Ecological and Biogeographical Influences on Stream Community Composition in Zoar Valley, New York

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ABSTRACT. Biotic communities in low order streams are influenced by multiple factors that may reflect both ecological conditions within individual watersheds, and also biogeographic considerations such as spatial proximity among streams and organism dispersal abilities. Our aim was to assess benthic invertebrate community composition in 23 first – third order streams in Zoar Valley, NY, across a gradient in habitat quality, and to further explore the role of local biogeography. Replicate Surber samples were collected from each stream on three dates during April – September 2006. One hundred and thirtyseven taxa were collected, representing fifty-five families, dominated by juvenile insects. Additionally we quantified ecological variables such as stream order, watershed area, habitat quality indices, and land cover, and we generated a spatial distance matrix to quantify geographic separation among streams. Similarity/dissimilarity among stream communities was quantified by multivariate ordination of genus/species distributions by Non-metric Multi-dimensional Scaling. Dipterans (true flies) tended to be a cohesive group, and loaded towards lower-order streams, whereas taxa of Ephemeroptera (mayflies) and Plecoptera (stoneflies) were more variable in distribution across stream orders and watershed sizes. Separate ordination of the thirty-one encountered genera/species of Chironomidae suggested specificity towards individual streams. Regression of distances in ordination space on geographic distances was non-significant, indicating these streams represented individual geographic units, apparently with little overlap among them. Given the high degree of disturbance inherent in many small woodland streams, these quantitative studies of the high integrity stream systems surrounding Zoar Valley canyon should prove valuable to conservation and restoration strategies.

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I. INTRODUCTION

"People who experience for the first time the diversity of life in a stream are invariable moved to wider awareness of what is at stake in the protection of water quality...Few disciplines exist in which the study of nature can offer so much direct benefit toward the preservation of the very habitat being studied" (Mandaville 2002).

The majority of woodland stream ecosystems in the eastern United States are recovering from some degree of historical human disturbance. Because of this, it is importance to assess and gain an understanding of these multi-faceted ecosystems. One way of doing this is through evaluating the dynamics of community structure and organization, and how these riparian systems respond across multiple spatial and temporal scales

The diversity of life found in any stream can be a notable discovery. This is especially true in streams that have rarely been explored, specifically in terms of community composition. Because aquatic communities can integrate multiple facets of overall system quality, it is important to look at such streams in detail.

This thesis will study the community composition of 23 first – third order streams in Zoar Valley, New York. The primary objective of the study was to concurrently evaluate the possible environmental dynamics and biogeographical influences on stream aquatic community composition and structure.

Lotic Habitats

Freshwater environments can be divided into two basic types, lotic systems such as streams and rivers, and lentic systems including standing water such as lakes. The major distinction between these two types of environments is the relative residence times of water within them (Townsend 1980). Lotic systems include everything from seepage springs or trickling headwaters to the larger rivers that empty into lakes and oceans (McCafferty 1998). Due to natural aeration from the turbulence of the flowing waters, animal life in streams and rivers are most often readily provided with oxygen (McCafferty 1998).

The flow of water and its ability to form patterns of streams and their beds are the fundamental properties of their biotic habitats (Hynes 1970). Streams can be generally categorized on the basis of flow reliability. Perennial streams have measurable flow throughout the year, whereas intermittent streams have discontinuous flow and may even dry up for periods of time (McCafferty 1998). Streams can also be categorized by stream order, a classification that reflects progression in size from small tributaries to the largest of all rivers. For example, a stream which has no tributaries is considered first-order, while a second-order stream is the convergence of two fist-order streams. When two second-order streams join, the result is a third-order stream, etc. The world's largest rivers are classified as being 10-12 order.

Riparian zones are a vital component of the river's ecosystem. These are the interfaces between terrestrial and aquatic ecosystems (Gregory *et al.* 1991). In their undisturbed condition, riparian zones can be characterized by dominant vegetation types that are tolerant of, and adapted to, relatively high soil moisture content. Riparian zones

contain some of the most diverse, dynamic, and complex of biophysical habitats (Naiman *et al.* 1993, Naiman *et al.* 1997). Because of this uniqueness, they serve as a template for understanding the organization, diversity, and dynamics of communities associated with fluvial ecosystems (Naiman *et al.* 1997).

The ecology of streams is particularly interesting due to the continuous and rapid throughput of water and other materials. In order to understand the distribution and abundance of species within a riparian ecosystem, a variety of dynamics must be examined. Such factors can generally be placed into three categories: 1) Factors associated with dispersal and/or behaviors of organisms, 2) Interspecific and intraspecific biotic factors such as predation and competition, and 3) Suitability of the abiotic environment including physical and chemical composition (Townsend 1980). Other factors that play a role in benthic community composition and abundance in riparian ecosystems include current speed, temperature, substratum, dissolved substances (i.e., oxygen, salinity, acidity, and hardness), liability to drought, food availability, shade, oviposition habits, and proximity of suitable habitats (Hynes 1970).

Environmental Influences on Stream Biotic Assemblages

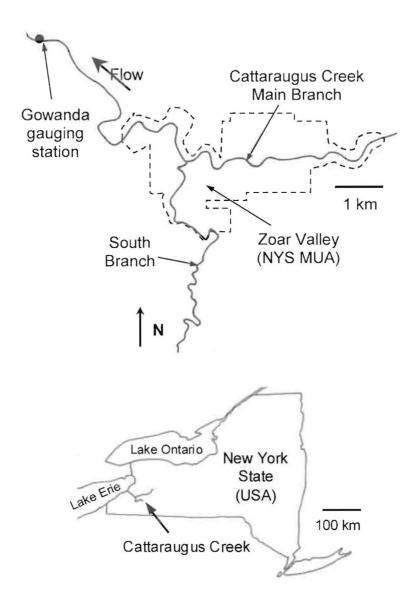
Habitat availability is considered to be a critical template that shapes organisms' life-history strategies. Johnson *et al.* (2004) stated that the environmental characteristics of a specific stream were not random, but instead controlled by macroscale geomorphic patterns. Therefore, aquatic communities are considered to be structured by processes operating at multiple spatial scales (Johnson *et al.* 2004). However as suggested by Ormerod et al. (2000), few studies have concurrently assessed the importance of both

regional and local factors on aquatic community structure. Recent work on broad-scale patterns in biotic diversity has primarily focused on how local habitat and environmental facors and historical processes have influenced the occurrence and persistence of species (Tonn 1990, Ricklefs and Schluter 1993, Poff 1997). However, it is logical to think that sites with similar habitats and/or environments might support similar biotic assemblages. But the distribution and abundance of species are not only influenced by environmental conditions, e.g. moisture, temperature regime, nutrient availability, and habitat structure (Brown et al. 1995), but also by biotic processes of competition, predation, dispersal, disturbance, and disease (Connell 1983). Therefore, it is reasonable to suggest that geographically proximal sites might also be more likely to support similar species assemblages than would sites that are farther apart (Legendre and Fortin 1989). Parris (2004) comments that as a consequence of spatial heterogeneity, there are three possible sources of variation in the composition of stream biotic assemblages: 1) pure environmental variation, 2) pure spatial variation, and 3) spatially-structured environmental variation (i.e. an interplay between both sources of variation).

Zoar Valley

The Zoar Valley Canyon, located in western New York (N 42°26', W 78°52'), is an 1185-ha state owned multi-use area. The depth of the main canyon ranges from 70 to 130 meters, which makes it the second deepest canyon system in New York State (Kershner 1994). The steep vertical walls of the canyon are cut by two branches of Cattaraugus Creek, the Main and the South branches. The Main Branch also forms the boundary between Erie and Cattaraugus Counties (Kershner 1994). (Fig.1)

Figure 1. Regional location of Zoar Valley, New York.



The Zoar Valley Canyon represents one of the premier riparian (i.e., a river and its surroundings) ecosystems in the Northeast, but only recently has quantitative ecological research been conducted here. As a consequence, the biota, in a sense, is still a mystery in a biologist's eyes. Previous and on-going studies here by YSU faculty and students have primarily focused upon Cattaraugus Creek itself and its canyon-bottom landforms, including trends in water quality (Basto-Salgado et al. 2005), riparian forest dynamics (Diggins and Kershner 2005, Pfeil et al. 2007), and fern biodiversity (Sinn and Chuey 2005).

This research that has focused primarily on the gorge leaves the entire upland portion of Zoar Valley basically unstudied. Numerous first – third order forest-covered streams can be found within this area above the canyon. These streams, which vary in origin, may be begin in the surrounding farmland and flow into second growth forest. From that point they may flow through a transition into old growth forest, then finally give way into precipitous cascades down into the canyon. Very little is known about the biota of these streams. What is known is that the land surrounding the streams has seen marked changes in terms of forest cover over the past century. An approximately 75-year record of aerial images (Fairchild Aerial Surveys 1929, USGS 1962, NYS Office of Technology 2002) reveals the various degrees of disturbance in the watersheds of these small streams. Such disturbances have ranged from minimal to near total. However, all watersheds have begun to renaturalize over the past few decades.

Goals and Objectives

This research compared stream community composition, i.e. benthic macroinvertebrates, to watershed characteristics of individual streams in the Zoar Valley study area. Three objectives were addressed during the course of this study: (1) to compare stream invertebrate community composition and structure from stream to stream, (2) to access the influence of watershed and/or habitat characteristics on community composition, and (3) to evaluate the role of local biogeography in patterns of community similarity/dissimilarity among streams.

By addressing these objectives, this thesis allowed us to quantitatively ask questions such as: What exact forces are shaping the community composition of these streams at an interface between high ecological integrity and landscape disturbance? Are watershed characteristics a bigger force on stream community composition versus the actual geographic/spatial distances between the streams? Are these streams essentially acting like aquatic islands in a sea of dry land, and will there be different patterns in community composition related to organism dispersal and colonization?

II. METHODS

Study Design

This research was designed to quantify the interplay between environmental/habitat quality and biogeographical dynamics in 23 first – third order streams above the Zoar Valley gorge. Stream biological community composition (i.e. benthic macroinvertebrates) and various watershed characteristics were quantified for each stream ecosystem. Identical sampling procedures in spring, summer, and fall 2006 were applied to all 23 streams. A complete watershed delineation of each stream was done with site-specific details pertaining to stream order as well as watershed land cover types, including mature forest, logged but not farmed land, and former farmland. Multivariate ordination analysis was employed to reveal patterns of similarity/dissimilarity in the distribution and abundance of macroinvertebrate taxa on the 23 streams. Given the complimentary objectives of assessing the influence of environmental and habitat characteristics and the influence of local biogeography on community composition, I chose to compare patterns in proximity of streams in ordination space to patterns in proximity of streams in geographical space (i.e. actual spatial distances). Such analyses have not been previously explored in a study of stream ecology.

Site Characterization

The study area contains three geographic subunits that were based on state-owned land, entrance assess, and parking availability. These areas were named southeast, southwest and north (Fig. 2). Sampling was conducted in these areas in first-, second-,

and third-order streams. The southwest study site contains a total of seven streams that flow to the South Branch of the Zoar Valley Canyon (Fig. 3). The southeast (Fig. 4) and North (Fig. 5) study zones contain ten and six streams respectively that flow into the Main Panch of Cattaraugus Creek from opposite sides of the canyon. Figure 6 shows the piotographs of various feeder-brook streams within study area.

Figure 2. The three geographic subunits of study area above the Zoar Valley Canyon. The three study areas were named and indicated by boxes. Parking access for each area indicated by asterisks.

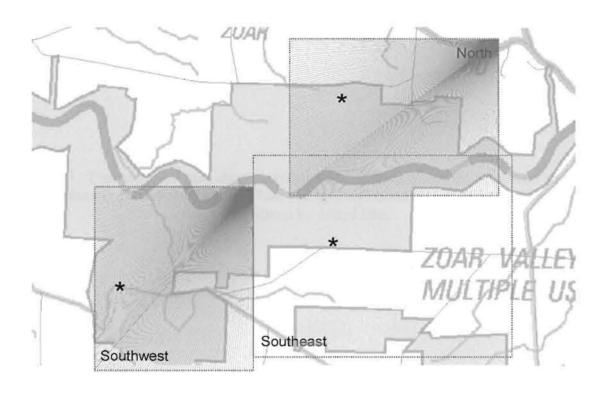


Figure 3. Topographical map showing locations of streams within the southwest study area. Streams are indicated by solid line whereas watershed size of individual streams are indicated by dotted line.

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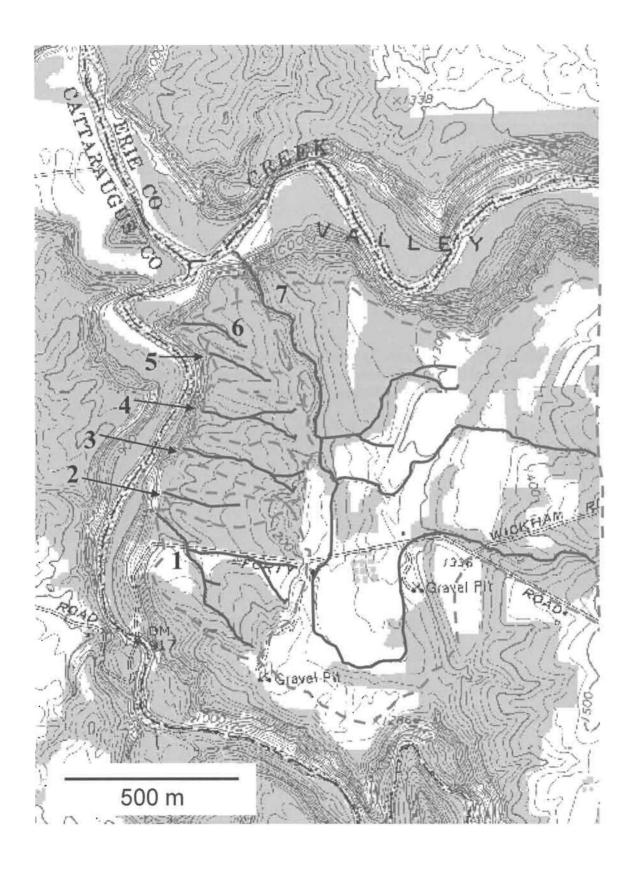


Figure 4. Topographical map showing locations of streams within the southeast study area. Streams are indicated by solid line whereas watershed size of individual streams are indicated by dotted line.

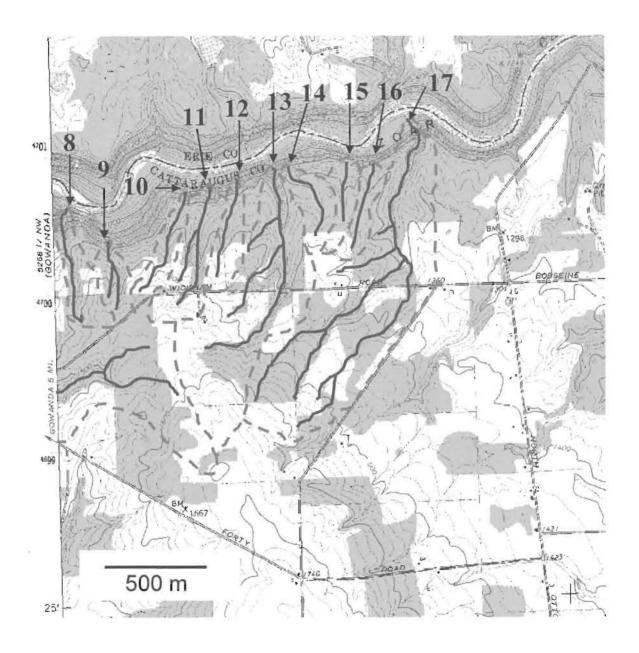


Figure 5. Topographical map showing locations of streams within the north study area. Streams are indicated by solid line whereas watershed size of individual streams are indicated by dotted line.

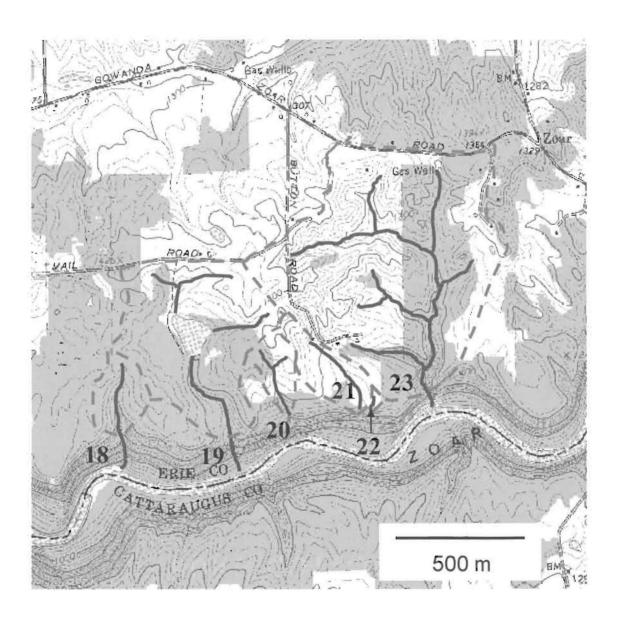


Figure 6. Photographs of various feeder-brook streams within study area.

1) Overlook of Zoar Valley canyon and Cattaraugus Creek, 2) Precipitous Cascade, 3)

First-order stream, 4) Second-order stream, and 5) Third-order stream











Habitat Characterization

Watershed delineation was achieved by examination of USGS 1:24,000 quadrangle topographic maps, augmented by extensive ground-truthing of each stream on foot. A Global Positioning System (GPS) was used to determine sampling locations on each stream. The parameters quantified included quality of forest surrounding each stream (i.e. mature forest, logged but not farmed, logged and farmed), percent canopy cover around sampling sites, percent mature forest of streams, and finally stream order. Canopy cover was gauged directly using an optical densitometer and percent mature forest cover in watersheds was determined by examination of historical aerial photographs and topographical maps, and verified by onsite observations. All watershed and/or forested areas on maps were measured by planimetry.

Habitat conditions of streams were assessed using a Qualitative Habitat Evaluation Index (QHEI; OhioEPA 2002; An 2002). Parameters evaluated included substrate type, instream cover, sinuosity, channel morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and the gradient of each stream. The health of the habitats was evaluated by the sum of scores obtained from the parameters with a maximum score of 100 and a minimum of 0. The scores can be categorized as four levels, optimal (>90%; score: >98), sub-optimal (75-89%; score: 82-98), marginal support (60-74%; score: 66-81), and poor (<59%) based on the criteria of the Ohio EPA (2002) (An 2002). While QHEI scores provide a comparative measure of habitat quality, it must be mentioned that these scores are relatively biased for larger streams (they are often employed to assess sport fish habitat).

Benthic Community Sampling

In-stream fauna of benthic macroinvertebrates was sampled for each stream on three separate sample dates to ensure temporal representation of emerging insects. Sampling during 2006 was conducted in spring (April 29, and May 6 and 16), summer (July 3, 5, and 6), and fall (September 15, 23, and 24). Invertebrates were collected approximately 100 m upstream from the canyon edge. For streams in which this was not possible due to exposed bedrock containing steep water chutes, sampling was done at the first usable location closest to canyon edge. A 30 x 30-cm Surber sampler with a 500-μm mesh was used to collect three replicated benthic samples from riffle/cobble areas of each study stream on each date. The substratum was agitated for approximately two minutes for each replicate. The contents found within the net of the Surber were rinsed and preserved in 70% ethanol in the field (Doviak 2002). Invertebrate specimens were then visually sorted from preserved samples in the laboratory under illuminated 3x magnifiers. Macroinvertebrates were identified to family, genus, and possibly species at magnification of 7 x 40x according to Pennak (1953), Peckarsky et al. (1990), Merrit and Cummings (1996), USEPA (2006), NYS DEC (2006), Wiggins (1977), Simpson et al. (1980) and/or Wiederholm (1983), Harper and Hynes (1971). Invertebrate collections are presently being stored in 70% ethanol, so voucher specimens may be obtained for any of the identified taxa.

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 2 – 5 minutes, after which they were permanently slide mounted in Canada balsam. Chironomid slides are also being stored as voucher specimens.

Statistical Analysis

Ordination of community composition was generated using Non-metric Multidimensional Scaling (NMDS) (SPSS 13.0, alscal algorithm). NMDS is increasingly utilized for indirect gradient analyses of species distributions because it is robust in the face of non-monotonic data distributions. (http://ordination.okstate.edu, 2007). This is opposed to statistically elegant Principle Components Analysis (PCA), which however can suffer some artifacts when used to ordinate species distributions. NMDS was used to identify patterns of similarity/dissimilarity of benthic community composition among streams. NMDS has previously been employed in studies of riparian ecosystems to examine patterns in community composition within benthic macroinvertebrate (Mykrä et al 2004), woody vegetation (Baker and Wiley 2004), and even diatom assemblages (Weilhoefer and Pan 2006), and thus has widely demonstrated utility as an analysis of species distributions.

Two separate analyses were run: 1) an ordination showing patterns including all taxa of macroinvertebrates, and 2) an ordination including only the very speciose Chironomidae. After these ordination plots were generated, Pearson correlation coefficients were calculated to compare original species abundances to NMDS dimension scores, to assess the influence of these abundances on the ordination axes. (These coefficients are the statistical equivalent of "loadings" that are generated by eigenvector-based analyses such as PCA.)

Distance matrices were constructed using ordination dimension scores from stream community composition, to quantify separation in ordination space between pairings of individual streams. Additional distance matrices were constructed to quantify

separation in geographic space. Separate matrices of both types were constructed for all possible pairings of streams and for adjacent pairs of streams only. Sets of these matrices were generated both for all taxa and for Chironomidae only. Ordination distances were then compared to geographic distances by simple linear regression (SPSS 13.0, Zar 1998).

Characterization of Streams

Areas of the individual watersheds surrounding the 23 first – third order streams were quite variable ranging from 1.22 ha - 220.12 ha (Table 1). However only three watersheds exceeded 100 ha while eighteen watersheds were less than 25 ha. The three streams whose watersheds exceeded 100 ha were all categorized as third order streams. There was, however, an additional third order stream whose watershed area was much smaller, at 22.27 ha (Table 1).

All streams were essentially perennial, but flow in Stream #'s 5, 6, 20, 21, and 22 was substantially reduced on the summer sampling date in June 2006 to the point were standard Surber samples were difficult or actually impossible to collect.

QHEI scores were also variable, ranging from 46 - 84 (Table 1). The lowest score was obtained from the habitat surrounding Stream #2, a first-order stream, while the highest was from Stream #23, a third-order stream. The three habitats that were of the highest quality (i.e. QHEI scores ≥ 80) were from Stream #13, second-order, and Streams #1 and #23, both third-order streams (Table 1).

Also measured were percent canopy cover surrounding each sampling location and percent mature forest of individual watersheds (Table 1). Percent canopy cover ranged from 93% in Stream #17 to 68% in Stream #20. Percent of mature forest ranged from 100% in both watersheds of Streams # 5 & 6 to 7% in Stream #13 (Table 1).

Table 1. Watershed and habitat characteristics of study streams.

Stream	Order	Latitude	Longitude	Watershed	Canopy	Mature
Number				Area	Cover	Forest
				(ha)	%	%
1	3	42.4306	-78.8951	22.27	90	20
2	1	42.4314	-78.8951	4.92	83	20
3	2	42.4329	-78.8932	5.95	91	28
4	2	42.4339	-78.8927	7.25	84	36
5	1	42.4358	-78.8926	4.66	88	100
6	1	42.4368	-78.8927	5.95	86	100
7	3	42.4368	-78.8891	220.10	85	34
8	1	42.437	-78.8738	19.79	85	43
9	1	42.4369	-78.8701	10.15	77	58
10	1	42.4387	-78.8646	12.69	83	30
11	2	42.4386	-78.8627	21.32	89	10
12	1	42.4394	-78.8595	12.18	89	44
13	2	42.4391	-78.856	83.23	89	7
14	1	42.4409	-78.8546	11.67	91	69
15	1	42.441	-78.8506	10.66	82	91
16	1	42.4408	-78.8485	9.14	82	76
17	3	42.4401	-78.8466	115.20	93	26
18	2	42.4448	-78.8665	8.39	86	84
19	2	42.4445	-78.8596	54.66	77	41
20	2	42.4448	-78.8564	5.18	68	65
21	1	42.4451	-78.85	10.00	78	21
22	1	42.4455	-78.849	1.22	70	50
23	3	42.4465	-78.8467	108.65	80	12

Table 1 Cont. Watershed and habitat characteristics of study streams. Summary scores given for five major QHEI components (Scores do not total to entire QHEI because some miscellaneous components are not listed here).

		QHEI Components				
Stream	QHEI	Substrate/20	Instream	Channel	Riparian	Pool/
Number	Score/100		Cover/20	Morphology/20	Zone/10	Current/12
1	82	20	15	19	8	6
2	46	3	11	13	7	4
3	77	18	16	17	8	5
4	71	18	12	16	8	5
5	52	8	11	15	7	4
6	59	11	10	15	8	4
7	78	16	14	19	9	7
8	71	19	11	15	7	6
9	76	19	14	17	7	6
10	59	17	6	15	8	4
11	73	20	11	16	8	7
12	68	19	11	16	8	4
13	80	20	11	19	8	8
14	62	16	12	15	7	3
15	56	13	11	13	7	4
16	57	17	5	15	7	4
17	78	20	11	19	8	8
18	75	20	16	17	7	4
19	79	20	18	17	8	4
20	62	17	9	15	7	2
21	50	11	8	13	6	1
22	51.5	17	5	13	6.5	1
23	84	20	16	19	8	7

Macroinvertebrate Diversity and Abundance

Trends in community composition of in-stream fauna were based on the identification of 137 taxa representing fifty-five families, dominated by juvenile insects (Appendix A-1, B-1, and C-1). From the 11 families in the order Diptera, thirty-one genera/species of the family Chironomidae were also collected (Appendix A-2, B-2, and C-2). List of averages of all collected taxa, in order of overall abundance in all 23 streams can be found in Table 2. The most abundant taxa, i.e. the upper quartile of all 137 taxa (n = 34), represented insect the orders Coleoptera, Diptera, Ephemeroptera, Odonata, Plecoptera, and Trichoptera (Table 3).

Macroinvertebrate Community

Three ordination graphs were generated deriving Dimensions 1 and 2 from the macroinvertebrate taxa of the streams. The first ordination (Fig. 7) included stream averages from all replicates for all taxa. This ordination, however, revealed a high amount of clustering, with only three major outlying streams and thus did not provide much useful information for the majority of our sites. Examination of raw data revealed that these outliers were a result of very high numbers in single replicates of the stonefly *Nemoura* in Streams #5 and #6, and the dipterans *Prosimulium* and *Simulium*, in Stream #7. Therefore, a second ordination graph was generated using all taxa, but omitting the four specific replicate x taxa data that generated the obvious outliers in Figure 7 (Fig. 8).

Table 2. List of averages of all collected taxa, in order of overall abundance in all 23 streams.

Order	Family	Subfamily	Tribe	Genus/species	Average
Plecoptera	Nemouridae			Amphinemua	17.50
Plecoptera	Leuctridae			Leuctra	12.81
Trichoptera	Hydropsychidae			Diplectrona	7.74
Ephemeroptera	Leptophlebiidae			Paraleptophlebia	6.83
Plecoptera	Nemouridae			Nemoura	6.52
Plecoptera	Chloroperlidae			Haploperla	6.13
Ephemeroptera	Heptageniidea			Epeorus (Iron)	5.71
Diptera	Chironomidae	Orthocladiinae		Parametriocnemus lundbecki	5.30
Plecoptera	Chloroperlidae			Suwallia	4.71
Ephemeroptera	Bactidae			Baetis	3.84
Tubificida	Oligocheatae				3.76
Ephemeroptera	Heptageniidea			Cingymula	3.56
Diptera	Ceratopogonidae			Probezzia	3.08
Plecoptera	Perlodidae			Isoperla	2.89
Trichoptera	Polycentropidae			Polycentropus	2.72
Diptera	Tipulidae	Limoniinae		Hexatoma	2.44
Ephemeroptera	Ameletidae	100 00000 0 WH 10		Ameletus	2.40
Trichoptera	Philopotamidae			Dolophilodes	2.30
Diptera	Tipulidae			Dicranota	2.27
Diptera	Simuliidae			Simulium	2.19
Trichoptera	Hydropsychidae			Hydropsyche	2.05
Diptera	Chironomidae	Tanypodinae		Thienemannimyia	1.96
Diptera	Chironomidae	Orthocladiinae		Eukiefferiella discoloripes	1.90
Diptera	Chironomidae	Chironominae	Tanytarsini	Tanytarsus guerlus	1.81
Diptera	Chironomidae	Orthocladiinae		Pseodorthocladius	1.65
Diptera	Tipulidae			Molophilus	1.51
Plecoptera	Peltoperlidae			Tallaperla	1.46
Odonata	Cordulegastridae			Cordulegaster	1.40
Ephemeroptera	Ephemerellidae			Scrratella	1.35
Diptera	Chironomidae	Diamesinae		Diamesa	1.33
Diptera	Chironomidae	Orthocladiinae		Heterotrissocladius marcidus	1.33
Coleoptera	Elmidae			Oulimnius	1.33
Diptera	Simuliidae			Prosimulium	1.18
Coleoptera	Elmidae			Microcylleopus	1.14
Odonata	Gomphidae			Stylogomphus	1.13
Diptera	Tipulidae			Pscudolimnophila	1.09
Trichoptera	Lepidostomatidae			Lepidostoma	1.07
Plecoptera	Peltoperlidae			Peltoperla	0.99
Diptera	Tabanidae			Chrysops	0.93
Decapoda	Cambaridae				0.93
Ephemeroptera	Ephemerellidae			Ephemerella	0.85
Trichoptera	Glossosomatidae			Glossosoma	0.84
Diptera	Chironomidae	Chironominae	Chironominae	Polypedilum scalaenum	0.80
Plecoptera	Perlidae	annum a narromaticalessa		Acroneuria	0.77
Trichoptera	Limnephilidae			Pycnopsyche	0.73
Diptera	Dixidae			Dixa	0.70
Collembola	1sotomidae				0.64

Table 2 Cont. List of averages of all collected taxa, in order of overall abundance in all 23 streams.

Order	Family	Subfamily	Tribe	Genus/species	Average
Plecoptera	Chloroperlidae			Sweltsa	0.61
Pelecypoda	Sphaeriidae				0.60
Colcoptera	Psephenidae			Ectopria	0.59
Diptera	Tipulidae			Ormosia	0.49
Coleoptera	Elmidae			Stenelmis	0.49
l Iemiptera	Veliidae			Microvelia	0.48
Ephemeroptera	Ephemeridae			Pentagenia	0.43
Trichoptera	Limnephilidae			Hesperophylax	0.43
Plecoptera	Perlidae			Perlesta	0.43
Diptera	Chironomidae	Orthocladiinae		Eukiefferiella bavarica	0.43
Diptera	Tipulidae			Tipula	0.39
Plecoptera	Perlodidae			Remenus	0.35
Megaloptera	Corydalidae			Chauliodes	0.33
Ephemeroptera	Ephemeridae			Ephemera	0.27
Megaloptera	Sialidae			Sialis	0.26
Diptera	Chironomidae	Chironominae	Tanytarsini	Heterotanytarsus	0.26
Diptera	Chironomidae	Chironominae	Tanytarsini	Tanytarsus glabrescens	0.26
Coleoptera	Elmidae			Macronychus	0.24
Trichoptera	Beraeidae			Beraea	0.22
Megaloptera	Corydalidae			Nigronia	0.22
Diptera	Tipulidae			Limnophila	0.22
Trichoptera	Limnephilidae			Psychoglypha	0.17
Trichoptera	Limnephilidae			Pseudostenophylax	0.17
Diptera	Chironomidae	Chironominae	Chironominae	Polypedilum	0.17
Diptera	Chironomidae	Orthocladiinae		Paracheatocladius	0.17
Odonata	Gomphidae			Lanthus	0.17
Coleoptera	Hydrophilidae			Hydrobius	0.17
Tubificida	Lumberculus				0.15
Trichoptera	Goeridae			Goera	0.13
Diptera	Chironomidae	Orthocladiinae		Thienemanniella xena	0.13
Trichoptera	Phryganeidae			Ptilostomis	0.09
Hemiptera	Veliidae			Rhagovelia	0.09
Diptera	Chironomidae	Diamesinae		Symposiocladius	0.09
Diptera	Chironomidae	Orthocladiinae		Thienemanniella	0.09
Diptera	Empididae			Hemerodromia	0.09
Trichoptera	Uenoisae			Neophylax	0.07
Plecoptera	Peltoperlidae			Agentina	0.04
Diptera	Dolichopodidae			Rhaphium	0.04
Trichoptera	Hydropsychidae			Cheumatopsyche	0.04
Trichoptera	Hydropsychidae			Parapsyche	0.04
Trichoptera	Polycentropidae			Nyctiophylax	0.04
Hemiptera	Gerridae			in the same hand are a	0.04
Hydrachnidia	Limnesia				0.04
Lepidoptera	Pyralidae				0.04

Table 2 Cont. List of averages of all collected taxa, in order of overall abundance in all 23 streams.

Order	Family	Subfamily	Tribe	Genus/species	Average
Diptera	Chironomidae	Chironominae	Chironominae	Paratendipes	0.04
Diptera	Chironomidae	Chironominae	Chironominae	Polypedilum	0.04
Diptera	Chironomidae	Chironominae	Chironominae	Polypedilum fallax	0.04
Diptera	Chironomidae	Chironominae	Chironominae	Stenochironomus	0.04
Diptera	Chironomidae	Chironominae	Tanytarsini		0.04
Diptera	Chironomidae	Diamesinae		Prodiamesa	0.04
Diptera	Chironomidae	Diamesinae		Sympotthastia	0.04
Diptera	Chironomidae	Orthocladiinae		Brillia	0.04
Diptera	Chironomidae	Orthocladiinae		Epoicocladius	0.04
Diptera	Chironomidae	Orthocladiinae		Parakielferiella	0.04
Diptera	Chironomidae	Tanypodinae		Larsia	0.04
Diptera	Pelecorhynchidae			Glutops	0.04
Diptera	Simuliidae			Twinnia	0.04
Trichoptera	Doliphopodidae			Raphium	0.04
Diptera	Psychodidae			Pericoma, Telmatoscopus	0.04
Diptera	Ptychopteridae			Ptychoptera	0.04
Odonata	Aeshnidae			Boyeria	0.04
Coleoptera	Elmidae			Ancyronyx	0.04
Coleoptera	Elmidae			Optioservus	0.04
Coleoptera	Dytiscidae			Rhantus	0.04
Coleoptera	Haliplidae			Halipus	0.04
Coleoptera	Hydrophilidae		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Sperchopsis	0.04
Coleoptera	Histeridae				0.04
Polydesmida					0.04
Gastropoda	Bithyniidae			Bithynia tentaculata	0.04
Mesogastropoda	Hydrobiidae				0.04
Basommatophora	Planorbidae				0.04

Table 3. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Coleoptera	Diptera		
	Family	Elmidae	Chironomidae		
	Subfamily		Chironominae	Diamesinae	Orthocladiinae
	Tribe				
-	-		Tanytarsus		Eukiefferiella
Stream	Genus	Oulimnius	guerlus	Diamesa	discoloripes
1		0.00	1.50	0.00	1.00
2		0.00	2.50	0.00	0.00
3		1.00	1.40	1.00	2.00
4		1.00	1.40	0.00	3.80
5		1.00	2.00	0.00	9.50
6		1.00	3.67	0.00	10.00
7		0.00	1.00	1.00	4.00
8		0.00	1.00	4.50	2.00
9		0.00	1.75	3.00	0.00
10		0.00	2.20	1.50	1.00
11		0.00	1.60	13.00	1.00
12		2.50	2.00	1.00	1.00
13		0.00	2.50	1.00	1.00
14		3.50	1.60	0.00	1.00
15		9.00	2.00	1.00	1.00
16		0.00	1.20	0.00	0.00
17		6.00	2.67	1.00	0.00
18		0.00	1.00	1.67	2.00
19		0.00	2.67	1.00	0.00
20		2.00	2.75	0.00	1.50
21		1.00	1.00	0.00	1.00
22		1.50	2.00	0.00	1.00
23		1.00	0.00	0.00	0.00

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Diptera		
	Family	Chironomidae		
	Subfamily	Orthocladiinae		
	Tribe			
Stream	Genus	Heterotrissocladius marcidus	Parametriocnemus lundbecki	Pseodorthocladius
1		0.00	1.50	1.00
2		3.00	5.14	1.33
3		2.00	6.29	2.00
4		1.00	4.50	2.33
5		2.50	13.67	1.00
6		2.50	6.67	3.50
7		0.00	1.00	1.00
8		1.00	3.29	1.00
9		2.00	3.43	0.00
10		2.00	9.33	0.00
11		0.00	4.50	0.00
12		1.00	6.43	1.50
13		1.00	3.83	0.00
14		1.00	6.63	1.50
15		1.00	3.25	4.00
16		3.00	6.14	2.75
17		1.00	2.17	4.00
18		0.00	1.83	1.50
19		1.67	8.86	2.00
20		1.00	8.80	1.50
21		3.00	8.75	6.00
22		0.00	2.00	0.00
23		1.00	4.00	0.00

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Diptera			
	Family	Chironomidae	Ceratopogonidae	Simuliidae	
	Subfamily	Tanypodinae			
	Tribe				
Stream	Genus	Thienemannimyia	Probezzia	Prosimulium	Simulium
1		0.00	0.00	0.00	0.00
2		1.40	1.50	0.00	0.00
3		1.00	2.33	0.00	0.00
4		1.00	3.00	4.00	1.00
5		1.00	2.00	14.00	29.00
6		1.00	4.00	3.00	2.33
7		0.00	0.00	167.00	307.00
8		3.00	1.33	0.00	0.00
9		2.83	5.00	0.00	1.00
10		3.25	1.50	2.00	1.00
11		1.75	1.50	2.00	0.00
12		3.00	6.00	0.00	2.00
13		0.00	1.00	0.00	5.00
14		2.40	2.40	0.00	1.00
15		0.00	3.00	0.00	0.00
16		2.50	2.80	0.00	0.00
17		1.00	1.50	0.00	1.00
18		3.00	3.00	0.00	0.00
19		2.67	1.00	1.00	1.00
20		5.20	4.00	0.00	0.00
21		5.00	24.00	0.00	0.00
22		1.00	0.00	0.00	2.40
23		3.00	0.00	0.00	1.50

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Diptera			Ephemeroptera	
	Family	Tipulidae			Ameletidae	Baetidae
	Subfamily					
0.1	Tribe	D.	TT.	36)))		75
Stream	Genus	Dicranota	Hexatoma	Molophilus	Ameletus	Baetis
1		2.00	1.00	0.00	0.00	5.40
2		1.00	2.00	1.00	1.00	4.00
3		3.00	2.00	0.00	2.00	6.75
4		1.00	3.25	2.33	6.25	1.00
5		1.00	0.00	0.00	2.00	0.00
6		0.00	0.00	0.00	12.00	1.00
7		0.00	2.25	1.00	0.00	14.33
8		2.75	1.00	0.00	2.25	1.43
9		1.00	1.00	0.00	2.50	3.33
10		4.50	2.13	1.00	1.33	1.40
11		1.75	2.60	1.00	2.00	4.33
12		3.00	3.67	3.00	1.00	1.00
13		4.60	2.83	0.00	0.00	7.60
14		3.00	4.00	2.00	2.33	7.00
15		2.25	3.00	0.00	1.00	4.00
16		3.50	1.33	1.40	6.00	3.00
17		3.00	2.71	0.00	7.50	3.50
18		3.38	1.33	1.00	0.00	3.75
19		3.33	1.00	1.00	0.00	7.00
20		3.00	5.00	1.00	0.00	1.50
21		2.00	10.80	14.50	0.00	0.00
22		2.00	1.50	0.00	1.00	5.00
23		1.00	1.67	4.50	5.00	2.00

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Ephermeroptera			
	Family	Ephemerellidae	Heptageniidea		Leptophlebiidae
	Subfamily				
	Tribe				
64	Camus	Comodollo	Cinavanula	Epeorus	Developted blobbs
Stream	Genus	Serratella 2.50	Cingymula 10.33	(Iron) 8.80	Paraleptophlebia 0.00
1					
2		1.00	0.00	0.00	4.50
3		2.00	4.40	3.33	7.83
4		1.00	1.00	3.00	4.38
5		0.00	0.00	0.00	0.00
6		5.00	0.00	0.00	12.00
7		1.50	2.20	14.50	4.00
8		1.00	3.33	5.75	7.14
9		0.00	1.80	4.80	6.43
10		0.00	1.00	4.25	3.17
11		1.00	4.40	12.40	4.00
12		8.00	2.33	3.50	5.29
13		0.00	9.60	11.00	4.17
14		2.50	7.00	15.00	3.11
15		0.00	3.33	6.00	2.60
16		0.00	1.00	1.00	17.75
17		4.00	19.50	15.33	8.25
18		0.00	1.00	12.60	1.00
19		1.50	2.00	3.00	10.11
20		0.00	0.00	0.00	10.75
21		0.00	1.00	0.00	30.40
22		0.00	6.67	6.00	4.17
23		0.00	0.00	1.00	6.00

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Odonata	Plecoptera		
	Family	Cordulegastridae	Chloroperlidae		Leuctridae
	Subfamily				
	Tribe				
Stream	Genus	Cordulegaster	Haploperla	Suwallia	Leuctra
1		0.00	2.00	2.00	6.33
2		3.33	0.00	1.00	29.25
3		1.00	2.00	3.75	40.71
4		1.00	14.00	11.75	4.80
5		0.00	0.00	4.00	2.00
6		0.00	1.50	13.00	7.00
7		1.00	5.00	3.00	4.33
8		1.00	15.00	2.00	17.13
9		1.00	4.00	2.00	25.57
10		2.33	2.20	2.50	11.75
11		4.00	7.00	2.75	14.43
12		2.00	4.00	18.25	15.00
13		0.00	25.00	1.00	14.50
14		1.67	9.75	8.00	14.33
15		2.50	8.00	3.00	8.50
16		1.00	0.00	2.00	6.86
17		1.00	26.67	1.33	2.67
18		1.00	8.00	10.80	8.50
19		2.00	0.00	9.00	23.57
20		2.20	0.00	1.00	14.00
21		3.25	0.00	0.00	5.60
22		1.00	6.67	6.00	9.00
23		0.00	0.00	0.00	8.67

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Plecoptera			
	Family	Nemouridae		Perlodidae	Peltoperlidae
	Subfamily				
	Tribe				
Stream	Genus	Amphinemura	Nemoura	Isoperla	Tallaperla
1		10.75	0.00	1.67	0.00
2		13.40	6.40	0.00	0.00
3		14.60	1.67	2.83	2.33
4		25.00	33.00	4.60	4.67
5		2.00	106.50	0.00	0.00
6		29.33	158.00	0.00	0.00
7		8.75	4.67	1.00	0.00
8		29.40	4.60	3.00	1.75
9		5.25	4.67	2.25	1.00
10		17.00	5.50	3.00	2.00
11		45.25	0.00	3.60	2.00
12		45.67	2.67	4.33	2.67
13		3.25	1.67	3.25	1.00
14		27.67	2.00	5.17	1.00
15		16.00	2.67	7.00	0.00
16		10.33	42.71	2.00	0.00
17		10.33	2.00	5.00	1.00
18		7.80	4.00	2.14	3.33
19		19.00	2.00	4.00	0.00
20		14.33	4.00	3.60	2.67
21		18.00	8.25	6.33	1.00
22		12.80	0.00	1.67	7.00
23		16.50	4.25	0.00	0.00

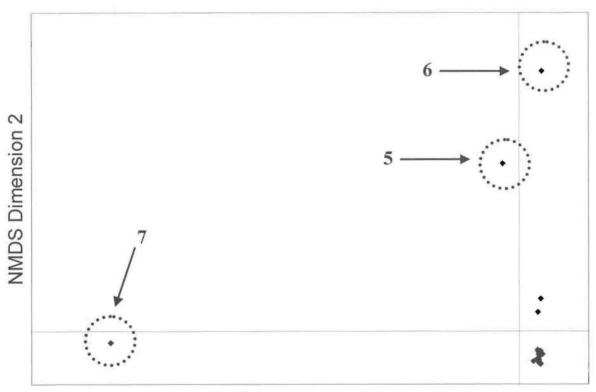
Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Trichoptera			
	Family	Hydropsychidae		Philopotamidae	Polycentropidae
	Subfamily				
	Tribe				
Stream	Genus	Diplectrona	Hydropsyche	Dolophilodes	Polycentropus
1		2.50	2.00	1.00	0.00
2		1.50	1.00	1.00	0.00
3		11.43	1.50	3.25	2.75
4		1.00	0.00	8.00	4.50
5		0.00	1.00	0.00	2.50
6		0.00	0.00	0.00	10.00
7		4.00	2.33	1.00	2.50
8		10.86	1.00	1.00	1.00
9		5.00	0.00	0.00	1.00
10		2.00	0.00	2.33	1.00
11		7.50	0.00	5.50	1.25
12		32.40	0.00	2.50	2.50
13		2.33	13.25	4.50	1.00
14		14.56	2.00	5.40	2.20
15		7.83	0.00	2.00	1.00
16		3.20	2.00	1.00	2.50
17		4.67	1.00	1.00	1.33
18		5.00	0.00	1.00	3.00
19		19.50	9.60	7.33	12.00
20		15.00	2.50	1.00	1.50
21		20.67	4.00	2.00	1.00
22		6.13	2.86	2.00	6.50
23		1.00	1.00	0.00	1.50

Table 3 Cont. Average occurrences (organisms per replicate Surber sample) of the upper quartile (n = 34) of macroinvertebrates found within study streams.

	Order	Tubificida
	Family	Oligocheatae
	Subfamily	
	Tribe	
Stream	Genus	1.00
1		1.00
2		3.14
3		1.67
4		1.25
5		11.00
6		2.67
7		1.00
8		1.00
9		1.00
10		1.00
11		1.00
12		7.50
13		1.00
14		3.20
15		10.50
16		7.33
17		1.00
18		5.33
19		2.33
20		9.00
21		11.67
22		1.00
23		1.00

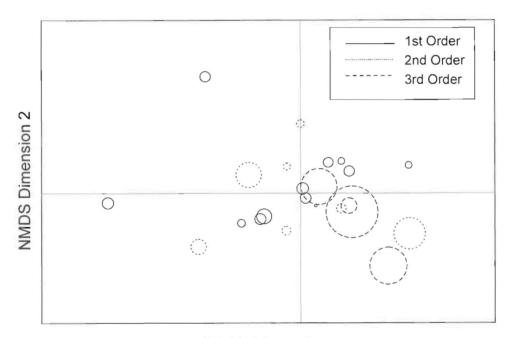
Figure 7. Ordination plot including all identified taxa of benthic aquatic macroinvertebrates.



NMDS Dimension 1

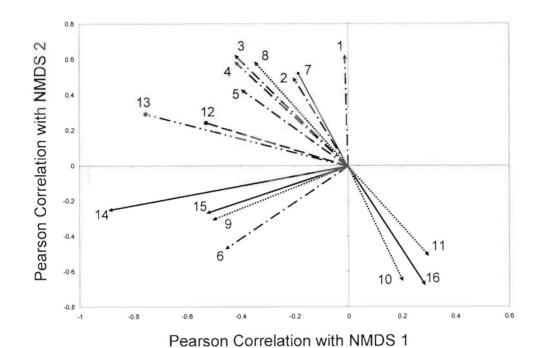
Figure 8. Ordination plot that includes all identified taxa (but omitting 4 outlying data – see text): 1) *Nemoura*, 2) *Prosimulium*, and 3) *Simulium*.

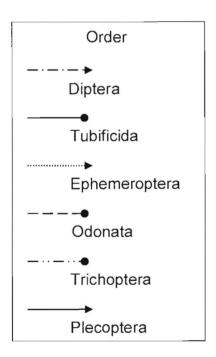
Size of plot symbols indicates size of watersheds.



NMDS Dimension 1

Figure 9. "Loadings" for the all taxa ordination plot (omitting 4 outlying data – see text).





Diptera

- Heterotrissocladius Chironomidae 1.
- Parametriocnemus Chironomidae
- Probezzia Ceratopogonidae Molophilus Tipulidae 3.
- 4.
- Hexatoma Tipulidae 5.
- Thienemannimyia Chironomidae 6.

Tubificida

Unidentified Tubificid

Ephemeroptera

- Paraleptophlebia Leptophlebidae
- Seratella Ephemereliidae
- 10. Epeorus (Iron) Heptageniidae
- 11. Cingymula Heptageniidae

Odonata

12. Cordulegaster - Cordulegastridae

Trichoptera

13. Diplectrona - Hydropsychidae

Plecoptera

- 14. Amphenimura Nemouridae
- 15. Suwallia Chloroperlidae
- 16. Haploperla Chloroperlidae

This ordination of the streams revealed clustering (in the lower right quadrant of the graph) of third-order streams, as well as of streams with larger watershed areas. However, within this cluster, additional first- and second-order streams with noticeably smaller watershed areas could also be found. Pearson correlation of taxon abundance with dimension scores (i.e. "loadings") revealed taxa from six orders that were significantly correlated (p <0.05) with either Dimension 1 or 2 or with both (Fig. 9). These taxa included six genera in the order Diptera, one unidentified Tubificid annelid worm, four genera of Ephemeroptera, one genus of Odonata, one genus of Trichoptera, and three genera of Plecoptera (Fig.9). Loading vectors for five of the six abundant dipterans shown were within 60° of each other in the upper left quadrant of the ordination plot. In contrast, two taxa of Ephemeroptera and one taxon of Plecoptera loaded strongly to the lower right quadrant, and thus were positively associated with larger streams.

To further investigate this apparent small stream/large stream axis demonstrated by these taxa, we reconstructed ordination plots using: 1) first order streams only (Fig. 10), and 2) second order streams only (Fig. 11). There were insufficient third order streams to conduct a reliable NMDS analysis alone (SPSS version 13.0). Within first order streams only (Fig. 10) related dipterans loaded closely together but were no longer a unified group (i.e. Chironomidae and Tipulidae diverged). Within second order streams only (Fig. 11), all taxa that suggested a directional axis in Figure 9 now showed no pattern whatsoever. Additionally, loadings of some of the dipterans had also become quite weak.

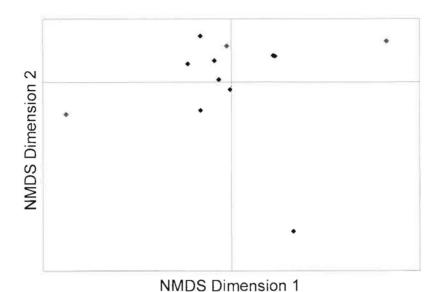
The third ordination plot that was generated included taxa only from the very speciose Chironomidae (Fig. 12). Ordination of the streams based solely on Chironomid

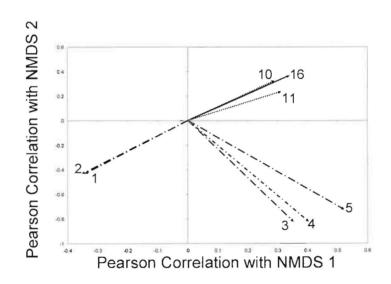
composition revealed a high degree of clustering of all watershed sizes and stream orders, and did not appear to reveal any size or order based trend as did the ordination of all taxa. Pearson correlations revealed that taxa from three subfamilies (Orthocladiinae, Chironominae and Diamesinae) were significantly associated (p <0.05) with either Dimension 1 or 2 or with both (Fig. 13). From those subfamilies, seven genera/species of Orthocladiinae, one genus/species of Chironomidae, and one genus/species of Diamesinae had the strongest correlation with the two dimensions (Fig. 13).

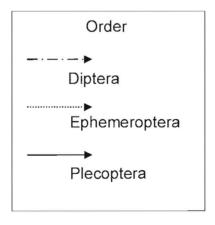
Spatial Proximity

Linear regression of ordination distances (i.e. similarity/dissimilarity of stream macroinvertebrate communities) between all possible pairings of streams, and between pairings only of adjacent streams, on geographic distances revealed a complete lack of significance (Figs. 14, 15, 16, & 17; Note $R^2s \le 0.0315$ and p-values from 0.309 to 0.715).

Figure 10. Ordination plot of first order streams only, with "loadings" of dipteran, plecopteran, and ephemeropteran taxa that were particularly informative in the ordination of all streams.







Diptera

- Heterotrissocladius Chironomidae
- Parametriocnemus Chironomidae
- Probezzia Ceratopogonidae Molophilus Tipulidae Hexatoma Tipulidae 3.
- 4.

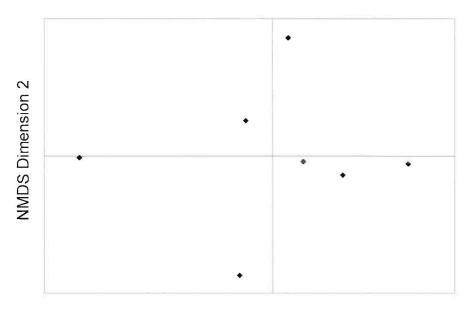
Ephemeroptera

- 10. Epeorus (Iron) Heptageniidae
- 11. Cingymula Heptageniidae

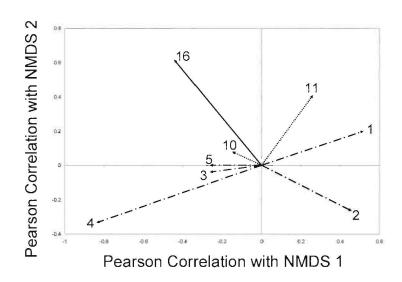
Plecoptera

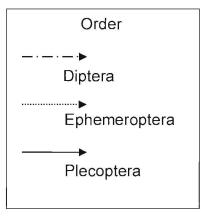
16. Haploperla - Chloroperlidae

Figure 11. Ordination plot of second order streams only, with "loadings" of dipteran, plecopteran, and ephemeropteran taxa that were particularly informative in the ordination of all streams.



NMDS Dimension 1





Diptera

- 1. Heterotrissocladius - Chironomidae
- Parametriocnemus Chironomidae
- Probezzia Ceratopogonidae Molophilus Tipulidae Hexatoma Tipulidae 3.
- 4.

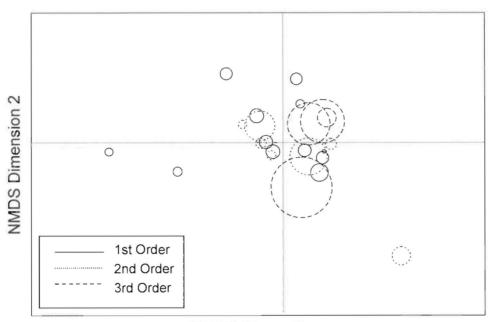
Ephemeroptera

- 10. Epeorus (Iron) Heptageniidae
- 11. Cingymula Heptageniidae

Plecoptera

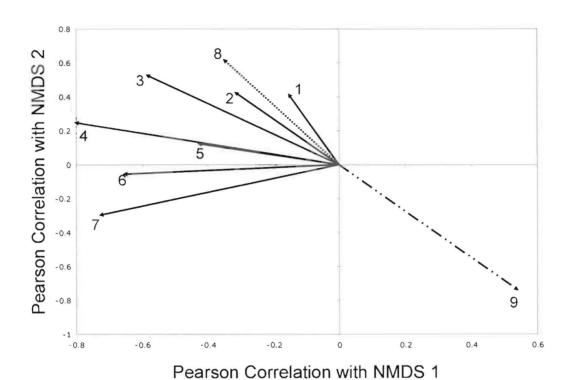
16. Haploperla - Chloroperlidae

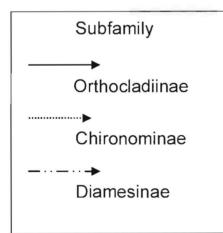
Figure 12. Ordination plot generated from Chironomidae genera only. Size of plot symbols indicates size of watersheds.



NMDS Dimension 1

Figure 13. "Loadings" for Chironomid genera only ordination plot.





Orthocladiinae

- Thienemanniella xena
- Pseudorthocladius 2.
- Heterotrissocladius marcidus 3.
- Parametriocnemus lundbecki
- Symposiocladius Parakiefferiella
- Eukiefferiella discoloripes

Chironominae

Polypedilum scalaenum

Diamesinae

Diamesa

Figure 14. Linear regression of all possible pairings of stream geographic/spatial distances to their actual ordination distances based upon all macroinvertebrate taxa

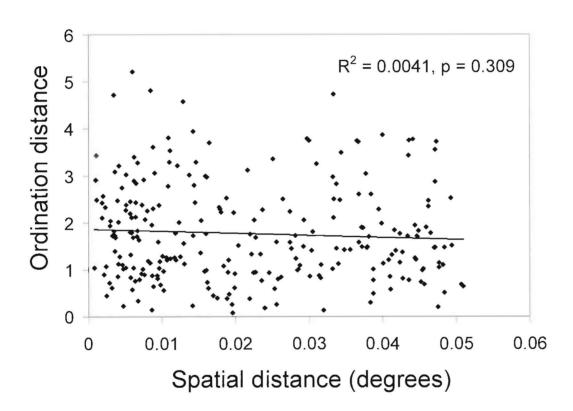


Figure 15. Linear regression of spatial distance to ordination distance of adjacent only streams based upon all macroinvertebrate taxa.

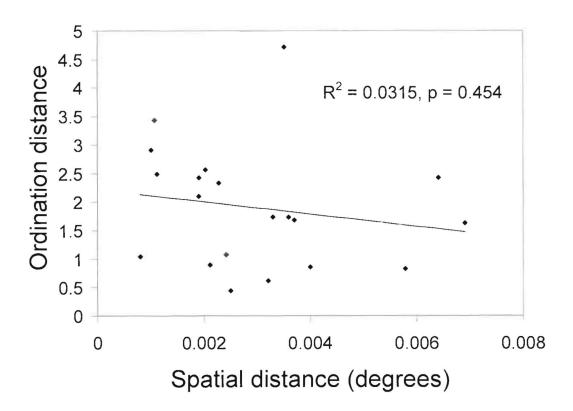


Figure 16. Linear regression of all possible pairings of stream geographic/spatial distances to their actual ordination distances based upon Chironomidae genera

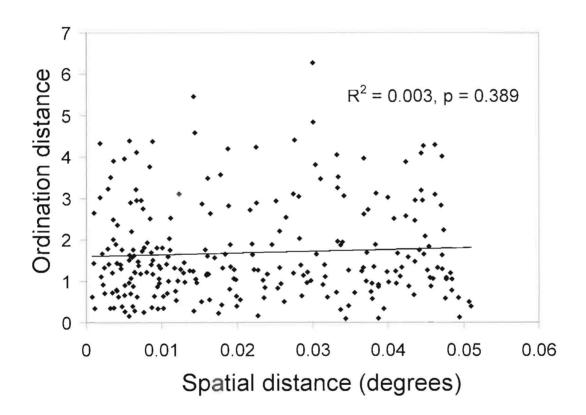
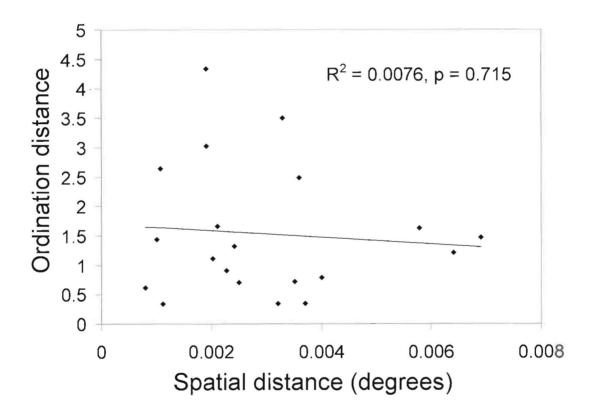


Figure 17. Linear regression of spatial distance to ordination distance of adjacent only streams based upon Chironomidae genera.



Total Macroinvertebrate Community Composition

Results of this study suggested that there was some influence of watershed and/or habitat characteristics on stream community composition. The all-taxa ordination (however, omitting the 4 taxa x replicate data that produced the major outliers in Fig. 7) showed a clustering of all third-order streams, along with the largest second-order stream. This could be a reflection of these streams having larger watershed sizes and more complex stream morphology than the lower order streams. All the large streams in this study area displayed both exemplary in-stream and riparian development. The loose clustering of these largest and highest order streams in this study represented an inclusive pattern, as all such streams were in the same general region in ordination space. This pattern, however, was not *exclusive* because a number of first- and second-order streams having smaller watersheds were also found in the same region of ordination space.

Dovciak and Perry (2002) similarly observed a distinction in ordination space (Principal Components Analysis) between streams of differing physical habitat scores, although across a broader geographic region (southwest Minnesota) and a wider range of environmental quality than in the present study. Riva-Murray et al. (2002), in a study of large tributaries in the Hudson River Basin, NY, included benthic invertebrate assemblages and derived indices (e.g. EPT richness, Hilsenhoff Biotic Index) in a direct gradient Canonical Correspondence Analysis that also included watershed, environmental, and water quality variables. The objectives of the present study, however, focused on ecological and biogeographic patterns of community composition, and so

included only species distributions, rather than the derived indices more often associated with assessments of environmental health in potentially stressed systems.

Taxa loadings for this ordination showed an obvious directional pattern among the dipterans. This suggests that the dominant dipterans were showing patterns of being a cohesive group in their contribution to community composition within these 23 streams. The dipterans also loaded in the opposite direction from the position of higher order streams in ordination space. Thus there was little association of dipterans with high order streams, suggesting they are more indicative of smaller streams. Average total abundances of all dipteran taxa were 45.2, 33.7, and 16.2 among first, second, and third order streams respectively, confirming the patterns suggested by ordination. It is reasonable to speculate that substrate type may play a role in the distribution of these insects. The substrate of higher order streams contained more boulders, cobbles, and gravel, while the lower order streams in which dipterans prevailed contained more silt/sand substrates.

In contrast, closely aligned loadings of three mayfly and stonefly taxa suggested association with the larger streams in our study. Although the dipterans were convincingly associated primarily with low order smaller streams, the Ephemeroptera and Plecoptera appeared to have a broader distribution, with various taxa associated both with larger or smaller streams. Interestingly the large stream/small stream axis suggested by the abundant taxa of Diptera and by some Ephemeroptera and Plecoptera weakened and ultimately broke down when looking at stream orders independently as opposed to all together. In Dovciak and Perry's (2002) PCA of stream macroinvertebrates several taxa

of Ephemeroptera and Trichoptera likewise loaded strongly on ordination axes and reflected environmental gradients, although not dipteran taxa as in the present study.

Chironomid Community Composition

Ordination of chironomid genera revealed a very dense and complex clustering of all stream/watershed types near the origin of the graph, although some individual streams diverged. Compared to this ordination of chironomids only, ordination of all invertebrate taxa demonstrated more utility in distinguishing similarities/differences among stream types (i.e. stream order, size, etc.). Ordination of chironomids, however, showed an ability to discriminate certain individual streams from the whole group. In a study by Diggins (2000), chironomid larvae from the polluted Buffalo River, New York, yielded a similar discriminatory ability among sites, over a short stretch of river that had relatively constant water conditions and sediment physical characteristics.

The specific discriminatory utility of chironomids in the present Zoar Valley study was further evidenced by loadings of individual genera. For example, all Orthocladiinae loading vectors were within 70° of each other, toward the left side of the ordination graph, where three 1st order streams were located separately from the complex cluster near the origin. Also, and in a completely opposite direction in ordination space, a genus of the Diamesinae loaded into the lower right quadrant where another stream diverged from the cluster.

When comparing the separate ordination analyses conducted on all taxa and conducted on chironomids alone, it appeared that the analysis of all taxa was more useful in detecting patterns in community composition that may reflect watershed

characteristics. However, it must be mentioned that, while these ordinations revealed trends, the gradient in stream characteristics was not that large. All 23 study streams are low order and have predominately forested watersheds. Also, in terms of QHEI scores, environmental quality was consistently free of degradation, and ranged from very high to moderate. In no circumstance was any stream classified as fair or poor. Even along such a subtle gradient, however, ordination analysis, especially in regard to "loading" vectors, was still highly informative.

Influence of Spatial Distance Among Streams

Somewhat surprisingly, this study failed to reveal any role of local biogeography in patterns of community similarity/dissimilarity among streams. There was absolutely no relationship between patterns in community similarity among streams and their geographic distances from one another. This suggests that despite close physical proximity of some streams (some adjacent streams were only tens of meters apart) they are biogeographically independent in terms of invertebrate community composition. This was not entirely expected because most invertebrate taxa possess dispersal terrestrial adult stages. The results presented here indicated that these small streams, although clearly located within a local ecological province, are acting very much as individualistic units. The present study did not specifically address lateral migration abilities of the resident insect taxa (or biological and environmental impediments to such dispersal) but investigating such questions could serve as the basis for valuable future research. Perhaps, in the case of these diverse and fascinating ecosystems in Zoar Valley, my

suggestion that streams may act "like aquatic islands in a sea of dry land" could be effectively true.

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APPENDIX A-1

Occurrence of benthic macroinvertebrate taxa on spring sample date (April 29, May 6 and 16, 2006), reported as number of individuals per Surber sample.

	Ппкломп					П						
	Stenelmis							4 0				
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	Optioservus			1		Н	1 1	-		H	- 1	
	Microcylleopus					н						
	Мастопусћиѕ					н			1 1	H		
Elmidae	Ancyronyx		ı			Н			П	П	Н	
Arthropoda Insecta Coleoptera Dytiscidae	Rhantus						-					
Phylum Class Order Family	Genus					П						
	Stream/Rep	222	2.2	3.1 3.2 3.3	4.1 4.2 4.3	5.1	6.1	7.1	8.2	9.1 9.2 9.3	10.1	H.1 H.2 H.3

Psephenidae Unknown	Unknown	2 1	-		-								
Histeridae Hydrophilidae	Hydrobius Sperchopsis					-							
Histeridae				П				П	П				
Arthropoda Insecta Coleoptera Haliplidae	Halipus						134						
Phylum Class Order Family	Genus												
	Stream/Rep	12.1 12.2 12.3	13.1 13.2 13.3	14.1 14.2 14.3	15.1	16.1	17.1 17.2 17.3	18.1	19.1 19.2 19.3	20.1	21.1	22.3	23.1 23.2 23.3
Unknown													
Psephenidae	Ectonria					П						ı	
	Sperchopsis					Ш						ı	-
Hydrophilidae	Trefrobins	emocratic de la constant de la const				Ш						l	
Histeridae						Ш						ı	
Arthropoda Insecta Coleoptera Haliphdae	H Sign	STATE OF THE PARTY											
Phylum Class Order Family	Semi												
	StroomBen	1.1	2.2	33	4.1	5.1	6.1	7.1 7.2 7.3	8.1 8.3 8.3	9.1 9.2 9.3	10.1	103	11.2

Dixidae Doliphopodidae	Raphium									
Dixidae	Dixa	Н	-		Ш			Ш		
Ceratopogonidae	Probezzia		- 8	3	-		-	2 9 1		
Diptera Chironomidae	See Appedix A-2									
Arthropoda Insecta Collembola Isotomidae				-						
Phylum Class Order Family	Genus	П								
	Stream/Rep 12.1 12.2 12.2	13.1	141 142 143 151	16.1 16.2 16.3	17.1 17.2 17.3	18.1	19.1 19.2 19.3	20.2	22.1 22.2 22.3	23.1 23.2 23.3
Doliphopodidae	Raphium									
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Ceratopogonidae	Probezzia	-	П		4				2	7 -
Diptera Chironomidae	See Appedix A- 2	W.								
Arthropoda Insecta Collembola Isotomidae				2	-					
Phylum Class Order Family	Genus	П								
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Ptychopteridae	Ptychoptera		Ш			
Psychodidae	Pericoma, Telmatoscopus					
Pelecorhynchidae	Glutops		Ш	Ш		
Arthropoda Insecta Diptera Empididae	Hemerodromia				Ш	
Phylum Class Order Family	Stream/Rep Genus 12.1 12.2 12.3	13.1 13.2 13.3 14.1 14.2 14.3	15.1 15.2 16.1 16.2 16.3 17.2	18.1 18.2 18.3 19.1 19.2	20.1 20.2 21.1 22.1 22.2 23.3	23.1 23.2 23.3

Ptychopteridae	Ptychoptera											
Psychodidae	Percoma, Telmatoscopus					I						
Pelecorhynchidae	Glutops			П				П				
Arthropoda Insecta Diptera Empididae	Hemerodromia											
Phylum Class Order Family	Genus											
	Stream/Rep	2 2 2	2.2	3.2 3.3 3.3	1.4 2.4 1.3	5.1	6.1	7.1	8.1 8.3 8.3	92 93	102 103	E 2 2

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APPENDIX A-2

Occurrence of Chironomid genera only on spring sample date (April 29, May 6 and 16, 2006), reported as number of individuals per Surber sample.

	Order					
	Family	Chironomidae				
	Subfamily	Chironominae				
	Tribe	Chironominae			Unknown Chironomini I	Unknown Chironomini 2
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Appendix B-1

Occurrence of benthic macroinvertebrate taxa on summer sample date (July 3, 5, and 6, 2006), reported as number of individuals per Surber sample.

Haliplidae	Unknown Halipus									
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	Dolichopodidae	Rhaphium							П		
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	Phylum Class Order Family	Arthropoda Insecta Tricoptera Goeridae	Hydropsychidae					Lepidostomatidae
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	Phylum Class Order Family	Arthropoda Insceta Tricoptera Linncophilidae				Philopotamidae	4	Pluygancidae
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Stream/Sample	Genus	Hesperophylax	ď			Dolophilodes		Pirlostomis
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	Phylum Class Order Family	Mollusca Gastropoda Basommatophora Planorbidae	Mesogastropoda Bithyniidae	Hydrobiidae	Pelecypoda Sphacriidae
Stream/Sample	Genus		Bithynia tentaculata		
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	Phylum Class Order Family	Mollusca Gastropoda Basommatophora Planorbidae	Mesogastropoda Bithyniidae	Hydrobiidae	Pelecypoda Sphaeriidae
Stream/Sample	Genus		Bithynia tentaculata		
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2.1					-
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	Phylum Class Order Family	Tubificida Lumberculus	Oligocheatae
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APPENDIX B-2

Occurrence of Chironomid genera on summer sample date (July 3, 5, and 6, 2006), reported as number of individuals per Surber sample.

Uhknown Chirenomini 1					П		
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Diptera Chironomidae Chironominae Chironominae Paratendipes							
Order Family Subfamily Tribe							
Stream/Sample	12.1	13.1 13.2 13.3	14.1 14.2 14.3	15.1 15.2 15.3 16.1 16.1 16.2	17.1 17.2 17.3	18.2 18.3 19.1 19.2 19.3	20.1 21.1 23.1 23.2 23.3

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Diptera Chironomidae Chironominae Chironominae	Paratendipes							П									
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Order Family Subfamily Tribe	Genus																									
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Order Family Subfamily Tribe	Genus																									Ī		1
	Stream/Sample	1.2	1.3	2.1	2.2	3.1	33	7.1	4.2	43	13	2.0	7.3	7.2	7.3	-0	- 20	8.3	-	9.2	9.3	Control of the local	1.0.1	10.2	10.3	-	11.2	113

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	Family	Chironomidae		
S	Subfamily	Tanypodinac		Unidentifiable
	Tribe			
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APPENDIX C-1

Occurrence of benthic macroinvertebrate taxa on fall sample date (September 15, 23, and 24), reported as number of individuals per Surber sample.

	Phylum	Arthropoda							
	Order	Coleoptera							
	Family	Dytiscidae	Elmidae						
				Macronychus	Microcylleopus	Optioservus	euinmiluO	Stonelmis	Unknown
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	Family	Phryganeidae	Polycentropidae		Uenoisae	Unidentifiable	
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	Phylum Class Order Family	Arthropoda Crustacea Decapoda Cambaridae	Diplopoda Polydesmida	Mollusca Castropoda Basommatophora Planorbidae	Mesogastropoda Bithyniidae
Stream/Sample	Genus				Bithynia tentaculata
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APPENDIX C-2

Occurrence of Chironomid genera on fall sample date (September 15, 23, and 24, 2006), reported as number of individuals per Surber sample.

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