The Faculty of Alfred University

AN ASSESSMENT OF STREAM CONDITIONS AND THEIR EFFECTS ON BENTHIC MACROINVERTEBRATE COMMUNITY STRUCTURE

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In Partial Fulfillment of
the Requirements for
The Alfred University Honors Program

Date____________________

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Thesis I examined the effects of environmental variables on benthic macroinvertebrate community structure in four stream catchments in the Upper Genesee Watershed of Allegany County. I proposed that some variables would be more pertinent in the determination of community composition especially those related to the effects of land abandonment.

Introduction

I would like to begin by introducing an internship I had the opportunity to work on this past summer with Dr. Beaudry. Not only would this internship be the best summer job I have had to date, but the experience would play a pivotal role in shaping my honors thesis. It steered me towards pertinent research and aided me with the organization of the study's experimental design.

Table 5. Changes in Land Use in Allegany County, Selected Years, 1910-1992				
Description	1910	1940	1969	1992
Farm numbers	4,937	3,018	1,112	682
		Percent of land area		
Improved land/cropland	55.8	34.2	19.7	13.4
All land in farms	87.4	65.9	38.0	24.1
Mostly forested: government and private ownership	41.2			81.6
Source: Census of Agriculture.				

Figure 1. Table 5 from Stanton and Bill, *The Return of Agricultural Lands to Forest: Changing Land Use in the Twentieth Century* (1996).

In preparation for the internship I was instructed to research and become familiar with the concept of "land abandonment," a common trend throughout the northeastern United States. Land abandonment plays an important role in the current state of Western New York's landscape, and in Allegany County it is largely the result of a shift away from dairy production.

According to research provided by Stanton and Bills (1996) the amount of farmland in Allegany dropped 42 percent from the years of 1910 to 1992 (figure 1).

Lands once used as pasture or cropland were left to the forces of ecological succession also known as reforestation or afforestation (figure 2). Where grasses closely cropped by large, nonnative herbivores were once prominent; sedges, shrubs and pine saplings were now able to take hold. When streams undergo succession, their riparian zones undergo a period of reforestation (figure 3). This is more of a localized event, but shifts in land use have more sweeping effects on a landscape scale that include the entirety of a stream's watershed or catchment.

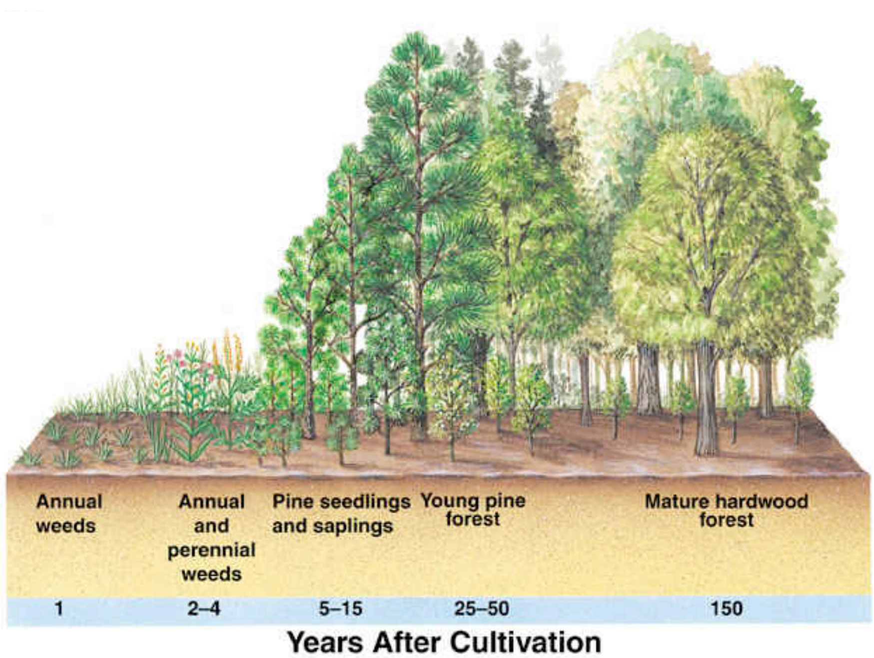

Figure 2. Diagram representing the process of secondary succession with time increasing from left to right. This is typical of lands once used in agriculture that have been abandoned. Credit: Raven & Berg, Environment, Third Edition; Figure 5.17; Harcourt, Inc.

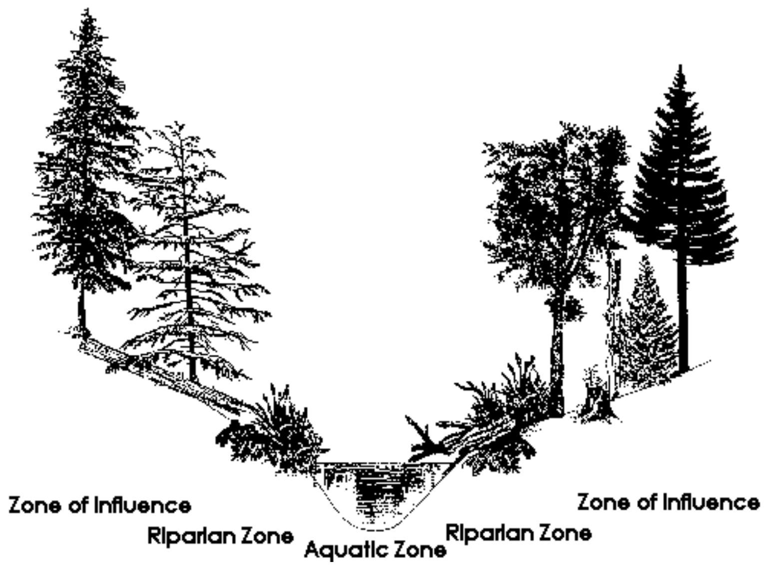

Figure 3. Diagram displaying the various areas associated with small streams. The riparian zone can be found as the immediate banks of the stream. The type of land cover (i.e. forested, not forested) may vary from stream to stream as well as along any given stream. Credit: Benton County, Oregon webpage.

The study's focus would ultimately lie in the importance of changes in land cover and its effects on small streams. Salamanders, which are fairly high on the food chain in small, woodland streams, were hypothesized to be effected more on a landscape scale. This was the thought I was to keep in mind throughout the summer months while driving about in University vehicles (i.e. Toyota Prius) that were far out-matched by Western NY's rugged back-roads, mucking around in knee-high boots, and flipping over rocks in search for salamanders. If anyone asked I would inform them that I was reliving my childhood.

Thus my interest in the concept of abandoned farmland was born.

The design of my study is laid out in greater detail as the methods section of my paper, but I find it important to touch on a few aspects here for the benefit of the reader. The first aspect is the study's focus on benthic macroinvertebrates (BMI) as a response variable. The term benthic refers to the lowest region of any body of water, which, in the study, is in the form of substrate found at the bottom of streams. BMI are important in ecology due to their sensitivity to external factors, such as shifts in environmental conditions, and also due to their position in terms of trophic levels.

Trophic levels are generally represented in the form of a pyramid with lower level organisms, primary producers like plants for example, comprising the bottom of the pyramid while higher level organisms (i.e. predators) make up the top. Inherently, those existing on a low trophic level have direct and indirect effects on organisms at higher trophic levels. The theory of bottom-up control suggests that low trophic organisms shape all others through the relationships they share. Once this is understood, the importance to fully understand each and every level becomes apparent.

The other aspect of my experimental design that I would like to address is the selection of study sites, each of which is a first order stream. The stream order definition is based on the Horton-Strahler number, which was first applied in mathematics. In terms of hydrology though, order is determined based on whether or not the stream has tributaries. A first order stream is assumed to not have any tributaries, drawing from a small watershed (catchment). First order streams flow into second order, which feed into third order and so on and so forth (figure 4). Only first order streams were surveyed in the study due to the sensitive relationship they hold with their catchments. Small alterations in their surrounds can be easily detected through examination of the stream itself.

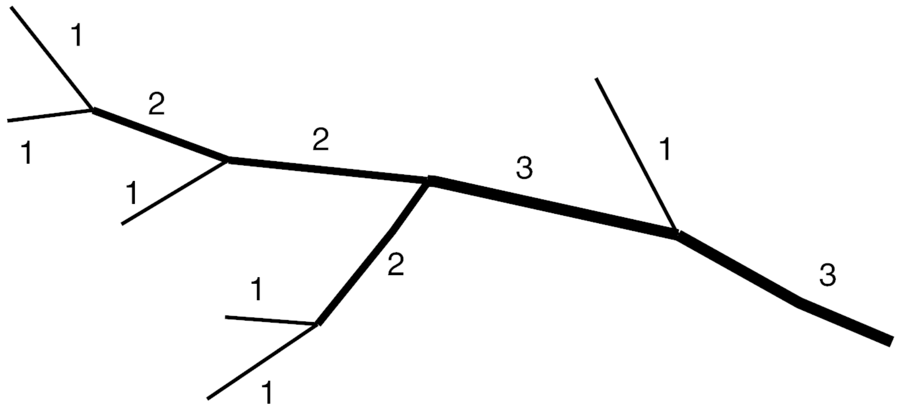

Figure 4. Diagram depicting the nature of Strahler stream order classification. The order of each stream is denoted by the number located nearest it. Credit: Wikipedia, creative commons.

Small streams are known to rely on one of two energy sources: allochthonous and autochthonous. Allochthonous refers to any system that acquires the majority of its energy through inputs in the form of detritus (i.e. dead organic matter). An allochthonous stream, for example, would receive high quantities of leaf litter both from the canopy overhead as well as anything that may wash in from its banks. Detritus provides energy to a number of low trophic level organisms known as detrivores, some of which fall into the BMI category.

The other type of energy, autochthonous, that may dominate a system comes in the form of primary production. Streams exposed to high amounts of sunlight provide habitats preferable to organisms like mosses and algae, which in turn act as a sort of browsing substrate for BMI.

There are several guilds of benthic macroinvertebrates, each of which can be defined by the type of nutrients it relies on. These guilds exist as the following feeding groups: shredders, collectors, scrapers and predators. Shredders have large mouthparts that enable them to feed on coarse particulate organic matter (CPOM), while collectors rely on fine particulate organic matter (FPOM; figure 5). Both CPOM and FPOM are components of an allochthonous system. Scrapers, on the other hand, have rasping mouthparts that are used to remove nutrients that are attached to rocks and other substrate like algae (figure 6). Finally, predators simply feed on other macroinvertebrates.

Figure 5. Illustration of a stonefly nymph of the shredder feeding group. Credit: Cummins & Wilzbach.

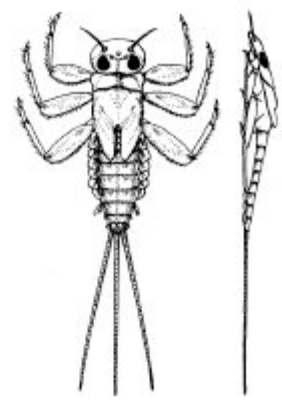

Figure 6. Illustration of a scraper. The flat body shape allows it to cling to substrate without being detached. Credit: Cummins & Wilzbach.

An Assessment of Stream Conditions and Their Effects on Benthic Macroinvertebrate Community Structure

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Abstract Agricultural land abandonment and reforestation are common occurrences in some areas of the northeastern United States. These changes in land cover have varying consequences for watersheds and the streams that drain them. Benthic macroinvertebrate (BMI) communities rely heavily on stream conditions and have been proven to respond to activities within the watershed. The purpose of my study was to examine some key variables affecting BMI community structure. These variables include physical and biological parameters for a selection of streams within the Upper Genesee watershed of Allegany County, New York. BMI sampling was accompanied by the collection of data on leaf litter, stream flow and autochthonous primary production as well as an examination of land cover. I found a positive relationship between the presence of algae and macroinvertebrates in the scraper feeding group, supporting the hypothesis that scrapers would be found in greater numbers where algae is most abundant. The prominence of algae is indicative of streams dominated by autochthonous inputs and is in part determined by land cover.

1. Introduction

Land abandonment is a phenomenon that has been occurring in the eastern United States since the 1870s (Cramer et al. 2007, Hart 1968). Allegany County, New York experienced a 43% drop in agricultural land-use from 1910 to 1992 (Stanton and Bills 1996). When left vacant, plots of land once actively used for agricultural purposes begin the process of ecological succession in which grasses are replaced by shrubs and trees shrubs replace grasses (Copenheaver 2008). These changes in vegetation lead to changes in the conditions of streams within the areas once farmland (Foster et al. 2003).

Streams found in agriculturally productive land receive a greater amount of direct sunlight, increasing temperature and bolstering algae growth, the primary source of productivity. Succession results in the reforestation of abandoned lands, which provides canopy cover to streams and decreases the amount of sunlight that reaches the water. Streams with more canopy cover receive greater amounts of leaf litter from overhead vegetation (Hagen et al. 2010). The decrease in available sunlight and the increase in leaf litter lead to a shift in the dominant energy source of the stream from autochthonous production (algae) to allochthonous detritus.

The composition of BMI feeding groups depends on the type of organic matter present in stream systems. The shredder guild feeds on nutrients that are indicative of allochthonous streams (CPOM), while scrapers rely mostly on nutrients found more abundantly in autochthonous streams (Cummins and Wilzbach 1985). An alteration from autochthonous production to allochthonous detritus has an effect on these feeding groups and the trophic networks that rely on them (McTammany 2004).

In the study I examined the link between BMI feeding groups and certain environmental conditions to determine the most prominent driver of community structure. The variables examined include catchment land cover, leaf litter inputs, stream flow, and the presence of algae and mosses.

2. METHODS

2.1. *Study sites*

Study sites included four randomly selected 1st order catchments within the Upper Genesee River watershed, located in the Allegany Plateau Ecoregion (Bryce et al. 2010). Strahler number of each stream was defined by National Hydrography Dataset Plus. The study area encompasses the portion of the watershed within Allegany County, New York. Individual streams within each selected catchment will be referred to by the name of the town in which they were sampled (figure 7). The study was conducted during the autumn months of 2011.

Deciduous and evergreen forests as well as agricultural lands characterize the watershed (USGS GAP data 2010). Land use was classified by heads-up digitizing an Esri imagery basemap using ArcGIS 10 (ESRI, Redlands, CA). Each study site was broken into three categories (forest, shrub land, and agriculture) that were deemed relevant to the study. Areas that did not fall into one of these categories were marked as “other” (figure 7). The categories were then calculated as a percentage of each study site.

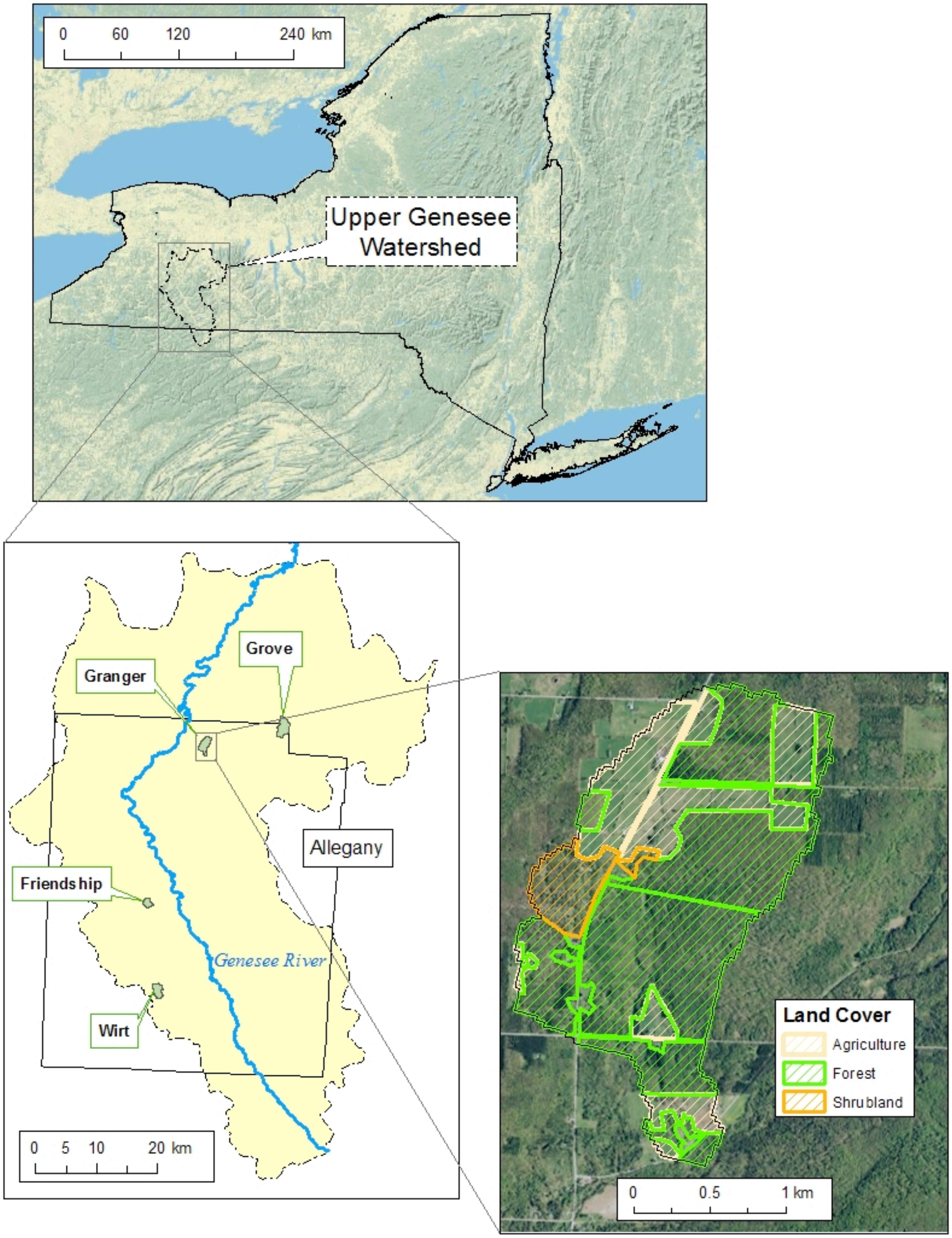

Figure 7. The four 1st order stream catchments are found at various locations across Allegany County. The method used in classifying land cover is shown here for the study site Granger.

2.2. *Macroinvertebrates*

Benthic macroinvertebrate samples were gathered from each study site using a mini Surber sampler with a mesh size of 500 µm. Streams were sampled on two separate occasions at four points, each sample with an area of $1.0ft^2$ ($0.093m^2$) were taken from each stream reach. The sampler was partially submerged while substrate was hand-rubbed within the horizontal frame for 60 seconds (Kroger 1972). Streams were sampled on two separate occasions at five points, giving a total of ten samples per stream.

Collected invertebrates were sorted and identified to the lowest level of taxonomy required to determine their appropriate feeding groups (collectors, predators, scrapers and shredders). Generally, the determination of the family of each individual was sufficient (Cummins 1985). Each feeding group was calculated as a percent of the total number sampled to provide a measure of community composition.

2.3. *Autochthonous and allochthonous inputs, stream flow*

Autochthonous production was indexed in each stream via visual assessments at various points along the sampled segment. Each point was given a value on a scale of zero to five for two categories of primary producers: algae and mosses (zero being none present, five indicating a very strong presence). The values of each category were then averaged to provide an index on a scale of zero to five. Browsing substrate was calculated by adding the moss index to the algae index.

Allochthonous inputs for each system were measured with the use of five vertical litter traps per stream, placed at 25.0m intervals along the length of the stream. Each trap was suspended at a height of approximately 1.5 m above the stream, or as near to the stream as possible, while occupying an area of 0.071 m^2 for a total area sampled of 0.355 m^2 per site. Litter was collected on four irregular occasions over the study period. Samples were then dried at 60°C and weighed to the nearest hundredth of a gram (Fisher and Likens 1973).

Stream flow was measured for each site on the same day at least one week after a major rain event. Measurements of flow were taken at five locations each approximately 25 m apart with the use of a Swoffer velocity meter Model 3000 (Swoffer Instruments, INC, Seattle, WA).

2.4. *Data analysis*

A multiple regression was applied to examine the relationships between the various environmental variables and BMI community composition, using Minitab 16.1.1 (Minitab Inc., 2010). Feeding group percentages were transformed using an arcsine square root data transformation. The predictor variables used in the analysis were: land cover, allochthonous inputs, stream flow, browsing substrate as well as algae.

3. RESULTS

3.1. *Benthic Macroinvertebrates*

A total of 322 benthic macroinvertebrates were collected and identified during the study period, ranging from 66 individuals for Wirt to 98 for Grove. Predators were most abundant at three sites (48-69 %), except for Wirt where collectors dominated (41 %; figure 8).

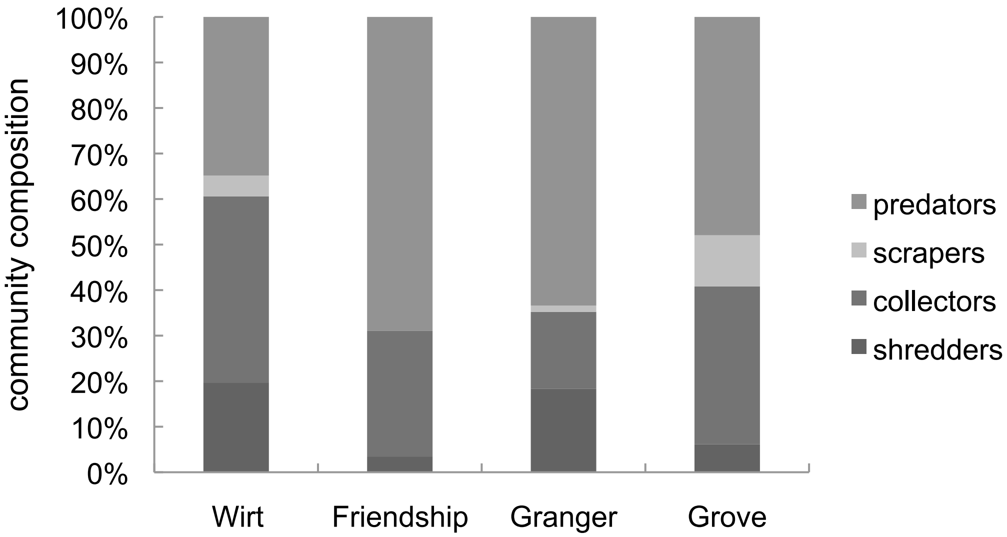

Figure 8. BMI individuals sampled during the study period organized into their appropriate feeding groups. Community composition is represented by expressing each feeding group as a percent of the total at each site (n = 10).

3.2. *Autochthonous and allochthonous inputs, stream flow*

Statistical analysis of environmental variables resulted in three significant relationships (table 1).

Visual index estimates assigned to each site for algae varied between 0.00 and 4.25, while mosses ranged from 0.00 to 2.33 (table 2). Based on the multivariate linear regression, algae was shown to be statistically significant as a predictor value for the shredder (t = 15.63, p = 0.041) and scraper (t = 14.99, p = 0.042) feeding groups. The relationship between the variables was positive in both cases (figure 9).

Allochthonous inputs, measured in terms of dry mass (g), was greatest for the Friendship site, 76.39 g, and lowest for the Grove site, 48.84 g (figure 10). There was a significant negative relationship between dry mass and scrapers (t = -88.30, p = 0.007; figure 11).

Mean stream flow varied between 0.07 and 1.12 m/s (figure 12). Analysis of flow resulted in no statistically significant relationships.

Table 1. Results derived from a multiple regression analysis of BMI as a response to environmental variables. Significant relationships are shown in bold.

predictor		response			
		% shredder transformed	% scraper transformed	% collector transformed	% predator transformed
dry mass (g)	coefficient	0.0004	-0.0119	-0.0053	0.0085
	SE coefficient	0.0007	0.0001351	0.0081850	0.0080
	t	0.52	**-88.30**	-0.65	1.06
	p	0.694	**0.007**	0.634	0.480
flow (m/s)	coefficient	0.0611	-0.3322	-0.3182	0.3660
	SE coefficient	0.1768	0.2742	0.1065	0.0867
	t	0.35	-1.21	-2.99	4.22
	p	0.788	0.439	0.206	0.148
browsing substrate index	coefficient	0.0455	0.05316	0.06219	-0.09926
	SE coefficient	0.0385	0.0597	0.0232	0.0189
	t	1.18	0.89	2.68	-5.26
	p	0.447	0.537	0.227	0.120
algae index	coefficient	0.0635	0.0112	-0.0064	-0.0325
	SE coefficient	0.0041	0.0007	0.0451	0.0440
	t	**15.63**	**14.99**	-0.14	-0.74
	p	**0.041**	**0.042**	0.910	0.595
% forest transformed	coefficient	-0.5921	-0.0223	0.3988	-0.0891
	SE coefficient	0.1857	0.6891	0.1990	0.3728
	t	-3.19	-0.03	2	-0.24
	p	0.086	0.979	0.295	0.851
% agriculture transformed	coefficient	0.5689	0.2836	0.6317	-0.8632
	SE coefficient	0.4153	0.87	0.2512	0.4706
	t	1.37	0.33	2.51	-1.83
	p	0.304	0.799	0.241	0.318
% shrubland transformed	coefficient	1.0796	0.5321	-0.0544	-0.7124
	SE coefficient	0.2638	0.7672	0.6846	0.7792
	t	4.09	0.69	-0.08	-0.91
	p	0.055	0.56	0.944	0.457

Table 2. Autochthonous production indices (moss and algae range: 0 – 5; browsing substrate range: 0 – 10) given to each study site based on the prominance of mosses and algae as browsing substrate.

Study site	algae	moss	browsing substrate
Wirt	4.25	2.33	6.58
Friendship	0.00	2.20	2.20
Granger	4.25	0.00	4.25
Grove	1.25	0.50	1.75

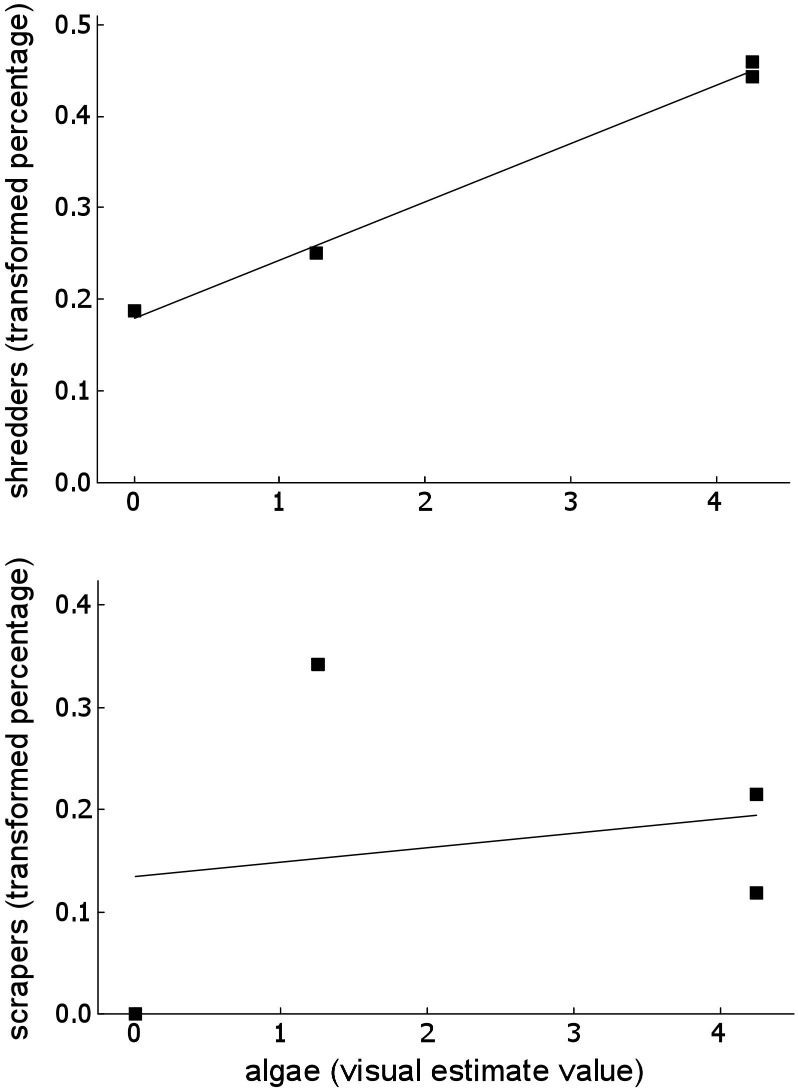

Figure 9. Algae index as a predictor value for transformed shredder and scraper data across all study sites.

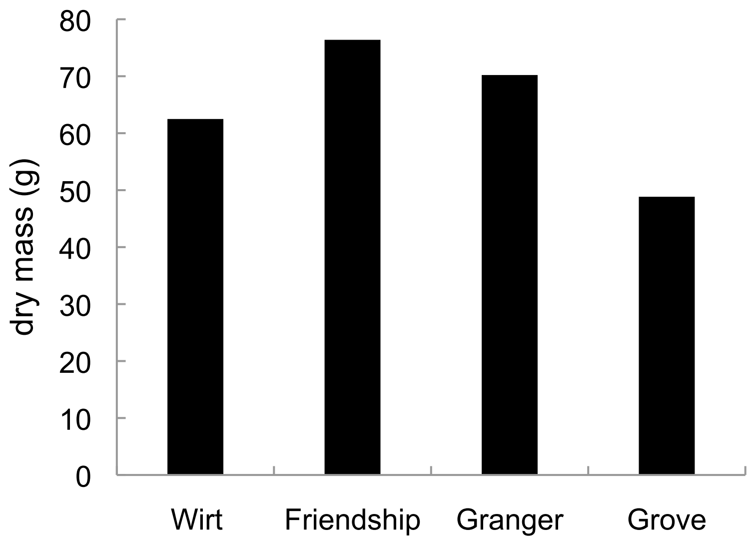

Figure 10. Summary data for allochothonous inputs in terms of dry mass (g) for each study site. Dry mass is a measure of the leaf litter collected throughout the study period (n = 4).

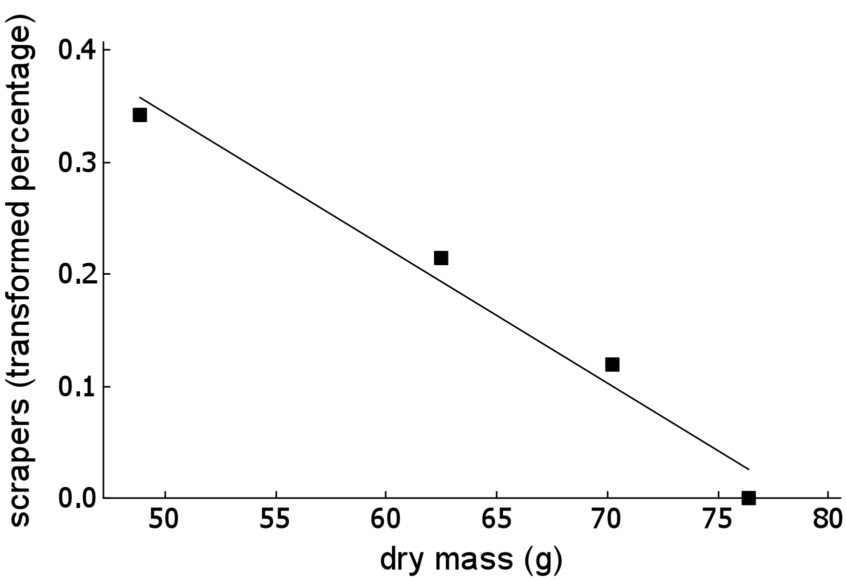

Figure 11. Allochthonous inputs as dry mass (g) as a predictor value for transformed scraper data across all study sites.

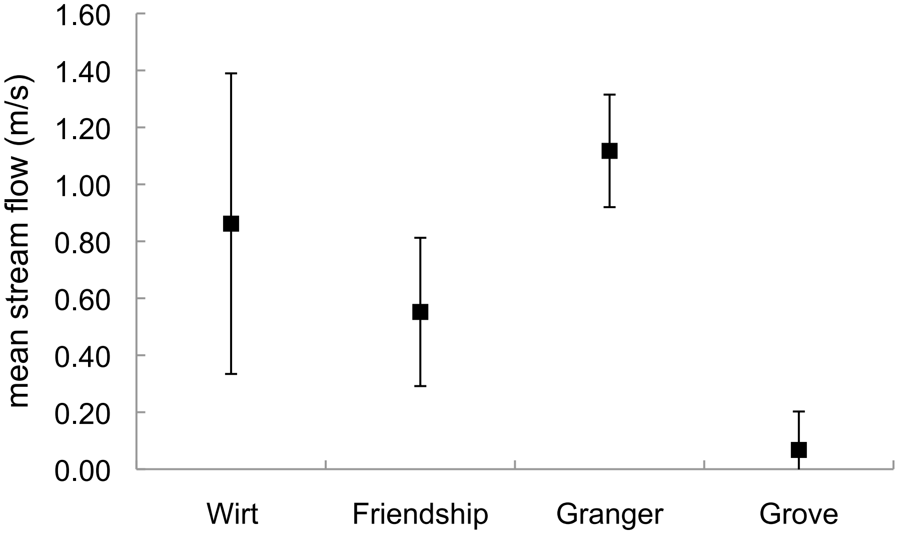

Figure 12. Mean (+/- standard deviation) stream flow measured at four locations for each site (n = 4).

3.3. *Land cover*

All study sites were predominantly forested with varying percentages of shrubland and agriculture (table 3). Land cover was not a statistically significant predictor of community composition.

Table 3. Land cover percentages for each study site.

Site name	forest (%)	shrubland (%)	agriculture (%)	other (%)
Wirt	80	6	13	1
Friendship	97	0	0	3
Granger	63	7	25	4
Grove	91	2	0	6

4. Discussion

4.1. *General conclusions*

Autochthonous and allochthonous inputs appear to play a more important role than other environmental variables in determining community composition of benthic macroinvertebrates, specifically with regard to shredder and scraper abundance.

There were two main expectations of the study: 1) a positive relationship between shredders and allochthonous inputs and 2) a positive relationship between scrapers and autochthonous primary production. The first was not supported by the results while the second proved statistically significant. I also expected that shredders would be negatively correlated with autochthonous primary production while scrapers would have an indirect relationship to allochthonous. Neither relationship was supported by the data.

4.2. *Sources of error*

The lack of strong statistical evidence is due to the small sample size of only four surveyed streams as well as low number of shredder and scraper macroinvertebrates identified during sampling. The small sample sizes prevented accurate determination of community composition in each stream and possibly resulted in a misrepresentation of each site. BMI sampling was also not random, but rather conducted systematically, possibly resulting in biases.

Close visual examination of environmental factors (allochthonous inputs, autochthonous inputs, stream flow and land cover) as well community composition suggests some variation among study sites. The sampled portion of each stream was forested and therefore had limited exposure to sunlight, which lessened the likelihood that the stream would be dominated by autochthonous primary production. Including no representation of this type of system limits the study to a comparison of streams indicative of those in successional forests and not those in the earlier stages where only shrubs and saplings are present.

The deployment of leaf litter traps may also have been a source of error. According to the International Biological Program handbook, *Methods for Estimating the Primary Production of Forests* by P.J. Newbould, leaf fall should be sampled using both vertical and lateral leaf litter traps, deployed in a stratified random pattern. Not only were lateral traps not included, which could have accounted for a fair amount of the leaf litter entering each stream had they been present, but vertical traps were not deployed as randomly. Instead, vertical traps were deployed systematically, wherever possible.

4.3. *Implications*

The allochthonous and autochthonous variables examined in the study were chosen as factors representative of land abandonment, but only have the potential to do so on a localized level. The analysis of land cover using ArcGIS was an attempt to complement the measured variables in hopes of establishing a clear link between land abandonment and community composition of benthic macroinvertebrates. Although these variables may have had an effect on the local level, without the clear association with land cover, it is impossible to infer that land abandonment has a direct effect on low trophic levels.

4.4. *Future research*

Continued research in this area of study would benefit by increasing the sample size and extending the study period from one season to a couple of years. The results of the study suggest that BMI community composition be examined on a local scale and that the landscape portion be eliminated. The inclusion of higher trophic level organisms (i.e. salamanders) would allow for the application of a landscape examination. Future research would also benefit from a more comprehensive set of riparian zone influences beyond those measured in this study.

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