Mississippi Headwaters Community Structure:

A comparative study of the invertebrate community and its longitudinal diversity.

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Abstract

Inputs into riverine ecosystems are highly variable with respect to longitudinal location within the system. These inputs help to shape the animal community within the river or stream, and have been hypothesized to be correlated with invertebrate diversity and community composition (Rosi-Marshall and Wallace 2002). In order to test this relationship, we sampled the benthic invertebrate community from three reaches of the Mississippi River near and within Itasca State Park, Minnesota. These samples were used to quantify invertebrate diversity and functional feeding group types (FFG). Significant differences were found between the community composition of each site with the Headwaters site showing the highest levels of invertebrates which feed upon allochthonous material, and the Downstream site showing the highest amount of invertebrates which feed upon autochthonous material ($p=1.84*10^{-12}$). The Headwaters site also demonstrated the highest levels of community diversity, due to the myriad of niches created by varying river conditions. The results of this study suggest that the invertebrate community composition is dependent on the primary inputs into the system, whether from allochthonous or autochthonous sources.

Introduction

The Mississippi River runs 2320 miles from Itasca State Park to the Gulf of Mexico. As it runs from its headwaters to its mouth, the river provides habitat for a variety of organisms ranging in trophic level from producers to third order consumers. This community is not static, but is rather in constant flux with respect to time and longitudinal distance in the river (Vannote et al. 1980). At the headwaters of the Mississippi, where the order of the river is low (approximately 3rd order) (Schiedegger 1965), allochthonous inputs can be expected to supply most of the energy for invertebrate communities in the stream. However, as the river grows in order, more solar energy should reach the stream, resulting in greater primary autochthonous production (Vannote et al. 1980). This fundamental change in energy source should theoretically allow for a change in invertebrate community structure. For instance, the invertebrate community in a low order stream (the headwaters) is expected to feed mainly on detritus such as leaves and organic material entering the stream, and would therefore be classified as shredders and collection feeders. The downstream community would rely more heavily on autochthonous organic material grown within the margins of the stream and stream bottom, and fine particulate organic matter, and would be classified as grazing or scraping feeders. This change in the community should not affect the relative sizes of each trophic level. The ratio of predators to first order consumers should remain approximately the same due to consumers being dependent upon prey availability and not direct organic inputs (Vannote et al. 1980). However, the specific predator species present will likely change in response to the changing prey community.

With knowledge of invertebrate communities, their functional feeding groups and trophic status within river segments, we can begin to assess the quality of actual riverine habitats in comparison with ideal concepts presented in *The River Continuum* (RCC) (Vannote et al. 1980). This study looks at the proportions of allochthonous and autochthonous feeders both near the headwaters of the Mississippi and farther downstream, in order to form a comparison with concepts presented in RCC. We expect to see a greater proportion of invertebrates that feed on allochthonous materials, and lower primary productivity, near the headwaters and a greater proportion of invertebrates who consume autochthonous organic material, and higher primary productivity, farther downstream. If we see such a difference, it is likely to be caused by lower levels of sunlight reaching the headwaters area of the stream and more sunlight reaching downstream areas, enabling higher levels of photosynthesis. Thus, we hypothesize that we will find a higher percentage of organisms falling in the collector/filterer and shredder categories near the headwaters, and a higher percentage of scrapers in downstream areas. Predator levels will remain approximately constant throughout the study area. With this information on community structure in the relatively unpolluted and unchanged headwater areas of the Mississippi River, studies on areas farther downstream could utilize invertebrate communities as indicator organisms of habitat quality.

Methods

The methods and sampling techniques utilized to research invertebrate density and chlorophyll-a content were carried out using tools supplied by the Itasca Biological Field Station. In order to determine densities and feeding group types of invertebrates, samples were collected from three separate reaches of the Mississippi River within Itasca State Park. The sites consisted of the headwaters area (Headwaters), a culvert which runs under the main park drive (Midstream), and a canoe access point near highway 200 (Downstream). Pool and riffle sections were sampled in each reach and sites were sampled beginning downstream and moving upstream to avoid sample contamination. Each sample point was selected based on three criteria: adequate flow (stagnant side pools were not sampled), distance from the previous sample (no sample points overlapped and were far enough apart to avoid bias), and by classification (riffle or pool). D-framed nets were used to sample invertebrates which were buried in the sediments by placing the net into the substrate and disturbing the substrate directly upstream for one minute. Samples were then flushed from the net into stacked 10mm and 100mm sieves for collection. Water was flushed through the sieve in order to remove excess substrate. All invertebrates sighted were placed into labeled jars and preserved with a 70% ethanol solution. Eight invertebrate samples were collected from the Headwaters and Midstream reaches, while ten were collected from the Downstream reach. Invertebrates were brought back to the lab and separated in groups according to their functional feeding groups (Bouchard, 2004). These groups consisted of shredders, collectors, scrapers, collectors/scrapers, and predator/parasite.

A two meter measuring tape, stopwatch, and an orange were utilized to measure flow rates at three points in each site. The measuring tape was held just above the stream surface, while the time required for the orange to travel 2 meters was recorded. Flow was determined using the R=D/T equation, where R was the rate at which the water was moving (m/s), D was the distance traveled (2m), and T was the time it took to cover the 2 meter distance (s).

Chlorophyll-a samples were collected in each stream reach. Two clay pots were placed into the substrate directly across from one another at each site. Pots were marked using orange flags which were implanted into the substrate through each pot. After one week in the stream, pots were recovered and algae was collected from a 1x1cm area. Each 1cm^2 section was scoured with a wire brush and flushed into a collection container using distilled (DI) water. Samples were then filtered and analyzed using a spectrophotometer. Laboratory procedures developed by Holm-Hanson (1978) were utilized.

Results

Statistical significance was determined using a Chi-Squared analysis comparing specific feeding groups between the different sites (fig. 1, table 1). The main abundance differences were found in the shredder and scraper categories ($p=1.84*10^{-12}$). Scrapers, invertebrates which feed upon periphyton, were more prevalent at the Downstream site, while shredders, invertebrates which feed upon allochthanous coarse particulate organic matter (CPOM), were most prevalent at the Headwaters site.

The relative densities of the feeding groups at each site were determined. Feeding groups at the Headwaters site (fig. 2) were split almost evenly among three of the four first-level feeding groups, with scrapers making up only a small percentage. The Midstream site, on the other hand, was almost completely dominated by organisms which function as both collectors and scrapers (fig. 3). At the Downstream site, collector organisms and scraper organisms dominate at almost equal levels (fig. 4). The Headwaters site showed the highest functional feeding group (FFG) richness, which was verified by a comparison of richness on the Shannon-Weaver Index (fig. 5). In addition, relative predator densities were significantly higher at the Headwaters reach compared to the other two sites. This test returned a p-value of .022.

Mean flow velocities were also calculated within each reach. Eight velocities were obtained from the Headwaters reach with a mean velocity of 3.02 ± 1.75 $m*s^{-1}$, four from the Midstream reach with a mean velocity of 1.45 ± 0.143 $m*s^{-1}$, and three were obtained from the Downstream reach with a mean velocity of 3.72 ± 1.42 $m*s^{-1}$ (table 2). Variation in flow velocity between all three sites can be seen in table 2.

One primary productivity sample was recovered from the Midstream site, and two were recovered from the Downstream site. Primary productivity at the Midstream measured 3.99$ug*L^{-1}*day^{-1}$, and the average primary productivity at the Downstream site was 0.419 $ug*L^{-1}*day^{-1}$.

An appendix was assembled which illustrates particular species found, their abundance within each site, and their functional feeding group (app. 1).

Discussion

Upon analyzing the data collected from the Headwaters, Midstream, and Downstream reaches of the Mississippi, our hypotheses regarding community makeup and diversity were supported. The Headwaters site contained a significantly higher percentage of collectors/filterers while the Downstream site showed the highest percentage of scrapers. This directly supports the ideas presented by Vannote et al. (1980) in the RCC. The habitat within the Headwaters area of the Mississippi is more heterogeneous when compared to that of the Midstream and Downstream reaches, so these findings were expected (Minshall et al. 1985). Minshall et al. found the streams that exhibit many differing characteristics (flow, sinuosity, etc.) also tend to hold a higher abundance and diversity of organisms when compared to streams that offer fewer differing habitat types. The Headwaters area encompassed several bends with a wide variation in flow rates, while the Midstream and Downstream reaches were relatively straight with less variation in flow (Table 2). These stream characteristics lead to differing habitats, which allow for a larger diversity of species to occupy the same river section, whereas without these differences the community makeup would be expected to be more homogeneous (Minshall et al. 1985). Higher diversity within the Headwaters study site is confirmed by figure 5, a Shannon-Weaver index analysis of diversity. This observation also supports concepts related to the gradient of expected feeding groups throughout a stream’s course.

Our findings support our expectation, derived from the RCC, that we would see a shift in the relative densities of species from allochthonous feeders in lower stream orders, to more autochthonous feeders in streams of higher order (Vannote et al. 1980). Functional feeding groups can be seen to change with respect to relative density between reaches (Fig. 2, 3 and 4). Because the Mississippi headwaters is not a true headwaters stream according to the RCC (due to a lake being the point of origin), our findings do not exactly match the expected tendencies of a first order stream. That being said, we still found a gradual transition from allochthonous feeders in the headwaters to more autochthonous feeders in the Midstream and Downstream reaches. Because the lake contains phytoplankton which flow into the stream, we are able to see a greater diversity of feeding groups in the headwaters which typically would not be seen until the stream reached a higher order.

One of the key tenants of the RCC is that predator/parasite levels are expected to remain constant throughout each river reach (Vannote et al. 1980). This is because even though functional feeding groups may change throughout river reaches, the amount of prey for predators and parasites remains relatively constant. Specific predator species may change, but the proportion is expected to remain the same. Our study did not support this pattern. The Midstream reach showed a significantly higher amount of predator/parasites when compared to the other reaches according to an ANOVA test. Wellborn et al. (1996) found that dragonfly larvae (*Progomphus serenus*), a common predator, prefer habitats where they are able to swim and actively forage. The ability for larval species to swim is largely dependent on the water velocity in a particular stream reach. The Midstream reach had the lowest average flow rate, as well as the least variation between flow rates (table 2). These characteristics would have allowed the predatory dragonfly larvae to congregate in a larger area, and therefore exhibit higher densities when compared to the other reaches. Another reason for the inconstant proportion of predator/parasites may be that the heterogeneous makeup of the headwaters and Downstream reaches allow for higher prey evasion opportunities. Peckarsky (1982) found streams that exhibit differing flows and diverse habitats tend to display lower predator densities because prey organisms have more opportunities to escape. Soft and deep sediments that allow for burrowing are also shown to aid in prey evasion (Peckarsky 1982). The headwaters reach was found to be quite sinuous with many different flow velocities, and the Downstream reach had large regions of deep, silty sediments along its margins. The differing habitats between these sites may account for the lower proportion of predator/parasites found. In order to further explore the reasoning behind the transition from allochthonous feeding groups to more autochthonous groups, chlorophyll-a content was sampled in each reach.

Due to outside interference in the headwaters reach, chlorophyll-a sampling could only be performed at the two remaining sites. Although a definitive conclusion can not be drawn from the data obtained, the Midstream reach showed much higher rates of primary production compared to Downstream. The reasoning for this may be attributed to the lower mean flow velocity present in the Midstream reach, as well as the specific placing of each pot within the stream margin. The pots that were collected from the Downstream reach may have been affected by organisms present at the site. Pots gathered from the Midstream site were clean of debris, while the pots gathered from the Downstream site were covered in snails and other unidentified larvae. Because flow velocities over each specific pot placement were not collected, differing flows effect on algal growth cannot be determined. The placement of pots in each reach would need to be standardized in regard to flow and sediment type in order to achieve accurate results. Future research involving primary production in each reach must be a priority in order to solidify any findings related to invertebrate community composition.

The data collected through this study strongly supported our hypothesis that community structure would change from an allochthonous base near the Headwaters to an autochthonous base near Downstream. Although predator levels were higher at the Midstream site, they followed an expected pattern throughout the rest of the river, and the variance observed can be attributed to a local, time sensitive addition of dragonfly larvae. Overall, our observations closely followed predictions made using the concepts put forth in *The River Continuum Concept*. With further research, we would hope that these concepts could be used as indicators of river ecosystem health. For instance, the presence of a large, diverse community of benthic organisms increases nutrient cycling in streams (Covich et al. 1999). This increase in nutrient cycling should increase the overall health of the ecosystem, promoting even higher nutrient turnover rates. If the ecosystem is disturbed, polluted, or damaged in some way, this cycle would be disrupted. Thus, the health of the benthic invertebrate community is likely to be an effective indicator of overall ecosystem health.

Appendix I

Species observed in the Mississippi River throughout this study, and the feeding groups to which they belong:

Species Present	Total Observed	Feed Group Type
Aquatic Earthworm	7	Collector
Beetle	2	Predator
Bloodworm	173	Collector, Scraper
Clam	66	Collector
Cranefly	1	Shredder
Dragonfly Nymph	12	Predator
Horsehair Worm	2	Parasite
Leech	12	Parasite
Mayfly	55	Collector, Scraper
Narrow Wing Damselfly	2	Predator
Northern Case-Maker Caddisfly	175	Shredder
Shrimp	110	Collector
Snail	86	Scraper
Unidentifiable	9	

Acknowledgements

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Figures and Tables

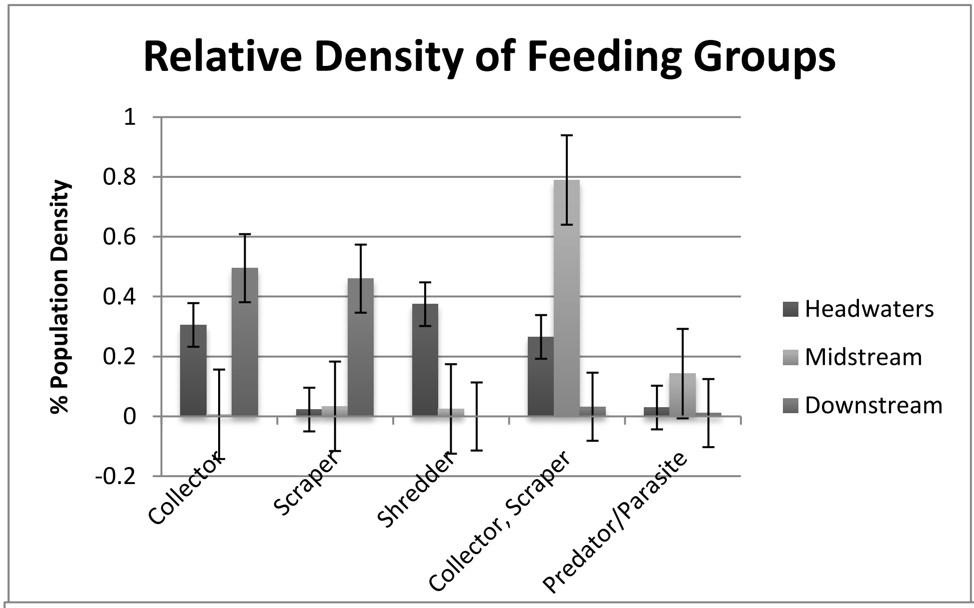

Figure 1. Comparative densities from each location arranged by feeding group. Error bars indicate ±1 SE.

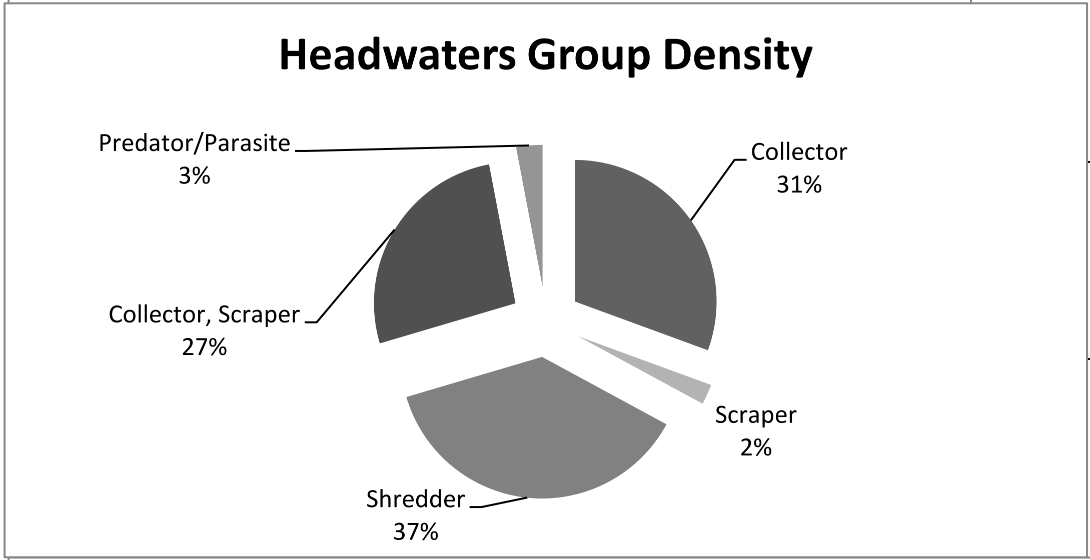

Figure 2. Feeding group density and diversity at the Headwaters site.

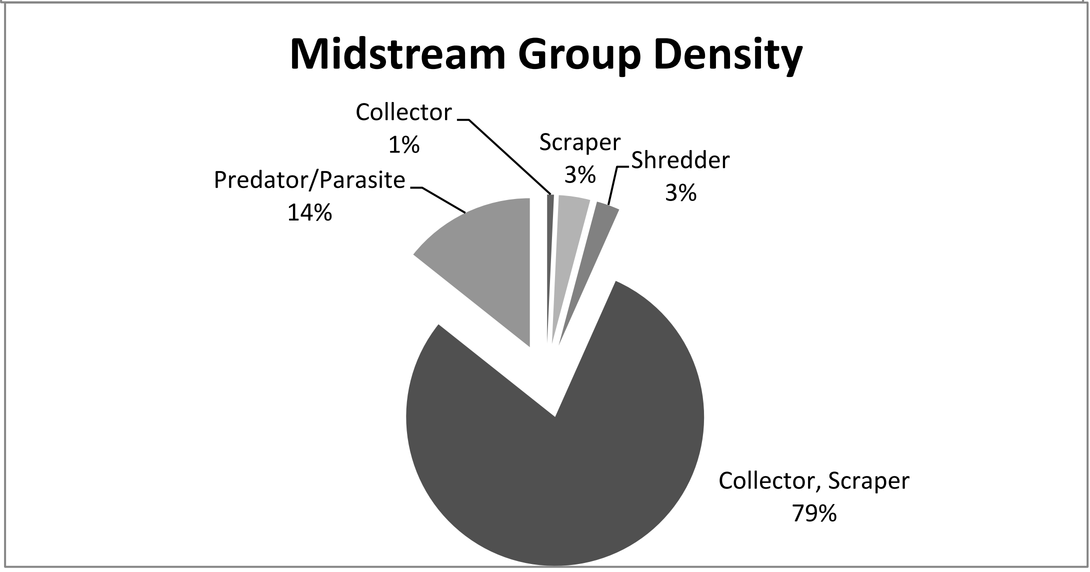

Figure 3. Feeding group density and diversity at the Midstream site.

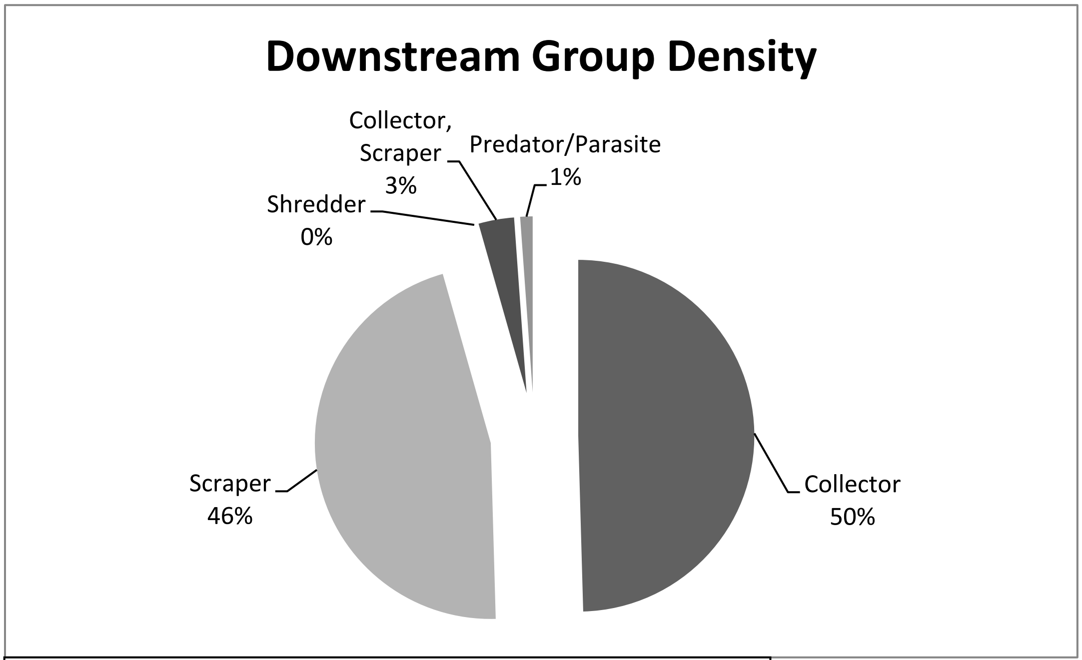

Figure 4. Feeding group density and diversity at the Downstream site.

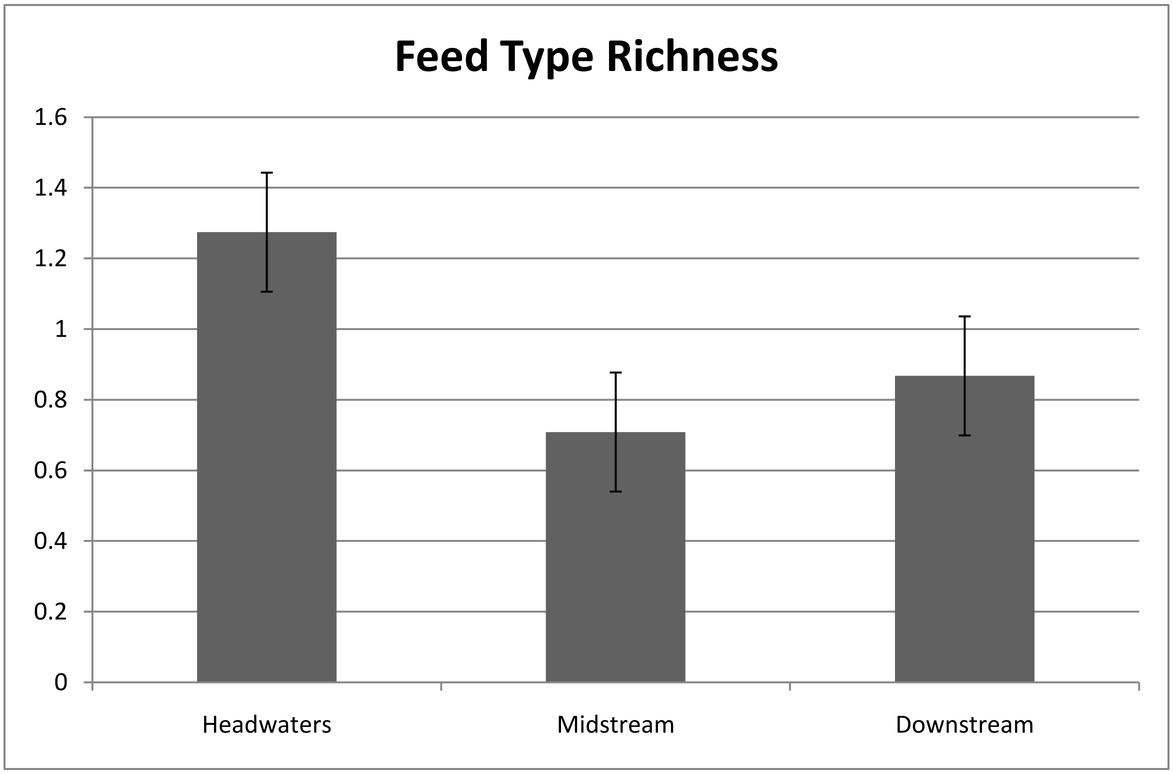

Figure 5. Diversity of feeding groups at the three sites, calculated using the Shannon-Weaver Index. Error bars indicate ±1 SE.

Table 1. Average counts by feeding group at each location, and values for a Chi-Square analysis of these data.

Feeding Group	Headwaters	Culvert	200
Collector	10.5	0.125	9.4
Scraper	0.625	0.375	7.8
Shredder	21.5	0.5	0
Collector, Scraper	13.875	13.25	1.1
	Chi-Square:	66.81	
	p-value	1.84E-12	

Table 2. Flow velocities at each study site and mean overall velocity for each.

	Headwaters	**Midstream**	**Downstream**
FLOW VELOCITY (m/s)	4.9	1.405	5.065
	2.83	1.265	3.86
	1.265	1.595	2.235
	6.375	1.515	
	1.985		
	2.64		
	2.58		
	1.58		
MEAN VELOCITY	3.019375	1.445	3.72