Environmental Factors Affecting the Functional Composition and Diversity of Montane Benthic Macroinvertebrate Communities

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Background

Discerning causal mechanisms for benthic macroinvertebrate distributions and functional composition in streams has often been difficult because of the dynamics of the stream environment and the diverse functional roles of taxonomic groupings. Traditionally, stream communities have been characterized by taxonomic diversity, which represents only one measure of species diversity (Bilton et al. 2006). Stream ecologists have begun to move away from this traditional approach, instead adopting a trait based perspective. This method has evolved from simply grouping insects by the dominant modes of feeding (Cummins 1973) to more sophisticated multivariate models (Poff et al. 2006). However, little is known about how functional traits vary along environmental gradients. This study explores relationships between functional trait and taxonomic composition with environmental factors in streams. By studying how multiple environmental factors influence trait and taxonomic composition, we hope to advance the understanding of community structure and function across natural stream gradients.

Methods

This study was conducted from 9-12 September 2008 in Copper Creek, a montane stream running through the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado. Aquatic macroinvertebrates were collected via 30 Surber samples within a 100m reach of Copper Creek (Figure 1). Macroinvertebrates were preserved in ethanol and identified to species and body length (mm) was measured. In each sample (area = 31 x 31 cm), nine measurements of near-bed velocity and depth were recorded and all cobble substrate was sized with a Gravel-o-Meter™. Averages were calculated for all three variables in each sample. However, standard deviations (SD) were also calculated for each environmental variable as a proxy for heterogeneity; as the SD increased, this was indicative of greater heterogeneity within a sample. Additional functional traits were assigned using a classification scheme created by Poff et al. 2006. We also calculated the abundance, effective richness and evenness for each sample to examine taxonomic diversity. Our analysis consisted of univariate linear regression, multiple regression, partial correlation, ordination, and structural equation modeling with observed variables using R and SPSS AMOS™ 17.0.

Figure 1. Copper Creek, a montane stream located near the Rocky Mountain Biological Laboratory, Gothic Colorado.

Table 1. Results of multiple regression analysis. In both Baetidae and Ephemerellidae, the standard deviation of near-bed velocity and substrate size explained a significant amount of variation in body length. The standard deviation of depth and substrate size explained a significant amount of the variation in body length in Perlodidae. No significant relationships were found in Heptageniidae, Taeniopterygidae and Chloroperlidae. Across all families, the average standard deviation (across all samples per family) of near-bed velocity and substrate size explained a significant amount of variation in average body length.

Family	Response Variable	Predictor Variable	R^2	$P \leq$
Baetidae	Body Length	Near-bed Velocity SD, Substrate SD	0.10	0.001
Ephemerellidae	Body Length	Near-bed Velocity SD, Substrate SD	0.61	0.001
Perlodidae	Body Length	Depth SD, Substrate SD	0.68	0.014
All Families	Average Body Length	Average Near-bed Velocity SD, Average Substrate SD	0.87	0.021

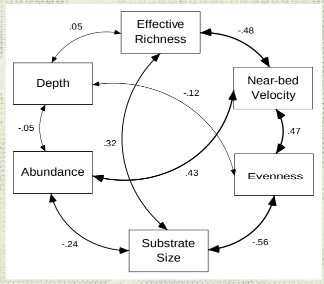

Figure 3. Path diagram depicting partial correlation coefficients between predictor and response variables. No one environmental variable accounted for a high percentage of the variation within each measure of diversity (Abundance, Effective Richness, and Evenness). Thicker arrows indicate a stronger relationship.

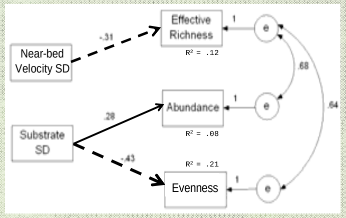

Figure 4. Structural equation model with observed variables illustrating the effects of near-bed current velocity and substrate size on effective richness, abundance, and evenness. Depth did not significantly account for any variation in these response variables. Dashed arrows indicate negative relationships and solid arrows positive relationships. Model fit: $\chi^2 = 4.50$, d.f. = 5, GFI = 0.92, $P = 0.47$.

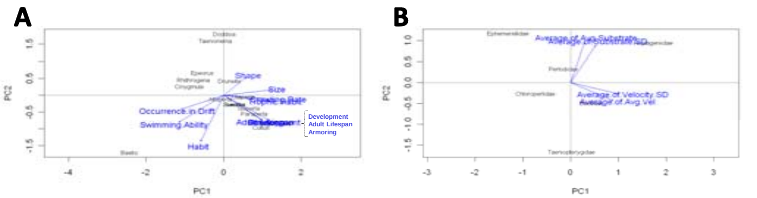

Figure 5A. Ordination plot resulting from Redundancy Analysis (RDA) of 15 macroinvertebrate genera and 10 functional traits. The plot illustrates the position of each genus in relation to the first two principal components. B. Ordination plot resulting from RDA of six macroinvertebrate families and several environmental factors. The plot shows the position of each family in relation to the first two principal components. Only significant vectors are shown in both plots ($P < .05$).

Figure 2. *Doddsia occidentalis* (Taeniopterygidae), *Drunella coloradensis* (Ephemerellidae) and *Baetis tricaudatus* (Baetidae) (left to right). Taeniopterygidae and Baetidae are two of the most abundant families, while Ephemerellidae were found in lower numbers.

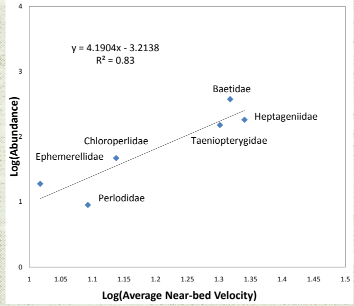

Figure 6. Log(abundance) as a function of log(average velocity). As average near-bed velocity (cm^2) increases, abundance increases linearly ($P = 0.011$). The three most abundant families occur in areas of higher average near-bed velocity. Data were log_{10} transformed to meet the assumptions of parametric tests prior to running a linear regression.

Results

- For all macroinvertebrate families in this study, as heterogeneity in near-bed current velocity increased, so did body length; however, body length was negatively associated with increasing heterogeneity of substrate size (Table 1). Depth did not account for any significant amount of variation in body length with the exception of the family Perlodidae, in which an increase in the heterogeneity of depth led to a decrease in body length.

- The three most abundant families favored areas with a higher average velocity, while the rarer taxa were found in slower average velocities (Figure 6). Species belonging to the more abundant families had a lower average body length than the other families (5.25mm and 7.41mm, respectively).

- A partial correlation matrix indicated that not any one environmental variable measured in this study affected effective richness, abundance, or evenness (Figure 3). Rather, they were most strongly correlated with near-bed current velocity and substrate size, and were weakly correlated with depth.

- In the structural equation model, effective richness (diversity) was negatively affected by near-bed current velocity (Figure 4; model fit: $\chi^2 = 4.50$, d.f. = 5, GFI = 0.92, $P = 0.47$). Macroinvertebrate abundance was positively affected by substrate size; however substrate size negatively affected evenness. All relationships are significant at the $P \leq 0.10$ level.

- Ordination plots revealed a separation of genera based on their functional traits (Figure 5A). The first two principal components account for 45% and 18% of the variation in the traits. Furthermore, the families in this study were found in areas of varying degrees of heterogeneity (Figure 5B). The first two principal components account for 45% and 30% of the variation in the environmental variables.

Conclusions

- The results from this study suggest that functional traits and taxonomic diversity are strongly influenced by habitat heterogeneity. Near-bed current velocity and substrate size best explained variation in diversity, abundance, evenness and functional trait composition. Stream depth had no role in accounting for any significant variation in these variables.

- Families with smaller overall body size were found in faster water suggesting that macroinvertebrate surface area may contribute to a separation in the distributions of macroinvertebrate taxa. Taxa with greater size may be susceptible to greater shear forces at high near-bed current velocities.

- Families that are present at high near-bed current velocities are highly abundant therefore decreasing evenness and effective richness in areas with high near-bed velocities (see Figures 4 and 6). This demonstrates that the abundances of a given taxa may play a strong role in shaping the diversity of benthic macroinvertebrate communities.

Literature Cited

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