A COMPARISON OF BENTHIC MACROINVERTEBRATE ASSEMBLAGES BETWEEN PERENNIAL AND INTERMITTENT HEADWATER STREAMS OF THE MATTOLE RIVER IN NORTHERN CALIFORNIA, USA

By

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ABSTRACT

A COMPARISON OF BENTHIC MACROINVERTEBRATE ASSEMBLAGES BETWEEN PERENNIAL AND INTERMITTENT HEADWATER STREAMS OF THE MATTOLE RIVER IN NORTHERN CALIFORNIA, USA

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Intermittent streams are common throughout the world and comprise 60% or more of total river lengths in the conterminous United States. Despite their prevalence, intermittent streams are understudied, particularly first-order headwater streams, which are vital for maintaining the function, health and biotic diversity of river networks. In June 2016, I sampled five intermittent and five perennial headwater streams in the Mattole River watershed in northwestern coastal California, USA, to compare benthic macroinvertebrate (BMI) assemblages between intermittent and perennial streams. BMI samples were collected using a 500µm mesh D-net at eight randomly located riffles along a 150-m reach, and then composited, on each of the 10 streams. Chemical (e.g. pH, dissolved oxygen, temperature, and flow) and physical (e.g. bed substrate composition, bank-full width, and slope) data were measured at each stream reach. BMI samples were identified using Standard Taxonomic Effort (STE). Major difference in assemblages among stream type were not detected except for a few individual taxa, families, and orders. Observed differences likely resulting from taxonomic differences in life history timing. The proportion of shredders was detectably lower in intermittent streams. Further studies with a temporal factor are needed to validate these findings.

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INTRODUCTION

Intermittent streams, i.e. waterways that have regularly occurring dry periods, are common throughout the world and occur in all climates. Perennial streams may cease to flow in drought years, but intermittent streams regularly experience drying even during years of average precipitation (Williams 1987,1996, Comin and Williams 1994). If intermittency is not an anthropogenic outcome, then it generally results from a lower groundwater table, or less available groundwater due to storage, than nearby perennial channels (Del Rosario and Resh 2000). Even though intermittent streams are a dominant freshwater ecosystem in Mediterranean-type climates, comprising 60% of the total river length in the conterminous United States (e.g., Nadeau and Rains 2007), ecologists have only recently considered them as unique freshwater habitats (Datry et al. 2014). Studies have shown that these temporary streams provide a wide range of ecosystem services in relation to interactions with soil, vegetation, and atmosphere, yet ecological understanding and functionality of these riverine systems is still largely unknown (Larned et al. 2010). Within the next century, intermittence of stream flow is expected to increase in regions that experience drying trends due to climate change and water extraction for socio-economic uses (Gerstengarbe et al. 2003, Larned et al. 2010).

Climate change induced hydrologic changes are presumed to have a greater impact on the drying rate and timing of 1st through 3rd order streams, also known as headwater streams (Lahmer and Becker 2000). Recent studies of intermittent streams have focused on higher-order reaches (e.g., 3rd or 4th order streams), while intermittent headwater streams receive less attention (Bogan et al. 2015). The drying process poses several physicochemical and biological challenges to the biota residing in these streams (Williams 1996), and thus behavioral and/or physiological adaptations to intermittency might lead to unique invertebrate assemblages in intermittent and perennial streams (Williams 1987). Consequently, there is less known about how invertebrate assemblages of intermittent headwater streams react to desiccation. It is important to understand the ecology of these streams because headwaters are vital for maintaining the function and health of whole river networks, and subsequently are important areas for maintaining biodiversity (Meyer and Wallace 2001, Gomi et al. 2002, Bernhardt et al. 2005, Lowe and Likens 2005, Wipfli et al. 2007). While many taxa contribute to biodiversity in headwater streams, benthic macroinvertebrates (BMIs) play a central ecological role in stream ecosystems (Boulton 2003, Vannote et al. 1980).

Benthic macroinvertebrates are among the most ubiquitous (Voelz and McArthur, 2000) and diverse (Strayer 2006) organisms in fresh waters. Surveying the composition of BMIs better reflects the ecological health of waterways than chemical or physical measures. This is because biomonitoring integrates all the biogeochemical influences to which benthic invertebrates are exposed (Barbour et al. 2000). Analyses of water chemistry or of highly mobile aquatic organisms, such as fish and amphibians, tend to reflect ecological integrity only at the given time samples are taken (McCafferty 1998). The use of BMIs as indicators can suggest changes in environmental conditions, such as altered temperature, sediment deposition, excess nutrients from agricultural runoff, and habitat degradation that may not be detected using chemical toxicity tests or attributes of vertebrate assemblages (Barbour et al. 2000).

Benthic macroinvertebrates are vital in the ecological processing of entire riverine systems by facilitating nutrient and organic matter breakdown and transport (Wallace and Webster 1996). Consumption habits of BMIs assist in the maintenance and modification of ecosystem function in ways that often transcend simple consumption of food (Naiman 1988). Consumers in this sense may benefit ecosystems as regulators rather than energy movers (Chew 1974). Regulatory functions of BMI consumers can include regulating rates of nutrient succession and cycling, transportation and mixing of materials, top-down influences (by predators and herbivores), and physical structuring of ecosystems (Jones et al. 1994).

The assemblage of BMIs in most streams is highly diverse and many individual taxa may be redundant in the sense that ecosystem functions can proceed if they are absent (Lawton 1991, Wallace et al. 1986). In the heterogeneous physical environment of streams, BMI taxa have evolved to share similar morphological and behavioral mechanisms for food acquisition and consumption (Wallace and Webster 1996), which have been separated into five Functional Feeding Groups (FFGs). The major FFGs are: *scrapers,* which consume algae associated material by scraping it from surfaces; *shredders*, which consume leaf litter or other coarse particulate organic matter (CPOM, < 1 mm diameter), including wood; *gathering collectors*, which collect fine particulate organic matter (FPOM, > 0.5 mm < 1 mm diameter) from the stream bottom; *filtering* *collectors*, which collect FPOM from the water column using a variety of filtering techniques; and *predators*, which feed on other consumers (Cummins and Klug 1979). These FFGs are a functional classification approach that is based on behavioral mechanisms of food acquisition rather than taxonomic groupings (Vannote et al. 1980).

Within intermittent stream systems, BMIs have been observed to have different strategies for survival that, in some cases, can result in unique community structures compared to the structures of invertebrate assemblages in perennial streams. BMIs can avoid desiccation with behavioral adaptations, such as burrowing into saturated substrates, migrating downstream, and migrating to receding pools (Williams and Hynes 1977). They may also endure drying with evolutionary life-history strategies (Clifford 1966), such as having desiccation-resistant forms (Williams 1987). The differences in life cycle length of different taxa, with some taxa living multiple years and others experiencing multiple annual generations, can also lead to the inhabitance of different stream types (Clifford 1966). These potential changes in intermittent stream community composition may lead to assemblages of taxa with different behavioral mechanisms of food acquisition, compared to those in perennial streams (Schlief and Mutz 2009). Therefore, intermittent streams may produce unique FFG proportions compared to those in perennial streams, which in turn could affect the ecological function of these stream types.

The headwaters of the Mattole River, located on the northern coast of California, USA, are composed of both perennial and intermittent streams (Klein 2009), and is therefore an ideal location to compare invertebrate community structure across these two stream types. Streamflow regimes and the extent of dry channel in a number of these streams has been well documented over the past decade by the non-profit groups Sanctuary Forest and the Mattole Salmon Group. The different streamflow regimes in the headwaters lead to differences in the timing and extent of which surface flow persists. Surface water variation in headwater streams of the Mattole River watershed is dramatic, with as much as 90% of the length of fish-bearing reaches lacking surface flow in summer months, while in similarly sized drainages nearby surface flow is maintained in the entire reach save perhaps a few riffles (Queener 2015).

METHODS

Study Sites

The majority of the 100 kilometer long Mattole River is located in southern Humboldt County, CA with a small portion of its upper watershed in northern Mendocino County, CA. The Mattole River, unencumbered by major dams, flows north along the eastern side of the coastal King Range and then west into the Pacific Ocean approximately 16 kilometers south of Cape Mendocino, the westernmost point in California (Mattole Salmon Group 2015). This study was conducted in the upper 11% of the total 777 km^2 watershed of the Mattole River, which is referred to by local management agencies as the “southern subbasin” (Coates et al. 2002, Downie et al. 2003) (Figure 1).

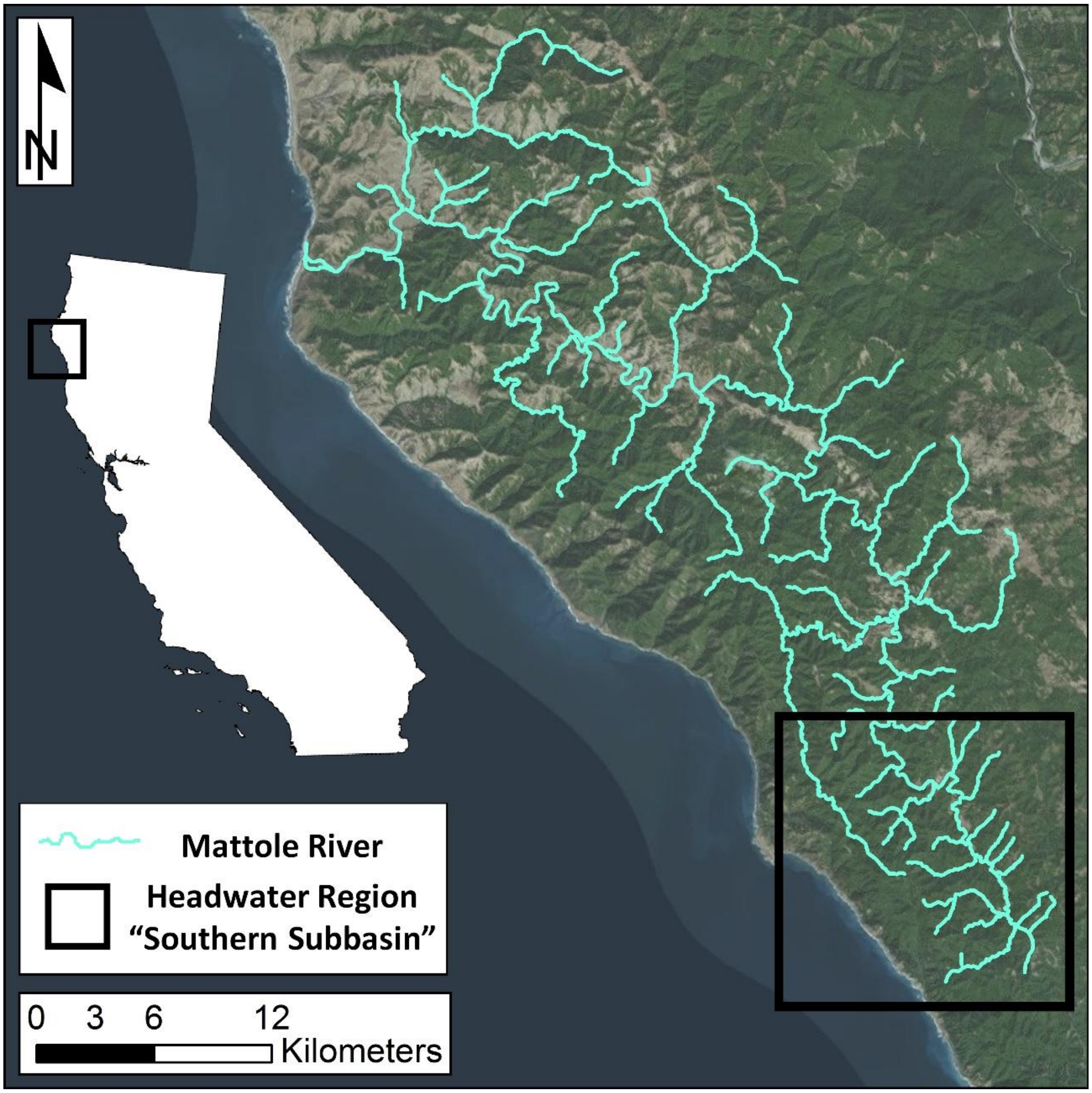

Figure 1. Location of the Mattole River Headwaters region location in southern Humboldt and northern Mendocino counties in California, U.S.A (Esri 2016).

The climate in this area is characterized as Mediterranean, with annual precipitation averaging 190-240 cm (Coates et al. 2002), and nearly all of its precipitation falling as rain between November and May. Vegetation in the region is comprised of mixed hardwood/conifer forest, dominated by Douglas fir *(Pseudotsuga menziesii),* coast redwood *(Sequoia sempervirens),* and tanoak *(Notholithocarpus densiflorus).* In the last 60 years, 95% of the forest in the southern subbasin was harvested, leaving forest composition dominated by relatively young and dense stands. Riparian tree species are predominantly red alder *(Alnus rubra),* with a minor component of Oregon ash *(Fraxinus latifolia)* (Downie et al. 2003). Streamside canopy cover in these headwater tributaries was rated as very good by the National Marine Fisheries Service, unlike the poorer rating given to riparian zones of downstream tributaries (SONCC Coho Recovery Plan 2011). Predominant land uses in the area are timber management, rural subdivision, and small scale agriculture, including marijuana cultivation (Queener 2015).

Ten tributaries of the Mattole River, all of which located in the “southern subbasin,” and which exhibited varying flow regimes, were sampled for this study (Figure 2). Stream sampling sites were selected based upon previously established streamflow regimes, which were well documented over the past decade by the non-profit groups Sanctuary Forest and the Mattole Salmon Group. Five of the tributaries have been characterized as intermittent, based on a flow record of 10 years (since 2006): Lost River (LOS), Baker Creek (BAK), Helen Barnum Creek (HEL), Mckee Creek (MCK), and Anderson Creek (AND). Five perennial streams were also sampled: Ancestor Creek

(ANC), Thompson Creek (THO), Mill Creek (MIL), Buck Creek (BUC) and the South Fork of Bear Creek (BEA). All intermittent streams ceased flow by mid-July during the year (2016) they were sampled. During the time of sampling, all streams maintained flow (Table 1).

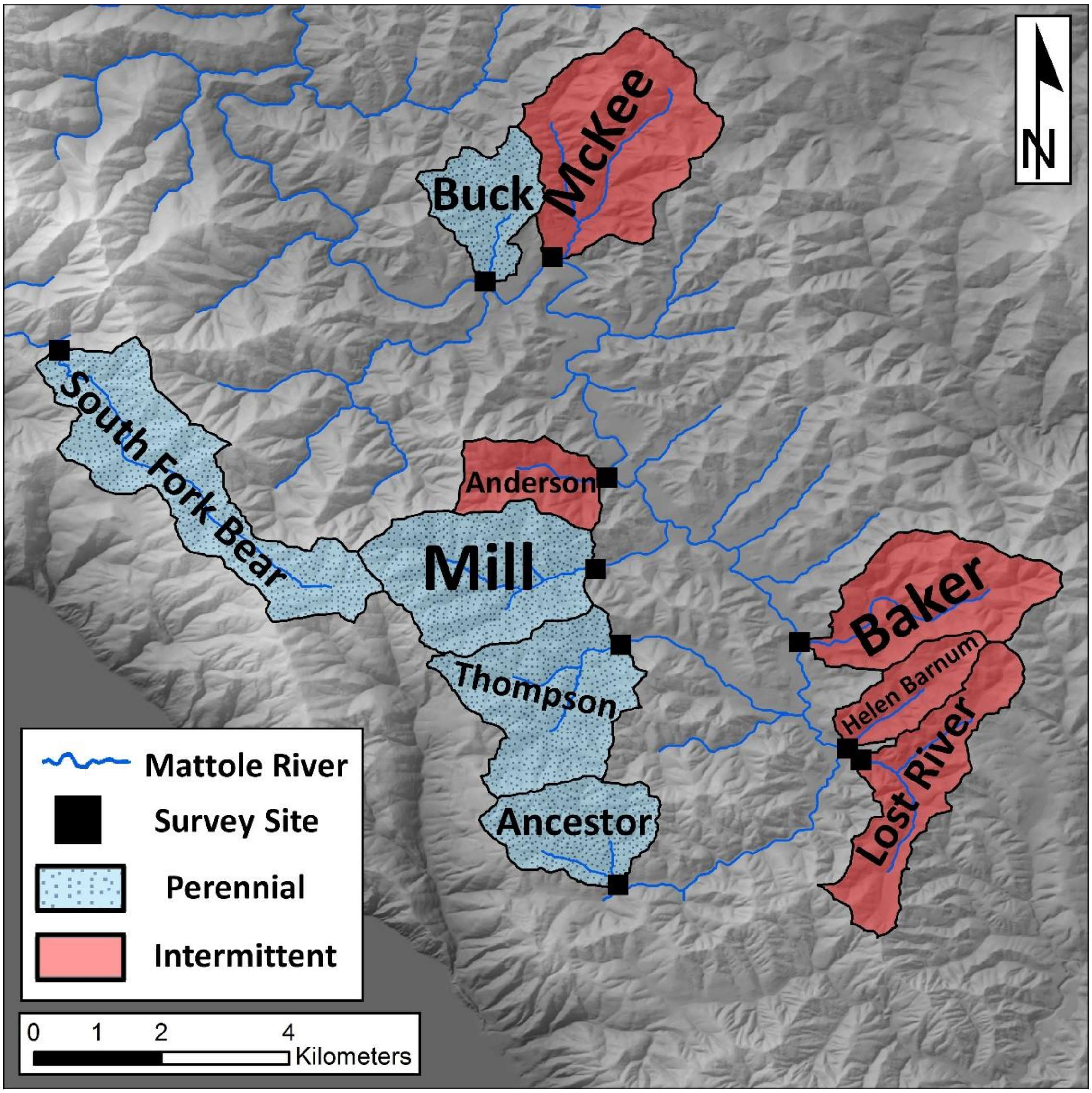

Figure 2. Watersheds for each sample stream in the Mattole River Headwaters (Southern subbasin) region.

Watershed drainage areas, upstream from the designated reach location, of the sampled streams were calculated in ArcMap 10.2.2 (Table 1). A nonparametric Wilcoxon's two sample test for each stream type drainage area was used to evaluate whether all drainage areas were comparable in size and therefore would not be a factor for observed differences in biological and chemical data collected.

Table 1. Surveyed stream condition (intermittent or perennial), drainage area upstream from sampled location.

Stream Name	Intermittent/Perennial	Watershed Area in km^2
McKee	I	5.45
Baker	I	4.01
Helen Barnum	I	1.61
Anderson	I	1.80
Lost River	I	3.37
South Fork Bear	P	3.27
Mill	P	4.36
Buck	P	2.00
Thompson	P	4.12
Ancestor	P	2.58

Riparian canopy cover was used as a proxy for amount of available primarily produced organic allochthonous matter. Therefore, riparian canopy cover of each reach was also compared for individual streams within each type. Density of canopy cover was calculated with a Landsat-derived Normalized Difference Vegetation Index (NDVI) layer. The NDVI is a geographical indicator used to analyze remote sensing measures, and in this case was used to assess whether imagery pixels around the study drainages contained live green vegetation or not. Each pixel is expressed as a percentage of live green vegetation. The NDVI was buffered to 30 meters (1-pixel width) on either side of the streams within the surveyed watersheds to assess riparian canopy cover. Buffered NDVI files were individualized for each stream to analyze relative riparian cover densities. Each pixel value was extracted and plotted in a histogram to determine the disruptions of proportional vegetation densities.

Benthic Macroinvertebrate Collection

I compared community composition of benthic macroinvertebrates (BMIs) between reaches of 5 intermittent and 5 perennial headwater streams in the Mattole River from collections I took between June 10th and June 19th, 2016. BMIs were collected using protocols from the Surface Water Ambient Monitoring Program (SWAMP), which, in the interest of methodological consistency, was adopted as the standard riffle protocol for bioassessment in California for state water resource agencies (California State Water Resource Control Board). The stream sampling sites were positioned within 150m reaches. Biological, physical and chemical data were collected from one reach for each selected stream. Eleven equidistant transects with ten additional transects (designated “inter-transects”) located between the main transects were defined. BMIs were collected using a 500-µm mesh D-frame net. One targeted riffle composite (TRC) sample was collected for each reach, consisting of eight individual kick samples of 1ft^2 (0.09 m^2) within the total 21 transects. Each individual kick sample was collected at 1 minute interval. The TRC was used in order to avoid biases from individual riffle samples which might display nonactual uniqueness from field sampling randomness. The collected specimens were placed in 95% ethanol in the field and transferred into 70% ethanol when taken back to the Entomology laboratory at Humboldt State University. In the laboratory, BMIs were sorted from organic and inorganic debris in all samples using a dissecting microscope and then all sorted samples, except one with low abundance (Ancestor Creek), were split in half with a plankton splitter for ease of identification effort. Specimens were identified to the lowest practical taxonomic level in accordance with the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) Standard Taxonomic Effort (STE) (Richards and Rogers 2011).

Habitat Data Collection

Chemical characteristics of sampled streams, such as temperature (°C), pH, dissolved O2 (mg/L), specific conductivity (µS/cm), and salinity (ppt), were collected at the downstream end of each sampling reach. Physical characteristics were collected at each transect and inter-transect, with the exception of streamflow, which was measured at the furthest downstream transect using March-McBirney 201D flowmeter. Physical characteristics measured included elevation, slope, aspect, soil/geology, bed substrate characterization (using the Wolman pebble count technique (Wolman 1954)), vegetation cover (using a modified convex spherical densitometer), bank-full width, wetted width, and water depths at left bank, left center, center, right center, and right bank. All of this chemical and physical data was collected in order to confidently determine that there were no other major fundamental differences, besides intermittence, among streams sampled.

Statistical Analysis

Community structure was analyzed using nonmetric multidimensional scaling (NMS) on observed taxonomic abundance to assess partitioning of the entire community by perennial or intermittent stream flow. The NMS included all observed taxa and measured covariates. This was done to determine any initial trends among stream types before further analysis took place. Multi-response permutation procedures (MRPP), a nonparametric procedure for testing the hypothesis of no differences between two or more groups of entities, was then used to analyze the observed findings from the NMS.

Each of the identified taxa, at the genus, family, and order level (134 in total) (Appendix), were tested for differences in population abundance and densities in each stream type with Welch two sample t-tests. The stream condition was compared to the taxon binomially (0 = intermittent stream and 1 = perennial stream).

Next, linear models for each individual BMI Genus, Family, and Order with measured flow were created to analyze the relationship between individual taxa and flow reduction. Since stream desiccation is what defines the major physical difference among the stream types, and each stream had a different flow at the time of sampling, varying stream flow was used as a surrogate to simulate the correlation of taxa in a stream approaching desiccation. The linear models were used to determine in which taxa abundance differed with flow, and then a General Additive Model (GAM) was created to more accurately model the observed relationship.

Each BMI community was then proportionally separated into FFGs for each stream site. Community composition of FFGs expresses more about the ecological functionality of a stream system than comparing basic taxonomic groups. Each stream's FFG proportion was plotted binomially, with 0 = intermittent stream and 1 = perennial stream. Welch two sample t-tests were used to analyze differences in consumers proportions in each stream type and then Generalized Linear Models (GLMs) were used to compare Akaike Information Criterion (AIC) values.

RESULTS

Physical Habitat

In general, the chemical (Table 2) and physical (Table 3) characteristics of all sampled streams were found to be similar enough to not impact the biological data, (based on Wilcoxon test) and therefore could justifiably be compared with one another. The intermittent and perennial watersheds had similar drainage areas (Wilcoxon test, p = 0.98). The canopy cover of each stream was also found to have similarly densities based on the distribution of the NDVI pixel histograms created (Figure 3). This signifies that there is a proportionally similar amount organic leaf matter available to each stream. The data collected from the densitometer further supports the NDVI analysis, but on a finer scale associated with the specific survey reach rather than the entire upstream channel. The densitometer measured the riparian canopy densities for the intermittent streams with a low of 90.6% and a high of 97.5% and the perennial streams with a low of 88.5% and a high of 95.1%.

Table 2. Chemical data collected for each stream, including stream type (intermittent or perennial), recorded in stream temperature (Temp. ℃), pH, Dissolved Oxygen (DO), specific conductivity, salinity, and the associated p - value for each measure compared among stream type (I or P).

Stream Name	Intermittent/ Perennial	Temp. ℃	pH	DO	Specific Conductivity	Salinity
Lost River	I	11.6	6.64	9.4	61.2	0
Baker	I	12.7	6.39	9.22	83.1	0
Anderson	I	10.8	6.35	9.93	67.9	0
McKee	I	12.3	6.5	9.53	89.1	0
Helen Barnum	I	11.5	5.6	81	63	0
Ancestor	P	12	6.99	9.5	76.4	0
S. Fork Bear	P	11.8	6.6	9.09	88.2	0
Thompson	P	11.6	7.14	8.7	71.7	0
Mill	P	10.4	6.7	10.18	79.4	0
Buck	P	11.6	5.55	9.88	57.4	0
p-value		0.51	0.4	0.37	0.82	NA

Table 3. Physical data collected for each stream, including stream type, recorded flow in cm^3/s, mean pebble count size, median pebble count size, mean percentage of Course Particulate Organic Matter (CPOM) in the Benthic Macroinvertebrate (BMI) sample, mean densitometer readings (out of 17), and the associated *p* - value for each measure compared among stream type (I or P).

Stream Name	Intermittent/ Perennial	Flow cm^3/s	Pebble Mean	Pebble Median	Mean CPOM	Percent Bedrock	Mean densitometer
Lost River	I	18122.78	22.22	15	0.11	0.3	16.22
Baker	I	11893.1	32.84	28	0.14	0.11	15.41
Anderson	I	4049.31	26.28	23	0.27	0.23	16.48
McKee	I	6796.04	28.83	25	0.39	0.1	15.91
Helen Barnum	I	10165.75	24.84	20	0.4	0.02	16.57
Ancestor	P	28090.31	22.59	16.5	0.13	0	16.16
S. Fork Bear	P	17329.91	29.09	27	0.09	0	15.25
Thompson	P	7164.16	24.65	20	0.23	0	15.06
Mill	P	24833.87	37.11	29	0.14	0.29	15.59
Buck	P	15291.1	40.13	30	0.31	0.2	15.86
p-value		0.1	0.37	0.53	0.29	0.52	0.1

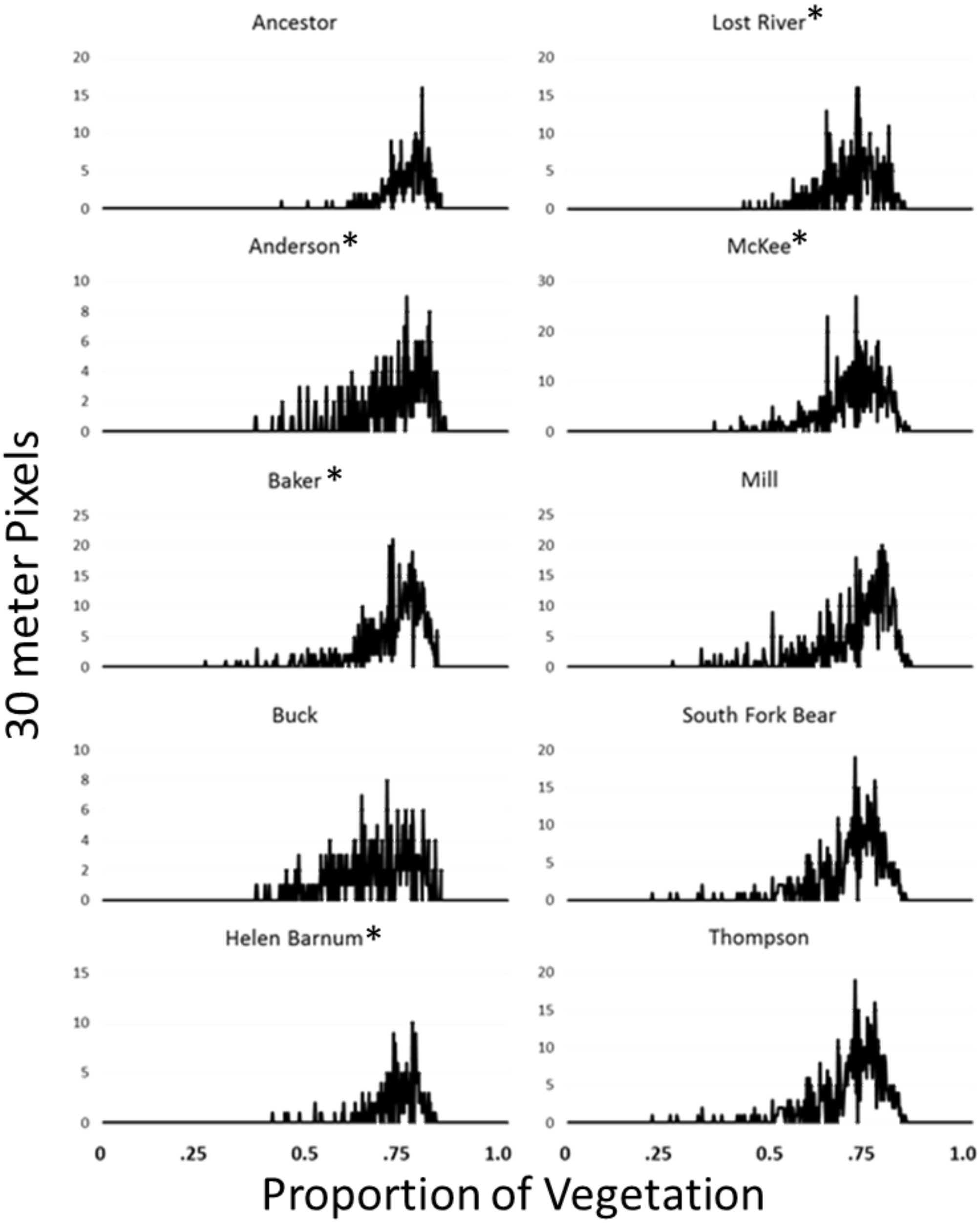

Figure 3. Histograms showing the distribution of riparian canopy cover in a 30 meter buffer around each sampled stream. X-axis shows the proportion of vegetation in each pixel and the Y-axis shows the number of 30 meter pixels that contain the proportion of vegetation cover value. Intermittent streams indicated with an “*”.

Benthic Macroinvertebrates

Of the 10 streams sampled 80 unique taxa were identified from 42 families and 12 orders. Taxa that occurred in fewer than 20% of the samples (i.e. one stream from each stream type) were deleted from the NMS input data to avoid interpretations reliant upon rare taxa. All 80 taxa and 15 measured covariates were mapped onto the resultant ordination space. The NMS ordination diagram suggested that there was no trend among stream types (Figure 4). The MRPP reinforced the visual suggestion of the NMS ordination diagram ($p = 0.35$), indicating that there are no assemblage differences detectable from the data.

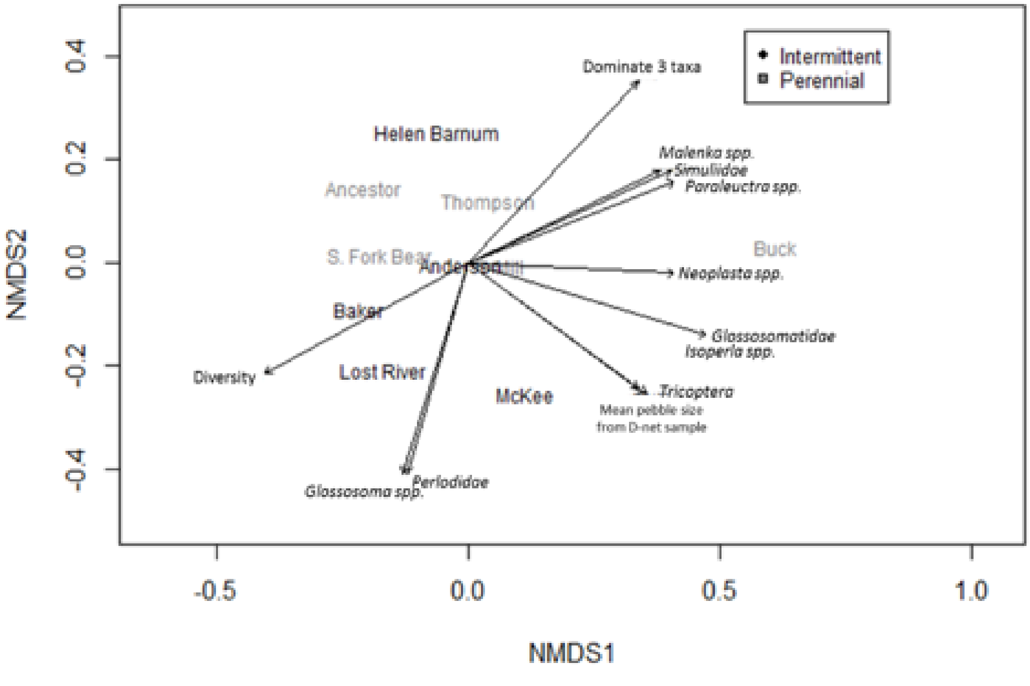

Figure 4. Nonmetric Multidimensional Scaling (NMS) ordination of the 80 unique taxa and 15 environmental covariates collected created in RStudio. All covariates with a p-value ≤ 0.05 displayed. Streams are plotted along a multidimensional plane with more similar streams (streams with a strong relationship) closer to one another. The significant covariates (p-value ≤ 0.05) displayed suggest, with low probability of random chance, that they are the drivers which account for these relationships.

Of all 134 taxa analyzed two species/groups, two genera, two families, and one order showed evidence of having different population densities in the different stream types (Table 2). The pupa of *Rhyacophila grandis spp.* (Rhyacophilidae) showed to have a difference in abundance in the stream types ($p = 0.007$) with more found in intermittent streams. However, the overall abundance of *Rhyacophila grandis spp.* (Rhyacophilidae) did not show as significant of a difference in the stream types ($p = 0.13$).

Table 4. Taxa in which population densities differed between intermittent and perennial stream reaches, along with their associated p-value from the Welch two sample t-test and which stream condition the taxa were more dominate in (P = perennial and I = intermittent).

Taxa		***p*-value**	**Population Density**
Species/Group			
	Octogomphus specularis	0.05	P > I
	Rhyacophila betteni spp.	0.07	P > I
Genus			
	Dicranota spp.	0.02	P < I
	Optioservus spp.	0.02	P > I
Family			
	Nemouridae	0.08	P > I
	Tipulidae	0.01	P < I
Order			
	Plecoptera	0.09	P > I

Of the 134 linear models generated with taxa and stream flow, only five of the models using individual BMI genera and three of the models using individual BMI families displayed a relationship between taxon abundance and measured stream flow on the date of sampling ($p < 0.05$). Of the five taxa groups that displayed a relationship with flow, four were observed to have a negative relationship, indicating that their abundance was greater in low rather than high flows. *Ephemerella spp*. exhibited a strong positive relationship with flow ($R^2 = 0.77$, $p = .001$, $n = 10$), indicating a greater abundance at higher flows (Figure 5).

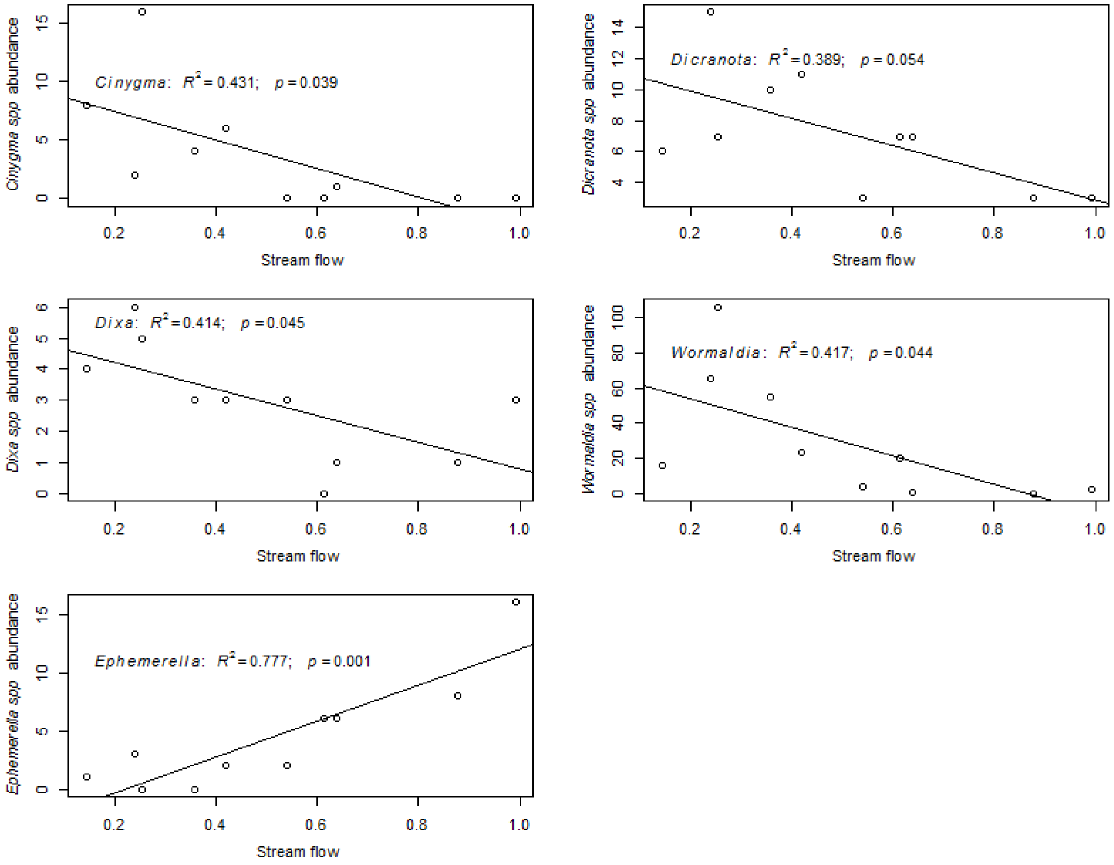

Figure 5. Linear models of the 5 taxa whose abundance correlated with recorded stream flow on the date of sampling. Abundance of *Cinygma spp*. (Heptageniidae), *Dicranota spp*. (Pediciidae), *Dixa spp*. (Dixidae), and *Wormalida spp*. (Philopotamidae) was negatively related with flow; abundance of *Ephemerella spp.* (Ephemerellidae) with flow was positive (n =10).

Since *Ephemerella spp.* abundance approached zero as flows decreased, their relationship to flow appeared to be the most significant in terms of an actual observed ecological response to stream desiccation. Because of this a GAM was created to more accurately display *Ephemerella spp.* abundance at varying stream flows (Figure 6).

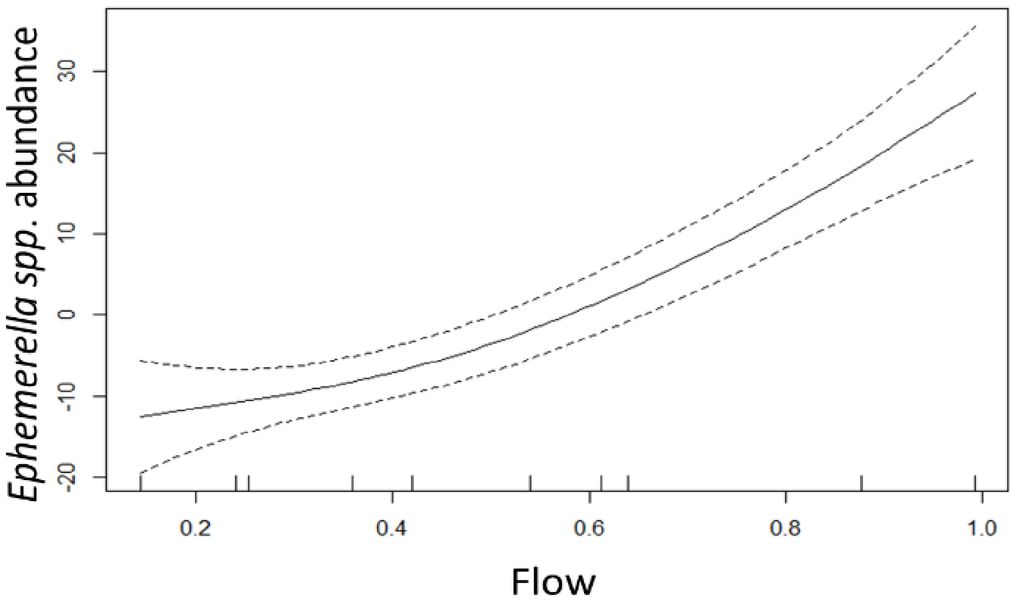

Figure 6. General Additive Model (GAM) of *Ephemerella spp*. (*Ephemerellidae*) abundance correlated to proportional stream flow with a gamma of 1.4.

BMI taxa for each of the streams were separated into FFGs in order to compare and analyze their composition in terms of ecological functioning relative to each stream (Figure 7). Overall a higher proportion of gathering collectors was observed among most streams sampled, with less constant proportions of other FFGs.

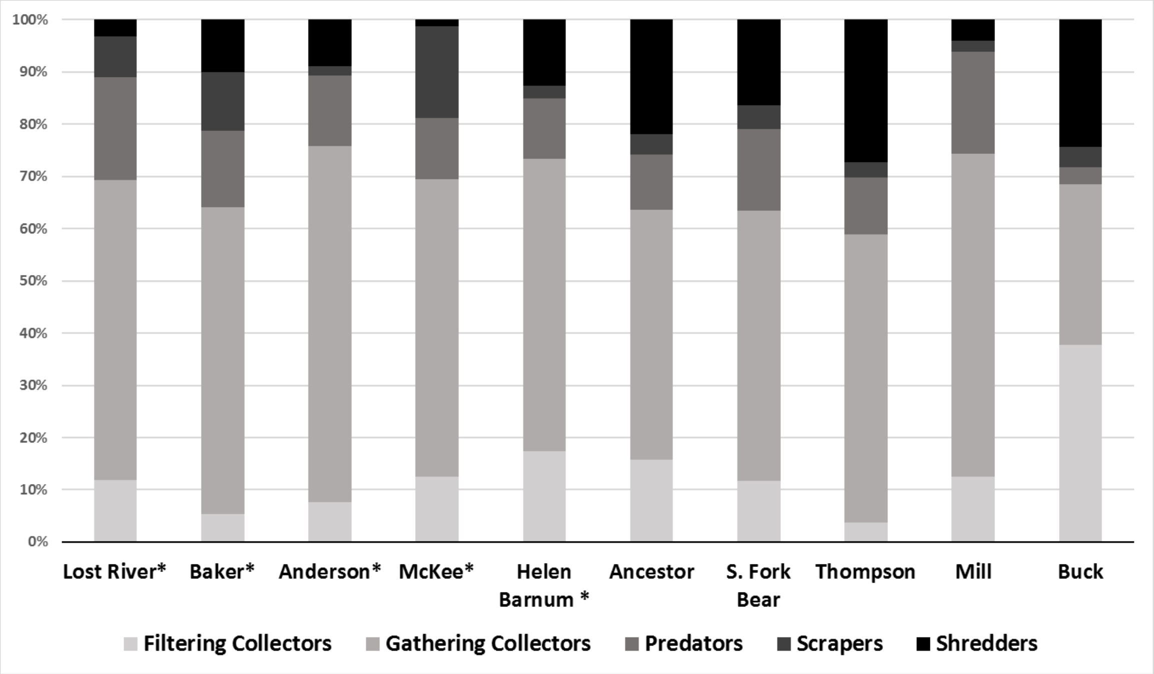

Figure 7. Precepts of benthic macroinvertebrate functional feeding groups for each stream sampled. Intermittent streams indicated with an “*”.

Associated p-values were obtained from the Welch Two Sample t-test and AIC values from GLMs created (Figure 8). This analysis showed that the only FFG that had a significantly different composition from intermittent to perennial streams were shredders (p = 0.046 and the lowest AIC = 12.66), with high proportions found in the perennial streams (Table 3).

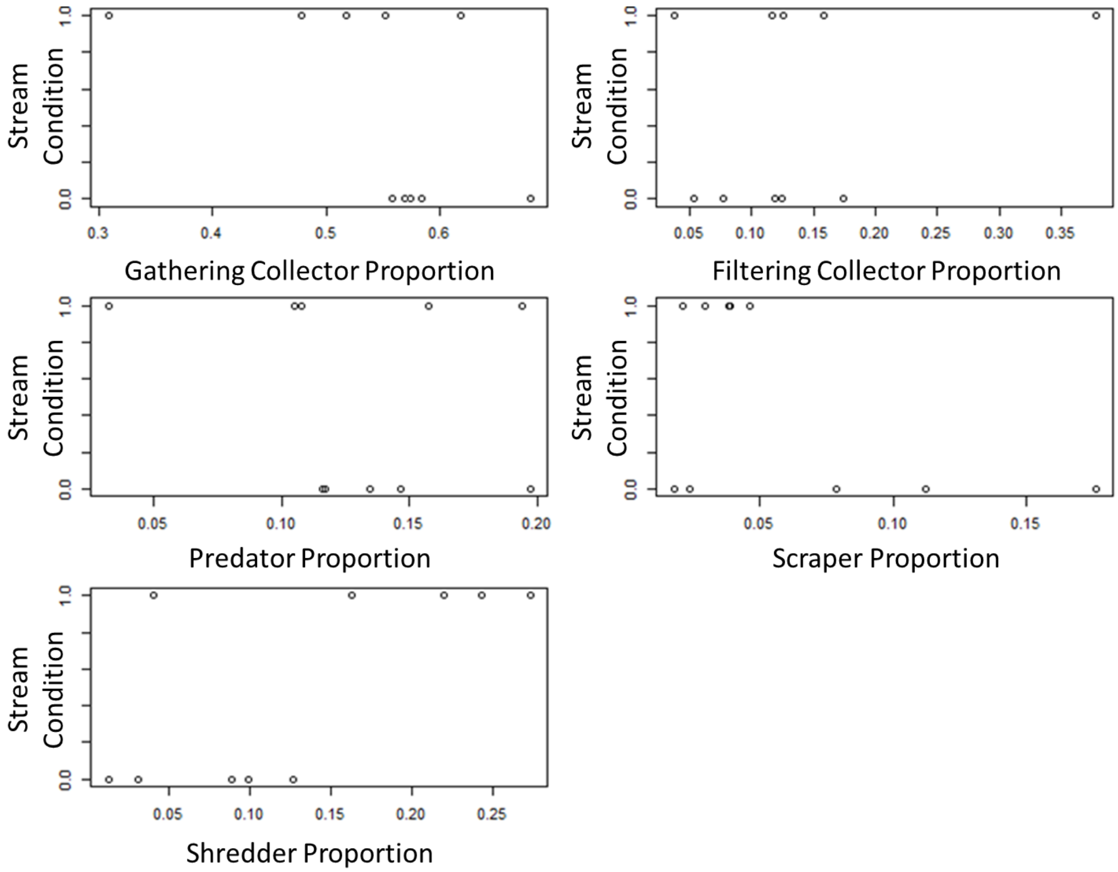

Figure 8. Binomial plots of each streams FFG proportion against both stream types (0= intermittent streams and 1= perennial streams).

Table 5. Mean proportional abundance of FFGs in intermittent and perennial streams, *p*-value derived from Welch Two Sample t-test, and AIC value from the Generalized Linear Models.

Functional Feeding Group	**Mean proportional abundance within Intermittent Streams**	**Mean proportional abundance within Perennial Streams**	***p*-value**	**AIC**
Gathering Collectors	0.59	0.49	0.13	14.01
Filtering Collectors	0.11	0.16	0.41	16.89
Predators	0.14	0.12	0.48	17.21
Scrapers	0.08	0.03	0.18	14.92
Shredders	0.07	0.18	0.04	12.66

Proportional abundance of shredders was greater in perennial than in intermittent stream reaches. I created a GLM prediction plot to observe the predicted gradient of change for shredder proportion from intermittent to perennial streams (Figure 9). However, since stream condition such as intermittent and perennial do not occur on a gradient, the plot can be interpreted by its confidence that a stream is perennial based on the proportion of shredders found in the sampled streams on the date they were sampled.

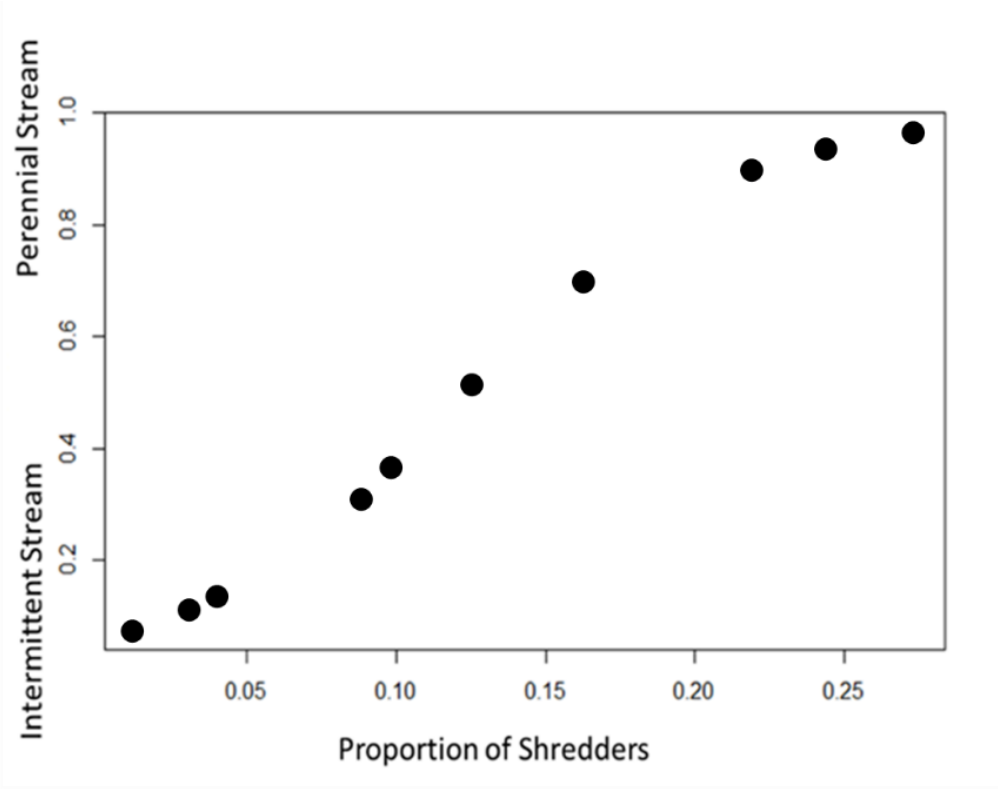

Figure 9. GLM of the predicted gradient of change of the proportion of shredders in intermittent and perennial streams.

DISCUSSION

Overall there was less biological difference observed among these two stream types than expected. With such drastically different habitats in the summer and early fall months, I anticipated to see more significant differences in terms of taxa composition. There may however be more observable differences different times of year. If sampling took place in the fall, more assemblage variance would be expected due to such different habitats occurring more recently. However, the lack of differences observed might mean that specific taxon survival rate might increase in intermittent streams in summer months, but are found in late spring as a result of recolonization of the intermittent channels in the fall and winter.

The MRPP did not support a finding of difference between taxonomic BMI community composition in perennial and intermittent streams in the Mattole River headwaters region ($p = 0.35$). A few taxa in this study displayed different densities in each stream type. This observation might be explained by different life history and developmental life cycle characteristics. For example, *Octogompuhs specularis* (Gomphidae) nymphs spend three years in water (Usinger 1956) and only occurred in the samples of four of the five perennial streams and none of the intermittent streams. Since *Octogompuhs specularis* require constant swift flowing current (Cannings 2002), and are in their aquatic nymph sage for longer than intermittent streams flow, it is expected to only observe them in samples of perennial streams. Similarly, *Optioservus spp.* (Elmidae), which were found to be more abundant in perennial streams, spend one to two years as a larvae, and may live for several years as an adult in the water inhabiting wetted riffle habitat (White 1978). When the larva of *Optioservus spp.* emerge as an adult they are capable of flying and recolonizing streams for a few days or weeks. However, once an adult *Optioservus spp.* reenters the water it becomes permanently bound and loses its ability for flight. These adults are long-lived and thus are unable to inhabit intermittent streams as a result of a lack of required habitat for an extended period of time (Brown 1987). However, other genera in the family Elmidae, for example *Narpus spp*., experience the same life cycle characteristics, but experienced similar abundance among the different stream types ($p = 0.94$). Perhaps not only life cycle traits can explain presence in intermittent streams, but also behavioral adaptations.

Another life cycle related observation pertained to *Rhyacophila grandis spp.* (Rhyacophilidae) pupa. All five of the sampled intermittent streams contained *Rhyacophila grandis spp*. pupa whereas only one of the perennial streams had a *Rhyacophila grandis spp*. pupa ($p = .007$). Since *Rhyacophila grandis spp*. are holometabolous insects, undergoing complete metamorphosis and require water for their gestation period before emerging as an adult (Voshell 2002), perhaps the streams approaching intermittency triggers *Rhyacophila grandis spp.* to pupate earlier in the intermittent streams to avoid desiccation in their pupa form.

With regard to the overall BMI assemblage found at each site, there was no evidence to show that the difference in perennial and intermittent nature of flow resulted in unique assemblages in terms of richness, diversity, and abundance. This lack of difference between perennial and intermittent stream reaches could be a result of sampling in mid-June, when the intermittent channels were wetted the longest over the previous hydrologic year. This means that sampling occurred when the BMIs had the longest amount of time to recolonize the stream channel after the previous year's desiccation. Resampling in early fall, when the intermittent channels become rewetted, would potentially yield a different pattern and more drastic differences in composition among stream type.

For five taxa, abundance showed a positive (n = 1) or negative (n = 4) relationship with flow measured on the date of sampling. Since intermittent stream flow can be expected to decrease more abruptly (terminating flow in summer months) than perennial streams, the significance of specific taxa abundance correlated to flow might explain noteworthy changes of ecological functioning. However, this does not necessarily indicate how certain taxa react to stream type, but rather shows a reaction to a desiccation gradient. Furthermore, the negative relationship to flow found in the four taxa might be explained by their preference to inhabit different stream niches, other than riffles. For example, *Dixa spp.* (Dixidae) are more commonly in calm, protected shallow water of marshes, borders of lakes, and shallow ponds most frequently found resting on surface film (Voshell 2002). This might explain why there was a higher observed abundance in the streams with lower flows. In contrast, *Ephemerella spp.* (Ephemerellidae) are more physically adapted for swifter currents by their ability to crawl and cling to the substrate, seeking protection in small spaces between rocks and crevices in woody debris (Voshell

2002). This abundance data can be a predictive indicator of stream desiccation. The GAM created for *Ephemerella spp*.'s reaction to stream flow showed that a reduction in flow leads to an extirpation of the taxa.

The relationship with *Ephemerella spp.* (Ephemerellidae) and flow ($p = 0.001$) might also be explained by an adapted life cycle. As recorded flows decreased there were less observed *Ephemerella spp.* in the streams. Since all ten of these streams were shown to be significantly similar, based on no large variation in chemical and physical features, using the recorded flows for the GAM can infer a temporal component of a single stream drying up. Perhaps it isn't that there are less *Ephemerella spp.* present as the flows decrease, but rather more are emerging as adults. Since *Ephemerella spp.* are hemimetabolous insects, meaning they have no pupal stage in the transition from larvae to adult (Voshell 2002), maybe as flows decrease *Ephemerella spp.* nymphs are triggered to emerge as adults. This would mean that *Ephemerella spp.* would have to emerged earlier in intermittent streams to avoid desiccation. There is the potential for perennial streams to harbor *Ephemerella spp.* nymphs for a longer period of time.

The most relevant finding pertains to the proportions of FFGs. Shredders and collectors, both gathering and filtering, are theoretically the most abundant, and therefore most significant, group in headwater streams because they are responsible for the breakdown of nutrients from CPOM to FPOM and their transport throughout the river network (Vannote et al. 1980, Wallace and Webster 1996). There was observed to be a higher proportion of gathering collectors throughout all the streams sampled. If these samples were collected in the fall, we might expect to see a larger proportion of shredders due to increased CPOM input, primarily in the form of detritus. The shredders in intermittent streams had a significantly smaller proportion size with a mean of 7% of total compared to a mean of 18% found in the perennial streams.

Leaf litter is a major source of energy for food webs in small forested streams (Wallace et al.. 1999, Webster et al. 1999). Shredder taxa increase conversion of CPOM to FPOM (Meyer and O'Hop 1983), and generally have low nutrient assimilation efficiencies (Golladay et al. 1983, Iversen 1979, McDiffett 1970), they are therefore largely responsible for the majority of transport of amenable nutrients downstream (Cuffney et al. 1990, Cushing et al. 1993, Wallace et al. 1982) from headwater streams (Vannote et al. 1980). The reduced shredder representation in communities of the intermittent streams might lead to decreased inputs of available FPOM which limits the downstream communities that are responsible for energy processing, balancing the efficient use of energy inputs (Vannote et al. 1980), and maintaining an equilibrium of ecological functionality. Biological communities in these scenarios can be characterized as forming a temporal continuum of synchronized species replacement, which functions to distribute the utilization of energy inputs over time. Thus, the biological system moves towards a tendency of balance between efficiency using energy inputs through resource partitioning (Vannote et al. 1980). If the inputs are not properly distributed, the efficiency and processing may become imbalanced and lead to instability and failure of proper ecological functioning in the riverine system.

The conversion of CPOM to FPOM is a secondary outcome of shredders sequestering the microbial matter that recruits in the CPOM. Therefore, shredders rate of CPOM breakdown relies heavily upon the associated microbial biomass of the detritus and other CPOM within a stream system (Vannote et al. 1980). However, some shredders obtain very little of their assimilated energy directly from microbial biomass (Findlay et al.. 1984), although enzymes derived from microbial endosymbionts, or microbes ingested with leaf tissue, have been shown to be important in cellulose hydrolysis (Sinsabaugh et al. 1985). The transformation of organic matter by shredders has been shown to be far more important than their ability to directly degrade organic material via metabolic respiration (Wallace and Webster 1996). Perhaps a regularly occurring sudden decrease of flow in the intermittent streams suppresses recruitment of microbial endosymbionts, and consequently results in decreased shredder presence in these stream types.

Schlief and Mutz 2009 compared shredder abundance in relation to alder leaf (*Alnus glutinosa*) decomposition in a natural flow regime scenario and a significant flow reduction scenario. They found that a sudden reduction of flow lowered leaf respiration and delayed leaf colonization by aquatic hyphomycetes. A simultaneous reduction in shredder presence and thus a reduction of shredder-mediated litter decomposition was recorded. This showed that flow reduction, leading to isolated pools in summer months, can affect litter decomposition and thus the supply of FPOM to the downstream food web. This observation has relevancy because climate change scenarios are predicting more stream intermittence and earlier shedding of deciduous trees leaves, when the stream channel has not yet become rewetted (Schlief and Mutz 2009)

Since streams are either intermittent or perennial, a GLM showing a gradient of change might not be the best approach for modeling proportional abundance and density. However, this model can be viewed as a logistic model which plots the probability that a stream will be perennial (approaching 1 on the y-axis of Figure 9) based on the proportion of shredders found in the stream. By this assessment, my data shows that as an observed shredder proportion, of the total BMI assemblage collected from a stream, approaches .25, it is more likely the stream is perennial, and as an observed shredder proportion approaches .05 of the total BMI assemblage, it is more likely that the stream is intermittent. This valuation shows that shredder proportion among both stream types is distinctively different, with a higher proportion of shredders found in perennial streams. This knowledge could be useful for future analysis of samples taken in the fall once the intermittent channels commence flow after summer desiccation. The shredder taxa collected in this study were sampled a few weeks before the intermittent streams dried, denoting their presence in the channel during the longest period of flowing water. The time frame of this sampling allowed the potential for ample recolonization of shredder taxa post desiccation of these channels. If BMI assemblages were radically different in the fall, there could be homogeneous stabilization among assemblages in the spring if the normal flow regime is maintained and the repopulating of less desiccation resilient taxa occurs.

Further support for this finding comes from the distribution of the histograms created from the NDVI pixels (Figure 3). Since the overall shape of all of the histograms is relatively the same, it can be concluded that there is an equal amount of potential allochthonous litter input from the riparian canopy, proportional to the channel size. It is this leaf litter input retained on the streambed that becomes colonized by microorganisms, fed on by shredders, and then broken down and converted into FPOM which is transported downstream (Wallace et al. 1982, Gomi et al. 2002). However, the NDVI analysis fails to determine canopy type, such as distinguishing broad-leafed deciduous trees from thin needled conifer trees. The difference in type of leaf litter inputs affects the retention in streams and the rates at which they are broken down by shredders (Inoue 2012). Therefore, the type of riparian canopy cover found at each stream type might help to explain the proportional differences in shredders among intermittent and perennial streams. Further analysis of dominate riparian canopy species in these study sites is needed to determine if it this is a causal impact to shredder proportion.

The limitations of this study come from a lack of a temporal component, making it difficult to assess whether or not the significant observations made are a product of individual sampling biases, or accurately documented phenomenon. Also, the benefits of adopting the standardized SWAMP protocol as my data colleting methodology may have been more detrimental than initially anticipated. This protocol is used to assess the condition of streams, and not generally used as a means to ask significant questions regarding research. A methodological approach that focused on more robust BMI samples, and less focus on instream habitat features would have lent itself to stronger and more observable findings.

In order to truly assess the BMI composition of each stream type, a temporal component needs to be adopted. Sampling multiple times in the fall, as flows starts to reappear, would show which taxa recruit in the previously dried stream channels. Sampling multiple times in the spring, as flows start to disappear, would also prove to be beneficial by showing how specific taxa avoid or adapt to intermittency. Sampling not only multiple times a year, but also sampling from other aquatic habitats such as pools, and the hyporheic region of the stream channels, would provide a more robust and complete understanding of how BMI communities differ in perennial and intermittent headwater streams.

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APPENDIX

Ancestor Creek (Perennial)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Amphipoda	Crangonyctidae		*stygobromus*			1	larvae	Shredder
Coleoptera	Elmidae		*Narpus*			9	adult	Scraper
Coleoptera	Elmidae		*Optioservus*			5	adult	Scraper
Coleoptera	Elmidae		*Optioservus*			10	larvae	Gathering Collector
Diptera	Dixidae		*Dixa*			3	larvae	Gathering Collector
Diptera	Dixidae		*Meringodixa*		*chalonensis*	2	larvae	Gathering Collector
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			4	larvae	Predator
Diptera	Tipulidae		*Hexatoma*			1	larvae	Predator
Diptera	Tipulidae		*Dicranota*			3	larvae	Predator
Diptera	Empididae		*Neoplasta*			1	larvae	Predator
Diptera	Empididae		*Chelifera*			1	larvae	Predator
Diptera	Simuliidae		*Simulium*			132	larvae	Filtering Collector
Diptera	Chironomidae	Orthocladiinae				259	larvae	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				3	Pupa	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				1	adult	Gathering Collector
Diptera	Chironomidae	Chironominae				36	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				7	larvae	Predator
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			84	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			7	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Cinygmula*			1	larvae	Scraper
Ephemeroptera	Baetidae		*Baetis*			16	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	7	larvae	Gathering Collector
Ephemeroptera	Ameletidae		*Ameletus*			1	larvae	Gathering Collector
Ephemeroptera	*Ephemerellidae*		*Ephemerella*			2	larvae	Gathering Collector

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Odonata	Gomphidae		*Octogomphus*		*specularis*	1	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	30	larvae	Shredder
Plecoptera	Leuctridae		*Paraleuctra*			1	larvae	Shredder
Plecoptera	Nemouridae		*Malenka*			21	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	138	larvae	Shredder
Plecoptera	Perlidae		*Calineuria*			16	larvae	Predator
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	15	larvae	Predator
Plecoptera	Chloroperlidae		*Sweltsa*			18	larvae	Predator
Plecoptera	Capniidae					1	larvae	Shredder
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		19	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		3	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		1	larvae	Predator
Tricoptera	Apataniidae		*Apatania*			1	larvae	Scraper
Tricoptera	Glossosomatidae		*Glossosoma*			1	larvae	Scraper
Tricoptera	Uenoidae		*Farula*			4	larvae	Gathering Collector
Tricoptera	Hydropsychidae		*Parapsyche*			2	larvae	Filtering Collector
Tricoptera	Philopotamidae		*Wormaldia*			4	larvae	Filtering Collector
Trombidiformes	Torrenticolidae		*Torrenticola*			1	larvae	

Anderson Creek (Intermittent)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Basommatophora	Physidae		*Physa*			1		
Coleoptera	Dryopidae		*Helichus*			3	adult	Shredder/Scrapper
Coleoptera	Elmidae		*Heterlimnius*			2	larvae	Gathering Collector
Coleoptera	Elmidae		*Narpus*			4	adult	Scraper
Coleoptera	Elmidae		*Narpus*			1	larvae	Gathering Collector
Coleoptera	Elmidae		*Optioserbus*			1	larvae	Gathering Collector
Coleoptera	Elmidae		*Zaitzevia*			1	adult	Scraper
Diptera	Ceratopogonidae		*Atrichopogon*			1	larvae	Predator
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			11	larvae	Predator
Diptera	Tipulidae		*Dicranota*			15	larvae	Predator
Diptera	Dixidae		*Dixa*			6	larvae	Gathering Collector
Diptera	Tipulidae		*Hesperoconopa*			1	larvae	Predator
Diptera	Dixidae		*Meringodixa*			1	larvae	Gathering Collector
Diptera	Simuliidae		*Simulium*			51	larvae	Filtering Collector
Diptera	Tipulidae		*Tipula*			1	larvae	Predator
Diptera	Chironomidae	Chironominae				44	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				93	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				814	larvae	Gathering Collector
Diptera	Chironomidae					5	pupa	
Ephemeroptera	Baetidae		*Baetis*			132	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygma*			2	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Cinygmula*			11	larvae	Scrapper
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	39	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Drunella*			10	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Ephemerella*			3	larvae	Gathering Collector

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Ephemeroptera	Heptageniidae		*Ironodes*			5	larvae	Scrapper
Ephemeroptera	Ephemerellidae		*Matriella*		*teresa*	1	larvae	Gathering Collector
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			13	larvae	Gathering Collector
Lepidoptera						1	pupa	
Plecoptera	Perlidae		*Calineuria*			28	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	21	larvae	Shredder
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	5	larvae	Predator
Plecoptera	Nemouridae		*Malenka*			106	larvae	Shredder
Plecoptera	Chloroperlidae		*Sweltsa*			29	larvae	Predator
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	7	larvae	Shredder
Tricoptera	Limnephilidae					1	larvae	Shredder
Tricoptera	Brachycentridae		*Amiocentrus*		*aspilus*	1	larvae	Gathering Collector
Tricoptera	Apataniidae		*Apatania*			2	larvae	Scraper
Tricoptera	Limnephilidae		*Ecclisomyia*			1	larvae	Shredder
Tricoptera	Lepidostomatidae		*Lepidostoma*			6	larvae	Gathering Collector
Tricoptera	Uenoidae		*Neophylax*		*splendens*	1	larvae	Gathering Collector
Tricoptera	Hydropsychidae		*Parapsyche*			6	larvae	Filtering Collector
Tricoptera	Odontoceridae		*Parthina*			2	larvae	Shredder
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		3	pupa	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		16	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		2	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		7	larvae	Predator
Tricoptera	Philopotamidae		*Wormaldia*			65	larvae	Filtering Collector
Tricoptera						1	pupa	
Trombidiformes	Torrenticolidae		*Torrenticola*			1		

Baker Creek (Intermittent)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Zaitzevia*			5	adult	Scraper
Coleoptera	Elmidae		*Narpus*			7	adult	Scraper
Coleoptera	Elmidae		*Narpus*			10	larvae	Gathering Collector
Coleoptera	Elmidae		*Optioservus*			4	adult	Scraper
Coleoptera	Elmidae		*Optioservus*			3	larvae	Gathering Collector
Coleoptera	Elmidae		*Ampumixis*		*dispar*	1	larvae	Gathering Collector
Coleoptera	Hydrophilidae		*Ametor*			1	larvae	Predator
Diptera	Simuliidae		*Simulium*			38	larvae	Filtering Collector
Diptera	Tipulidae		*Dicranota*			11	larvae	Predator
Diptera	Tipulidae					1	larvae	Predator
Diptera	Dixidae		*Dixa*			3	larvae	Gathering Collector
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			4	larvae	Predator
Diptera	Chironomidae	Chironominae				63	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				27	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				463	larvae	Gathering Collector
Diptera	Chironomidae					10	pupa	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			6	larvae	Scrapper
Ephemeroptera	Ephemerellidae		*Ephemerella*			2	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Drunella*			2	larvae	Gathering Collector
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			14	larvae	Gathering Collector
Ephemeroptera	Ameletidae		*Ameletus*			2	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			132	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	3	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygmula*			92	larvae	Scraper
Ephemeroptera	Heptageniidae		*Cinygma*			6	larvae	Scraper

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	1	larvae	Predator
Plecoptera	Perlodidae		*Isoperla*			12	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	11	larvae	Shredder
Plecoptera	Chloroperlidae		*Sweltsa*			26	larvae	Predator
Plecoptera	Perlidae		*Calineuria*			73	larvae	Predator
Plecoptera	Nemouridae		*Malenka*			19	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	86	larvae	Shredder
Plecoptera	Capniidae					3	larvae	Shredder
Plecoptera	Peltoperlidae		*Yoraperla*			2	larvae	Shredder
Tricoptera	Philopotamidae		*Wormaldia*			23	larvae	Filtering Collector
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		14	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		5	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Rotunda*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		7	larvae	Predator
Tricoptera	Hydropsychidae		*Hydropsyche*			2	larvae	Filtering Collector
Tricoptera	Hydropsychidae		*Parapsyche*			3	larvae	Filtering Collector
Tricoptera	Brachycentridae		*Micrasema*			1	larvae	Gathering Collector
Tricoptera	Apataniidae		*Apatania*			6	larvae	Scraper
Tricoptera	Limnephilidae		*Ecclisomyia*			3	larvae	Shredder
Tricoptera	Uenoidae		*Farula*			4	larvae	Gathering Collector
Tricoptera	???					5	pupa	

Buck Creek (Perennial)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Plecoptera	Chloroperlidae		*Sweltsa*			1	larvae	Predator
Plecoptera	Nemouridae		*Malenka*			399	larvae	Shredder
Ephemeroptera	Baetidae		*Baetis*			98	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygma*			16	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Cinygmula*			1	larvae	Scrapper
Tricoptera	Philopotamidae		*Wormaldia*			106	larvae	Filtering Collector
Tricoptera	Hydropsychidae		*Parapsyche*			17	larvae	Filtering Collector
Tricoptera	Glossosomatidae		*Glossosoma*			15	larvae	Scraper
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		17	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		1	pupa	Predator
Tricoptera	Apataniidae		*Apatania*			16	larvae	Scraper
Tricoptera	Brachycentridae		*Micrasema*			6	larvae	Gathering Collector
Tricoptera	Limnephilidae		*Ecclisomyia*			1	larvae	Shredder
Tricoptera	Lepidostomatidae		*Lepidostoma*			3	larvae	Gathering Collector
Tricoptera						1	pupa	
Coleoptera	Elmidae		*Optioserbus*			15	larvae	Scraper
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			4	larvae	Predator
Diptera	Ceratopogonidae		*Atrichopogon*			1	larvae	Predator
Diptera	Dixidae		*Dixa*			5	larvae	Gathering Collector
Diptera	Empididae		*Neoplasta*			5	larvae	Predator
Diptera	Tipulidae		*Dicranota*			7	larvae	Predator
Diptera	Simuliidae		*Simulium*			499	larvae	Filtering Collector
Diptera	Chironomidae	Orthocladiinae				368	larvae	Gathering Collector
Diptera	Chironomidae					4	pupa	Gathering Collector
Diptera	Chironomidae	Chironominae				22	larvae	Gathering Collector

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Diptera	Chironomidae	Tanypodinae				17	larvae	Predator
Tricoptera	Limnephilidae		*Ecclisomyia*			1	larvae	Shredder

Helen Barnum Creek (Intermittent)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Narpus*			3	adult	Scraper
Coleoptera	Hydrophilidae		*Ametor*			3	larvae	Predator
Diptera	Simuliidae		*Simulium*			143	larvae	Filtering Collector
Diptera	Dixidae		*Dixa*			4	larvae	Gathering Collector
Diptera	Dixidae		*Meringodixa*			4	larvae	Gathering Collector
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			10	larvae	Predator
Diptera	Empididae		*Neoplasta*			1	larvae	Predator
Diptera	Tipulidae		*Dicranota*			6	larvae	Predator
Diptera	Tipulidae		*Hesperoconopa*			1	larvae	Predator
Diptera	Tipulidae		*Hexatoma*			1	larvae	Predator
Diptera	Chironomidae	Chironominae				18	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				46	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				389	larvae	Gathering Collector
Diptera	Chironomidae					6	pupa	
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			32	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygmula*			9	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Ironodes*			2	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Cinygma*			8	larvae	Scrapper
Ephemeroptera	Ephemerellidae		*Ephemerella*			1	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			24	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	41	larvae	Gathering Collector
Megaloptera	Sialidae		*Sialis*			1	larvae	Predator
Plecoptera	Chloroperlidae		*Sweltsa*			7	larvae	Predator
Plecoptera	Perlidae		*Calineuria*			28	larvae	Predator

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Plecoptera	Nemouridae		*Malenka*			32	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	16	larvae	Shredder
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	1	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	6	larvae	Shredder
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		3	larvae	Predator
Tricoptera	Philopotamidae		*Wormaldia*			16	larvae	Filtering Collector
Tricoptera	Limnephilidae		*Pseudostenophylax*		*edwardsi*	65	larvae	Filtering Collector
Tricoptera	Lepidostomatidae		*Lepidostoma*			1	larvae	Shredder
Tricoptera	Hydropsychidae		*Parapsyche*			4	larvae	Filtering Collector
Tricoptera	???					2	pupa	
Tricoptera	Limnephilidae		*Hesperophylax*			4	larvae	Gathering Collectors

Lost River (Intermittent)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Optioserbus*			1	adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			2	larvae	Scraper
Coleoptera	Elmidae		*Narpus*			1	larvae	Scraper
Coleoptera	Hydrophilidae		*Ametor*			4	adult	Predator
Coleoptera	Hydrophilidae		*Ametor*			1	larvae	Predator
Diptera	Simuliidae		*Simulium*			32	larvae	Filtering Collector
Diptera	Simuliidae		*Simulium*			1	pupa	Filtering Collector
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			11	larvae	Predator
Diptera	Chironomidae	Chironominae				31	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				28	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				309	larvae	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				1	pupa	Gathering Collector
Diptera	Dixidae		*Dixa*			3	larvae	Gathering Collector
Diptera	Tipulidae		*Dicranota*			10	larvae	Predator
Ephemeroptera	Heptageniidae		*Cinygmula*			48	larvae	Scraper
Ephemeroptera	Heptageniidae		*Cinygma*			4	larvae	Scraper
Ephemeroptera	Ephemerellidae		*Drunella*			3	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			3	larvae	Scrapper
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			15	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			53	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	5	larvae	Gathering Collector
Plecoptera	Chloroperlidae		*Sweltsa*			8	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	1	larvae	Shredder
Plecoptera	Perlidae		*Calineuria*			49	larvae	Predator
Plecoptera	Perlodidae		*Kogotus*			5	larvae	Predator

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Plecoptera	Perlodidae		*Isoperla*			14	larvae	Predator
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	5	larvae	Shredder
Plecoptera	Nemouridae		*Malenka*			16	larvae	Shredder
Plecoptera	Nemouridae		*Malenka*			1	pupa	Shredder
Plecoptera	Peltoperlidae		*Yoraperla*			1	larvae	Shredder
Tricoptera	Philopotamidae		*Wormaldia*			55	larvae	Filtering Collector
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		7	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		3	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		5	pupa	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		3	larvae	Predator
Tricoptera	Hydropsychidae		*Parapsyche*			2	larvae	Filtering Collector
Tricoptera	Uenoidae		*Neophyalx*			2	larvae	Shredder
Tricoptera	Brachycentridae		*Micrasema*			1	larvae	Gathering Collector
Tricoptera	Apataniidae		*Apatania*			1	larvae	Scrapper
Tricoptera	Uenoidae		*Farula*			16	larvae	Gathering Collector

McKee Creek (Intermittent)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Dytiscidae		*Agabus*			1	larvae	Predator
Coleoptera	Elmidae		*Narpus*			3	adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			1	adult	Scraper
Diptera	Dixidae		*Dixa*			1	larvae	Gathering Collector
Diptera	Simuliidae		*Simulium*			95	larvae	Filtering Collector
Diptera	Empididae		*Neoplasta*			3	larvae	Predator
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			2	larvae	Predator
Diptera	Tipulidae		*Dicranota*			7	larvae	Predator
Diptera	Tipulidae		*Cryptolabis*			1	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				239	larvae	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				1	Pupa	Gathering Collector
Diptera	Chironomidae	Chironominae				77	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				23	larvae	Predator
Ephemeroptera	Baetidae		*Baetis*			87	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	6	larvae	Gathering Collector
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			3	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Ephemerella*			6	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Matriella*		*teresa*	1	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygmula*			39	larvae	Scraper
Ephemeroptera	Heptageniidae		*Cinygma*			1	larvae	Scraper
Hemiptera	Gerridae		*Gerris*			1	larvae	Predator
Megaloptera	Corydalidae		*Neohermes*		*teneral*	1	larvae	Predator
Plecoptera	Chloroperlidae		*Suwallia*			28	larvae	Predator
Plecoptera	Chloroperlidae		*Sweltsa*			1	larvae	Predator
Plecoptera	Perlodidae		*Kogotus*			1	larvae	Predator
Plecoptera	Perlodidae		*Isoperla*			6	larvae	Predator

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Plecoptera	Leuctridae		*Despaxia*		*augusta*	1	larvae	Shredder
Plecoptera	Perlidae		*Calineuria*			4	larvae	Predator
Plecoptera	Nemouridae		*Malenka*			4	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	1	larvae	Shredder
Plecoptera	Capniidae					1	larvae	Shredder
Tricoptera	Glossosomatidae		*Glossosoma*			8	larvae	Scraper
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		2	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		5	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		4	Pupa	Predator
Tricoptera	Philopotamidae		*Wormaldia*			1	larvae	Filtering Collector
Tricoptera	Limnephilidae		*Pseudostenophylax*		*edwardsi*	2	larvae	Shredder
Tricoptera	Apataniidae		*Apatania*			85	larvae	Scraper
Tricoptera	Brachycentridae		*Micrasema*			18	larvae	Gathering Collector
Tricoptera	Hydropsychidae		*Hydropsyche*			1	larvae	Filtering Collector
Tricoptera	Lepidostomatidae		*Lepidostoma*			5	larvae	Gathering Collector
Tricoptera	Limnephilidae		*Ecclisomyia*			1	larvae	Shredder

Mill Creek (Perennial)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Narpus*			4	adult	Scraper
Coleoptera	Elmidae		*Narpus*			1	larvae	Gathering Collector
Coleoptera	Elmidae		*Optioservus*			2	adult	Scraper
Coleoptera	Elmidae		*Optioservus*			1	larvae	Gathering Collector
Diptera	Simuliidae		*Simulium*			102	larvae	Filtering Collector
Diptera	Tipulidae		*Dicranota*			7	larvae	Predator
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			7	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				405	larvae	Gathering Collector
Diptera	Chironomidae	Chironominae					larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				45	larvae	Predator
Diptera	Chironomidae					1	pupa	
Ephemeroptera	Ephemerellidae		*Ephemerella*			6	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			3	larvae	Scrapper
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			9	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Drunella*			3	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			169	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	17	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygmula*			8	larvae	Scraper
Odonata	Gomphidae		*Octogomphus*		*specularis*	2	larvae	Predator
Plecoptera	Perlidae		*Calineuria*			76	larvae	Predator
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	20	larvae	Predator
Plecoptera	Nemouridae		*Malenka*			34	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	6	larvae	Shredder
Plecoptera	Chloroperlidae		*Sweltsa*			2	larvae	Predator
Tricoptera	Philopotamidae		*Wormaldia*			20	larvae	Filtering Collector

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		20	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		5	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Grandis*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		5	larvae	Predator
Tricoptera	Uenoidae		*Neophyalx*			1	larvae	Shredder
Tricoptera	Uenoidae		*Neophyalx*			1	pupa	Shredder
Tricoptera	Glossosomatidae		*Glossosoma*			2	larvae	Scraper
Tricoptera	Hydropsychidae		*Parapsyche*			2	larvae	Filtering Collector
Tricoptera	Lepidostomatidae		*Lepidostoma*			3	larvae	Gathering Collector
Tricoptera	???					1	pupa	

South Fork Bear Creek (Perennial)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Ampumixis*		*dispar*	1	Adult	Scrapper
Coleoptera	Elmidae		*Ampumixis*		*dispar*	12	larvae	Gathering Collector
Coleoptera	Elmidae		*Narpus*			5	Adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			12	Adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			1	larvae	Gathering Collector
Coleoptera	Elmidae		*Zaitzevia*			1	Adult	Scraper
Diptera	Simuliidae		*Simulium*			160	larvae	Filtering Collector
Diptera	Dixidae		*Dixa*			3	larvae	Gathering Collector
Diptera	Tipulidae		*Dicranota*			3	larvae	Predator
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			13	larvae	Predator
Diptera	Empididae		*Neoplasta*			2	larvae	Predator
Diptera	Chironomidae	Chironominae				45	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				76	larvae	Predator
Diptera	Chironomidae	Orthocladiinae				464	larvae	Gathering Collector
Diptera	Chironomidae					5	Pupa	Gathering Collector
Ephemeroptera	Ameletidae		*Ameletus*			1	larvae	Gathering Collector
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			37	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Ephemerella*			16	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Drunella*			10	larvae	Gathering Collector
Ephemeroptera	Ephemerellidae		*Matriella*		*teresa*	6	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			90	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	7	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			4	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Epeorus*			2	larvae	Scrapper
Ephemeroptera	Heptageniidae		*Ecdyonurus*			4	larvae	Scrapper

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Ephemeroptera	Heptageniidae		*Cinygmula*			26	larvae	Scrapper
Megaloptera	Corydalidae		*Neohermes*		*teneral*	1	larvae	Predator
Odonata	Gomphidae		*Octogomphus*		*specularis*	1	larvae	Predator
Plecoptera	Perlidae		*Calineuria*			74	larvae	Predator
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	3	larvae	Predator
Plecoptera	Chloroperlidae		*Sweltsa*			7	larvae	Predator
Plecoptera	Leuctridae		*Despaxia*		*augusta*	4	larvae	Shredder
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	45	larvae	Shredder
Plecoptera	Nemouridae		*Malenka*			174	larvae	Shredder
Plecoptera	Capniidae					1	larvae	Shredder
Plecoptera	Perlodidae		*Isoperla*			1	larvae	Predator
Tricoptera	Philopotamidae		*Wormaldia*			2	larvae	Filtering Collector
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		36	larvae	Predator
Tricoptera	Glossosomatidae		*Glossosoma*			1	larvae	Scraper
Tricoptera	Limnephilidae		*Ecclisomyia*			1	Pupa	Shredder
Tricoptera	Lepidostomatidae		*Lepidostoma*			12	larvae	Gathering Collector
Tricoptera	Apataniidae		*Apatania*			8	larvae	Scraper
Tricoptera	Odontoceridae		*Parthina*			2	larvae	Shredder
Tricoptera	???					1	Pupa	
Trombidiformes	Torrenticolidae		*Torrenticola*			1		

Thompson Creek (Perennial)

Order	Family	Subfamily	Genus	Group	Species	Number of Individuals	Life Stage	Functional Feeding Group
Coleoptera	Elmidae		*Narpus*			3	adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			7	adult	Scraper
Coleoptera	Elmidae		*Optioserbus*			11	larvae	Gathering Collector
Coleoptera	Elmidae		*Heterlimnius*			1	larvae	Gathering Collector
Coleoptera	Elmidae		*Ordobrevia*		*nubifera*	3	larvae	Gathering Collector
Diptera	Dixidae		*Dixa*			1	larvae	Gathering Collector
Diptera	Ceratopogonidae		*Bezzia/Palpomyia*			2	larvae	Predator
Diptera	Tipulidae		*Dicranota*			3	larvae	Predator
Diptera	Tipulidae		*Antocha*			2	larvae	Gathering Collector
Diptera	Empididae		*Neoplasta*			1	larvae	Predator
Diptera	Simuliidae		*Simulium*			41	larvae	Filtering Collector
Diptera	Chironomidae	Orthocladiinae				1	adult	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				8	Pupa	Gathering Collector
Diptera	Chironomidae	Orthocladiinae				459	larvae	Gathering Collector
Diptera	Chironomidae	Chironominae				32	larvae	Gathering Collector
Diptera	Chironomidae	Tanypodinae				19	larvae	Predator
Ephemeroptera	Ephemerellidae		*Ephemerella*			8	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Ironodes*			1	larvae	Scrapper
Ephemeroptera	Leptophlebiidae		*Paraleptophlebia*			18	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Baetis*			64	larvae	Gathering Collector
Ephemeroptera	Baetidae		*Diphetor*		*hageni*	31	larvae	Gathering Collector
Ephemeroptera	Heptageniidae		*Cinygmula*			10	larvae	Scraper
Odonata	Gomphidae		*Octogomphus*		*specularis*	1	larvae	Predator
Plecoptera	Chloroperlidae		*Sweltsa*			18	larvae	Predator
Plecoptera	Perlidae		*Hesperoperla*		*hoguei*	10	larvae	Predator

Order	**Family**	**Subfamily**	**Genus**	**Group**	**Species**	**Number of Individuals**	**Life Stage**	**Functional Feeding Group**
Plecoptera	Leuctridae		*Despaxia*		*augusta*	14	larvae	Shredder
Plecoptera	Perlidae		*Calineuria*			56	larvae	Predator
Plecoptera	Nemouridae		*Zapada*		*cinctipes*	143	larvae	Shredder
Plecoptera	Nemouridae		*Malenka*			162	larvae	Shredder
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Hyalinata*		1	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Betteni*		13	larvae	Predator
Tricoptera	Rhyacophilidae		*Rhyacophila*	*Sibirica*		2	larvae	Predator
Tricoptera	Hydropsychidae		*Parapsyche*			2	larvae	Filtering Collector
Tricoptera	Glossosomatidae		*Glossosoma*			2	larvae	Scraper
Tricoptera	Lepidostomatidae		*Lepidostoma*			2	larvae	Gathering Collector
Tricoptera	Brachycentridae		*Micrasema*			1	larvae	Gathering Collector
Tricoptera	Brachycentridae		*Amiocentrus*			1	larvae	Gathering Collector
						13	adult	