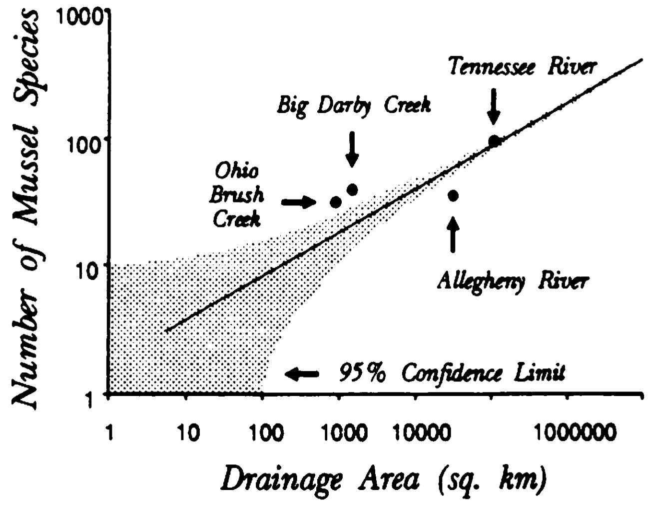

Figure 7. Log-log plot of numbers of species of unionids vs. drainage areas. Line represents best fit power function for regression. Shaded area represents 95% confidence interval of slope. Drainages above line are higher than average diversity systems; those below line have lower than average diversity.

rally diversity-poor, usually due to unfavorable habitats. However, inspection should reveal whether this diversity is due to correctable impacts or natural conditions. Second, this analysis cannot be used for a site, but only for the system as a whole. Third, the results apply only to the Ohio River drainage. Preliminary work suggests that each major drainage or region may have its unique signature curve. This will be the subject of future studies.

Summary

Within the Ohio River drainage, the diversity of mussels is related to the fish diversity and the drainage area of any given system, regardless of size. The ability to compute an expected unionid diversity for any given system has potential for management and conservation efforts. It is possible to determine how a river fares in relation to an *average* system, and to identify high- and low-diversity drainages. Low-diversity systems could be examined for a cause of the below-average diversity. If the cause is human-made, efforts may be made to restore the system to an average diversity level. Conversely, high-diversity drainages may be identified for protection. In monitoring studies and indices employing comparison with average or above-average systems, these choices may be made with statistical confidence.

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Literature Cited

Angermeier, P.L., and I.J. Schlosser. 1989. Species-area relationships for stream fishes. Ecology 70:1450–1462.

Clark, H.W., and C.B. Wilson. 1912. The mussel fauna of the Maumee River. U.S. Bureau of Fisheries Document 757. 72 pp.

Hoggarth, M.A. 1992. An examination of the glochidia-host relationships reported in the literature for North American species of Unionacea (Mollusca: Bivalvia). Malacology Data Net 3:1–30.

Jaccard, P. 1908. Nouvelles recherches sur la distribution florale. Bulletin de Societe Vaudoise Science et Nature 44:223.

Swift, C.C., C.R. Gilbert, S.A. Bortone, G.H. Burgess, and J.W. Yerger. 1986. Zoogeography of the freshwater fishes of the southeastern United States: Savannah River to Lake Pontchartrain. Pages 213–265 *in* C. H. Hocutt and E. O. Wiley, eds. The zoogeography of North American freshwater fishes. J. Wiley and Sons, New York.

Walker, B. 1913. The Unione fauna of the Great Lakes. Nautilus 27(2):18–23; 27(3):29–34; 27(4):40–47; 27(5):56–59.

Watters, G.T. 1992a. An annotated bibliography of the reproduction and propagation of the Unionacea. Prepared for the Division of Wildlife, Ohio Department of Natural Resources. 125 pp. + appendices.

Watters, G.T. 1992b. Unionids, fishes, and the species area curve. Journal of Biogeography 19(5):481–490.