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The Distribution of Macroinvertebrates in the Schoolcraft/Mississippi River-Lake System

Honors Thesis/Biology Capstone Project

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Abstract

During the spring and fall of 2002, macroinvertebrates were collected at river inlets and outlets along the Schoolcraft and Mississippi Rivers in northern Minnesota. Sites included the outlet of Lake Plantagenet, the inlet and outlet of Lake Marquette, the outlet of Lake Irving, the inlet and outlet of Lake Bemidji, and downstream from the Power Dam, located on the Mississippi River. The total number of individuals present was higher during the fall sampling period (473 spring; 833 fall). Species richness was also higher in the fall (mean 8.1 in spring; mean 13.7 in fall). This difference is exemplified at the final site, where species richness was 3 in the spring and 19 in the fall. Proportions of functional feeding groups also differed temporally. In the spring, shredders dominated (mean 81.5%). Although shredders continued to dominate in the fall, other groups had more of an impact. Specifically, predators occupied 21% of the fall samples, and 8.7% of the spring samples, and scrapers occupied 9.3% of fall samples and 2.5% of spring samples. Later in the growing season (during the fall), a larger and more diverse population exists, and the composition of this population follows a predictable model.

Introduction

As a river flows from its headwater origins to its mouth, the benthic macroinvertebrate communities change in a predictable manner. Specifically, the shaded, low-order streams are dominated by shredders (organisms that shred detritus), while mid-order streams contain scrapers (organisms that scrape periphyton from substrate) and collectors (consumers of fine particulate organic matter (FPOM)). High-order streams are dominated by collectors. This theory of predictable changes along a river is known as the River Continuum Concept (RCC), and it provides a model for the river as a whole(Vannote et al., 1980). However, individual sites may be influenced by other factors, such as urbanization, pollution, vegetation, and the presence or absence of microhabitats (Neumann et al., 2002; Kemp 1997; Merritt and Cummins, 1996; Miller 1989).

This study examines the effect of upstream habitats, specifically lakes and man-made dams, on the riverine benthic macroinvertebrate communities. Compared to streams, lakes contain fewer benthic macroinvertebrates, which are mostly concentrated in the littoral zone and often must be adapted to conditions of anoxia (Thorp and Covich, 2001; Goldman and Horne, 1983). Lakes may function as a source of zooplankton (Akopian, et al., 1999; Pourriot, et al., 1997), but the amount of plankton produced in a flow-through lake depends upon the degree of advective removal and the river discharge (Pace et al., 1992; Welker and Walz, 1999). If the lake is an effective source of zooplankton, downstream macroinvertebrate communities may contain increased numbers of collectors (which feed upon plankton). It may also contain more total individuals, since the zooplankton may serve as an additional food source. However, the degree of zooplankton influx may not be high enough to affect macroinvertebrate communities, which are also influenced by other environmental factors, including those discussed previously.

Lakes, which generally contain more oligochaetes, nematodes, flatworms, snails, crayfish, and chironomids, have the potential to act as a source of macroinvertebrates, as well. Drift, whether passive or active, is one of the most important mechanisms of aquatic macroinvertebrate dispersal. Active drift occurs in organisms seeking new food sources or habitats (Smock, 1996). Organisms actively drifting from lakes would not drift to downstream rivers unless a food source or other environmental condition was present that made the stream conducive to their survival. Therefore, actively drifting macroinvertebrates should not explain differences in the downstream community, but merely reflect preexisting conditions. Passively drifting organisms enter the drift accidentally (Merritt and Cummins, 1996) and are often weakened by disease (Wilzbach, 1990). They may explain differences in the downstream community, however, weakened organisms in the water column are more subject to predation and so may not have a noticeable effect on the downstream community.

Methods

To quantify spatial and temporal differences in benthic macroinvertebrate communities, we sampled seven sites on a 25 km stretch of the Schoolcraft and Mississippi Rivers, located in north-central Minnesota. Samples were taken within one-half of a kilometer of the inlet and outlet of lakes Plantagenet, Marquette, Irving, and Bemidji (Figure 1). Each site was sampled both in early and late summer of 2002.

Habitat was assessed, and samples were taken in all habitats. When the habitat was homogeneous, one sample was taken in the littoral zone and one in the benthos. When the habitat was heterogeneous, the number of samples in each habitat corresponded to the proportion of habitat present. This process was repeated at each site. For sampling, a 0.25 m^2 quadrate was placed over the sample area, and the substrate removed with a benthic net. The organisms present were removed with forceps, preserved in 80% isopropyl alcohol, and identified later in the lab. In rocky habitats, the organisms on the bottom of rocks were manually removed and preserved.

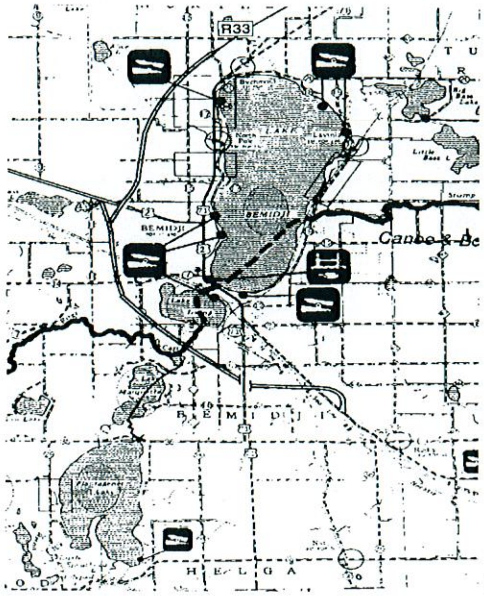


Figure 1. Map of sites.

The resulting data were graphed and analyzed using SPSS. We compared total number of individuals, species richness, and functional feeding groups temporally and spatially.

At the lake outlets, discharge was calculated by multiplying width, average depth, and velocity (in meters). Depth measurements were not always available for the entire river width, and these were inferred through calculation of slope. Some data did not fit a regression model, so for these, average depth was estimated.

Results

The total number of invertebrates increased from spring to fall (473 spring; 833 fall; Figure 2). Individuals did not increase at every site, however. At the Lake Marquette outlet and the Lake Bemidji inlet, the total number of individuals decreased from spring to fall (Figure 3). At lake inlets and outlets, the numbers of individuals remained consistent during each sampling period, with the exception of spring outlets, which averaged 69.3 species, while the inlets averaged 85.3 (Figure 4). Species richness increased from spring to fall (8.1/site spring; 13.7/site fall; Figure 5). Species richness at inlets and outlets remained consistent within sampling periods, with the exception of the spring outlets, which averaged 7 species while the inlets averaged 13 species (Figure 6).

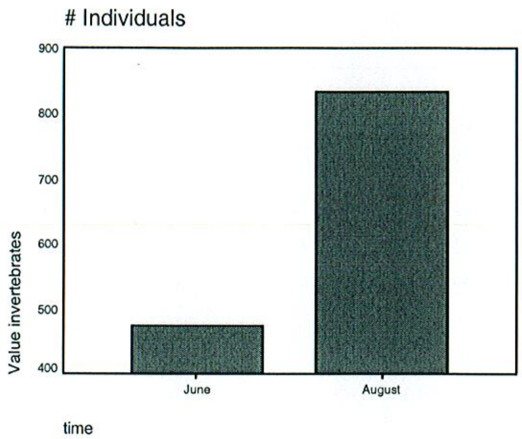


Figure 2.

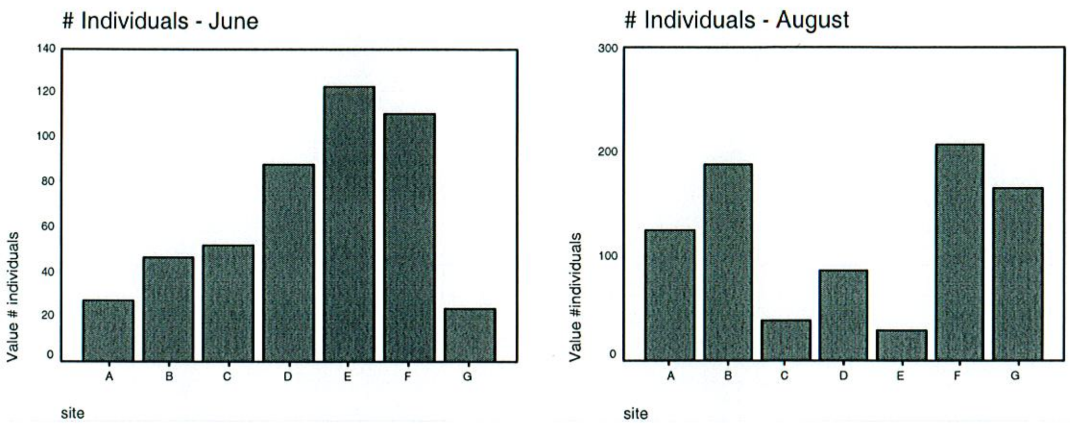


Figure 3. Mean number of individuals by site.

A = L. Plantagnet outlet
B = L. Marquette inlet
C = L. Marquette outlet
D = L. Irving outlet
E = L. Bemidji inlet
F = L. Bemidji outlet
G = Power Dam

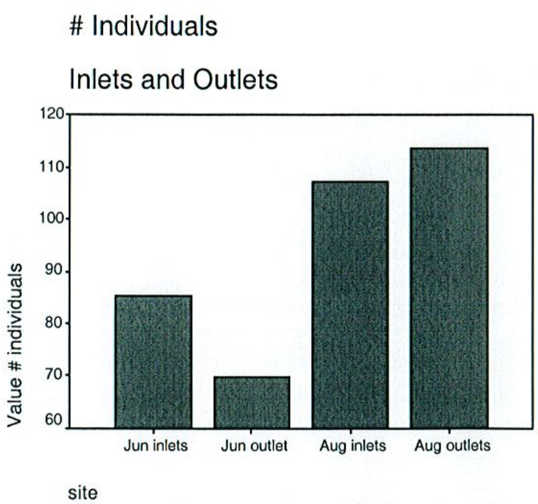


Figure 4.

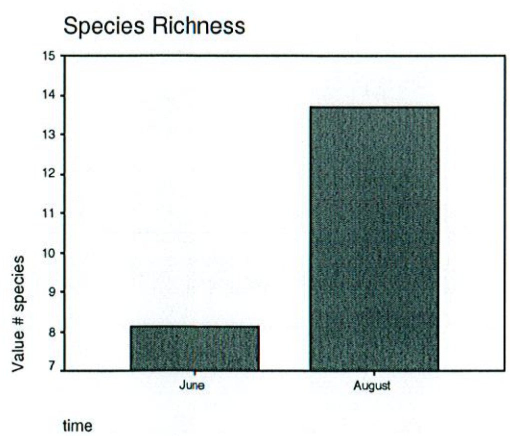


Figure 5.

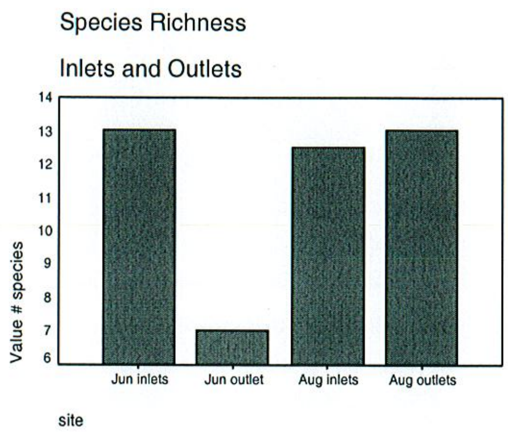
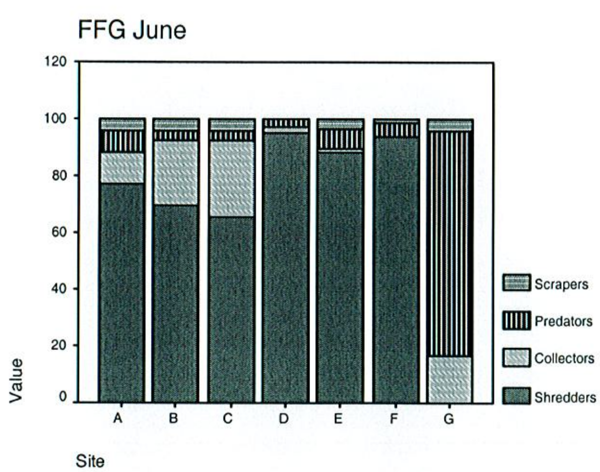


Figure 6.

Samples were categorized into functional feeding groups in order to obtain insight into ecological functioning. For our purposes, individuals were placed into the coarse groups of shredders, collectors, predators, and scrapers. Shredders (mainly *Hyalella*) dominated at all sites in the spring (70%), with the exception of the site downstream from the Power Dam, where predators accounted for 79% of the species present. In the fall, shredders continued to dominate (52%), but to a lesser degree, as other functional feeding group numbers increased. Specifically, the number of predators increased (17% fall; 4.9% spring, excluding the Power Dam), as did the number of scrapers (14% fall; 3% spring; Figure 7).



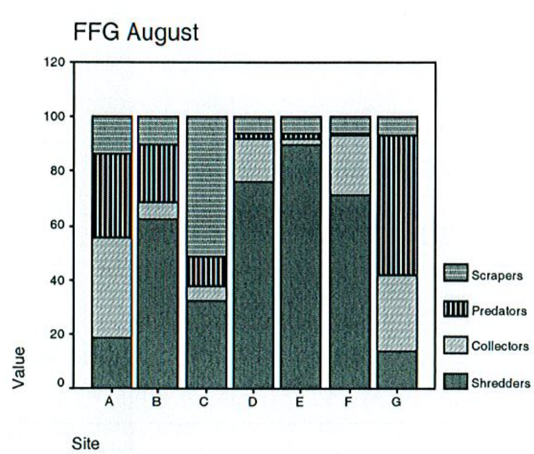


Figure 7. Functional feeding groups by site and time.

A = L. Plantagnet outlet
B = L. Marquette inlet
C = L. Marquette outlet
D = L. Irving outlet
E = L. Bemidji inlet
F = L. Bemidji outlet
G = Power Dam

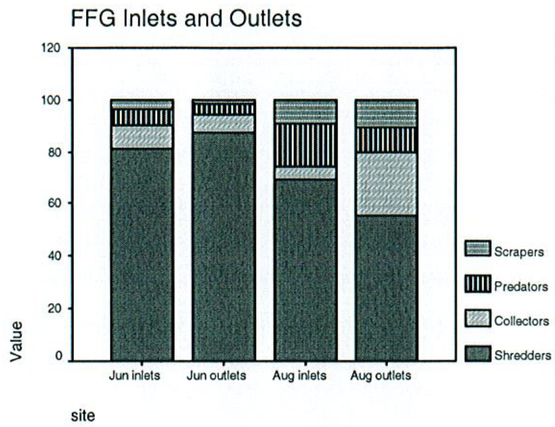


Figure 8. Functional feeding groups at inlets and outlets.

The final site in our survey is located within 100 meters of the Stump Lake, a man-made reservoir created by a dam. This site was not always consistent with other sites in the survey. The number of total individuals increased from spring to fall (24 spring; 164 fall), as did species richness (3 spring; 19 fall; Figure 9). However, while shredders dominated at all other sites at all times, the Power Dam contained no shredders in the spring and 21 in the fall. Instead, predators dominated, followed by collectors. The functional feeding group ratios remained approximately the same for both the spring and fall (Figures 7 and 8).

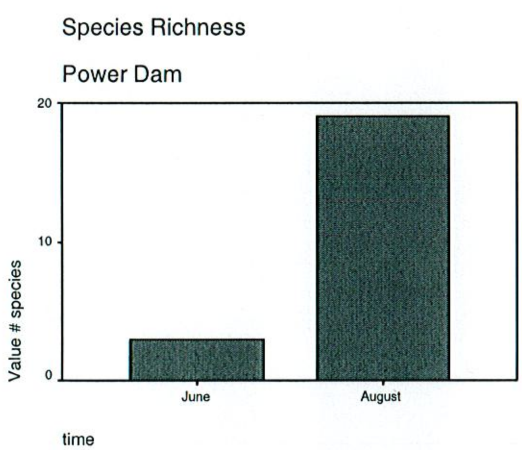


Figure 9.

Discussion

Spatial and temporal shifts in macroinvertebrate density, species composition and functional feeding groups were seen in our survey. Shredders dominated at all sites and times, with the exception of the site downstream from the Power Dam. The RCC predicts that in low-order streams (all our sites fit this criterion), shredders will dominate, and so in the

Schoolcraft/Mississippi river-lake system, the RCC remains a viable model for predicting benthic macroinvertebrate communities when applied to areas with uninterrupted flow.

General Patterns

As the growing season progresses and food availability and temperature increase, the system can support more individuals. The variety of food sources also increases from spring to fall as algae accumulate and shredders convert CPOM to FPOM (Petersen and Cummins, 1974; Cuffney et al., 1990). While in the spring, edible material is dominated by CPOM, the palette diversifies by fall and includes more FPOM, more algae, and more options for prey. This was clearly seen in our study, as non-shredder functional feeding group numbers increased in the fall.

Another source of FPOM are zooplankton, which do not require the activity of shredders to become a food source for collectors. However, we sampled early in June, less than a month after the ice cleared off many sites. Since meiofauna (including algae) and zooplankton do not reach peak abundance until mid-summer (Shiozawa, 1991), the main macroinvertebrate food source was probably unconsumed vegetative detritus from the previous growing season. In addition, all sites were located on low-order streams, where the food supply is rich in CPOM (Angradi, et al., 2001) and favors shredders (Vannote, et al., 1980).

By late August (our second sampling period), shredders continued to dominate. However, probably due to increased algal and periphytonic concentrations, scrapers occupied a larger percentage of the habitat. As the types of prey diversified (evidenced both by changes in functional feeding group composition and increased species richness), predators increased, as well.

Aberrations

Not all sites followed this pattern of increased density and diversity in the fall. Two aberrant sites (Lake Marquette outlet (site C) and Lake Bemidji inlet (site E)) decreased in total number of individuals from spring to fall. Site C also showed a shift in functional feeding group composition: in the spring, it had proportionately more collectors than any other site, and in the fall it had proportionately more scrapers than any other site. We do not yet have an explanation for this phenomenon.

Site E decreased in total number of individuals from spring to fall, and also decreased in total species richness. This difference may be explained, in part, by experimental error. The second sample collected from site E in August contained only four individuals, represented by two species, while the first sample contained 45 individuals represented by seven species. Since the two samples at each site were averaged, a poor second sample may partially account for the discrepancy.

Because of these two aberrations, a t-test comparing the means of the June and August samples was not significant ($P = 1.20$). This t-test compared the mean numbers of individuals of each sample period, not total numbers of individuals, and so the two negatively correlated sites skewed the outcome. A t-test run without data from sites C and E was significant ($P = .022$).

We discovered another surprising set of results when comparing inlets and outlets. The June outlets had fewer total individuals and lower species richness than the June inlets (79.5 individuals, 13 species at inlets; 69.8 individuals, 7 species at outlets; Figures 4 and 6). This difference is not a function of site, since the August inlets and outlets were consistent both in density and diversity. It may, however, be the result of unusual findings at the Lake Bemidji inlet (site E). During the spring, 123.5 individuals representing 13 species were present at site E. Only two sites in the survey were inlets, so when comparing means, site E had a greater effect on the resulting numbers than if it had been an outlet (and so averaged with 3 other sites).

Power Dam

The site downstream from the Power Dam does not fit the general pattern followed by the rest of the sites, but neither does it possess the same geomorphological features. Instead of being preceded by a natural lake with continuous river flow-through, it is preceded by a human-made lake with river flow determined by a dam. At this site, shredders did not dominate. In fact, no shredders were present until the fall sampling period, when they made up 14% of the sample (the smallest proportion of any of the samples). Instead, predators and collectors made up the majority of the samples from both spring and fall (Figure 7).

Water velocity was higher at the Power Dam than at most other sites. This may partially account for the lack of shredders due to detrital food sources being washed downstream. In the fall, when shredder numbers rose slightly, more macrophytes were present along the shoreline, possibly trapping and providing some detritus to shredders. However, other sites with comparable water velocity (Lake Plantagenet and Lake Marquette outlets) did not have lower proportions of shredders.

A more likely explanation of this result is that the Power Dam traps upstream detritus and prevents it from flowing downstream. Shredders do not have a food source until the fall, when autochthonous detritus becomes available. Akopian et al. (1999), noted that reservoirs (such as Stump Lake) serve as a source of zooplankton. Since the river flow is halted by the dam, zooplankton have a greater opportunity to proliferate than in lakes with continuous flow-through (Pace et al., 1992). The detritus trapped by the dam is likely consumed by shredders, which convert CPOM to FPOM (Petersen and Cummins, 1974; Cuffney et al., 1990). The water spilling over the dam is then rich in FPOM, thus increasing the number of collectors downstream. Predators increase as well, as diverse food sources arriving from the reservoir support a wide variety of potential prey.

Our study on the Schoolcraft /Mississippi river-lake system demonstrates that the density and diversity of riverine benthic macroinvertebrate communities increase temporally and differ spatially. Interruptions to natural flow (such as dams) change the composition of these communities. This study also shows that while lakes may affect the plankton dynamics of downstream lotic systems, other environmental factors are more important in determining the structure of the macroinvertebrate community. Stream order is one such environmental factor, and when continuous channel flow is maintained, stream order (as described in the RCC) is a viable method for predicting macroinvertebrate community structure in a river-lake system.

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