Investigation of the relationship between aquatic macroinvertebrate distribution and abiotic and biotic factors in a northern Michigan river

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Biology 381 – General Ecology
8/16/2012
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Abstract

Conditions in streams and rivers can vary greatly and influence species composition, especially that of macroinvertebrate communities. Functional feeding groups or guilds also have an impact on the distribution of different types of macroinvertebrates in rivers. This study analyzed how abiotic and biotic factors influenced macroinvertebrate distribution in a river. It was hypothesized that different abiotic and biotic conditions would produce differences in macroinvertebrate dispersal patterns. Four different sites along the Maple River near Pellston, MI were sampled. At these sites, rocks were chosen for analysis, a multitude of abiotic and biotic factors, and aquatic macroinvertebrates were classified to family and order and counted. Patterns were found in macroinvertebrate distribution, with temperature, water depth, rock size, filamentous green algae (FGA) cover, and flow rate accounting for most of the variation observed. Trends were also found between abiotic factors and between the presence or absence different macroinvertebrates. Future studies should focus on perfecting the methods of this kind of study and expanding this analysis to different areas and aquatic ecosystems.

Introduction:

Aquatic ecosystems are made up of many components. Different areas and habitats within the ecosystem allow for complex communities and patches to exist (Bond et al.2000; Downes et al.1993; Malmqvist 2002). Organisms that make up river and stream communities are highly adapted to living in varying flowing water conditions. These organisms include algae, aquatic macroinvertebrates, and fish that all interact within these systems (Allan and Cushing 2001). Communities and patches in rivers and streams will differ due to differences in abiotic factors. These factors include flow rate, temperature, and canopy cover, among many others. Biotic factors, such as percent filamentous green algae (FGA) on rocks, can also impact diversity in different areas of a river or stream. River and stream communities can be classified by different zones. The benthic community, the bottom of a river or stream, performs many important functions for these areas, and the diversity in this community can be a good indicator for assessing the quality of an aquatic ecosystem. (Allan and Cushing 2001).

Within rivers and streams, distribution of different organisms can vary immensely (Butcher *et al.* 1997). Aquatic macroinvertebrates are some of the most common organisms found in these habitats. Many are larvae of different insect species that will become terrestrial as adults, while others will remain aquatic throughout their entire life cycle (Berg et al. 2008; Ciborowski et al. 1996). These organisms fill many niches in freshwater habitats and perform important functions in river and stream communities. Being an essential part of aquatic food webs, macroinvertebrates play important roles in nutrient cycling and energy flow. Changes in macroinvertebrate species composition can greatly alter the processes of a stream or river ecosystem (Covich et al. 1999). Differences in abiotic factors, especially flow rate, can greatly influence the distribution of aquatic macro invertebrates found in stream and river habitats (Fonesca and Hart 1996; Higler and Statzner 1986; Hoffsten and Malmqvist 2000).

Aquatic macroinvertebrates can be placed into different guilds or functional feeding groups. Scrapers and grazers consume algae and other plant matter from underwater surfaces. This group consists of macroinvertebrates like *Gastropods* and certain members of *Ephemeroptera*. Shredders consume leaf material and include macroinvertebrates like aquatic sowbugs and members of *Diptera*. Gathering collectors obtain fine particulate organic matter from the stream bottom. *Trichoptera* and *Chironomids* are members of this guild. Filtering collectors obtain fine particulate organic matter from the water column and include *Sphaeriidae* and *Simuliidae*. *Megaloptera* and *Plecoptera* are predators, which feed on other consumers. Omnivores feed on both animal and plant matter and include macroinvertebrates like *Decapods* and *Geridae*. Feeding behaviors and food items determine in which conditions different macroinvertebrates can be found (Berg et al. 2008; Jørgensen et al. 2002). For instance, scrapers and grazers are more likely to be found on surfaces covered with algae than on bare surfaces. Also, the presence of a predator in an area could drive other guilds away.

In this study, abiotic factors of aquatic ecosystems were measured and analyzed at four different sites along the Maple River near Pellston, MI, in order to look for patterns in macroinvertebrate distribution based on abiotic factors. Differences in abiotic and biotic factors between the sampling sites should result in differences in aquatic macroinvertebrate distribution.

Methods:

Data were collected at the mainstream of the Maple River beyond the Kathy Lake Dam, the mainstream of the Maple River by Maple River Rd., the west branch of the Maple River near U.S. 31 and the east branch of the Maple River near Riggsville Rd. (Figure 1). At each site, 20 were randomly selected for sampling. Range in size of rocks used was between 3cm X 3cm X 3cm up to 40cm X 40 cm X 40 cm. Distance of the rock from the bank was measured in meters

(m) using a measuring tape. Depth of the rock was measured using a meter stick and measured in centimeters (cm). Temperature was measured in Celsius (°C) by placing a thermometer at the rock's location in the water for thirty seconds. Flow rate (m/s) was measured at the rock's location in the water using an electronic flow meter. The flow meter was kept in the water until it gave a stable reading. Rocks were chosen and placed in a plastic bin in order to catch any invertebrates falling off the rock while it was being analyzed. Aquatic macroinvertebrates were classified by order and family. Macroinvertebrates were counted and classified to family or order. The length, width, and height (cm) of each rock were also measured using a meter stick. These measurements were then used to calculate the volume of the rock. The percentage of filamentous green algae (%FGA) was quantitatively estimated for each rock. Canopy cover at each rock location was determined using a spherical densiometer. Weather conditions and substrate composition were also recorded. Data were analyzed using a redundancy analysis (RDA). A Monte Carlo permutation test was used to analyze how much of the variation was explained by the RDA.

Results:

Abiotic factors that influenced macroinvertebrate diversity most were depth, temperature, flow, rock size and FGA. These factors varied to different degrees (Table 1). We found that most of the variation in macroinvertebrate distribution was explained by temperature (44%). Depth alone explained 16% of the variation in macroinvertebrate distribution, rock size 14%, and flow 12%. The first axis in the RDA accounted for 9.7% of the differences seen in macroinvertebrate diversity, and both the first and second axis together accounted for 14.1% of the variation observed (Figure 2). The Monte Carlo permutation test showed that the ordination given by the RDA accounted for significantly more of the variation ($p<0.05$) than would be expected by chance alone. Therefore, the patterns observed in macroinvertebrate distribution due to abiotic factors are significant.

A few factors showed little correlation with one another. Temperature and flow rate were not correlated with each other, nor were temperature and depth. Rock size and flow rate were also found to be unrelated. Some factors showed correlations with one another though. Flow rate and depth were negatively correlated with each other. The deeper the water in which a rock was located, the slower the flow. Temperature was highly correlated with location, and remained constant at each site sampled (Figure 3). Also, FGA was negatively correlated with depth and percent canopy cover. As depth and percent canopy cover increased, FGA decreased (Figure 2).

Many relationships were found between biotic factors and the distribution of macroinvertebrates. The presence of *Ephemeroptera*, adult *Plecoptera*, and *Coleoptera* was strongly influenced by temperature. As temperature increased, the presence of these macroinvertebrates increased. Substrate type was negatively correlated with the presence of these macroinvertebrates as well. They were found in rocky substrates more often than sand or silt. *Chironomids* and *Amphipods* were found on smaller rocks, rocks with greater filamentous green algae cover, in shallower water, with little or no canopy cover. Flow rate had a very strong positive relationship with the presence of *Simuliidae*. Caddisflies (*Tricoptera*) juvenile *Plecoptera*, *Megaloptera*, and *Platyhelminthes* were found mostly on larger rocks as opposed to smaller rocks, and in colder water (Figure 2).

Correlations were also found between different macroinvertebrates. *Amphipods* and *Chironomids* were often found together, as were *Emphemeroptera* and adult *Plecoptera*. Negative correlations were found between the presence of *Tricoptera* and *Amphipoda* as well as between *Megaloptera* and *Coleoptera*. There were also negative correlations between the presence of bloodworms and midge larvae, both members of *Chironomidae*. Some of the types of macroinvertebrates found did show correlations though. The presence of black fly larvae showed little correlation with the presence of any of the other macroinvertebrates. Also, the presence of *Ephemeroptera* and adult *plecoptera* had almost no relationship to the presence of juvenile *Plecoptera* and *Tricoptera* (Figure 2).

Discussion:

It was shown that both abiotic and biotic factors in streams could strongly influence variation in aquatic macroinvertebrate distribution.

Temperature was the most important variable in explaining the observed variation in macroinvertebrate distribution. This could be due to how the macroinvertebrates studied are exothermic and cannot maintain there own body temperature. They must live in habitats where the temperature is within a range that will allow them to function best. Temperature only varied by 3°C in our study, yet still differences were seen in the distribution of macroinvertebrates. For instance, the presence of adult *plecoptera*, *ephemeroptera*, and *coleoptera* was strongly influenced by temperature. This makes sense, because temperature and dissolved oxygen (D.O.) are strongly correlated, and macroinvertebrates like *ephemeroptera* are greatly affected by the concentrations of D.O (Berg et al. 2008). This finding is supported by other studies that have found temperature to be the most important factor in determining which types of macroinvertebrates will be found in streams. One study found that temperature explained most macroinvertebrate distribution patterns, and that species richness was positively correlated with temperature (Encalada et al. 2003).

However, temperature still varied very little in our study, and it is unlikely that this alone could have had such a big impact on the patterns in macroinvertebrate distributions we found.

Temperature tended to remain constant at each site sampled, so differences in macroinvertebrate distributions were also explainable by location. Other factors differing between each location are likely to have had strong influences on macroinvertebrate diversity. Depth, flow, rock size, and FGA were also important variables in this study. Greater water depth can allow for a greater range of substrates, which in turn can support a greater diversity of macroinvertrbrates (Kolasa and Therriault 1999). Flow was negatively correlated with depth, so species that prefer lower flow rates could also be found at greater depths. Conversely, species that prefer higher flow, like *Simuliidae* that need higher flow to get oxygen, are more likely to be found in shallower waters, which was the case in this study (Berg et al. 2008). Rock size was also found to explain the observed variation in macroinvertebrate dispersal. Larger rocks are better able to support macroinvertebrates that cling to and move around on rocks like *Trichoptera* and *Plecoptera* (Berg et al. 2008). In our study, these organisms were found more on larger rocks than on smaller ones. Macroinvertebrates that feed on algae like *Amphipods* would be found on rocks with higher FGA, as was found in this study (Last and Whitman 1999). FGA also had strong negative correlations with canopy cover and depth. This makes sense, since with greater canopy cover and depth there is less light available. Algae need light to perform photosynthesis, so rocks with high FGA, and in turn macroinvertebrates that eat plant matter, are less likely to be found in deep water or areas with high canopy cover.

The observed patterns in macroinvertebrate diversity can also be explained by the presence or absence of certain macroinvertebrates. When *Plecoptera* larvae get large enough, they become carnivorous and will eat other macroinvertebrates like *Ephemeroptera*, *Trichoptera*, and *Chironomids* (Berg et al. 2008). Although this was not seen in our study, typically other macroinvertebrates will not be as common where *Plecoptera* larvae are present (Allan 1982).

The absence of a negative correlation between presence of *Plecoptera* and presence of other macroinvertebrates could have been due to abiotic and biotic factors being more important in explaining trends in macroinvertebrate distribution. For instance, *Ephemeroptera* are prey items of *Plecoptera*, but they also have the same habitat requirements (Berg et al. 2008). This explains why there was such a strong positive correlation between the presence of adult *Plecoptera* and the presence of *Ephemeroptera.* The same explanation can be applied to why two types of macroinvertebrates that compete for the same resources were found in the same area. Both *Chironomids* and *Amphipods* will eat herbaceous matter, and there was a positive correlation between the presence of *Chironomids* and the presence of *Amphipods* in this study (Last and Whitman 1999; Berg et al. 2008). Although they are competing for the same resource, they have the same habitat requirements and were found in similar conditions.

This study could be improved by further differentiating the macroinvertebrates analyzed in species. This would give a more accurate picture of the diversity of macroinvertebrates in this community. Also, a more thorough examination of the rocks used would give better data and possibly reveal some patterns that were undetectable with the methods that were used for this study. More accurate counts of macroinvertebrates would also improve the data and give more realistic results. Only quick estimations were made for data collection, and this could have limited our ability to observe patterns in macroinvertebrate diversity and distribution. When pulling rocks up out of the water, many organisms could have fallen off or swam away, so our observations may not have given an accurate picture of what organisms are present. Devising a way to collect organisms that may escape when a rock is pulled up would greatly improve this study. Expanding this study to more sites and types of aquatic ecosystems could yield more macroinvertebrate dispersal patterns than this study could show. This could also give more variation in abiotic and biotic variables measured, like temperature and FGA, which could also generate different and more realistic trends.

In conclusion, patterns were found in macroinvertebrate distribution based abiotic and biotic factors, and temperature, depth, rock size, flow, and FGA explained most of the patterns observed. Patterns were also found between abiotic and biotic factors and between different types of macroinvertebrates. Future studies should focus on improving the methods of this kind of study to give a more realistic picture of trends in macroinvertebrate distribution. Repeating this kind of study for different aquatic ecosystems could allow for comparisons in distribution patterns with greater variation in abiotic and biotic factors. Looking at similar ecosystems but in different areas could also produce models for aquatic macroinvertebrate distribution.

Acknowledgements

Thanks to Dr. Bob Pillsbury and Mr. David Edwards for all of their help in conducting this study.

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Figures and Tables:

Table 1. Abiotic factor summary.

	Depth (cm)	Temperature (Celsius)	Flow (m/s)	Rock Size (cm^3)	Percent FGA
Maximum	81	19	0.77	15840	75
Minimum	10	16	0	226	0
Range	71	3	0.77	15614	75
Mean	37.75	17.788	0.271	3247.525	6.938
Standard Deviation	14.002	0.951	0.178	3122.1536	14.845

Key for Figures.

Rksize: Rock size
Sub: Substrate type
Dist.Ban: Distance from the bank
PerCC: Percent Canopy Cover
Temp: Temperature
FGA: Percent of filamentous green algae on rock
Flow: Flow rate
BFlyLar: Black Fly Larvae (*Simuliidae*)
Midges: Midges (*Chironomidae*)
BeetLar: Beetle larvae (*Coleoptera*)
Cray: Crayfish (*Decopoda*)
Scuds: Scuds (*Amphipoda*)
Flat: Flat worms (*Platyhelminthes*)
StonJuv: Juvenile stonefly (*Plecoptera*)
Stone: Adult stonefly (*Plecoptera*)
Mega: Helgramite (*Megaloptera*)
Caddis: Caddisfly (*Tricoptera*)
Blood: Bloodworm (*Chironomidae*)
May: Mayfly (*Ephemeroptera)*

Figure 1. Map of sites sampled.

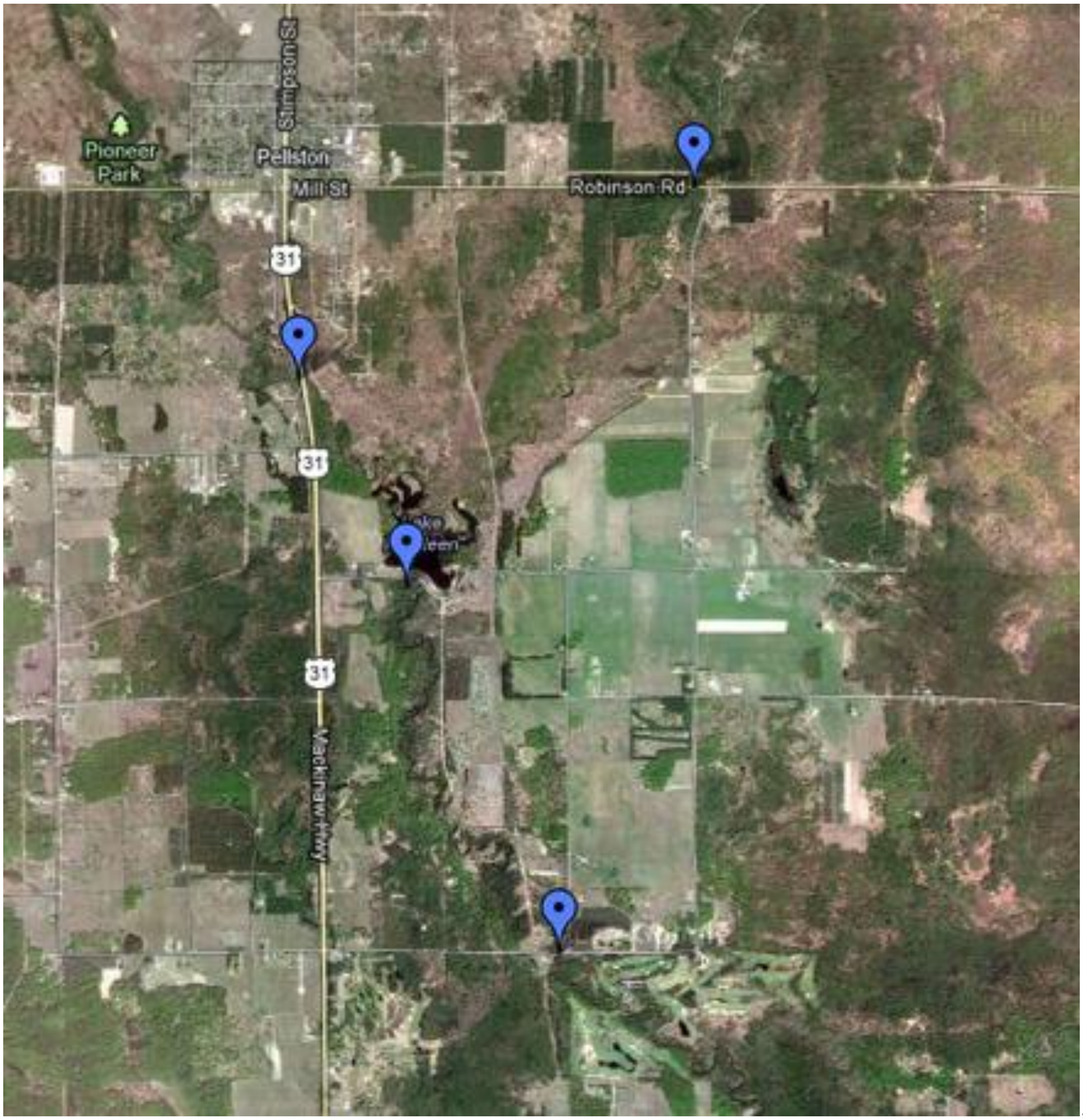

Figure 2. Biplot of Redundancy Analysis (RDA) showing the relationship between abiotic stream factors and aquatic invertebrate community composition.

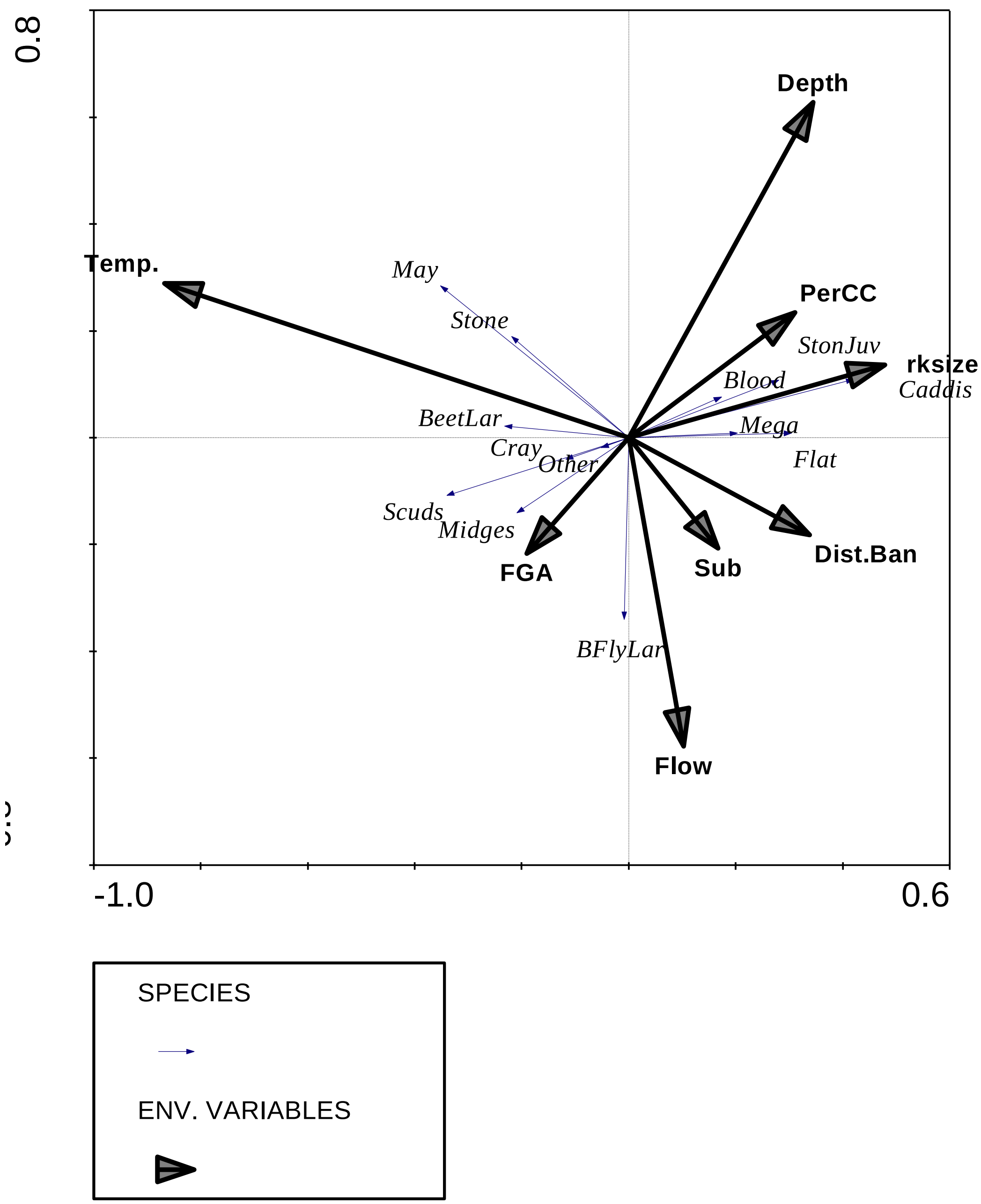

Figure 3. Biplot of RDA showing distribution of sites using environmental variables.