Spatial structuring of benthic invertebrate communities within and among wooded headwater stream networks

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ABSTRACT

Biotic communities in low order streams are influenced by multiple factors that may reflect both environmental conditions within individual watersheds, and also bio-geographic considerations such as spatial proximity of streams and organism dispersal/recruitment abilities. Prior work in small streams of Western New York (Allegheny Plateau) revealed little or no spatial structuring of biota among separate steams, but instead convincing effects of stream and watershed environmental factors. In this study, we further explored the roles of spatial vs. environmental influences by now comparing 1^{st} – 3^{rd}-order streams longitudinally within a stream network in addition to comparing physically separated streams. Within-stream drift adds a new dispersal dimension that is not present between streams. Four stream networks, each with a consecutive series of a 1^{st}, a 2^{nd}, and a 3^{rd}order segment, were selected in a contiguously wooded sector (2^{nd} growth through moderately disturbed old growth northern hardwoods) of Allegheny State Park near the Pennsylvania border. Three replicate Surber samples and a qualitative sample were collected from each stream site in fall 2010 and spring 2011. Similarity/dissimilarity among streams was explored by Euclidean distance matrices for community composition, stream/watershed environmental characteristics (in-stream habitat, watershed land cover, etc.), and spatial distance. Non-metric multidimensional scaling ordination of community composition and Principal Components Analysis ordination of environmental variables of the twelve stream segments were employed. Community composition of in-stream biota was based on the identification of 117 taxa representing fifty-three families. Spearman rank correlation indicated ten out of twelve of most abundant taxa were associated with the larger streams, trending away from the first orders. A One-Factor ANOVA of site-to-site biotic distances revealed no significant differences among longitudinal within stream pairings, like order pairings, and all possible remaining pairs. The streams in this study were quite readily grouped by ordination of the environmental variables, but this did not generally translate to biotic structuring. A significant partial correlation was, however, found between distances based on environmental "channel only "variables (i.e. not including watershed geography) and based on the biota within stream orders, when controlling for spatial distances. There was no evidence of spatial structuring of benthic communities. The macroinvertebrate community composition appeared to comply somewhat with the niche-based sorting theory and decidedly not with neutral theory/spatial autocorrelation. Continuing to decipher the dynamics of macroinvertebrate community composition can prove valuable to conservation and restoration approaches.

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TABLE OF CONTENTS

Spatial structuring of benthic invertebrate communities within and among wooded headwater stream networks

Sara Wright

ABSTRACT iii

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS vi

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER PAGE

I. INTRODUCTION 1
- Stream Systems 2
- Community Assembly Frameworks 2
- Benthic Invertebrate Movement 4
- Longitudinal Trends 5
- Allegany State Park 7
- Goals and Objectives 14

II. METHODS 15
- Habitat Characterization 15
- Benthic Community Sampling 17
- Statistical Analysis 19

III. RESULTS 21
- Characterization of Streams 21
- Macroinvertebrate Abundance 21
- Macroinvertebrate Community Composition 22
- Environmental Variables vs. Biota 22

IV. DISCUSSION 49
- Overall Macroinvertebrate Community Composition 49
- Influence of Environmental Variables 49
- Influence of Spatial 50

REFERENCES 53

APPENDIX A

Benthic macroinvertebrate taxa list from first sample date. 60

APPENDIX B

Benthic macroinvertebrate taxa list from second sample date. 97

LIST OF TABLES

Table 1. Watershed and habitat characteristics of study streams. 24

Table 2. Components of PCA from the environmental variables. 25

Table 3. List of abundance of collected taxa at each stream site, in order of overall 38

Table 4. Biological distance matrix. 37

Table 5. ANOVA table comparing the different groupings of streams. 38

Table 6. Correlations for environmental variables with NMDS dimension scores. 43

Table 7. Spatial distance matrix. 45

Table 8. Environmental distance matrix. 46

Table 9. Channel distance matrix. 47

Table 10. Partial correlations of distance matrices for all possible pairings of stream sites. 48

LIST OF FIGURES

Figure 1. Regional location of Allegany State Park, New York. 9

Figure 2. Locations and proximity of study streams. 10
Figure 3. Pictures of a 1st, 2nd, and 3rd order stream (respectively) from study sites. 11

Figure 4. Watershed areas of study streams 16

Figure 5. Pictures of sampling. 18

Figure 6. PCA ordination plot of environmental variables. 26

Figure 7. Ordination plot including all identified taxa of benthic aquatic macroinvertebrates. 36

Figure 8. "Loadings" for the upper quartile of taxa on ordination plot by the Order Ephemeroptera. 39

Figure 9. "Loadings" for the upper quartile of taxa on ordination plot by the Order Plecoptera. 40

Figure 10. "Loadings" for the upper quartile of taxa on ordination plot by the Order Trichoptera. 41

Figure 11. "Loadings" for the upper quartile of taxa on ordination plot by the Order Coleoptera. 42

Figure 12. Loadings" for the environmental variables onto NMDS ordination plot. 63

I. INTRODUCTION

The eastern United States has been affected by human disturbance in many ways, so streams in this area have been recovering from varying degrees of disturbance for some time now. Streams are dynamic, complex mosaics of habitat types and environmental gradients which are characterized by high connectivity and spatial complexity. Disentangling the variance within and between streams can therefore be complicated. Examining community composition is one way of assessing how these systems respond to both natural and anthropogenic changes across multiple scales.

Benthic community structure can be an important indicator of ecosystem health because aquatic benthic macroinvertebrates have specific tolerances for water conditions (i.e. changes in dissolved oxygen content), relatively short life cycles, and slower dispersal rates compared to other stream biota such as fish (Rosenberg & Resh, 1993). Specific changes in community composition can reliably indicate stream degradation. For example, decreases in Plecoptera (stoneflies), which are usually restricted to clean, cool running waters with high dissolved oxygen content, can indicate degradation of ecosystem quality (Bouchard, Jr., 2004). This decrease is usually associated with a corresponding increase in Chironomid larvae, which are particularly tolerant to highly polluted environments with low dissolved oxygen levels (Bouchard, Jr., 2004). Environmental contaminants can reduce detritus processing by decreasing the abundance or feeding activity of detritivores. The feeding rate of *Gammarus pulex* (Amphipoda), a detrivore, has been observed to decline downstream of motorway discharge (Forrow & Maltby, 2000). Another indicator of poor ecosystem health is the presence of specimens of certain Chironomidae (aquatic midges) larvae with morphological deformations, which are most likely attributed to the accumulation of heavy metals and other mutagens, (Diggins & Stewart, 1993).

Stream Systems

Lotic habitats are dependent on the flow and subsequent patterns of water in a stream (Hynes 1970). Streams are categorized by order, which reflects the progression in size from a small tributary to large river. A stream with no tributaries is a first order stream (Strahler, 1957). A first order stream is in fact a tributary, usually with a steep gradient. A second order stream is the convergence of two first order streams. The junction of two second order streams forms a third order stream and so on. First through 3rd order streams are known as headwater streams and constitute the waterways in the upper reaches of the watershed. Anything larger than a 6^{th} order is usually referred to as a river. The Ohio River is an eighth order stream while the Mississippi River is a tenth order stream (Benke & Cushing, 2005). The world's largest river, the Amazon, is considered a 12th order. Stream discharge, channel size, and watershed area are directly proportional to stream order within any given river corridor (Strahler, 1957).

Community Assembly Frameworks

There are two main theories used to describe community structure. The first is the niche theory, which postulates that communities are structured by local ecological factors (Tilman, 1982; Chesson, 1991; Chase & Leibold, 2003). The theory suggests that community similarity is positively associated with similarity in the local environment or habitat conditions. Neutral theory, in contrast, posits that communities are structured entirely by drift, migration, and/or speciation (Hubbell 2001) and is based on the concept that all species are ecologically equivalent (Bell, 2001; Chave, 2004). According to the neutral theory, community similarity decreases as distance between sites increases.

It has been suggested that there may be interplay between the two seemingly competing theories in determining local patterns of diversity. Thompson and Townsend (2006) examined macroinvertebrate data from 10 streams varying in environmental conditions and spatial proximity to determine what was driving community composition. The researchers found that both niche and neutral processes structured communities of invertebrates possessing low to moderate dispersal ability, while communities of invertebrates with high dispersal abilities were not predicted well by either theory. The low to moderately dispersing communities were structured by both niche and neutral processes depending on trophic level and species trait. Therefore, local patterns of diversity can be explained by both environmental factors and dispersal processes.

Spatial autocorrelation is any systematic pattern in the spatial distribution of a variable (Legendre, 1993). Nearby or neighboring areas that are more alike are positively spatial autocorrelated. This concept needs to be taken into account when conducting analyses which assume that samples are independent of one another. If there is spatial autocorrelation some spatial variable is actually contributing to the pattern of results. Geographic proximity has been found by some studies to be more important than regional landscape variables in structuring stream invertebrate assemblages (Hawkins & Vinson, 2000; Mac Nally, Lloyd, & Lake, 2006; Grenouillet et al., 2007).

However, other studies have demonstrated that similarities between streams' benthic invertebrates are not necessarily related to spatial autocorrelation (Lloyd, Mac Nally, & Lake, 2005; Heino and Mykra, 2008; Diggins & Newman, 2009). Diggins and

Newman (2009), in western New York, examined watershed and habitat characterization in addition to biological sampling and found no predictable spatial autocorrelation among the streams of the study area. Spatial variation had no association with the results of the biological sampling, countering dispersal-based neutral theory as a major factor in community composition organization. The study revealed instead that benthic community composition was associated, although modestly, with environmental factors (i.e. watershed and habitat characterization). Therefore despite a stream's proximity to its neighbors environmental filters are operating at the individual stream scale providing evidence for a niche-based species sorting (Diggins and Newman, 2009).

Benthic Invertebrate Movement

There has been extensive research on benthic invertebrate movement in rivers (Lloyd, Mac Nally, & Lake, 2006). Movement can consist of drifting, flight, and crawling. The downstream transport of aquatic organisms in the water column is known as 'drift' (Brittain & Eikeland, 1988). This process has been suggested to regulate upstream biota by preventing overabundance of organisms. Drifting and flight are highly variable, but sites more than a few kilometers apart may be the upper limit of travel (Bilton, Freeland, & Okamura, 2001). Communities of aquatic organisms are thought to be found throughout the longitudinal life of a stream due to the assistance from the water flow. Benthic communities are affected by the downstream movement of stream currents in two ways (Townsend & Hildrew, 1976): 1) The density of the benthic community is reduced by loss into the water column, and 2) the invertebrates are continuously settling out from the drift, therefore affecting colonization. These two effects lead to a continuous redistribution of benthic invertebrates downstream. In addition to mating, the purpose of flight for most invertebrates is to attempt to find ideal conditions for oviposition. For most invertebrates oviposition and subsequent hatching is concentrated to a stream's upper reaches (Muller, 1954).

Longitudinal Trends

According to the River Continuum Concept (RCC) rivers and streams are considered to be longitudinally linked where the downstream processes are associated with those upstream (Vannote et al. 1980). The RCC suggests that there is a consistent pattern of adjustments of organic matter along the length of the river. Therefore, there is a balance of energy input and output along a river's continuum. The organization of macroinvertebrates depends mainly on environmental variables (e.g. substrate types, instream cover, and altudinal gradient) and spatial heterogeneity. Community structure can be seen as synchronized replacement where organisms drift from upstream, settling out of the water column along the way, and migrating back upstream for oviposition (Minshall et al., 1985). Variable habitats are seen in the progression of headwaters to higher order reaches, each of which can be fit into a template. These templates have patterns of community composition both in terms of species diversity and for specific functional groups. The RCC predicts that macroinvertebrate assemblages change gradually from headwaters to large rivers downstream and headwaters with streambed slopes greater than 10% provide a best fit for RCC predictions in benthic macroinvertebrate data (Brussock & Brown, 1991). Despite the fact that the RCC was derived primarily from forested streams in North America, it has been widely used as a framework for explaining changes that occur longitudinally (Ward, 1986).

Grubaugh et al. (1996) examined longitudinal changes in community structure (richness, mean annual abundance, and biomass of benthic taxa) in habitats along a first- through seventh-order stream continuum in the southern Appalachian Mountains. The researchers examined variations in community composition due to changes in elevation and stream size. Influence of local stream geomorphology on taxonomic structure was demonstrated in mid-order reaches by greater biotic replacement and higher taxon richness. These mid-order reaches seemed to represent a transitional area between the steeply sloped higher elevation streams and shallow sloped streams of low elevation. When functional feeding-group composition (i.e. shredders, grazers, predators, etc.) data were analyzed, results indicated effects of environmental characteristics of specific habitats, such as catchment size and habitat availability. Longitudinal patterns in abundance and biomass-based estimates generally agreed with those predicted by RCC.

Finn and Poff (2005) examined benthic communities along four different streams in the Rocky Mountain region of Colorado. The researchers were interested in comparing the effects of longitudinal position and physical variables on community composition. It was determined that longitudinal position of the particular site was the most important factor in community composition when looking at taxonomy, but altitude explained more variance than reach-scale physical habitat.

Heino et al. (2005) examined headwater streams (1st and 2nd orders), mid-sized rivers (3rd order), and main channel sections (5th order) in a boreal watershed in Finland and found that stream size was the major factor influencing community composition. There was an increase in species richness as stream size progressed. The researchers did not find any species restricted to the headwaters, but mid-sized riffle samples contained mayfly species not found in the smaller headwaters.

Most studies investigating the longitudinal trends of a river or stream have been conducted on mountain systems with altitudinal gradients, ranging from 410 to 1250 meters (Hawkins & Sedell, 1981; Younes-Baraille, Garcia, & Gagneur, 2005; Finn & Poff, 2005; Turner, Williams, & Alkins-Koo, 2008; Jacobsen et al., 2010). There is a shortage of research on longitudinal trends associated with more modest altudinal gradients. Also, despite numerous studies on community composition conducted over large spatial scales, those examining longitudinal patterns within a small region are scant. It is (implicitly) assumed that because biotic gradients tend to be associated with certain environmental gradients, streams within a region that are physically similar might possess analogous longitudinal biological patterns (Finn & Poff 2005). Microhabitat studies have found differences in community composition from one rock to another within the same riffle of a stream (Downes et al., 1993). Therefore, it is may be advantageous to examine community structure within first, second, and third- order streams in order to determine whether there is justification for groups these all together under one heading, "headwaters", as is suggested by the RCC.

Allegany State Park

Allegany State Park, located in southwestern New York (42° 0' N / 78° 45' W) just north of Allegheny National forest comprises 65,000-acres and is the largest state park in New York (New York State Office of Parks, Recreation and Historic Preservation, 2011) (Fig. 1). The park area is a dissected plateau that is known for its primitive, forested valleys and unglaciated landscape. The area experienced light to heavy logging in the 20th century. The heavy cutting of hardwoods provided ideal conditions for fires, which eliminated white pine and greatly reduced hemlock in most of the forest (World Wildlife Fund, 2001). Therefore, the area now contains only pockets of old growth, totaling approximately 2.8 km^2 (700 acres), among modest secondary growth.

Four streams within Allegany State Park were chosen for study: France Brook (FB), English Creek (EC), Red House Brook (RHB), and Stony Brook (SB) (Fig. 2). Each of the streams had 1st, 2nd, and 3rd orders that were able to be traveled to for study (Fig. 3). These streams were relatively close to one another, the farthest distance being 8.3 kilometers between EC 3rd order and RHB 1st order.

Figure 1. Regional location of Allegany State Park, New York.

Figure 2. Locations and proximity of study streams.

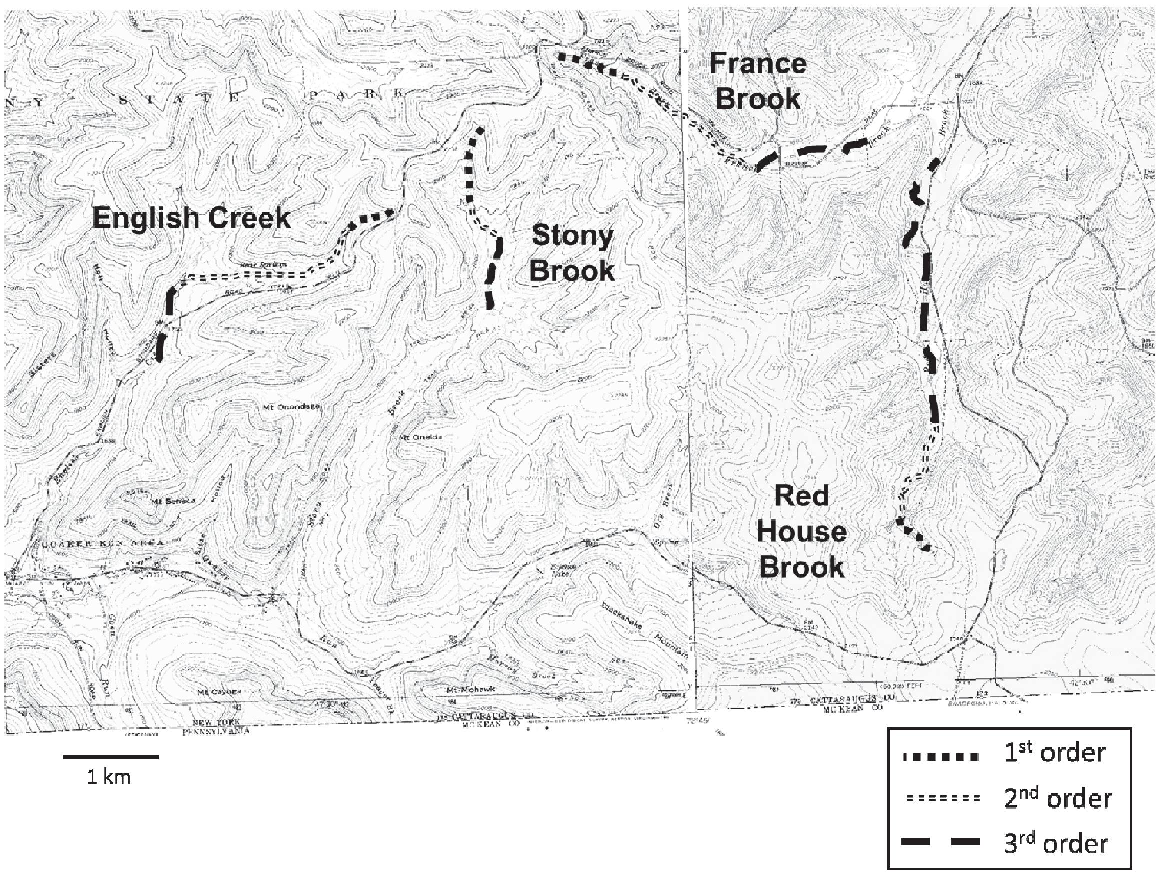
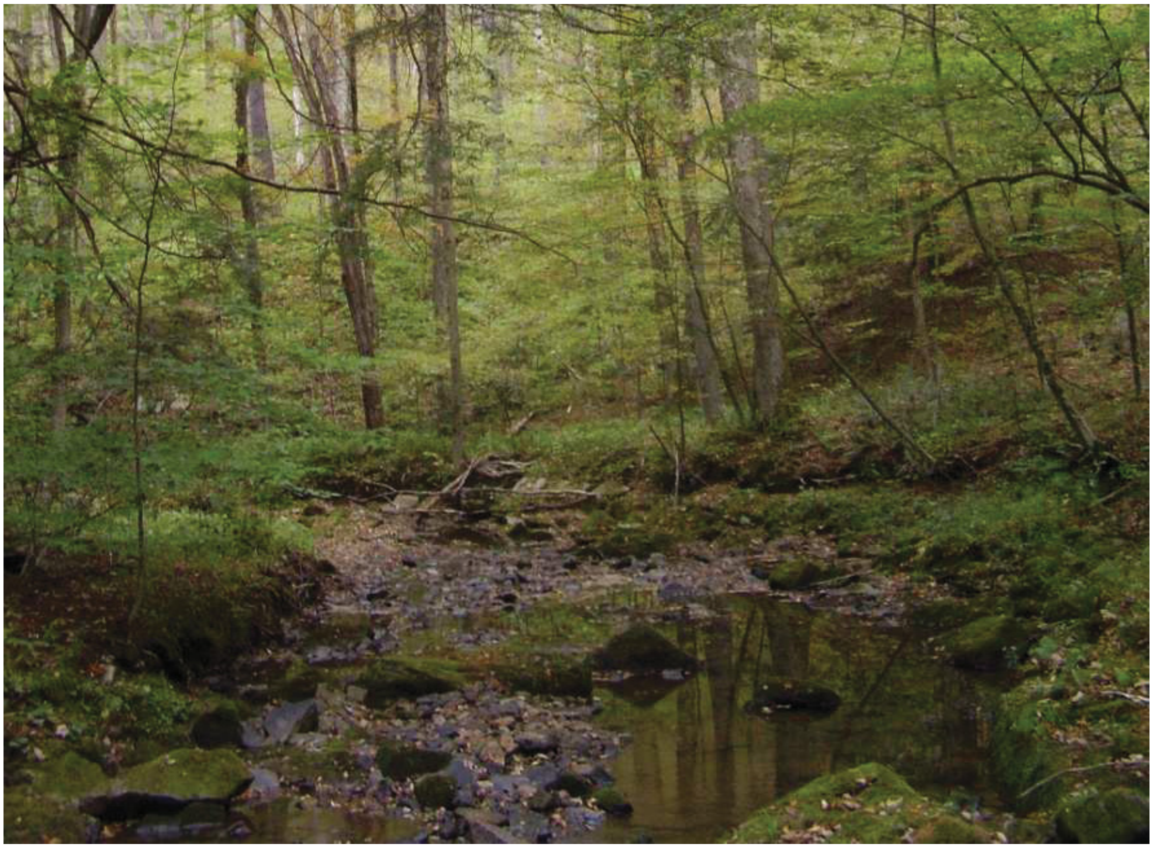


Figure 3. Pictures of a 1st, 2nd, and 3rd order stream (respectively) from study sites.

3 a. 1st order.

3 a. 2nd order.



3 c. 3rd order.

Goals and Objectives

The current study investigated the longitudinal structuring of benthic invertebrate assemblages in streams in Allegany State Park in New York and is a corollary to the study conducted by Diggins and Newman (2009) in which the researchers compared stream community composition to watershed characteristics of separate individual streams in the Zoar Valley study area. The current study built on that of Diggins and Newman (2009) by comparing stream orders longitudinally within watersheds, in addition to comparing among watersheds. In addition, the study area appeared to contain more homogeneous habitat and watershed characteristics (reducing their impact as potential variables) as opposed to the environmental variability found among the watersheds around Zoar Valley.

The current study quantified environmental and habitat quality in addition to biogeographic dynamics in order to look at their interplay and how they influence biological community composition. The goal of the current study was to determine whether there was biotic similarity within each stream system (e.g. isolated 1st order tributary and its higher order trunk streams) or similarity between similar orders of physically separate streams (e.g. 2 isolated 1st order streams). The objectives were to 1) compare 1st, 2nd, and 3rd order communities within one stream to one another, 2) compare like stream orders among independent streams, and 3) compare the trends in benthic fauna among streams to the longitudinal trends within the streams. Within-stream drift and juvenile migration add new dimensions to longitudinal community organization that do not influence laterally adjacent streams where emergence and aerial dispersal represent the major route to biotic similarity (Diggins and Newman, 2009). Therefore, the main question addressed was proposed by Diggins and Newman (2009): “Would fauna of first-order tributaries share more compositional similarity with their higher-order trunk streams, or with other nearby but physically separate first-order streams?"

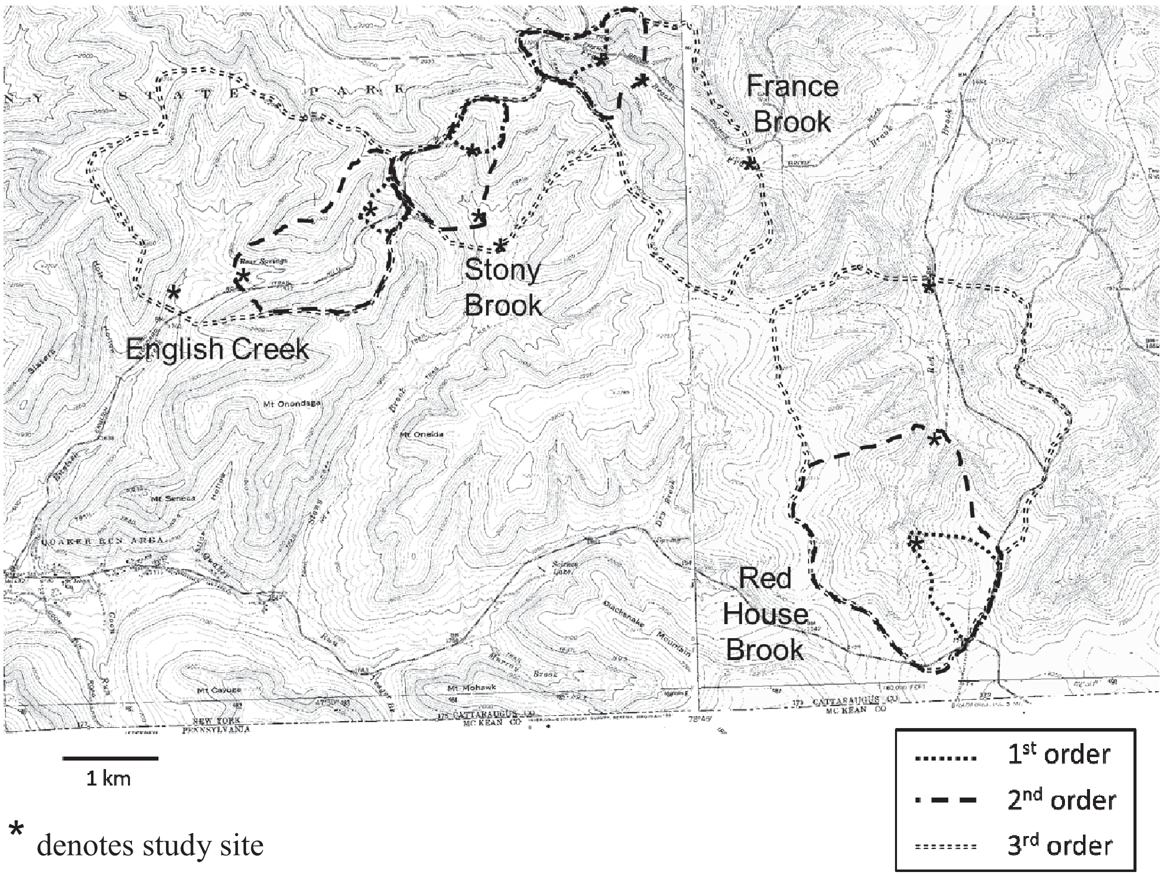
Biotic communities in low order headwater streams can be influenced by multiple factors that may reflect ecological conditions within individual watersheds (Vinson, 1998).

II. METHODS

Habitat Characterization

Watershed delineation, including stream gradients, was assessed by examination of a USGS 1:30,000 quadrangle topographic map and a planimeter (Fig. 4). Habitat conditions of streams were assessed using a Qualitative Habitat Evaluation Index (QHEI; OhioEPA 2006), which provides a comparative measure of habitat quality. Parameters evaluated included substrate type, instream cover, sinuosity, channel morphology, stability, riparian zone, bank erosion, pool and riffle quality, as well as the gradient of each stream site. The health of the habitats was evaluated by the sum of scores obtained from the parameters with a maximum score of 100 and minimum of 0. Based on criteria from the Ohio EPA, scores can be divided into four categories: poor (< 66), fair (66-81), good (82-98), and excellent (>98). The QHEI scores are often employed to assess fish habitats, and consequently tend to be relatively biased for larger streams.

Figure 4. Watershed areas of study streams.



* denotes study site

Benthic Community Sampling

Benthic macroinvertebrates were sampled in fall 2010 and spring 2011 in each stream in order to avoid exclusion of insect taxa that might be missed on a single sample date. Three replicate Surber samples (30 x 30 cm, 500-µm mesh) were collected from each study site of each stream on each date (a total of 36 samples on each of the dates). The substratum within the sampler frame was agitated for 2 min, and organisms and debris were cleaned off of larger cobbles as completely as possible (Diggins & Newman, 2009). In addition to the Surber samples, a qualitative sample was taken at each site where rocks from within the sample area of the full range of size present were collected for ten minutes and rinsed in a bin (Fig. 5). Surber net contents and contents from the qualitative sample were then preserved in 70% ethanol in the field (Doviak & Perry, 2002). Macroinvertebrates were sorted from the preserved samples in the laboratory under illuminated 3x magnifiers. Invertebrate taxa were identified at7-40x magnification to the lowest practical level using general and order/family-specific taxonomic keys (e.g., Pennak, 1953; Pecharsky et al., 1990; Merritt & Cummins, 1996). Voucher specimens for any identified taxa may be obtained from the collections presently stored in 70% ethanol.

Chironomids were prepared and slide mounted as described by Diggins and Stewart (1993, 1998). Head capsules were separated from the body and digested using warm 10% KOH for 15 minutes, after which they were permanently slide mounted in Canada balsam. Chironomid slides are also being stored as voucher specimens.

Figure 5. Pictures of sampling.

Statistical Analysis

The statistical analyses conducted in this study are similar to those conducted by Diggins and Newman (2009). Macroinvertebrate taxon abundances from both sample dates and replicates were totaled at each stream to yield whole season abundance data for each taxon for each site.

The abundance data were used to generate ordination by Non-metric Multidimensional Scaling (NMDS) (SPSS 13.0, alscal algorithm). NMDS ordination reveals degree of similarity or dissimilarity among samples by condensing multiple variables into statistically derived dimension "scores" that can be graphed onto a pair of axes. NMDS is preferred to Principal Components Analysis (PCA) when analyzing biological data as it is more robust in the face of non-monotonic taxon distribution data. PCA is useful when variables are linearly related to each other (e.g. environmental gradients), but biological data are frequently nonlinearly related (Palmer, 2011). NMDS has been widely used in ecology in the analysis of species distributions (Bowman, 1987; Baber et al., 2002; Weilhoefer and Pan 2006), including benthic macroinvertebrate community composition (Boulton et al., 1992; Mykrä, Heino, & Muotka, 2004). PCA was run to look for similarities among stream sample sites based on environmental characteristics (i.e. QHEI scores and watershed area).

After the NMDS biotic ordination plot was generated, Spearman correlation coefficients, which are the statistical analog of "loadings" generated by eigenvector-based analyses such as PCA, were calculated to compare original species abundances to NMDS dimension scores to assess the influence of the abundances on the ordination axes.

A Euclidean distance matrix of stream community composition was generated in order to quantify separation in ordination space between the pairings of individual streams sites. The distances from the biota distance matrix were placed into groups:

1. All longitudinal pairings within each stream (1st order to 2nd and 3rd of same stream)
2. All like order pairings (1st order to other 1st orders
3. All possible remaining pairs (i.e. neither of the same stream order nor within the same stream corridor)

A One-factor ANOVA was run to investigate whether biotic distances within any of these groupings differed from distances within any other grouping

Additional Euclidean distance matrices were constructed to quantify separation of the streams in environmental and geographic spaces, resulting in four distance matrices:

1. Biotic distance matrix
2. Geographical distance matrix
3. Environmental distance matrix
4. Channel distance matrix (not including environmental variables associated only with the watershed and not specifically with the channel where sampled)

The score from each of these matrices were broken into the previously mentioned three groups, with an additional group for all possible pairings of streams. The groups of scores were compared by partial Spearman correlations. The remaining pairs grouping was not expected to show any association that is not explained by the association of all pairs (group 1).

III. RESULTS

Characterization of Streams

Total (i.e. 1-3 orders) areas of the individual study stream watersheds ranged from 210 ha - 862 ha (Table 1). The largest watershed of each order was found in Red House Brook. The watershed relief: area ratios ranged from 0.2 m/ha in Red House Brook's third order to 2.2 m/ha in Stony Brook's first order.

The QHEI scores were variable, ranging from 51-79 (Table 1). The habitat obtaining the lowest score was the first order stream of Stony Brook, while the highest score was obtained from Red House Brook's third order stream.

An estimate of overstory stand age for hardwoods surrounding each sampling location was determined in addition to the percentage of hemlock old growth within the riparian zone (Table 1). Overstory stand age ranged from 60 years in English Creek's third order to 250 years (i.e. old growth hardwoods) in Red House Brook's first and second orders. The highest percentage of hemlock old growth (80%) was also found in Red House Brook's first and second orders (Table 1).

Principal Components Analysis revealed that two components (Table 2) explained a cumulative variance of 86%, with the list component alone only explaining 55%. An ordination graph was generated using Component 1 and 2 derived from PCA (Table 2). The graph shows substantial clustering by stream order (Fig. 6).

Macroinvertebrate Abundance

Community composition of in-stream biota was based on the identification of 117 taxa representing fifty-three families (Appendix A and B). The 30 most abundant taxa (i.e. the upper quartile) represented macroinvertebrates from the orders Coleoptera (beetles), Ephemeroptera (mayflies), Plecoptera, Trichoptera (caddisflies), and Diptera (true flies) (Table 3).

Macroinvertebrate Community Composition

An ordination graph was generated deriving NMDS Dimensions 1 and 2 from the macroinvertebrate taxa of the streams. This ordination (Fig. 7) included stream site averages from all replicates for all taxa from both sampling dates. Three out of the four first order streams were distributed to the right of the y-axis. Another trend was seen in the lower left hand quadrant where the streams associated with large amounts of old growth were found. The One-Factor ANOVA on the biological distance matrix (Table 4) revealed no significant differences between any of the groupings (i.e. longitudinal within stream pairings, like order pairings, and all possible remaining pairs) (Table 5).

Spearman correlation of taxon abundance (only the upper quartile) with dimension scores (i.e. "loadings") revealed taxa from four orders that were significantly correlated ($p < 0.05$) with either Dimension 1 or 2 or with both. These taxa included four genera of the order Ephemeroptera (Fig. 8), four genera of Plecoptera (Fig. 9), two genera of Trichoptera (Fig. 10), and two genera of Coloptera (Fig. 11). Chironomids of the Diptera were not significantly associated with axes.

Environmental Variables vs. Biota

A two-tailed Spearman correlation of environmental variables from Table 1 with the NMDS dimension scores revealed only one variable to be significantly correlated ($p < 0.01$) with Dimension 1 (Table 6). Given the reasonable directionality expected for watershed area and watershed relief ratio (i.e. they both varied relatively predictably with stream order), a one-tailed Spearman correlation was run and revealed these variables to also be significantly correlated ($p < 0.05$) with Dimension 1 (Fig. 12). There were no variables significantly associated with Dimension 2.

Partial Spearman correlations among biotic, spatial, environmental, and channel distances (Tables 4, 7, 8, & 9) revealed a significant relationship ($p < 0.05$) between biota and channel variables for stream order when controlling for spatial distance (Table 10). Channel variables were the environmental variables from Table 1 without watershed area, watershed relief, and relief: area ratio. No other significant partial correlations were found.

Table 1. Watershed and habitat characteristics of study streams.

Stream-Order	**QHEI**	**QHEI Reporting**	**gradient (ft/mi)**	**hardwood overstory stand age est.**	**hemlock old growth (%)**	**watershed area (ha)**	**watershed relief (m)**	**watershed relief:area (m/ha)**
FB 1	63	poor	320	80	0	49	85	1.7
FB 2	69	fair	210	100	25	103	110	1.1
FB 3	68	fair	105	80	25	379	149	0.4
EC 1	54	poor	350	110	0	33	67	2
EC 2	77	fair	210	110	50	187	116	0.6
EC 3	78	fair	140	60	25	608	146	0.2
RHB 1	69	fair	530	250	80	64	88	1.4
RHB 2	65	poor	140	250	80	354	131	0.4
RHB 3	79	fair	210	100	50	862	165	0.2
SB 1	51	poor	460	100	0	28	61	2.2
SB 2	68	fair	175	80	0	108	94	0.9
SB 3	67	fair	140	80	25	210	104	0.5

Table 2. Components of PCA from the environmental variables.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	3.280	54.666	54.666	3.280	54.666	54.666
2	1.882	31.369	86.035	1.882	31.369	86.035
3	.472	7.870	93.905			
4	.318	5.295	99.199			
5	.031	.516	99.716			
6	.017	.284	100.000			

Original component loadings

	Component	
	1	2
QHEI	.885	.040
gradient	-.748	.447
hardwood stand age	-.049	.971
hemlock old growth	.502	.856
watershed area	.848	-.069
relief ratio	-.982	.025

Figure 6. PCA ordination plot of environmental variables. Ellipses encompassing like orders.

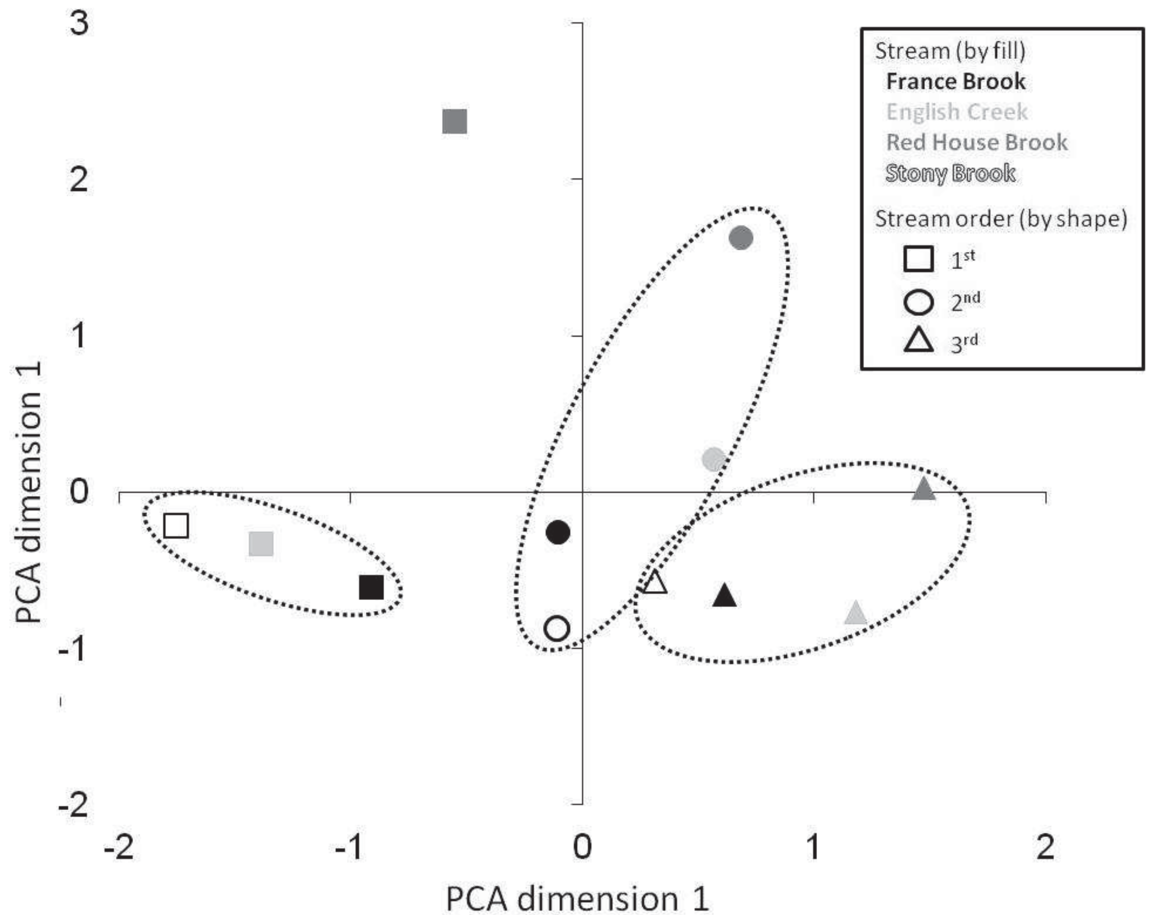


Table 3. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Coleoptera	Ephemeroptera	Plecoptera	Plecoptera
		Family	Elmidae	Leptoplebiidae	Capiidae	Perlodidae
		Tribe				
Stream	**Order**	**Genus**	Ancyronyx	Paraleptoplebia	Allocapnia	Remenus
FB	1		6	6	1	11
FB	2		33	31	13	13
FB	3		52	120	119	21
EC	1		8	11	13	12
EC	2		160	50	18	44
EC	3		113	58	10	47
RHB	1		145	7	76	74
RHB	2		306	14	46	51
RHB	3		149	87	12	7
SB	1		9	42	57	36
SB	2		92	45	30	33
SB	3		201	85	132	54

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Plecoptera	Trichoptera	Ephemeroptera
		Family	Chloroperlidae	Hydropsychidae	Leptoplebiidae
		Tribe			
Stream	**Order**	**Genus**	Suwallia	Parapsyche	Neochoroterpes
FB	1		34	24	5
FB	2		47	21	7
FB	3		39	6	24
EC	1		24	64	37
EC	2		18	77	74
EC	3		15	33	25
RHB	1		26	17	4
RHB	2		36	13	9
RHB	3		23	17	38
SB	1		55	10	11
SB	2		7	15	27
SB	3		27	20	41

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Diptera	Trichoptera	Plecoptera	Ephemeroptera
		Family	Chironomidae	Hydropsychidae	Leuctridae	Heptageniidea
		Tribe	Orthocladiinae			
Stream	**Order**	**Genus**	Eukiefferiella	Hydropsyche	Leuctra	Epeorus
FB	1		146	0	0	2
FB	2		19	6	1	64
FB	3		8	20	22	18
EC	1		0	16	2	0
EC	2		13	48	7	15
EC	3		8	5	3	22
RHB	1		22	17	61	2
RHB	2		8	14	38	14
RHB	3		8	42	14	57
SB	1		3	9	44	4
SB	2		8	36	14	3
SB	3		1	30	36	3

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Ephemeroptera	Trichoptera	Ephemeroptera
		Family	Heptageniidea	Polycentropodidae	Ephemerellidae
		Tribe			
Stream	**Order**	**Genus**	Stenonema	Neureclipsis	Drunella
FB	1		1	11	0
FB	2		11	4	0
FB	3		2	13	43
EC	1		21	6	0
EC	2		29	18	4
EC	3		17	10	0
RHB	1		18	11	0
RHB	2		14	19	0
RHB	3		12	64	1
SB	1		18	17	42
SB	2		8	9	53
SB	3		36	4	39

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Diptera	Ephemeroptera	Ephemeroptera
		Family	Chironomidae	Heptageniidea	Ephemerellidae
		Tribe	Orthocladiinae		
Stream	**Order**	**Genus**	Orthocladius	Cinygmula	Serratella
FB	1		89	4	1
FB	2		60	64	56
FB	3		4	23	5
EC	1		0	9	20
EC	2		14	28	4
EC	3		5	22	9
RHB	1		1	0	1
RHB	2		0	8	1
RHB	3		0	0	3
SB	1		0	1	22
SB	2		2	4	10
SB	3		2	3	9

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Trichoptera	Trichoptera	Coleoptera
		Family	Polycentropodidae	Hydropsychidae	Elmidae
		Tribe			
Stream	**Order**	**Genus**	Polycentropus	Arctopsyche	Rhizelmis
FB	1		1	7	0
FB	2		2	10	0
FB	3		6	0	10
EC	1		7	43	0
EC	2		8	47	31
EC	3		9	14	2
RHB	1		17	6	13
RHB	2		12	4	26
RHB	3		11	1	20
SB	1		31	1	0
SB	2		13	0	0
SB	3		23	1	32

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Plecoptera	Trichoptera	Plecoptera
		Family	Perlodidae	Glossosomatidae	Nemouridae
		Tribe			
Stream	**Order**	**Genus**	Skwala	Glossosoma	Amphinemura
FB	1		7	0	0
FB	2		8	0	7
FB	3		2	9	25
EC	1		9	0	0
EC	2		10	3	12
EC	3		6	61	2
RHB	1		17	0	4
RHB	2		12	0	14
RHB	3		0	6	0
SB	1		37	1	23
SB	2		6	36	15
SB	3		15	12	19

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Plecoptera	Ephemeroptera	Ephemeroptera
		Family	Chloroperlidae	Ephemerellidae	Baetidae
		Tribe			
Stream	**Order**	**Genus**	Sweltsa	Ephemerella	Baetis
FB	1		7	0	0
FB	2		22	3	0
FB	3		3	13	41
EC	1		21	0	2
EC	2		2	18	11
EC	3		3	3	11
RHB	1		17	1	7
RHB	2		7	4	12
RHB	3		9	1	15
SB	1		18	28	0
SB	2		6	20	2
SB	3		2	24	9

Table 3 Cont. List of abundance of collected taxa at each stream site, in order of overall abundance for the upper quartile (n = 30).

		Order	Coleoptera	Ephemeroptera	Trichoptera
		Family	Psephenidae	Ameletidae	Philopotamidae
		Tribe			
Stream	**Order**	**Genus**	Ectopria	Ameletus	Wormaldia
FB	1		2	6	2
FB	2		6	4	0
FB	3		1	24	0
EC	1		1	0	1
EC	2		15	11	0
EC	3		5	19	32
RHB	1		6	6	10
RHB	2		11	7	3
RHB	3		9	1	1
SB	1		0	2	5
SB	2		11	1	17
SB	3		23	0	6

Figure 7. Ordination plot including all identified taxa of benthic aquatic macroinvertebrates.

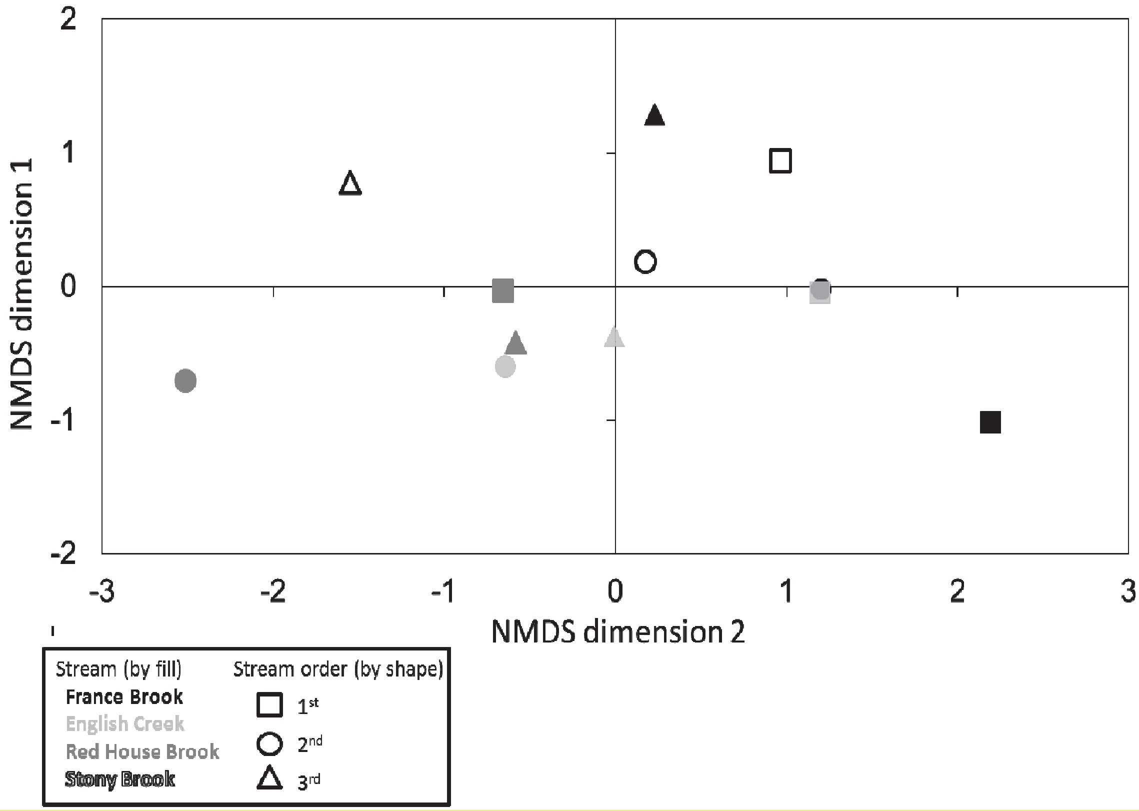


Table 4. Biological distance matrix.

	FB1	FB2	FB3	EC1	EC2	EC3	RHB1	RHB2	RHB3	SB1	SB2	SB3
FB1	0											
FB2	174	0										
FB3	252	190	0									
EC1	189	138	196	0								
EC2	258	201	208	181	0							
EC3	222	157	173	155	127	0						
RHB1	241	202	186	192	154	141	0					
RHB2	354	306	296	318	196	224	173	0				
RHB3	257	191	183	200	132	130	164	204	0			
SB1	216	164	153	142	224	180	177	315	209	0		
SB2	216	163	148	146	146	95	135	239	140	143	0	
SB3	320	264	177	264	166	187	140	171	178	234	173	0

Table 5. ANOVA table comparing the different groupings of streams.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4642.495	2	2321.247	.795	.456
Within Groups	183951.444	63	2919.864		
Total	188593.939	65			

Figure 8. "Loadings" for the upper quartile of taxa on ordination plot by the Order Ephemeroptera.

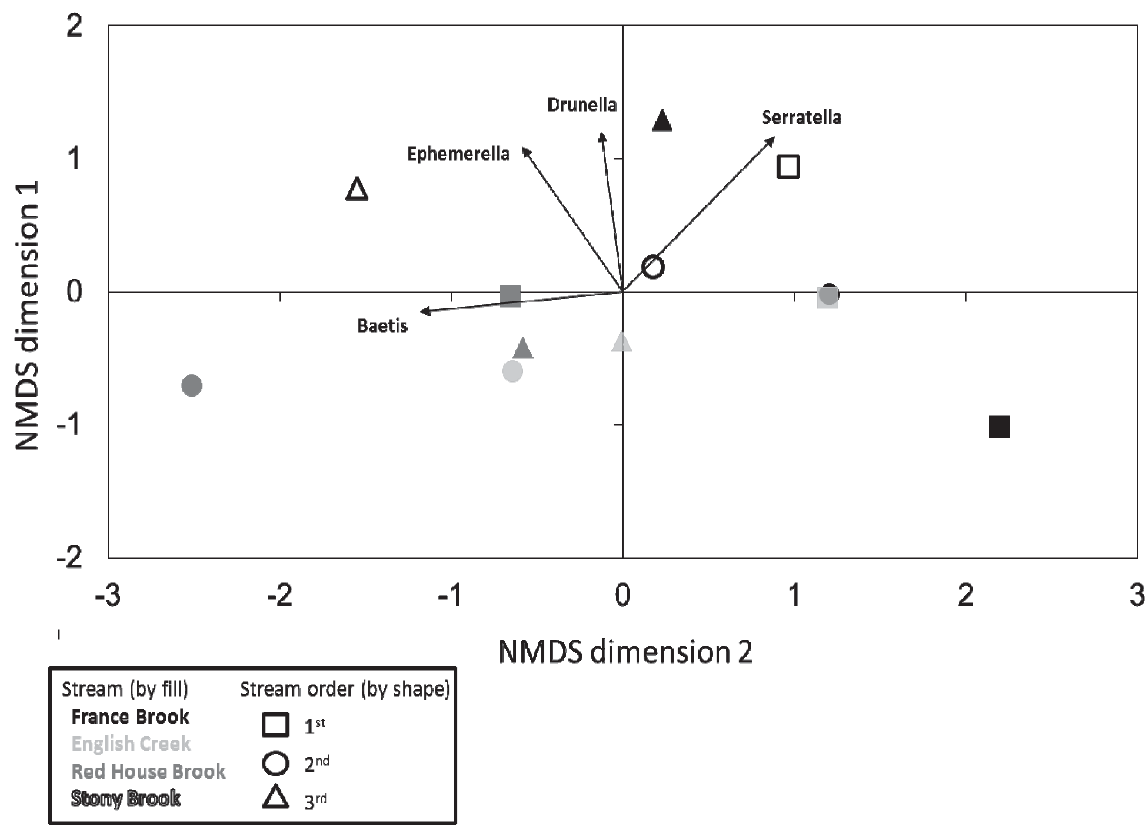


Figure 9. “Loadings” for the upper quartile of taxa on ordination plot by the Order Plecoptera.

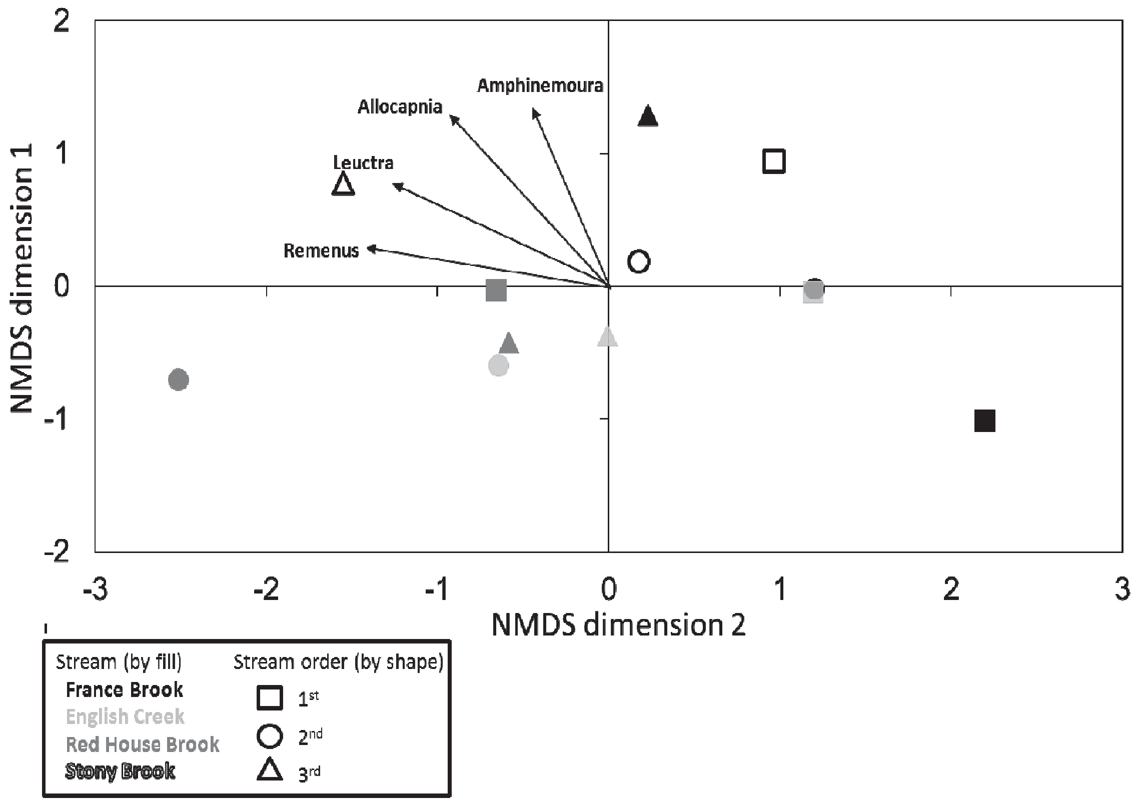


Figure 10. “Loadings” for the upper quartile of taxa on ordination plot by the Order Trichoptera.

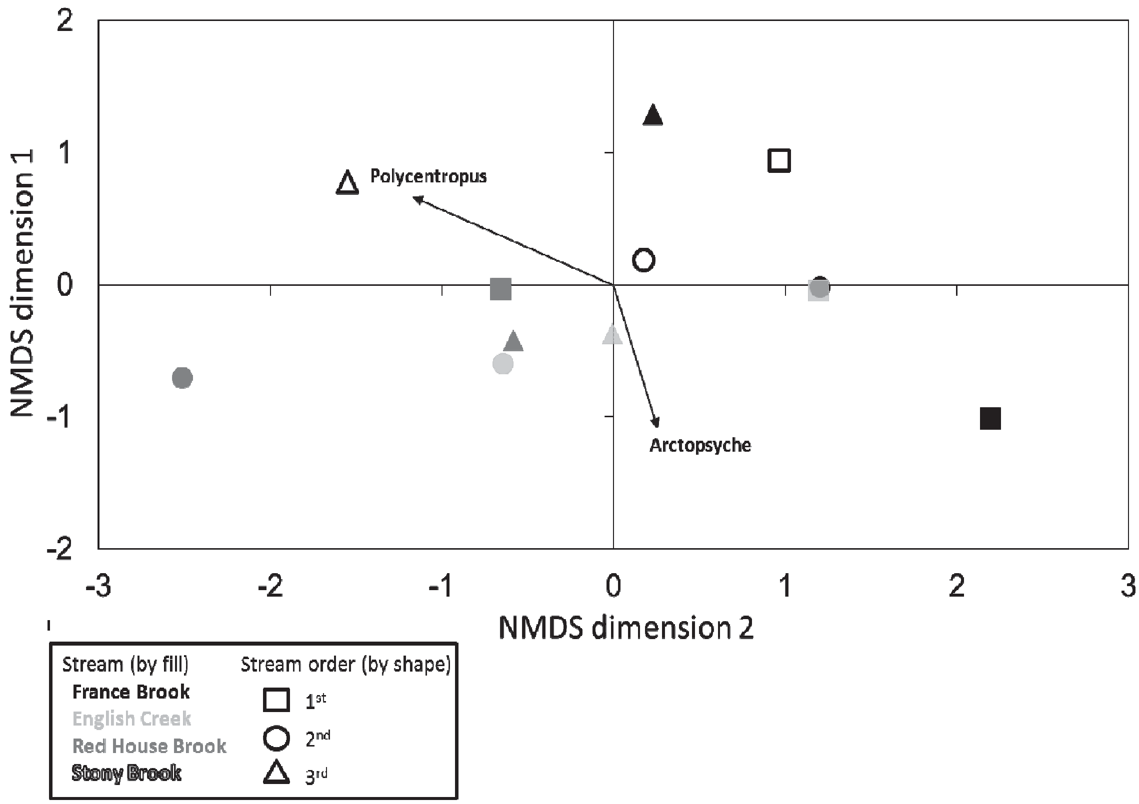


Figure 11. “Loadings” for the upper quartile of taxa on ordination plot by the Order Coleoptera.

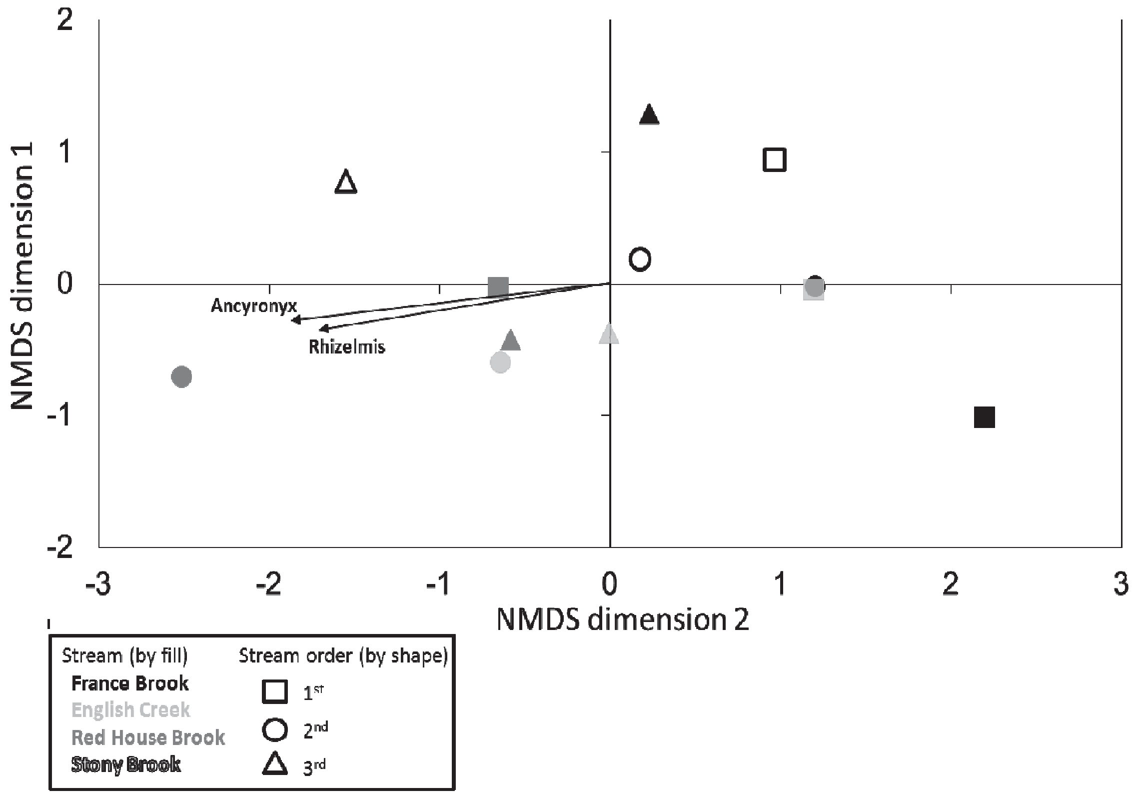


Table 6. Correlations for environmental variables with NMDS dimension scores.

			Dimension 1	Dimension 2
Spearman's rho	QHEI	Correlation Coefficient	-.319	-.182
		Sig. (2-tailed)	.312	.570
		N	12	12
	gradient	Correlation Coefficient	.326	-.142
		Sig. (2-tailed)	.301	.660
		N	12	12
	hardwood stand age	Correlation Coefficient	-.327	-.288
		Sig. (2-tailed)	.299	.364
		N	12	12
	hemlock old growth	Correlation Coefficient	-.764**	-.306
		Sig. (2-tailed)	.004	.334
		N	12	12
	watershed area	Correlation Coefficient	-.517*	-.119
		Sig. (1-tailed)	.042	.713
		N	12	12
	relief ratio	Correlation Coefficient	.540*	.151
		Sig. (1-tailed)	.035	.640
		N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

Figure 12. "Loadings" for the environmental variables onto NMDS ordination plot.

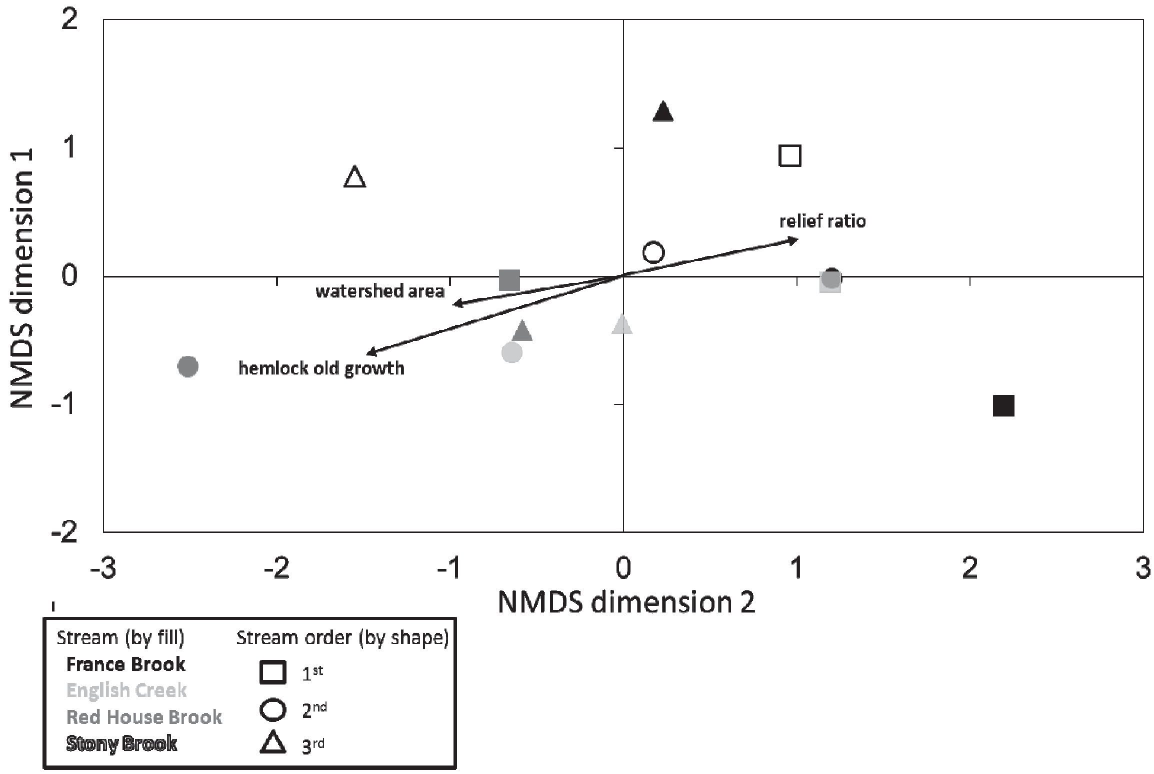


Table 7. Spatial distance matrix.

	FB1	FB2	FB3	EC1	EC2	EC3	RHB1	RHB2	RHB3	SB1	SB2	SB3
FB1	0											
FB2	500	0										
FB3	1900	1450	0									
EC1	2900	3200	4100	0								
EC2	4500	4750	5500	1550	0							
EC3	5250	5500	6250	2250	750	0						
RHB1	6100	5650	4400	6800	7700	8300	0					
RHB2	5400	4900	3500	6450	7550	8200	1100	0				
RHB3	4250	3750	2300	6000	7300	8000	2700	1600	0			
SB1	1650	1950	3000	1250	2800	3550	6350	5850	5100	0		
SB2	2100	2250	2900	1100	2600	3350	5800	5400	4850	750	0	
SB3	2250	2300	2800	1400	2750	3500	5450	5050	4600	1100	400	0

Table 8. Environmental distance matrix.

	FB1	**FB2**	**FB3**	**EC1**	**EC2**	**EC3**	**RHB1**	**RHB2**	**RHB3**	**SB1**	**SB2**	**SB3**
FB1	0											
FB2	127	0										
FB3	395	296	0									
EC1	46	160	426	0								
EC2	186	89	222	215	0							
EC3	588	511	233	615	430	0						
RHB1	282	360	558	244	371	698	0					
RHB2	401	306	184	416	231	322	486	0				
RHB3	822	759	495	843	675	268	873	535	0			
SB1	143	263	501	111	302	665	188	488	873	0		
SB2	157	48	281	193	105	502	404	312	757	297	0	
SB3	243	129	173	278	84	399	453	229	657	370	111	0

Table 9. Channel distance matrix.

	FB1	FB2	FB3	EC1	EC2	EC3	RHB1	RHB2	RHB3	SB1	SB2	SB3
FB1	0											
FB2	115	0										
FB3	217	106	0									
EC1	43	143	248	0								
EC2	125	28	112	150	0							
EC3	183	81	41	219	90	0						
RHB1	281	357	461	242	351	437	0					
RHB2	260	174	182	265	160	198	390	0				
RHB3	123	27	110	151	10	84	354	169	0			
SB1	141	252	357	110	256	325	185	363	256	0		
SB2	145	47	74	178	69	48	402	191	65	286	0	
SB3	181	72	35	214	81	23	428	179	78	322	43	0

Table 10. Partial correlations of distance matrices for all possible pairings of stream sites.

Correlation	Controlled for	Coefficient	p-value
all data			
biota x spatial	environmental	.099	.432
biota x environmental	spatial	-.090	.476
biota x channel	spatial	.117	.354
longitudinal			
biota x spatial	environmental	.469	.146
biota x environmental	spatial	-.439	.177
biota x channel	spatial	.057	.867
order			
biota x spatial	environmental	.104	.693
biota x environmental	spatial	.150	.565
biota x channel	spatial	.500	.041*
remainder			
biota x spatial	environmental	.022	.902
biota x environmental	spatial	-.159	.362
biota x channel	spatial	.057	.745

*Significance at $p<0.05$.

IV. DISCUSSION

Overall Macroinvertebrate Community Composition

The all-taxa NMDS ordination (Fig. 7) showed a potential trend among first-order streams, except for hemlock old growth dominated RHB 1, plotting right of the y-axis. Ten out of twelve of the loadings of abundant taxa were associated with the larger streams, moving away from the first orders. This could have been a reflection of these smaller streams having less complex stream morphology, i.e. less heterogeneous habitat and/or structure.

Influence of Environmental Variables

Environmental variables were behaving in sample sites largely as expected. The streams in this study were quite readily grouped by the environmental variables. The PCA (environmental variables) ordination plot (Fig. 6) illustrated clustering among streams within each order, except for old-growth dominated RHB 1. The effects of the hemlock old growth in the surrounding riparian zone may be strongly driving RHB 1 both in biotic and environmental terms.

However, the clustering of the streams that occurred due to the environmental variables did not appear to translate into a structuring of the biological community. The only significant environment-biota association found was when environmental variables were broken down into the channel specific variables. A significant partial correlation was found between distances based on environmental channel variables and based on the biota within stream orders, when controlling for spatial distances. Thus, like-order pairings of sample sites similar in regards to channel variables also tended to be more similar in biological composition. These results provide some support for niche theory, in which community similarity is positively associated with similarity in local environmental or habitat conditions (Tilman, 1982). However, stronger structuring may be seen on a smaller scale than the current study investigated, as has been demonstrated in patch dynamics (Downes et al., 1993; Costa & Melo, 2008). Patch dynamics can cover a magnitude of spatial scales, but at the smallest scale, a stream site is broken down into smaller components or microhabitats, such as a stone within a riffle or submerged roots of terrestrial plants (Downes et al., 1993).

Influence of Spatial Distance

The results do not show any spatial autocorrelation (Legendre, 1993). The structuring of community composition was not related to the spatial distances for any between site pairings, whether within-stream longitudinal pairings, within-order pairings, or among all pairings. Therefore, despite the proximity of the streams sites to one another, they appeared to be spatially independent in terms of macroinvertebrate community composition. Most invertebrate taxa possess the ability to disperse terrestrially via flight, making this result unexpected. This would suggest that each of these streams is acting as an individual unit.

However, this study did not find any spatial structuring longitudinally within the study streams either. Macroinvertebrates are also subject to drift, which makes this result unexpected as well. The absence of spatial structuring suggests that community composition structuring does not comply with neutral theory where ecological equivalence and dispersal limitation play a role. Perhaps the biota’s dispersal abilities are not limited within the Allegany State Park study area. It is possible that because study sites were chosen for their modest environmental gradients the environmental component was removed so much that the structuring was lost. The area may be so unified that spatial structuring was also factored out. It may be that there is a large regional species pool that has been there long enough that there is no strong internal determination for where the organisms are to go. The present study did not investigate the specific migration abilities or drift tendencies of the macroinvertebrates, but these factors may be important for future research.

Conversely, the current study may not have been looking at a *large* enough longitudinal/stream order scale to see structuring (*sensu* Vannote et al. 1980). Biotic structuring may be occurring farther downstream, as inter-order and inter-site variability likely increase. Stream networks can become more regionally varied as one moves to higher orders, as each increase in order adds many new streams, some of which may differ markedly from tributaries upstream or downstream. At the small headwater stream scale in this study, the new streams may instead be integrating the system at the stream/reach level. Perhaps it is the case that 1^{st}, 2^{nd}, and 3^{rd} order streams are acting similar enough that they can be considered as one group as headwaters as the RCC suggests (Vannote et al., 1980). The theory predicts that biotic changes will not be seen until medium sized streams (4-6 orders).

Another suggested outcome/utility is that this area is acting as a template for community composition where there is little or no anthropogenic degradation. The system could be exemplifying how these 1^{st} – 3^{rd} order streams behave in wooded northeastern forests in in the absence of degradation and human impact. Therefore if biotic differences are seen among streams of suspected human impact (or lack thereof), this could indicate the need for action.

It may be that the streams studied here are acting individualistically. A particular 1st order may be contributing more structurally to its 2nd and 3rd orders than the other 1st orders within the same dendritic stream network. The current study did not investigate all the contributing low-order streams to each higher-order within the system. A study that took samples from all 1st orders and all 2nd orders that contributed to the 3rd order could give a better picture of what is going on within these stream systems at the scale of the entire network. It would also be interesting to compare a highly branched stream system to a more direct system with fewer contributing streams.

Similar results were found by Heino and Mykra (2008), i.e. no spatial structuring and limited environmental structuring of biological communities. The study investigated the contribution of spatial and environmental factors to aquatic insect assemblage structure in boreal streams in northeastern Finland. There were no effects of spatial distance on the community composition, and environmental variables only explained up to 32% of the total variance (results were obtained by Canonical correspondence analysis). It appears that as in Heino and Mykra (2008) macroinvertebrate community composition in the series of Allegany State Park headwaters studied here, is complying with the niche-based sorting theory and decidedly not with neutral theory/spatial autocorrelation.

References

An, Kwank-Guk, Seok Soon Park, Joung-Yi-Shin, 2002. An evaluation of a river health using the index of biological integrity along with relations to chemical and habitat conditions. Environment International 28: 411-420.

Baber, M. J., D. L. Childers, K. J. Babbitt, & D. H. Anderson, 2002. Controls on fish distribution and abundance in temporary wetlands. Canadian Journal of Fisheries and Aquatic Sciences, 59: 1441-1450.

Bell, G., 2001. Ecology neutral macroecology. Science 239: 2413-2418.

Benke, A. C. & C. E. Cushing, 2005. Rivers of North America. Academic Press, New York.

Bilton, D. T., J. R. Freeland, & B. Okamur, 2001. Dispersal in freshwater invertebrates. *Annual* Review of *Ecology,* Evolution, and Systematics 32:159-81.

Bouchard, Jr., R. W., 2004. Guide to Aquatic Invertebrates of the Upper Midwest. Minnesota: Regents of the University of Minnesota.

Boulton, A. J., C. G. Peterson, N. B. Grimm, & S. G. Fisher, 1992. Stability of an aquatic macroinvertebrate community in a multiyear hydrologic disturbance regime. Ecology 73:2192-207.

Bowman, D. M. J. S., 1987. Environmental relationships of woody vegetation patterns in the Australian monsoon tropics. Australian Journal of Botany 35:151-69.

Brittain, J. E. & T. J. Eikland, 1988. Invertebrate drift- A review. Hydrobiologia 166: 77-93.

Brussock, P. P., & A. V. Brown, 1991. Riffle-pool geomorphology disrupts longitudinal patterns of stream benthos. Hydrobiologia 220: 109-117.

Chase, J. M. & M. A. Leibold, 2003. Ecological niches: linking classical and contemporary approaches, University of Chicago Press, Chicago Illinois.

Chave, J., 2004. Neutral theory and community ecology, Ecology Letters 7: 241-253.

Chesson, P. 1991. A need for niches. Trends in Ecology and Evolution 6: 263.

Costa, S. S. & A. S. Melo, 2008. Beta diversity in stream macroinvertebrate assemblages: Among-site and among-microhabitat components. Hydrobiologia 598:131-138.

Diggins, T. P. & A. Newman, 2009. Environmental and spatial influences on benthic community composition in wooded headwater streams in Zoar Valley, New York, USA. Hydrobiologia 630: 313-326.

Diggins, T.P. & K.M. Stewart. 1993. Deformities of Aquatic Larval Midges (Chironomidae: Diptera) in the Sediments of the Buffalo River, New York. Journal of Great Lakes Research 19(4): 648-659.

Diggins, T. P. & K. M. Stewart, 1998. Chironomid deformities, benthic community composition, and trace elements in the Buffalo River (New York): Area of concern. Journal of the North American Benthological Society 17: 311-323.

Doviak, A .L. & J. A. Perry, 2002. In Search of Effective Scales for Stream Management: Does Agroecoregion, Watershed, or Their Intersection Best Explain the Variance in Stream Macroinvertebrate Communities? Environmental Management 30: 365-377.

Downes, B. J., P. S. Lake, & E. S. G. Schreiber, (1993). Spatial variation in the distribution of stream invertebrates: implications of patchiness for models of community organization. Freshwater Biology 30: 119-132.

Finn, D. S. & N. L. Poff, 2005. Variability and convergence in benthic communities along the longitudinal gradients of four physically similar Rocky Mountain streams. Freshwater Biology 50: 243-261.

Forrow, D. M., & L. Maltby. 2000. Toward a mechanistic understanding of contaminant-induced changes in detritus processing in streams: direct and indirect effects on detrivore feeding. Environmental Toxicology and Chemistry 19(8): 2100-2106.

Grenouillet, G., S. Brosse, L. Tudesque, S. Lek, Y. Baraillé, & G. Loot, 2007. Concordance among stream assemblages and spatial autocorrelation along a fragmented gradient. Diversity and Distributions 14: 592–603.

Grubaugh, J. W., J. B. Wallace, & E. S. Houston, 1996. Longitudinal changes of macroinvertebrate communities along an Appalachian stream continuum. Canadian Journal of Aquatic Science 53: 896-909.

Hawkins, C. P. & J. R. Sedell, 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62: 387-397.

Hawkins, C. P. & M. R. Vinson, 2000. Weak correspondence between landscape classifications and stream invertebrate assemblages: Implications for bioassessment. Journal of North American Benthological Society 19(3): 501-517.

Heino, J. & H. Mykrä, 2008. Control of stream insect assemblages: roles of spatial configuration and local environmental factors. Ecological Entomology 33: 614-622.

Heino, J., J. Parviainen, R. Paavola, M. Jehle, P. Louhi, & T. Muotka, 2005. Characterizing macroinvertebrate assemblage structure in relation to stream size and tributary position. Hydrobiologia 539:121–130.

Hubbell, S.P., 2001. The Unified Neutral Theory of Biodiversity and Biogeography. Princeton University Press, Princeton.

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press.

Jacobsen, D., O. Dangles, P. Andino, R. Espinosa, L. Hamerlik, & E. Cadier, 2010. Longitudinal zonation of macroinvertebrates in an Ecuadorian glacier-fed stream: Do tropical systems fit the temperate model? Freshwater Biology 55: 1234-1248.

Legendre, P., 1993. Spatial autocorrelation: Trouble or new paradigm? Ecology 74: 1659-1673.

Lloyd, N.J., R. Mac Nally, & P.S. Lake, 2005. Spatial autocorrelation of assemblages of benthic invertebrates and its relationship to environmental factors in two upland rivers in southeastern Australia. Diversity and Distributions 11: 375-386.

Lloyd, N.J., R. Mac Nally, & P.S. Lake, 2006. Spatial autocorrelation of assemblages of benthic invertebrates in two upland rivers in south-eastern Australia and its implications for biomonitoring and impact assessment in streams. Environmental Monitoring and Assessment 115: 69-85.

Mac Nally, R., Lloyd, N.J., & P.S. Lake, 2006. Comparing patterns of spatial autocorrelation of assemblages of benthic invertebrates in upland rivers in south-eastern Australia. Hydrobiologia 571: 147-156.

Merrit, R.W., & K.W. Cummins, 1996. An Introduction to the Aquatic Insects of North America (3rd ed.). Iowa: Kendall/Hunt Publishing Co.

Minshall, G. W., K. W. Cummins, R. C. Petersen, C. E. Cushing, D. A. Bruns, J. R. Sedell, & R. L. Vannote, 1985. Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences 42: 1045-1055.

Muller, K., 1954. Investigations on the organic drift in North Swedish streams. Report of the Institution of Freshwater Research Drottningholm 35: 133-148.

Mykrä, H., J. Heino, T. Muotka, 2004. Variability of lotic macroinvertebrate assemblages and stream habitat characteristics across hierarchical landscape classifications. Environmental Management 34: 341-352.

New York State Office of Parks, Recreation and Historic Preservation, 2011. *Allegany State Park - Red House Area.* Retrieved October 22, 2011 from http://nysparks.state.ny.us/parks/73/details.aspx

Ohio EPA, 2006. Methods for assessing habitat in flowing waters: Using the qualitative habitat evaluation index (QHEI). http://www.epa.state.oh.us/dsw/documents/ QHEIManualJune2006.pdf.

Palmer , M., 2011. Ordination Methods for Ecologists. http://ordination.okstate.edu.

Peckarsky B.L., P.R. Fraissinet, M.A. Penton, & D.J. Conklin Jr., 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca.

Pennak, R. W., 1953. Freshwater Invertebrates of the United States. The Roland Press Company, New York.

Rosenberg, D.M., Resh, V.H., 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York.

SPSS 13.0 for Windows, Student Version, 2005. SPSS Inc.

Strahler, A. N., 1957. Quantitative analysis of watershed geomorphology. Transactions & American Geophysical Union 38(6), 913-920.

Thompson, R. & C. Townsend., 2006. A truce with neutral theory: local deterministic factors, species traits and dispersal limitation together determine patterns of diversity in stream invertebrates. Journal of Animal Ecology 75: 476-484.

Tilman, D., 1982. Resource Competition and Community Structure. Princeton University Press.

Townsend, C.R., & A. G. Hildrew, 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. Journal of Animal Ecology 45: 759-772.

Turner, D., Williams, D. D., & M. Alkins-Koo, 2008. Longitudinal changes in benthic community composition in four neotropical streams. Caribbean Journal of Science 44(3): 380-394.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, & C. E. Cushin, 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130–137.

Ward, J.V., 1986. Altitudinal zonation in a Rocky Mountain stream. Arch. Hydrobiol. Suppl. 74: 133-199.

Weilhoefer, C.L., & W. Pan, 2006. Diatom assemblages and their associations with environmental variables in Oregon coast range streams, USA. Hydrobiologia 561: 207-219.

World Wildlife Fund, 2001. *Allegheny Highlands forests*. Retrieved October 22, 2011, from http://www.worldwildlife.org/wildworld/profiles/terrestrial/na/na0401_full.html

Younes-Baraille, Y., Garcia, X., & J. Gagneur, 2005. Impact of longitudinal and seasonal changes of water quality on the benthic macroinvertebrate assemblages of the Andorran streams. Comptes Rendus Biologies 328: 963-976.

APPENDIX A

Occurrence of benthic macroinvertebrate taxa on fall sample date (September 26, October 3 and 4, 2010), reported as number of individuals per sample.

Order	Ephemeroptera						
SubOrder							
Family	Heptageniidea				Ephemerellidae		
Tribe							
Genus	Epeorus	Cinygmula	Heptagenia	Stenonema	Serratella	Ephemerella	Eurylophella
Species							
Stream/Order/Rep							
FB 1 A	1						
FB 1 B		2		1	1		1
FB 1 C							1
FB 1 Q		2					
FB 2 A		4		3	13		
FB 2 B					13	2	
FB 2 C	1	2			1		1
FB 2 Q		3	2	2	3		
FB 3 A	2	5			1		1
FB 3 B	1						
FB 3 C		5	4	2	1		
FB 3 Q	1	1	1				
EC 1 A		7		5	8		
EC 1 B			1	7	4		
EC 1 C		1		4	3		1
EC 1 Q		1		5	5		1
EC 2 A		3	3	4			1
EC 2 B		4		1			
EC 2 C		3	1	9			1
EC 2 Q	1	8	3	14			1
EC 3 A			3	5			1
EC 3 B	1	1	1	2			
EC 3 C		2		1			
EC 3 Q	2	4	3	7			

Order	Ephemeroptera						
SubOrder							
Family	Heptageniidea				Ephemerellidae		
Tribe							
Genus	Epeorus	Cinygmula	Heptagenia	Stenonema	Serratella	Ephemerella	Eurylophella
Species							
Stream/Order/Rep							
RHB 1 A	1			5			
RHB 1 B				5	1		1
RHB 1 C				2		1	
RHB 1 Q				1			
RHB 2 A	4	1		5	1	2	
RHB 2 B		3		1		2	2
RHB 2 C				5			1
RHB 2 Q	1	1		3			2
RHB 3 A	2			2			
RHB 3 B	4			9	1		
RHB 3 C				1			
RHB 3 Q							1
SB 1 A				9	5		12
SB 1 B				6			
SB 1 C				1	3		1
SB 1 Q		1		1	2		3
SB 2 A							
SB 2 B							1
SB 2 C				3	1		1
SB 2 Q				4	2		
SB 3 A				2			
SB 3 B							
SB 3 C				7	1		4
SB 3 Q				8	1		2

Order	Ephemeroptera					
SubOrder						
Family	Ephemeridae		Baetidae	Leptoplebiidae		Ameletidae
Tribe						
Genus	Ephemera	Pentagenia	Baetis	Paraleptoplebia	Neochoroterpes	Ameletus
Species						
Stream/Order/Rep						
FB 1 A						
FB 1 B				1	1	2
FB 1 C				3	4	
FB 1 Q				2		
FB 2 A				9	3	
FB 2 B				15	4	
FB 2 C				1		
FB 2 Q						
FB 3 A				6	9	
FB 3 B				2		
FB 3 C		1		10	14	2
FB 3 Q						
EC 1 A			1	5	6	
EC 1 B			1	1	13	
EC 1 C					11	
EC 1 Q				5	7	
EC 2 A			2	2	8	
EC 2 B					1	
EC 2 C			3	33	57	5
EC 2 Q		4	2	5	7	6
EC 3 A				20	14	5
EC 3 B			1	14	5	2
EC 3 C				3	2	1
EC 3 Q				8	4	8

Order	Ephemeroptera					
SubOrder						
Family	Ephemeridae		Baetidae	Leptoplebiidae		Ameletidae
Tribe						
Genus	Ephemera	Pentagenia	Baetis	Paraleptoplebia	Neochoroterpes	Ameletus
Species						
Stream/Order/Rep						
RHB 1 A			3	2	1	1
RHB 1 B			3	4	3	3
RHB 1 C			1			1
RHB 1 Q				1		1
RHB 2 A			6	6	2	4
RHB 2 B			3		1	
RHB 2 C			1	7	6	2
RHB 2 Q			2	1		1
RHB 3 A			5	12	3	1
RHB 3 B	5	1	7	67	34	
RHB 3 C			1	2		
RHB 3 Q					1	
SB 1 A				15	5	1
SB 1 B				10		
SB 1 C				5	6	1
SB 1 Q						
SB 2 A				6	2	
SB 2 B		1	1	2	1	
SB 2 C				11	19	1
SB 2 Q			1		2	
SB 3 A		1	1	9	11	
SB 3 B				5	7	
SB 3 C			5	21	18	
SB 3 Q			2			

Order	Plecoptera					
SubOrder						
Family	Chloroperlidae			Nemouridae	Capiidae	Leuctridae
Tribe						
Genus	Sweltsa	Suwallia	Alloperla	Zapada	Allocapnia	Leuctra
Species						
Stream/Order/Rep						
FB 1 A	3	1				
FB 1 B	2	14	5			
FB 1 C		12	1			
FB 1 Q		5				
FB 2 A	12	11	1		6	
FB 2 B	7	11	4		3	
FB 2 C	3	10	3		4	
FB 2 Q						
FB 3 A	2	6				4
FB 3 B		3				
FB 3 C	1	7	2		1	8
FB 3 Q		1				
EC 1 A	5	3			1	
EC 1 B	11	12		1	6	1
EC 1 C	2	2		2	3	
EC 1 Q	3	7			3	1
EC 2 A		2			3	
EC 2 B		1				1
EC 2 C	2	8	2		3	6
EC 2 Q		2			3	
EC 3 A		7				2
EC 3 B	2	2			2	
EC 3 C					1	1
EC 3 Q	1	2				

Order	Plecoptera					
SubOrder						
Family	Chloroperlidae			Nemouridae	Capiidae	Leuctridae
Tribe						
Genus	Sweltsa	Suwallia	Alloperla	Zapada	Allocapnia	Leuctra
Species						
Stream/Order/Rep						
RHB 1 A	5	5			24	33
RHB 1 B	6	13	1		13	20
RHB 1 C	5	2	2		4	8
RHB 1 Q						
RHB 2 A	4	8			7	6
RHB 2 B	2	1			3	3
RHB 2 C	1	17			19	28
RHB 2 Q		1			1	
RHB 3 A	5	10			3	3
RHB 3 B	1	3		1	6	11
RHB 3 C	3	4				
RHB 3 Q						
SB 1 A	4	16		4	10	14
SB 1 B	9	15	5	1	15	5
SB 1 C	4	10		2	8	6
SB 1 Q	1	4		13	1	2
SB 2 A	2	1				
SB 2 B					5	1
SB 2 C	3	4			2	4
SB 2 Q	1					1
SB 3 A	2	5			2	7
SB 3 B		2			3	2
SB 3 C		16			19	18
SB 3 Q					1	

Order	Plecoptera						
SubOrder							
Family	Perlodidae			Perlidae	Peltoperlidae		
Tribe							
Genus	Isoperla	Remenus	Skwala	Acroneuria	Viehoperla	Yoraperla	Tallaperla
Species							
Stream/Order/Rep							
FB 1 A		1					
FB 1 B	3	1			1		
FB 1 C		1			1		
FB 1 Q		1	1				
FB 2 A	1	6					
FB 2 B		5	5				
FB 2 C							
FB 2 Q		1					
FB 3 A		4	1				
FB 3 B				1			
FB 3 C	2	2		4			
FB 3 Q					1		
EC 1 A		3	4				
EC 1 B	4	3			4		2
EC 1 C	1	3	2				1
EC 1 Q	1	3	3		5		1
EC 2 A		5					
EC 2 B	1						
EC 2 C	5	33	5	2			
EC 2 Q		6			1		
EC 3 A		9	1	2			
EC 3 B		18	4	1			
EC 3 C		9		1	1		
EC 3 Q		10					

Order / SubOrder / Family / Tribe / Genus / Species							
Order	Plecoptera						
Family	Perlodidae			Perlidae	Peltoperlidae		
Genus	Isoperla	Remenus	Skwala	Acroneuria	Viehoperla	Yoraperla	Tallaperla
Stream/Order/Rep							
RHB 1 A		24	2				
RHB 1 B		32	8		2		
RHB 1 C		11	4		1		
RHB 1 Q							
RHB 2 A		14	7				
RHB 2 B		5					
RHB 2 C		24	3				
RHB 2 Q		2	1				
RHB 3 A		2					
RHB 3 B	3	4			9	11	4
RHB 3 C					2		
RHB 3 Q		1					
SB 1 A	3	6	20		6		2
SB 1 B	2	11	5		15		10
SB 1 C	4	7	6		6		4
SB 1 Q	2	2	5		4		6
SB 2 A		2	1				
SB 2 B		1					
SB 2 C		25					
SB 2 Q		1	2		3		
SB 3 A		14					
SB 3 B		2	1				
SB 3 C		24	7				
SB 3 Q		3					

Order	Plecoptera	Trichoptera			
SubOrder					
Family	Pteronarcyidae	Apataniidae	Brachycentridae		Glossosomatidae
Tribe					
Genus	Pteronarcys	Pedomoecus	Amiocentrus	Brachycentrus	Glossosoma
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A			1		
FB 2 B					
FB 2 C					
FB 2 Q			2		
FB 3 A		1			
FB 3 B		1			
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A			1		
EC 2 B					
EC 2 C			1		
EC 2 Q					
EC 3 A					
EC 3 B					
EC 3 C					
EC 3 Q					1

Order / SubOrder / Family / Tribe / Genus / Species	Plecoptera	Trichoptera			
	Pteronarcyidae	Apataniidae	Brachycentridae		Glossosomatidae
	Pteronarcys	Pedomoecus	Amiocentrus	Brachycentrus	Glossosoma
Stream/Order/Rep					
RHB 1 A	1				
RHB 1 B			1		
RHB 1 C					
RHB 1 Q					
RHB 2 A					
RHB 2 B					
RHB 2 C				4	
RHB 2 Q			21	7	
RHB 3 A					
RHB 3 B	7				
RHB 3 C					
RHB 3 Q			1		
SB 1 A		14	2	2	
SB 1 B		24	8		
SB 1 C			1		
SB 1 Q		1	1		
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					
SB 3 A			2		
SB 3 B					
SB 3 C			4	1	
SB 3 Q					

Order	Trichoptera						
SubOrder							
Family	Hydropsychidae				Hydroptilidae		
Tribe							
Genus	Diplectrona	Hydropsyche	Arctopsyche	Parapsyche	Neotrichia	Orthotrichia	Leucutrichia
Species							
Stream/Order/Rep							
FB 1 A							
FB 1 B							
FB 1 C			4	22	3		
FB 1 Q			3	2	1		
FB 2 A	3		3	4			
FB 2 B			6	4			
FB 2 C							
FB 2 Q			1	2			
FB 3 A				1			
FB 3 B							
FB 3 C				1			
FB 3 Q							
EC 1 A		3	7	13			
EC 1 B		9	20	27			
EC 1 C		1	10	11			
EC 1 Q		3	6	13		1	
EC 2 A		9	12	15			
EC 2 B		1					
EC 2 C		8	23	36			
EC 2 Q		13	12	26			
EC 3 A		1	3	4			
EC 3 B		2	7	12			
EC 3 C			2	4			
EC 3 Q		1	2	11			

Order / **SubOrder** / **Family** / **Tribe** / **Genus** / **Species**							
Order	Trichoptera						
SubOrder							
Family	Hydropsychidae				Hydroptilidae		
Tribe							
Genus	Diplectrona	Hydropsyche	Arctopsyche	Parapsyche	Neotrichia	Orthotrichia	Leucutrichia
Species							
Stream/Order/Rep							
RHB 1 A		9	3	11			
RHB 1 B	1	6		3			
RHB 1 C		2		2			
RHB 1 Q							
RHB 2 A		7	4	3			
RHB 2 B		1					
RHB 2 C		1		1			
RHB 2 Q		5		7			
RHB 3 A		6		3			
RHB 3 B		33		11			
RHB 3 C				1			
RHB 3 Q		3					
SB 1 A				1			
SB 1 B		2		1			
SB 1 C		1	1	2			
SB 1 Q				2			
SB 2 A				1			
SB 2 B							
SB 2 C		8		7			1
SB 2 Q		2		2			
SB 3 A		1	1	2			
SB 3 B		1					
SB 3 C		6		16			
SB 3 Q		1		2			

Order	Trichoptera				
SubOrder					
Family	Hydroptilidae	Molannidae	Odontoceridae	Philopotamidae	
Tribe					
Genus	Palaeagapetus	Molannodes	Psilotreta	Dolophilodes	Wormaldia
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					
FB 3 A					
FB 3 B			1		
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					1
EC 1 Q		1			
EC 2 A					
EC 2 B					
EC 2 C					
EC 2 Q				9	
EC 3 A					
EC 3 B					12
EC 3 C					
EC 3 Q					15

Order / SubOrder / Family / Tribe / Genus / Species	Trichoptera				
	Hydroptilidae	Molannidae	Odontoceridae	Philopotamidae	
	Palaeagapetus	Molannodes	Psilotreta	Dolophilodes	Wormaldia
Stream/Order/Rep					
RHB 1 A	2				
RHB 1 B					2
RHB 1 C	1			1	
RHB 1 Q					1
RHB 2 A					2
RHB 2 B					
RHB 2 C	5				1
RHB 2 Q				1	
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q					
SB 1 A			1		
SB 1 B			1		
SB 1 C			3		2
SB 1 Q			5		
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					
SB 3 A					
SB 3 B					
SB 3 C					
SB 3 Q					

Order	Trichoptera			Megaloptera	
SubOrder					
Family	Polycentropodidae		Rhyacophilidae	Corydalidae	Sialidae
Tribe					
Genus	Polycentropus	Neureclipsis	Rhyacophila	Nigronia	Sialis
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					1
FB 1 C					
FB 1 Q	1				
FB 2 A			5		
FB 2 B					
FB 2 C					
FB 2 Q					
FB 3 A		2			
FB 3 B		2			
FB 3 C		2			
FB 3 Q	2				
EC 1 A	1	1			
EC 1 B		4			
EC 1 C	2	1			
EC 1 Q	4				
EC 2 A	1	6			
EC 2 B	1	2			
EC 2 C	4	5			
EC 2 Q		5			
EC 3 A	4	1			
EC 3 B	2	4			
EC 3 C	1	1			
EC 3 Q		2			

Order	Trichoptera			Megaloptera	
SubOrder					
Family	Polycentropodidae		Rhyacophilidae	Corydalidae	Sialidae
Tribe					
Genus	Polycentropus	Neureclipsis	Rhyacophila	Nigronia	Sialis
Species					
Stream/Order/Rep					
RHB 1 A	3	1			
RHB 1 B	4	3			
RHB 1 C	1	3			
RHB 1 Q					
RHB 2 A	2	2			
RHB 2 B	1	3			
RHB 2 C	5	8	1		
RHB 2 Q	1	2			
RHB 3 A		3			
RHB 3 B	10	57		1	
RHB 3 C		4			
RHB 3 Q					
SB 1 A	4	1			
SB 1 B	5	3			
SB 1 C	8	2			
SB 1 Q	7	11			
SB 2 A		1		1	
SB 2 B					
SB 2 C	6	3			
SB 2 Q	1	3			
SB 3 A	2	2			
SB 3 B	2				
SB 3 C	12	2		1	
SB 3 Q					

Order	Collembola	Hemiptera	Lepidoptera	Odonata	
SubOrder	Entomobryomorpha	Heteroptera		Anisoptera	
Family	Entomobryidae	Hebridae	Pyralidae	Corduliidae	Gomphidae
Tribe					
Genus	Sinella	Lipogomphus	Acentria	Somatachlora	Arigomphus
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B				2	
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B				1	1
FB 2 C				1	
FB 2 Q					
FB 3 A					
FB 3 B					1
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A			1		
EC 2 B					
EC 2 C					2
EC 2 Q					
EC 3 A					
EC 3 B					
EC 3 C					
EC 3 Q					

Order	Collembola	Hemiptera	Lepidoptera	Odonata	
SubOrder	Entomobryomorpha	Heteroptera		Anisoptera	
Family	Entomobryidae	Hebridae	Pyralidae	Corduliidae	Gomphidae
Tribe					
Genus	Sinella	Lipogomphus	Acentria	Somatachlora	Arigomphus
Species					
Stream/Order/Rep					
RHB 1 A					5
RHB 1 B					
RHB 1 C					
RHB 1 Q					
RHB 2 A					3
RHB 2 B					
RHB 2 C					9
RHB 2 Q					
RHB 3 A					
RHB 3 B					7
RHB 3 C					
RHB 3 Q					
SB 1 A					2
SB 1 B					
SB 1 C		1			1
SB 1 Q					
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q	2				
SB 3 A	1				
SB 3 B					
SB 3 C	1				3
SB 3 Q					

Order	Odonata	Coleoptera					Coleoptera
SubOrder	Zygoptera						
Family	Coenagrionidae	Elmidae					Psephenidae
Tribe							
Genus	Argia	Ancyronyx	Dubiraphia	Oulimnius	Rhizelmis	Stenelmis	Ectopria
Species							
Stream/Order/Rep							
FB 1 A		1					
FB 1 B		2					
FB 1 C		2					
FB 1 Q		1					2
FB 2 A		21					
FB 2 B		3					
FB 2 C		5				1	1
FB 2 Q		1					4
FB 3 A		7					
FB 3 B		8			4		
FB 3 C		23		2	6		1
FB 3 Q		1					
EC 1 A	1	7					1
EC 1 B							
EC 1 C							
EC 1 Q		1					
EC 2 A		14			5		1
EC 2 B		5	1				
EC 2 C		105		1	26		5
EC 2 Q		8					5
EC 3 A		27					
EC 3 B		18			1		
EC 3 C		7			1		
EC 3 Q		6					3

Order	Odonata	Coleoptera					
SubOrder	Zygoptera						
Family	Coenagrionidae	Elmidae					Psephenidae
Tribe							
Genus	Argia	Ancyronyx	Dubiraphia	Oulimnius	Rhizelmis	Stenelmis	Ectopria
Species							
Stream/Order/Rep							
RHB 1 A		40		5	5		3
RHB 1 B	1	70		3			
RHB 1 C		28		1	8		
RHB 1 Q		3					3
RHB 2 A		130			16		
RHB 2 B		22		1			
RHB 2 C		122			10		3
RHB 2 Q		6					8
RHB 3 A		34		2	11		
RHB 3 B		71		2	4		2
RHB 3 C		25		1	1		1
RHB 3 Q		12		1	2		3
SB 1 A							
SB 1 B		3					
SB 1 C		6					
SB 1 Q							
SB 2 A		21		2			1
SB 2 B		9					1
SB 2 C		32		2			6
SB 2 Q		5					3
SB 3 A		49			7		2
SB 3 B		13		2			
SB 3 C		100		7	25		6
SB 3 Q		24					14

Order	Coleoptera		Tubificida		Diptera
SubOrder					Brachycera
Family	Psephenidae	Salpingidae	Enchytraeidae	Tubificidae	Athericidae
Tribe					
Genus	Psephenus			Limnodrilus	Atherix
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C	1				
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					
FB 3 A					
FB 3 B					
FB 3 C					
FB 3 Q					
EC 1 A	1				
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					
EC 2 B			1		
EC 2 C					
EC 2 Q					
EC 3 A					
EC 3 B					
EC 3 C					
EC 3 Q					

Order	Coleoptera		Tubificida		Diptera
SubOrder					Brachycera
Family	Psephenidae	Salpingidae	Enchytraeidae	Tubificidae	Athericidae
Tribe					
Genus	Psephenus			Limnodrilus	Atherix
Species					
Stream/Order/Rep					
RHB 1 A		1			
RHB 1 B					
RHB 1 C					
RHB 1 Q					
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B				18	2
RHB 3 C				6	
RHB 3 Q					
SB 1 A					
SB 1 B					
SB 1 C					
SB 1 Q					
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					
SB 3 A					
SB 3 B					
SB 3 C					
SB 3 Q					

Order	Diptera				
SubOrder	Brachycera			Nematocera	
Family	Empididae	Pelecorhynchidae	Sciomyzidae	Dixidae	Ceratopogonidae
Tribe					
Genus	Chelifera	Glutops	Dictya	Dixa	Artichopogon
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					
FB 3 A					
FB 3 B					
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C				1	1
EC 1 Q					
EC 2 A					
EC 2 B					
EC 2 C					
EC 2 Q				1	
EC 3 A					
EC 3 B					
EC 3 C					
EC 3 Q			1		

Order	Diptera				
SubOrder	Brachycera			Nematocera	
Family	Empididae	Pelecorhynchidae	Sciomyzidae	Dixidae	Ceratopogonidae
Tribe					
Genus	Chelifera	Glutops	Dictya	Dixa	Artichopogon
Species					
Stream/Order/Rep					
RHB 1 A	1				
RHB 1 B					
RHB 1 C					
RHB 1 Q					
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q					
SB 1 A				1	
SB 1 B		2			
SB 1 C				2	
SB 1 Q				4	
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					
SB 3 A					
SB 3 B					
SB 3 C					
SB 3 Q					

Order	Diptera								
SubOrder	Nematocera								
Family	Simuliidae	Tipulidae							Chironomidae
Subamily									Tanypodinae
Tribe									
Genus	Simulium	Dicranota	Hexatoma	Molophilus	Ormosia	Paradelphomyia	Leptotarsus	Holorusia	Nilotanypus
Species									
Stream/Order/Rep									
FB 1 A									
FB 1 B		2		1					
FB 1 C		1	1	1					
FB 1 Q			1						
FB 2 A			1				1		
FB 2 B			1						
FB 2 C							1		
FB 2 Q									
FB 3 A									
FB 3 B			1						
FB 3 C			1						
FB 3 Q									
EC 1 A		2	5			1			
EC 1 B		4	6				3	1	
EC 1 C		11	1						
EC 1 Q		3	4						
EC 2 A							1		
EC 2 B		1							
EC 2 C		1							
EC 2 Q									
EC 3 A		1							
EC 3 B	2								
EC 3 C							1		
EC 3 Q							1		

Order	Diptera								
SubOrder	Nematocera								
Family	Simuliidae	Tipulidae							Chironomidae
Subamily									Tanypodinae
Tribe									
Genus	Simulium	Dicranota	Hexatoma	Molophilus	Ormosia	Paradelphomyia	Leptotarsus	Holorusia	Nilotanypus
Species									
Stream/Order/Rep									
RHB 1 A			1						
RHB 1 B			2						
RHB 1 C		6	1						
RHB 1 Q									
RHB 2 A		1	2						
RHB 2 B	1		2						
RHB 2 C		2	1	1			1		1
RHB 2 Q		7							
RHB 3 A		1							
RHB 3 B	2	8	2						
RHB 3 C									1
RHB 3 Q									
SB 1 A		1	1				4		
SB 1 B		1	2				2		
SB 1 C			3	1					
SB 1 Q			1		2				
SB 2 A									
SB 2 B					2				
SB 2 C			2						
SB 2 Q									
SB 3 A		1	2						
SB 3 B									
SB 3 C			7	5					
SB 3 Q									

Order	Diptera					
SubOrder	Nematocera					
Family	Chironomidae					
Subamily	Tanypodinae			Chironominae		
Tribe				Chironomini		
Genus	Pentaneura	Thienemannimyia	unknown	Microtendipes	Paratendipes	Polypedilum
Species						convictum
Stream/Order/Rep						
FB 1 A						
FB 1 B						
FB 1 C						
FB 1 Q						
FB 2 A						
FB 2 B						
FB 2 C						
FB 2 Q	3					
FB 3 A		1		1	1	
FB 3 B		1				
FB 3 C						
FB 3 Q		1				
EC 1 A						
EC 1 B						
EC 1 C						
EC 1 Q				2		
EC 2 A						
EC 2 B						
EC 2 C						
EC 2 Q						
EC 3 A						
EC 3 B						
EC 3 C						
EC 3 Q						

Order	Diptera					
SubOrder	Nematocera					
Family	Chironomidae					
Subamily	Tanypodinae			Chironominae		
Tribe				Chironomini		
Genus	Pentaneura	Thienemannimyia	unknown	Microtendipes	Paratendipes	Polypedilum
Species						convictum
Stream/Order/Rep						
RHB 1 A						
RHB 1 B						
RHB 1 C		1				
RHB 1 Q				1		
RHB 2 A						2
RHB 2 B						
RHB 2 C		4		2		1
RHB 2 Q		1				1
RHB 3 A						
RHB 3 B						
RHB 3 C						1
RHB 3 Q		1		1		
SB 1 A	1					
SB 1 B		1				
SB 1 C	2	1				
SB 1 Q	1			1		
SB 2 A						
SB 2 B						
SB 2 C				1		
SB 2 Q						
SB 3 A						1
SB 3 B						
SB 3 C		1		1		
SB 3 Q				1		1

Order	Diptera					
SubOrder	Nematocera					
Family	Chironomidae					
Subamily	Chironominae					
Tribe	Chironomini				Orthocladiinae	
Genus	Polypedilum		Trieblos	unknown	Corynonemura	Eukiefferiella
Species	scalaenum	unknown	jucundas		tarsis	bavarica
Stream/Order/Rep						
FB 1 A						5
FB 1 B						2
FB 1 C						
FB 1 Q						
FB 2 A						1
FB 2 B						
FB 2 C						
FB 2 Q						3
FB 3 A						
FB 3 B		1				3
FB 3 C						
FB 3 Q						
EC 1 A						1
EC 1 B						
EC 1 C						
EC 1 Q			1			
EC 2 A						
EC 2 B	1					
EC 2 C						1
EC 2 Q						1
EC 3 A						
EC 3 B						
EC 3 C						
EC 3 Q						

Order	Diptera					
SubOrder	Nematocera					
Family	Chironomidae					
Subamily	Chironominae					
Tribe	Chironomini				Orthocladiinae	
Genus	Polypedilum		Trieblos	unknown	Corynonemura	Eukiefferiella
Species	scalaenum	unknown	jucundas		tarsis	bavarica
Stream/Order/Rep						
RHB 1 A						5
RHB 1 B						2
RHB 1 C						
RHB 1 Q						
RHB 2 A						1
RHB 2 B						
RHB 2 C						
RHB 2 Q						3
RHB 3 A						
RHB 3 B		1				3
RHB 3 C						
RHB 3 Q						
SB 1 A						1
SB 1 B						
SB 1 C						
SB 1 Q			1			
SB 2 A						
SB 2 B	1					
SB 2 C						1
SB 2 Q						1
SB 3 A						
SB 3 B						
SB 3 C						
SB 3 Q						

Order	Diptera							
SubOrder	Nematocera							
Family	Chironomidae							
Subamily	Chironominae							
Tribe	Chironomini							Tanytarsini
Genus	Eukiefferiella		Nanocladius	Parachaetocladius	Parametriocnemus	Thienemanniella	unknown	Rheotanytarsus
Species	dicoloripes	unknown						
Stream/Order/Rep								
FB 1 A								
FB 1 B								
FB 1 C								
FB 1 Q								
FB 2 A								
FB 2 B								
FB 2 C								
FB 2 Q								
FB 3 A								
FB 3 B								
FB 3 C								
FB 3 Q								
EC 1 A								
EC 1 B								
EC 1 C								
EC 1 Q								
EC 2 A								
EC 2 B								
EC 2 C								
EC 2 Q							2	
EC 3 A					1			
EC 3 B								
EC 3 C								
EC 3 Q						3		1

Order	Diptera							
SubOrder	Nematocera							
Family	Chironomidae							
Subamily	Chironominae							
Tribe	Chironomini							Tanytarsini
Genus	Eukiefferiella		Nanocladius	Parachaetocladius	Parametriocnemus	Thienemanniella	unknown	Rheotanytarsus
Species	dicoloripes	unknown						
Stream/Order/Rep								
RHB 1 A								
RHB 1 B	1							1
RHB 1 C								
RHB 1 Q			1				1	
RHB 2 A	1							1
RHB 2 B				1				
RHB 2 C	1							
RHB 2 Q		1						
RHB 3 A								
RHB 3 B	3		1					
RHB 3 C				2				
RHB 3 Q				2				
SB 1 A								
SB 1 B								
SB 1 C								
SB 1 Q								
SB 2 A				1				1
SB 2 B								
SB 2 C				1				
SB 2 Q	1		1				2	
SB 3 A								
SB 3 B								
SB 3 C				1			1	1
SB 3 Q								

Order	Diptera			Veneroida	Basommatophora
SubOrder	Nematocera				
Family	Chironomidae			Sphaeriidae	Ancylidae
Subamily	Chironominae				
Tribe	Tanytarsini				
Genus	Tanytarsus		unknown	Pisidium	Laevapex
Species	guerlus	unknown			fuscus
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					
FB 3 A					
FB 3 B			1		
FB 3 C					
FB 3 Q					1
EC 1 A				1	
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					
EC 2 B					
EC 2 C					
EC 2 Q					
EC 3 A				1	
EC 3 B					
EC 3 C				1	
EC 3 Q					

Order	Diptera			Veneroida	Basommatophora
SubOrder	Nematocera				
Family	Chironomidae			Sphaeriidae	Ancylidae
Subamily	Chironominae				
Tribe	Tanytarsini				
Genus	Tanytarsus		unknown	Pisidium	Laevapex
Species	guerlus	unknown			fuscus
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C					
RHB 1 Q					
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B	1				
RHB 3 C					
RHB 3 Q					9
SB 1 A					
SB 1 B					
SB 1 C					
SB 1 Q			1		
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q			2		
SB 3 A					
SB 3 B					
SB 3 C		1		10	
SB 3 Q					

Order / SubOrder / Family / Tribe / Genus / Species	Basommatophora	
Family	Lymnaeidae	Planorbidae
Genus	Fossaria	Promenetus
Species		exacuous
Stream/Order/Rep		
FB 1 A	1	
FB 1 B		
FB 1 C		
FB 1 Q		
FB 2 A		
FB 2 B		
FB 2 C		
FB 2 Q		
FB 3 A		
FB 3 B		
FB 3 C		
FB 3 Q		
EC 1 A		
EC 1 B		
EC 1 C		
EC 1 Q		
EC 2 A		
EC 2 B		
EC 2 C		
EC 2 Q		1
EC 3 A		
EC 3 B		
EC 3 C		
EC 3 Q		

Order	Basommatophora	
SubOrder		
Family	Lymnaeidae	Planorbidae
Tribe		
Genus	Fossaria	Promenetus
Species		exacuous
Stream/Order/Rep		
RHB 1 A		
RHB 1 B		
RHB 1 C		
RHB 1 Q		
RHB 2 A		
RHB 2 B		
RHB 2 C		
RHB 2 Q		
RHB 3 A		
RHB 3 B		
RHB 3 C		
RHB 3 Q		
SB 1 A		
SB 1 B		
SB 1 C		
SB 1 Q		
SB 2 A		
SB 2 B		
SB 2 C		
SB 2 Q		
SB 3 A		
SB 3 B		
SB 3 C		
SB 3 Q		

APPENDIX B

Occurrence of benthic macroinvertebrate taxa on spring sample date (April 25 and June 6, 2011), reported as number of individuals per sample.

Order	Ephemeroptera							
SubOrder								
Family	Heptageniidea				Ephemerellidae			
Tribe								
Genus	Epeorus	Cinygmula	Heptagenia	Stenonema	Serratella	Drunella	Ephemerella	Eurylophella
Species								
Stream/Order/Rep								
FB 1 A								
FB 1 B								
FB 1 C								
FB 1 Q	1							
FB 2 A	10	27			16		1	
FB 2 B	4	3			2			
FB 2 C		3						
FB 2 Q	49	22	7	6	8			
FB 3 A		1			3		3	
FB 3 B		5				21	5	
FB 3 C	1	3				6	1	
FB 3 Q	13	3				16	4	
EC 1 A								
EC 1 B								
EC 1 C								
EC 1 Q								
EC 2 A	1	2				1	4	
EC 2 B	2			1	1		9	
EC 2 C		4			1		2	
EC 2 Q	11	4	4		2	3	3	
EC 3 A	1			2	2		1	
EC 3 B		2			1		2	
EC 3 C	3	2						1
EC 3 Q	15	11	3		6			

Order	Ephemeroptera							
SubOrder								
Family	Heptageniidea				Ephemerellidae			
Tribe								
Genus	Epeorus	Cinygmula	Heptagenia	Stenonema	Serratella	Drunella	Ephemerella	Eurylophella
Species								
Stream/Order/Rep								
RHB 1 A				1				
RHB 1 B								
RHB 1 C				1				
RHB 1 Q	1			3				
RHB 2 A								
RHB 2 B	2							
RHB 2 C	2							
RHB 2 Q	5	3						
RHB 3 A	2							
RHB 3 B	3				1			
RHB 3 C	2							
RHB 3 Q	44				1	1	1	
SB 1 A							3	
SB 1 B					6	13	19	1
SB 1 C					1			
SB 1 Q	4			1	5	29	6	1
SB 2 A					1	10	8	
SB 2 B		3		1	2	8	5	
SB 2 C						8	3	
SB 2 Q	3	1			4	27	4	1
SB 3 A					3	6		
SB 3 B				6	3	9	6	
SB 3 C		1		5		7	11	1
SB 3 Q	3	2		8	1	17	7	

Order	Ephemeroptera				Plecoptera
SubOrder					
Family	Baetidae	Leptoplebiidae		Ameletidae	Chloroperlidae
Tribe					
Genus	Baetis	Paraleptoplebia	Neochoroterpes	Ameletus	Sweltsa
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B				1	
FB 1 C				2	2
FB 1 Q				1	
FB 2 A		2		2	
FB 2 B		1			
FB 2 C		1		1	
FB 2 Q		2		1	
FB 3 A	9	14	1	5	
FB 3 B	17	63		12	
FB 3 C	2	23		2	
FB 3 Q	13	2		3	
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A		6	1		
EC 2 B	1	4			
EC 2 C	1				
EC 2 Q	2				
EC 3 A		7		2	
EC 3 B	2	2			
EC 3 C	1	1			
EC 3 Q	7	3		1	

Order	Ephemeroptera				Plecoptera
SubOrder					
Family	Baetidae	Leptoplebiidae		Ameletidae	Chloroperlidae
Tribe / Genus	Baetis	Paraleptoplebia	Neochoroterpes	Ameletus	Sweltsa
Species					
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C					
RHB 1 Q					1
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A	1				
RHB 3 B		1			
RHB 3 C		3			
RHB 3 Q	1	2			
SB 1 A					
SB 1 B		3			
SB 1 C		4			
SB 1 Q		5			
SB 2 A		1			
SB 2 B		8			
SB 2 C		12	2		
SB 2 Q		5	1		
SB 3 A					
SB 3 B		18	1		
SB 3 C	1	24	4		
SB 3 Q		8			

Order / SubOrder / Family / Tribe / Genus / Species	Plecoptera				
Family			Nemouridae		
Genus	Suwallia	Haploperla	Amphinemura	Nemoura	Zapada
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q	2				
FB 2 A	12		4	1	
FB 2 B			1		
FB 2 C	1		1		
FB 2 Q	2		1	5	
FB 3 A	7		1		
FB 3 B	14		2		
FB 3 C			6		
FB 3 Q	1		16		
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A	2		2		
EC 2 B			4		
EC 2 C	1		2		
EC 2 Q	2		4		
EC 3 A					2
EC 3 B	3		1		
EC 3 C					
EC 3 Q	1		1	1	

Order SubOrder Family Tribe Genus Species	Plecoptera				
			Nemouridae		
	Suwallia	Haploperla	Amphinemura	Nemoura	Zapada
Stream/Order/Rep					
RHB 1 A					
RHB 1 B	2		1	1	
RHB 1 C	1			1	3
RHB 1 Q	3		3	1	
				3	1
RHB 2 A					
RHB 2 B	1				
RHB 2 C	3			1	
RHB 2 Q	2			2	
	3		14	5	
RHB 3 A					
RHB 3 B	4				
RHB 3 C					
RHB 3 Q	2				
SB 1 A					
SB 1 B	2				
SB 1 C	4		11		
SB 1 Q					
	4		12		
SB 2 A					
SB 2 B					
SB 2 C	1		3		
SB 2 Q	1	2	2		
			10	1	
SB 3 A					
SB 3 B					
SB 3 C	2	2	4		
SB 3 Q	1	2	5	1	

Order	Plecoptera				
SubOrder					
Family	Capiidae	Leuctridae	Perlodidae		
Tribe					
Genus	Allocapnia	Leuctra	Isoperla	Remenus	Skwala
Species					
Stream/Order/Rep					
FB 1 A				1	
FB 1 B					
FB 1 C				1	3
FB 1 Q	1			5	3
FB 2 A			2	1	
FB 2 B					2
FB 2 C					1
FB 2 Q		1			
FB 3 A	21			12	
FB 3 B	73	4		3	1
FB 3 C	20	3			
FB 3 Q	4	3			
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A	3				1
EC 2 B	1				2
EC 2 C	4				
EC 2 Q	1				2
EC 3 A	3				
EC 3 B					
EC 3 C	2			1	1
EC 3 Q	2				

Order / SubOrder / Family / Tribe / Genus / Species					
Order	Plecoptera				
SubOrder					
Family	Capiidae	Leuctridae	Perlodidae		
Tribe					
Genus	Allocapnia	Leuctra	Isoperla	Remenus	Skwala
Species					
Stream/Order/Rep					
RHB 1 A	8				1
RHB 1 B	4				
RHB 1 C	20			7	1
RHB 1 Q	3				1
RHB 2 A	6			2	
RHB 2 B	5	1			1
RHB 2 C				1	
RHB 2 Q	5			3	
RHB 3 A					
RHB 3 B	1		1		
RHB 3 C	2				
RHB 3 Q					
SB 1 A					
SB 1 B	9	9		3	
SB 1 C	1	1		1	
SB 1 Q	13	7		6	1
SB 2 A	9	2			
SB 2 B	4	1		3	1
SB 2 C	4	2			
SB 2 Q	6	3		1	2
SB 3 A	8				
SB 3 B	33				1
SB 3 C	62	5		8	3
SB 3 Q	4	4		3	3

Order / SubOrder / Family / Tribe / Genus / Species					
Order	Plecoptera				Trichoptera
SubOrder					
Family	Perlidae	Peltoperlidae		Pteronarcyidae	Brachycentridae
Tribe					
Genus	Acroneuria	Viehoperla	Tallaperla	Pteronarcys	Brachycentrus
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					1
FB 3 A					
FB 3 B					
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					
EC 2 B					
EC 2 C					
EC 2 Q				1	
EC 3 A					
EC 3 B					
EC 3 C					
EC 3 Q					

Order	Plecoptera				Trichoptera
SubOrder					
Family	Perlidae	Peltoperlidae		Pteronarcyidae	Brachycentridae
Tribe					
Genus	Acroneuria	Viehoperla	Tallaperla	Pteronarcys	Brachycentrus
Species					
Stream/Order/Rep					
RHB 1 A					
RHB 1 B			2		
RHB 1 C					
RHB 1 Q			3		
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B	1			1	
RHB 3 C					
RHB 3 Q					
SB 1 A					
SB 1 B					
SB 1 C			1		
SB 1 Q		1	1		1
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					2
SB 3 A					
SB 3 B					
SB 3 C					
SB 3 Q					1

Order	Trichoptera				
SubOrder					
Family	Glossosomatidae	Hydropsychidae			Hydroptilidae
Tribe					
Genus	Glossosoma	Hydropsyche	Arctopsyche	Parapsyche	Palaeagapetus
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A		1		2	
FB 2 B		1		1	
FB 2 C					
FB 2 Q		4		8	
FB 3 A	3	1			
FB 3 B	1	7			
FB 3 C	1	3		1	
FB 3 Q	4	9		3	
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A	1				
EC 2 B	1	4			
EC 2 C					
EC 2 Q	1	13			
EC 3 A					
EC 3 B		1			
EC 3 C					
EC 3 Q	60			2	

Order	Trichoptera				
SubOrder					
Family	Glossosomatidae	Hydropsychidae			Hydroptilidae
Tribe					
Genus	Glossosoma	Hydropsyche	Arctopsyche	Parapsyche	Palaeagapetus
Species					
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C				1	
RHB 1 Q			1		
			2		1
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q				1	
				1	
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q					
	6		1	2	
SB 1 A					
SB 1 B					
SB 1 C		3			
SB 1 Q				1	
	1	3		3	
SB 2 A					
SB 2 B	1	3			
SB 2 C		2		3	
SB 2 Q	1	5			
	34	16		2	
SB 3 A					
SB 3 B	1	3			
SB 3 C	1	3			
SB 3 Q	3	2			

Order	Trichoptera				
SubOrder					
Family	Odontoceridae	Philopotamidae	Polycentropodidae		Rhyacophilidae
Tribe					
Genus	Psilotreta	Wormaldia	Polycentropus	Neureclipsis	Rhyacophila
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B		1		1	
FB 1 C				7	
FB 1 Q	7	1		3	
FB 2 A				3	
FB 2 B					
FB 2 C	1				
FB 2 Q	6		2	1	
FB 3 A				3	1
FB 3 B			1		
FB 3 C			1		
FB 3 Q			2	4	
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					
EC 2 B					
EC 2 C					
EC 2 Q			2		
EC 3 A			1		
EC 3 B			1		
EC 3 C					
EC 3 Q	1	5		2	7

Order / SubOrder / Family / Tribe / Genus / Species	Trichoptera				
Family	Odontoceridae	Philopotamidae	Polycentropodidae		Rhyacophilidae
Genus	Psilotreta	Wormaldia	Polycentropus	Neureclipsis	Rhyacophila
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C	1		7	1	
RHB 1 Q		7	1	1	
	4		1	2	
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q			1	1	1
	7		2	3	
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q					
	8	1	1		
SB 1 A					
SB 1 B			1		
SB 1 C	1		2		
SB 1 Q					
	1	3	4		
SB 2 A					
SB 2 B		2	2	1	
SB 2 C	1	2			2
SB 2 Q		3		1	
	3	10	4		27
SB 3 A					
SB 3 B		4	2		
SB 3 C			4		
SB 3 Q					

Order	Collembola	Hemiptera	Lepidoptera	Odonata	Coleoptera
SubOrder	Entomobryomorpha	Heteroptera			
Family	Entomobryidae	Hebridae	Pyralidae	Gomphidae	Elmidae
Tribe					
Genus	Sinella	Lipogomphus	Acentria	Arigomphus	Ancyronyx
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					1
FB 2 C					
FB 2 Q					2
FB 3 A					6
FB 3 B					7
FB 3 C				1	
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					22
EC 2 B					1
EC 2 C				1	4
EC 2 Q					1
EC 3 A					10
EC 3 B					10
EC 3 C					8
EC 3 Q					27

Order / SubOrder / Family / Tribe / Genus / Species	Collembola / Entomobryomorpha / Entomobryidae / / Sinella	Hemiptera / Heteroptera / Hebridae / / Lipogomphus	Lepidoptera / / Pyralidae / / Acentria	Odonata / / Gomphidae / / Arigomphus	Coleoptera / / Elmidae / / Ancyronyx
Stream/Order/Rep					
RHB 1 A					1
RHB 1 B					3
RHB 1 C					
RHB 1 Q					
RHB 2 A					11
RHB 2 B					2
RHB 2 C					1
RHB 2 Q					12
RHB 3 A					3
RHB 3 B					
RHB 3 C	1				2
RHB 3 Q					2
SB 1 A				1	
SB 1 B			1		
SB 1 C					
SB 1 Q					
SB 2 A		1			1
SB 2 B					18
SB 2 C					2
SB 2 Q					4
SB 3 A					3
SB 3 B					3
SB 3 C					7
SB 3 Q		1			2

Order	Coleoptera				
SubOrder					
Family				Psephenidae	Scirtidae
Tribe					
Genus	Macronychus	Oulimnius	Rhizelmis	Ectopria	Prionocyphon
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q				1	
FB 3 A					
FB 3 B	1				
FB 3 C					
FB 3 Q					
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A		1		1	
EC 2 B					
EC 2 C				1	
EC 2 Q				2	
EC 3 A	1			1	
EC 3 B					
EC 3 C		1			
EC 3 Q				1	

Order	Coleoptera				
SubOrder					
Family				Psephenidae	Scirtidae
Tribe					
Genus	Macronychus	Oulimnius	Rhizelmis	Ectopria	Prionocyphon
Species					
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C					1
RHB 1 Q					
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q			2	3	
SB 1 A					
SB 1 B					
SB 1 C					
SB 1 Q					
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					
SB 3 A		2			
SB 3 B					
SB 3 C					
SB 3 Q				1	

Order	Tubificida	Diptera			
SubOrder		Brachycera			
Family	Enchytraeidae	Athericidae	Empididae	Ceratopogonidae	Simuliidae
Tribe					
Genus		Atherix	Chelifera	Serromyia	Simulium
Species					
Stream/Order/Rep					
FB 1 A					
FB 1 B					1
FB 1 C					
FB 1 Q					
FB 2 A					
FB 2 B					
FB 2 C					
FB 2 Q					1
FB 3 A					
FB 3 B					
FB 3 C					
FB 3 Q					1
EC 1 A					
EC 1 B					
EC 1 C					
EC 1 Q					
EC 2 A					
EC 2 B					
EC 2 C		1			
EC 2 Q					
EC 3 A	7				
EC 3 B					
EC 3 C	1				
EC 3 Q					1

Order	Tubificida	Diptera			
SubOrder		Brachycera			
Family	Enchytraeidae	Athericidae	Empididae	Ceratopogonidae	Simuliidae
Tribe					
Genus		Atherix	Chelifera	Serromyia	Simulium
Species					
Stream/Order/Rep					
RHB 1 A					
RHB 1 B					
RHB 1 C	1			2	
RHB 1 Q					1
RHB 2 A					
RHB 2 B					
RHB 2 C					
RHB 2 Q					
RHB 3 A					
RHB 3 B					
RHB 3 C					
RHB 3 Q					5
SB 1 A					
SB 1 B			1		
SB 1 C					
SB 1 Q					
SB 2 A					
SB 2 B					
SB 2 C					
SB 2 Q					1
SB 3 A					
SB 3 B			1		
SB 3 C					
SB 3 Q					

Order	Diptera							
SubOrder	Brachycera							
Family	Tipulidae							
Tribe								
Genus	Dicranota	Hexatoma	Molophilus	Ormosia	Paradelphomyia	Cryptolabis	Leptotarsus	Holorusia
Species								
Stream/Order/Rep								
FB 1 A								
FB 1 B	1	1	1					
FB 1 C						4		
FB 1 Q	1	1		1				
FB 2 A								
FB 2 B		1	2				1	
FB 2 C								
FB 2 Q								
FB 3 A	1							
FB 3 B	1							
FB 3 C							1	
FB 3 Q	1							
EC 1 A								
EC 1 B								
EC 1 C								
EC 1 Q								
EC 2 A	4			1				
EC 2 B								
EC 2 C								
EC 2 Q								
EC 3 A								
EC 3 B								
EC 3 C								
EC 3 Q								

Order	Diptera							
SubOrder	Brachycera							
Family	Tipulidae							
Tribe								
Genus	Dicranota	Hexatoma	Molophilus	Ormosia	Paradelphomyia	Cryptolabis	Leptotarsus	Holorusia
Species								
Stream/Order/Rep								
RHB 1 A								
RHB 1 B			1					
RHB 1 C		2	4					
RHB 1 Q				1				
RHB 2 A					1			
RHB 2 B								
RHB 2 C								
RHB 2 Q								
RHB 3 A		1						
RHB 3 B								
RHB 3 C								
RHB 3 Q								
SB 1 A								
SB 1 B	1	3						
SB 1 C								
SB 1 Q					1			1
SB 2 A								
SB 2 B	1							
SB 2 C	1							
SB 2 Q								
SB 3 A	1							
SB 3 B		1		1				
SB 3 C	2							
SB 3 Q	1							

Order	Diptera					
SubOrder						
Family	Chironomidae					
Subamily	Tanypodinae					
Tribe				Chironomini		
Genus	Nilotanypus	Pentaneura	Thienemannimyia	Microtendipes	Paratendipes	Polypedilum
Species						convictum
Stream/Order/Rep						
FB 1 A						
FB 1 B		1				
FB 1 C						
FB 1 Q						
FB 2 A			1			
FB 2 B						
FB 2 C						
FB 2 Q				3		
FB 3 A						
FB 3 B			2			7
FB 3 C						1
FB 3 Q						1
EC 1 A						
EC 1 B						
EC 1 C						
EC 1 Q						
EC 2 A	1					
EC 2 B						
EC 2 C						
EC 2 Q	5			2		5
EC 3 A		1				
EC 3 B			1			
EC 3 C	1		1			
EC 3 Q	2		2	1		

Order	Diptera					
SubOrder						
Family	Chironomidae					
Subamily	Tanypodinae			Chironominae		
Tribe				Chironomini		
Genus	Nilotanypus	Pentaneura	Thienemannimyia	Microtendipes	Paratendipes	Polypedilum
Species						convictum
Stream/Order/Rep						
RHB 1 A						
RHB 1 B			1			
RHB 1 C				1		
RHB 1 Q						
RHB 2 A						
RHB 2 B						
RHB 2 C						
RHB 2 Q				1		
RHB 3 A						
RHB 3 B						
RHB 3 C						
RHB 3 Q						
SB 1 A						
SB 1 B		1	2			
SB 1 C						
SB 1 Q	1	1	2			
SB 2 A			1			
SB 2 B						
SB 2 C						
SB 2 Q	2					
SB 3 A						
SB 3 B						1
SB 3 C				1		
SB 3 Q	1		3	1		

Order	Diptera					
SubOrder						
Family	Chironomidae					
Subamily	Chironominae					
Tribe	Orthocladinae					
Genus	Cricotopus	Corynoneura	Eukiefferiella			Nanocladius
Species	bicinctus	tarsis	bavarica	devonica	dicoloripes	
Stream/Order/Rep						
FB 1 A					1	
FB 1 B			6		5	
FB 1 C			26			
FB 1 Q			37		71	
FB 2 A						
FB 2 B				1		
FB 2 C						
FB 2 Q			12		6	
FB 3 A			2			
FB 3 B			1	1		
FB 3 C						
FB 3 Q	2		3			
EC 1 A						
EC 1 B						
EC 1 C						
EC 1 Q						
EC 2 A			2			
EC 2 B						
EC 2 C						
EC 2 Q			7			
EC 3 A						
EC 3 B						
EC 3 C						
EC 3 Q			6			

Order	Diptera					
SubOrder						
Family	Chironomidae					
Subamily	Chironominae					
Tribe	Orthocladinae					
Genus	Cricotopus	Corynoneura	Eukiefferiella			Nanocladius
Species	bicinctus	tarsis	bavarica	devonica	dicoloripes	
Stream/Order/Rep						
RHB 1 A					1	
RHB 1 B			2	2	1	
RHB 1 C			2	2		
RHB 1 Q			2		2	
RHB 2 A						
RHB 2 B			1			
RHB 2 C						
RHB 2 Q						
RHB 3 A						
RHB 3 B						
RHB 3 C					2	
RHB 3 Q						
SB 1 A						
SB 1 B			1			
SB 1 C						
SB 1 Q			1			
SB 2 A						
SB 2 B			1			
SB 2 C						
SB 2 Q			2		2	1
SB 3 A						
SB 3 B						
SB 3 C			1			
SB 3 Q						

Order	Diptera						
SubOrder							
Family	Chironomidae						
Subamily	Chironominae						
Tribe	Orthocladinae						
Genus	Orthocladius		Parametriocnemus	Sympsiocladius	Synorthocladius	Thienemanniella	unknown
Species	euorthocladius	ombratus					
Stream/Order/Rep							
FB 1 A	1						
FB 1 B							1
FB 1 C	51		9				3
FB 1 Q	37						
FB 2 A	7						
FB 2 B	5		3				
FB 2 C							
FB 2 Q	48						3
FB 3 A							
FB 3 B	2						
FB 3 C							
FB 3 Q	2						
EC 1 A							
EC 1 B							
EC 1 C							
EC 1 Q							
EC 2 A		1					
EC 2 B	2						
EC 2 C							
EC 2 Q		11			2		2
EC 3 A							
EC 3 B							
EC 3 C							
EC 3 Q		5				2	

Order	Diptera						
SubOrder							
Family	Chironomidae						
Subamily	Chironominae						
Tribe	Orthocladinae						
Genus	Orthocladius		Parametriocnemus	Sympsiocladius	Synorthocladius	Thienemanniella	unknown
Species	euorthocladius	ombratus					
Stream/Order/Rep							
RHB 1 A							
RHB 1 B							
RHB 1 C			1	1			
RHB 1 Q	1						
RHB 2 A							
RHB 2 B			2				
RHB 2 C			1				
RHB 2 Q							
RHB 3 A							
RHB 3 B			1				
RHB 3 C							1
RHB 3 Q							
SB 1 A							
SB 1 B			1				
SB 1 C							
SB 1 Q			1				
SB 2 A							
SB 2 B							
SB 2 C							
SB 2 Q	1	1					
SB 3 A							
SB 3 B							
SB 3 C		1					
SB 3 Q		1					

Order	Diptera			Veneroida
SubOrder				
Family	Chironomidae			
Subamily	Chironomidae			Sphaeriidae
Tribe	Tanytarsini			
Genus	Rheotanytarsus	Tanytarsus		Pisidium
Species		guerlus	unknown	
Stream/Order/Rep				
FB 1 A				
FB 1 B		1		
FB 1 C	4			1
FB 1 Q	15			1
FB 2 A				
FB 2 B				
FB 2 C				
FB 2 Q				
FB 3 A			1	
FB 3 B				
FB 3 C				
FB 3 Q				
EC 1 A				
EC 1 B				
EC 1 C				
EC 1 Q				
EC 2 A				
EC 2 B				
EC 2 C				
EC 2 Q				
EC 3 A				
EC 3 B				
EC 3 C				
EC 3 Q		1		

Order	Diptera			Veneroida
SubOrder				
Family	Chironomidae			
Subamily	Chironomidae			Sphaeriidae
Tribe	Tanytarsini			
Genus	Rheotanytarsus	Tanytarsus		Pisidium
Species		guerlus	unknown	
Stream/Order/Rep				
RHB 1 A				
RHB 1 B		4		1
RHB 1 C		3		
RHB 1 Q				
RHB 2 A				
RHB 2 B				
RHB 2 C				
RHB 2 Q				
RHB 3 A				
RHB 3 B				
RHB 3 C				
RHB 3 Q				
SB 1 A				
SB 1 B				
SB 1 C				
SB 1 Q		3		
SB 2 A				
SB 2 B				
SB 2 C				
SB 2 Q		3		
SB 3 A				
SB 3 B		1		
SB 3 C			1	
SB 3 Q				