How moderate agriculture affects the food web of macroinvertebrates in fresh water streams in Kings County,Nova Scotia

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Abstract

Moderate agriculture changes physical and chemical factors in streams resulting in a fertilizing effect by increasing available nutrients to macroinvertebrates through increased detritus breakdown and algal growth (Karr & Schlosser, 1978; Gulis*et al*. 2006; Young *et al.*, 2008; Huryn*et al.*, 2002; Paul *et al.*, 2006; Gulis&Suberkropp, 2003; Magbanua*et al*,.2010). Increases in species tolerant to agricultural inputs have been observed as well as a basal carbon shift towards algal sources which is detectible through carbon isotope analysis (Wetzel *et al.*, 1997; Gulis*et al.*, 2006; Bunn *et al.*, 1999; England *et al.* 2004). The goal of this study was to detect changes in the food web within 4 study streams and relate it to agriculture in the stream watershed. Three streams with agriculture and one without were visited in April 2010 for samples of invertebrates, water, detritus, stream width, temperature and flow over a 2km length of the stream. Then again in June 2010 for canopy cover and water over the same 2 km area as well as 500 metres upstream from the sample sites. Ephemeroptera, Tricoptera and Plecoptera(EPT) were sorted and counted from invertebrate samples and 5 predator species (*R. minor, R. vibox, R. fuscula, I. montana,* and *S. naica*) were also counted and measured to determine instar. Physical, chemical and invertebrate results were compared within and between streams using the general linear model and a t-test was used to determine a significant change in carbon isotopes. Wheaton, the stream with the most agriculture, had the highest conductivity, densities of EPT, Ephemeroptera, Plecoptera, *R. vibox, S. naica*and *I. montana*. The reference stream, with the least agriculture, had the lowest densities of EPT, Ephemeroptera, Tricoptera, and *I. montana*. The higher densities show a fertilizing effect in Wheaton. The other two streams had very different levels of agriculture in the entire watershed while having a closer level in a 50 metre buffer of the stream. The two streams also had some very similar densities which could mean the agriculture in the buffer is what is influencing the invertebrates the most. The carbon isotope results showed that the most downstream site in Turner Brook was more depleted in C^{13} than the furthest upstream site. This shows a basal carbon diet shift downstream.

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Acknowledgements

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Introduction

Context

In Vannote (1980) the strong connection between streams and the terrestrial environment is proposed as follows. At the head waters of streams the main nutrient input is allochthonous, or leaves from the surrounding riparian plants. At this point the stream is narrow so the branches of trees provide cover to a large portion of the stream; limiting the growth of algae, or autochthonous material, while also providing ample allochthonous material. Further downstream the width increases, resulting in a smaller proportion of the stream being covered by the forest canopy. This change in light availability leads to a change in available nutrients and the change is reflected in the species of insects that are present at different points in the stream. Stream headwaters are dominated by species that are adapted to feed on allochthonous material and belong in a feeding guild called shredders. They break down the coarse organic matter into fine particles. Downstream reaches are wider so more light reaches the stream and autochthonous algae are more prolific as well as species that consume algae.

Changes to the physical and chemical aspects of streams are expected to lead to changes in species communities. Farming can change many of the factors affecting the food web within streams. Clear cutting close to streams increases the light reaching the stream and also increases the available energy for algal growth (Vannote *et al.*, 1980). Clearing land in the watershed changes the hydrology of the landscape as well as the nutrient input. Farming also tends to increase the temperature of the stream and the flushing of leaves downstream (Young *et al.*, 2008). Increased microbial and fungal activity, due to the fertilizing effect of runoff, can increase the quality of detritus available increasing invertebrate populations (Huryn *et al.*, 2002; Paul *et al.*, 2006; Gulis & Suberkropp, 2003).

Changing the base of the food web can have effects on the entire food web. Some species that are sensitive to the fertilizing effect may be out competed by more tolerant species (Gulis *et al.*, 2006). This can change the dominance of different species throughout tropic levels as the base of the food web shifts.

Of the four streams in this study, three of them have agriculture in the water shed. The fourth one does not and will act as a reference stream. Previous studies have found evidence of the effects of agriculture within the streams studied even though the agriculture is of low intensity (Blair *et al*., 2010). No studies yet have examined how this low intensity agriculture can affect the base of the food web within the streams.

The goal of this study is to examine the effect of farming on the food web in these streams. Light data, water chemistry, temperature and species density will be measured to evaluate the effects of agriculture on the streams. Carbon isotope analysis will be used to determine the basal source of carbon. It is hypothesized that the presence of farming will significantly increase the density of invertebrates as well as ingestion of algae by macro-invertebrates by increasing availability.

Topic Importance

Streams provide habitat for many species, and also connect other components of the water cycle like rivers, lakes and oceans. Changes in the headwaters of a stream can affect these downstream components (Vannote *et al.*, 1980). Farming changes the head waters by opening up the canopy, changing the hydrology of the watershed and also changing the amount of nutrients that reach the stream (Magbanua *et al*,.2010). The effects of farming on streams are important to study because farming is a widespread practice and the need for it will increase as the global human population grows (Green *et al.,* 2005). Farming is a major source of biodiversity loss (Green *et al.,* 2005), and understanding the effects of low intensity agriculture will aid in making the practice more sustainable.

There are also populations of brook trout in three of four streams being studied. Any changes in the streams could affect these populations. Brook trout catches have been declining, and additional stress from agricultural effects could lead to further decline (DFO, 2009). Their diet also includes insects that could be affected by changes in the streams such as Plecoptera, Tricoptera and Ephemeroptera (Giberson *et al.,* 1996). The invertebrates in the stream which could be affected by the farming are part of not only the stream food web, but the terrestrial food web when they emerge as adults.

This study will investigate the effects of farming on the food web of stream macro-invertebrates and is expected to show that farming results in a change to the base of the food web. If this is the case this, it can have an effect on all the other species in the food web. Even small farming operations like hayfields or pastures cause significant changes in the food web of a stream. It will also highlight the importance of protecting streams due to the important habitat they contain for sensitive species.

Literature review

Introduction

This chapter will provide an overview of relevant literature. It will highlight the importance of detritus as well as the importance of algae in headwater stream food webs. It will explain how land use changes due to agriculture can cause the food web to shift from relying on detritus to relying on algae. This literature review was conducted by searching the Dalhousie University's holdings. Some of the search terms included macroinvertebrate, agriculture, effect, watershed, conductivity, runoff, algae, canopy cover, and the five predator species selected. All the sources of in the literature review were peer-reviewed and were in English only.

Relative importance of different carbon sources within streams

The River Continuum Concept (Vannote *et al.*, 1980) hypothesizes the importance of detritus as a source of carbon for head water streams as well as its importance to the downstream reaches. Canopy cover is at its highest at the headwaters due to the narrowness of the stream resulting in only small amounts of light reaching the stream, limiting in stream primary production. Large amounts of detritus enter the stream from the riparian zone, creating a basal source of carbon. This input is known as allochthonous as it originates outside the stream. There are two feeding guilds dominant at the headwaters, shredders and collectors. The shredders break down the detritus or coarse particulate organic matter (CPOM) into fine particulate organic matter (FPOM), which the collectors then consume. The waste from the collectors flows downstream and is used by other feeding guilds. The consumption of the FPOM downstream creates a connection between the downstream reaches and the riparian input upstream.

Although gut analysis of insects and sheer quantity of detritus that enters head water streams would lead one to conclude that detritus is the sole source of carbon, studies have found that detritus serves as a reliable source for the food web while algae is a substantial supplemental source when present (Reid *et al.,* 2008; England *et al.*, 2004; McCutchan *et al.,* 2002). Algae have a higher nutritional quality and more accessible carbon than terrestrial detritus, explaining why in densely forested streams algae are still consumed (England *et al.,* 2004). This means that increasing the growth of algae could increase its consumption, as it is more nutritious.

The effects of agriculture on carbon sources

Altering the watershed can lead to a reduction in the inputs of detritus to streams (Wallace *et al.,* 1997). Agriculture is a land use practice that can drastically alter the watershed and as food demand expected to more than double by 2050 (Green *et al*., 2005) it will also be an increasing practice. It is important to understand the impacts agriculture can have on streams to ensure they are mitigated in the future ensuring sustainability.

There are several aspects of farming that result in changes to streams, including increased nutrient, sediment and pesticide inputs (Townsend *et al.,* 2008). There are also changes in hydrology and light inputs (McTammany *et al*., 2008). These changes can alter algal growth and leaf breakdown within the stream and the magnitude of the effects depends on the intensity of the agriculture (Gulis *et al*., 2006; McTammany *et al.,* 2008). Studies have found that small changes leading to moderate eutrophication can have a fertilizing effect on streams (Gulis *et al.,* 2006), but with increasing intensity this effect stops, likely due to other factors such as increased pesticide concentrations and anoxic conditions.

Opening the canopy of the stream increases the amount of light energy available directly in the stream due to the loss of shading. This increase in energy can cause streams to have elevated temperatures (McTammany *et al*., 2008; Bunn *et al.*, 1999) when compared to long term forested streams, which in turn can increase the rate of leaf breakdown. England (2004) found that small amounts of deforestation in the riparian zone resulted in a decline in detritus. The increase in light available has also been found to increase algal growth in the stream (England *et al.* 2004; Bunn *et al.*, 1999).

There are several differences between runoff water from a forest and runoff water from a farm or pasture. One difference is that precipitation reaches the stream faster when it falls on cleared agricultural land as it is less permeable, resulting in a higher peak volume in the stream as well as a faster velocity. This can flush detritus and algae down the stream before it can be broken down for nutrients (Young *et al.,* 2008). The nutrients present in runoff can increase microbial activity, which in turn increases the breakdown of detritus and the growth of algae (McTammany *et al*., 2008; Gulis *et al*., 2006). Even small inputs of nutrients to the head waters have significant effects on the speed of the breakdown of detritus and the growth of algae (Gulis *et al*., 2006), as headwaters are typically nutrient poor (Vannote *et al.*, 1980). The conductivity of a stream is a measure of the streams ability to conduct electricity and it will increase as ions are added to the water. Some of the things that increase conductivity include natural factors like soil and bed rock inputs. Anthropogenic contributors include animal feces, fertilizers, pesticides and herbicides. All of which are associated with agriculture. Welch (1977) found that agricultural runoff was found to increase the conductivity of streams.

Effects of becoming autotrophic on the stream food web

Terrestrial detritus was found to support the streams when algae are not present (Wetzel *et al.,* 1997). Reid (2008) found that algae were only a major contributor during the summer months when it is prolific. These studies found detritus to be the dependable carbon source while algae were supplemental when available.

Some species of macroinvertebrates are sensitive to the inputs of agriculture that facilitate the increased growth of algae. Gulis (2006) found that increased nutrients increased the biomass of macroinvertebrates but there was a decrease in Ephemeroptera, Plecoptera and Tricoptera (EPT) taxa as well as a decrease in shredder species biodiversity. The decline could be due to the species being sensitive to the nutrients inputs or the other inputs that are common in agricultural runoff, such as pesticides. The biodiversity of the stream decreases as the few species that are tolerant to the changes associated with agriculture increase in abundance.

Changing the base of the food web can have bottom-up effects on upper level predators. In a litter exclusion experiment, a species of salamander (*Eurycea bislineata)* was found to decline in abundance and also experience reduced growth compared to the reference stream and downstream from the exclusion (Johnson *et al*., 2005), likely due to reductions in prey availability. The fish present in the study streams could be affected negatively if there is a decline in their prey abundance due to a shift to autochthonous carbon sources.

The changes experienced upstream could affect the food web further downstream. The shredders in the head waters break CPOM into FPOM (Vannote *et al.*, 1980), which then flows downstream where it is consumed by collectors. If detritus is reduced and shredders are in lower abundance then the amount of FPOM could be reduced. Webster (1999) found that the FPOM produced can flow long distances before it is consumed. Therefore, changes in the amount of FPOM could have far reaching consequences.

Carbon isotope analysis

Previous studies have used carbon isotope analysis to identify the source of carbon for streams (Reid *et al.*, 2008; McCutchan *et al.*, 2002; Mulholland *et al.*, 2000). Carbon isotope analysis has a major advantage over gut analysis. It shows what carbon sources have been absorbed into the tissues over long periods of time, whereas gut analysis shows what was consumed recently (Finlay *et al*., 2001). Also terrestrial plants and aquatic algae have different C^{13} and C^{12} ratios (France *et al.*, 1996). Algal C^{13} is determined by weathering of rocks within the stream, from the dissolved atmospheric CO^2 and from respiration within the stream while terrestrial C^{13} is from the atmosphere (Mook & Tan, 1991). Finlay (2001) found that in headwaters, algal C^{13} and terrestrial detritus C^{13} had distinct values and could be used to determine the source of carbon in the food web.

Methods

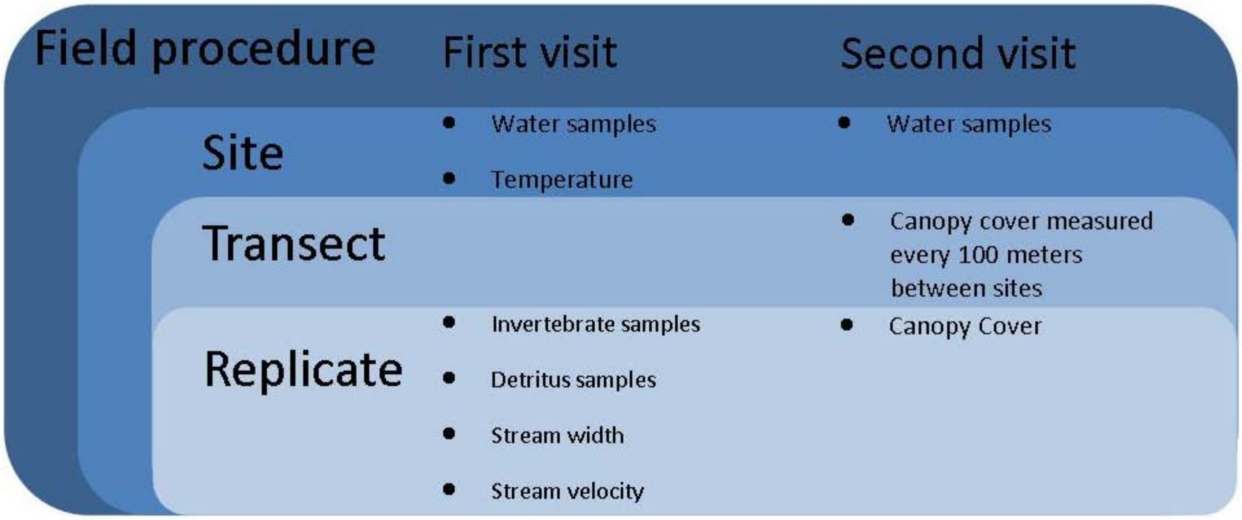
Site Selection

The four streams chosen were Wheaton, Black Hole Brook, Turner Brook and Robinson. All four of the streams originate on a basalt ridge called the North Mountain in Kings County, Nova Scotia and drain into the Bay of Fundy. The streams were chosen based on several criteria. The most important factor was the degree of agriculture present in the watershed of the stream and the location of the agriculture in the watershed. The percent of the watershed devoted to agriculture is 37% for Wheaton, 9% for Black Hole, 29% for Turner Brook and 1.9% for Robinson. The area of a 50-metre buffer of the streams devoted to agriculture is 22% for Wheaton, 11% for Black Hole, 14% for Turner Brook, and 2.7% for Robinson (unpublished data). The starting site at each stream is below the agriculture in the water shed. Robinson was selected as a reference stream due to its similarity to the other streams aside from the degree of agriculture in the watershed. Turner Brook, Black Hole and Robinson all have brook trout (*Salvelinus fontinalis*) present and Wheaton does not. The streams were chosen based on similarity in size and distance from each other in order to ensure their comparability.

Field Sampling

The same protocol was followed for each of the streams. There were two field sampling visits to each of the streams and each stream had four sample sites. The first sample site, located downstream from agriculture, and subsequent sites were all 500 metres apart. At each site there were four replicates all within 50 metres of the site and the location of the replicates was determined using a random number generator.

During the first visit, stream width, velocity and temperature were measured; invertebrates, leaves and water samples were collected sampling a total length of 2 kilometres per stream. During the second visit, light measurements and temperature data was recorded over the same 2-kilometre span of stream as well an additional 500 metres upstream for a total of 2.5 kilometres.



Field procedure	First visit	Second visit
Site	- Water samples - Temperature	- Water samples
Transect		- Canopy cover measured every 100 meters between sites
Replicate	- Invertebrate samples - Detritus samples - Stream width - Stream velocity	- Canopy Cover

Figure 1: Summary of what was collected at each of the three visits to the streams.

The first field visit was in April 2010 and was completed over four consecutive days. Each stream took one day to sample. One water sample was collected at each site by rinsing the bottle in stream water than filling it up. One temperature probe was left at each site in the stream. The desired site for a probe was a deep pool under overhanging roots to reduce the possibility of sunlight hitting the probe and increasing the temperature. They were placed in sites like this when possible. At each of the 4 sub sites invertebrate and detritus samples were collected as well as stream width and flow data. Invertebrate samples were collected using the ‘kick’ method in which the stream bed is disturbed across the width of the stream while a net is held downstream to catch what was churned up. A fifth invertebrate sample was also collected at each site using the ‘kick’ method for two minutes in the middle of the stream. Maple (*Acer* *sp*) and beech (*Betula sp*) leaves were collected at each replicate from within the stream but were mixed with other samples from the same site. After the first field visit was complete there were a total of four water samples, four detritus samples, and 20 invertebrate samples.

The second field visits were conducted over several weeks during June 2010 and July 2010. Each stream was sampled over the period of one day. Water samples and canopy cover data were collected at each site. Two water samples were taken at each site, one to be tested for conductivity and the other to be sent to Capital Health lab to be tested for pH, ammonia, nitrites/nitrates and ortho phosphate. The canopy cover data was collected using a densiometer, a tool used in the forest industry to estimate cover. Data was collected at each of the replicates as well as between sites every 100 metres and 500 metres upstream from the sample sites. The bank full width of the stream was measured than starting on one side of the stream measurements were taken at 50 cm intervals across the bank full width. Using bank full width rather than stream width gives a better idea of the riparian coverage right next to the stream.

Laboratory Analysis

The birch and maple leaves were separated and dried. When dry they were analyzed for carbon isotope ratios. Water samples were tested for conductivity and nutrient concentrations.

Invertebrate samples were stored in alcohol after being collected in the field then sifted to remove small species and silt. Three orders, Tricoptera, Plecoptera and Ephemeroptera, (EPT) were separated from the detritus and counted. Five predatory species were taken out of each of the samples and their gastrointestinal tracts were removed. The five species were *Ryacophila minor*, *Ryacophila fuscula* and *Ryacophila vibox* as well as *Sweltsa naica* and *Isoperla montana.* The largest of the species were analyzed for carbon isotope ratios.

Statistical Analysis

The chemical and physical variables studied included stream velocity, width, conductivity, temperature, average shade and depletion of C^{13}. The invertebrate variables studied were density and proportions of EPT taxa, the five selected predators as well as smaller and larger instars of the selected predators.

Significant between stream results were compared to the degree of agriculture in the watershed while within stream trends were compared with each other while also accounting for the influence of upstream agriculture. Regression analysis was employed to compare the upstream and downstream reaches of each stream, as well as using the general linear model to compare between streams and within streams. A P-value of <0.05 was accepted as a significant result.

Carbon isotope 13 results were processed from two sites in Turner Brook. The most upstream being site 1 and the most downstream being site 4. A one tailed t-test was used to determine which site had more C13 and a P-value of < 0.05 was accepted as significant.

Limitations

The biggest limitation to the scope of this study is time. The streams are located an hour and a half outside of Halifax, NS. This makes multiple trips difficult and only three trips were made. The weather plays a strong role in the collection of samples from the field. Consecutive sampling days with similar weather is ideal and was the case for the samples collected in April 2010. Heavy rainfall can change a lot of things within the stream causing any samples collected that day to not be comparable to samples collected on a sunny day. Water samples collected in Wheaton in June 2010 were not tested for nitrite and nitrate concentration due to the rainfall on the day of collection. The lab component of this study is also restricted by time as a more in-depth study could be conducted if all the species were keyed out and tested for carbon isotopes. This was limited to only five predatory species in this study. The literature review of this study is limited by Dalhousie University's library holdings.

Delimitations imposed on this project included restricting several factors: the number of streams studied, the number samples from each stream, the number of orders counted and the number of predators processed. Also samples were collected over a short time span so results are representative of that period.

Results

Physical and chemical results

Streams and sites within streams differed significantly in conductivity, average shade, temperature and the concentration of nitrates and nitrites (Figure 2). Robinson was found to be the warmest while also having the lowest average shade of the streams. It also had the lowest conductivity in June. Robinson's concentrations of nutrients were all below the detection levels. Black Hole Brook had the lowest conductivity in April. Turner Brook had the highest average shade and the highest concentrations of nitrites and nitrates. Wheaton had the highest conductivity in both April and June 2010. Wheaton's June water samples were not tested for nutrients as they were collected on a day of heavy rain and would not be comparable to the other streams.

Table 1: Physical and chemical results between streams found using the general linear model. ANOVA's are outlined in black. Significant results with a P-value <0.05 are in bold face.

Variable	Source	Degrees of freedom	F-ratio	P-value
Velocity	Stream	3	0.028	0.994
Velocity	Site	1	1.861	0.186
Velocity	Interaction	3	0.148	0.93
Velocity	stream	3	1.218	0.323
Velocity	site	1	2.160	0.154
June Conductivity	**Stream**	**3**	**167.153**	**0.000**
June Conductivity	**Site**	**1**	**10.074**	**0.004**
June Conductivity	**interaction**	**3**	**11.692**	**0.000**
April Conductivity	**Stream**	**3**	**1096.748**	**0.000**
April Conductivity	**Site**	**1**	**6.008**	**0.022**
April Conductivity	**Interaction**	**3**	**43.114**	**0.000**
Temperature	**stream**	**3**	**21.824**	**0.000**
Temperature	**site**	**1**	**4.658**	**0.042**
Temperature	**interaction**	**3**	**27.912**	**0.000**
Average Shade	stream	3	1.321	0.291
Average Shade	**site**	**1**	**8.049**	**0.009**
Average Shade	**interaction**	**3**	**4.032**	**0.019**
Concentration of Nitrites and Nitrates	**Stream**	**2**	**351.447**	**0.000**
Concentration of Nitrites and Nitrates	**Site**	**3**	**4.281**	**0.017**

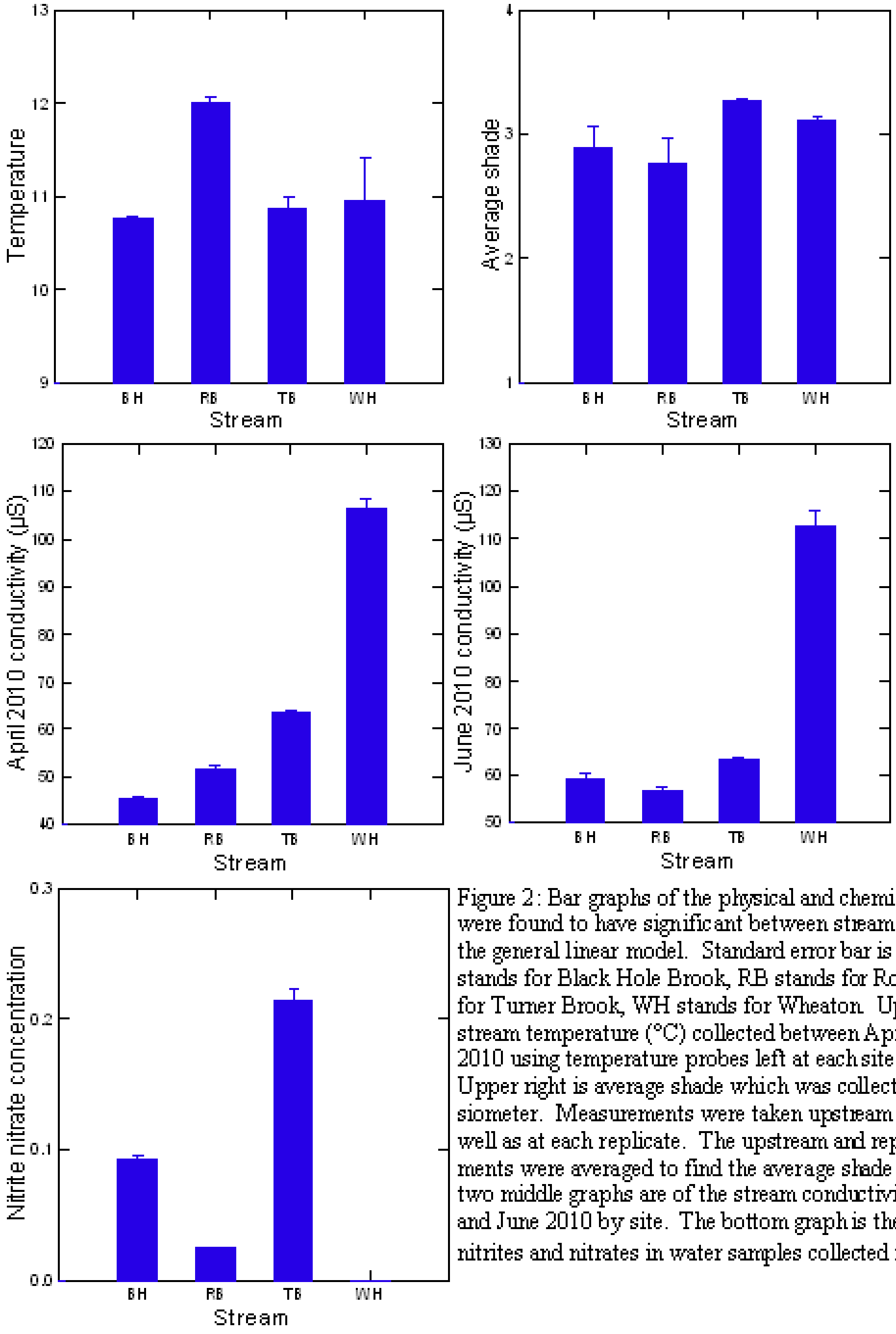


Figure 2: Bar graphs of the physical and chemical variables that were found to have significant between stream differences using the general linear model. Standard error bar is included. BH stands for Black Hole Brook, RB stands for Robinson, TB stands for Turner Brook, WH stands for Wheaton. Upper left is the in stream temperature (°C) collected between April 2010 and June 2010 using temperature probes left at each site in the streams. Upper right is average shade which was collected using a densiometer. Measurements were taken upstream from each site as well as at each replicate. The upstream and replicate measurements were averaged to find the average shade at each site. The two middle graphs are of the stream conductivity in April 2010 and June 2010 by site. The bottom graph is the concentration of nitrites and nitrates in water samples collected in June 2010.

There were also downstream relationships in all the streams for conductivity and some of the streams for temperature and average shade (Figure 3). Wheaton showed a decreasing downstream conductivity in both April and June while temperature also decreased downstream while there was no trend in average shade. Turner Brook has increasing than decreasing conductivity in both April and June as well as increasing downstream temperature and average shade. Concentration of nitrites and nitrates increased at site 2 in Turner Brook than decreased downstream. Black Hole Brook had decreasing downstream conductivity in April and the trend reversed and increased downstream in June. Average shade increased than decreased and there was no trend for temperature. Black Hole Brook had a decreasing downstream concentration of nitrites and nitrates. Robinson had an increasing downstream conductivity in both April and June as well as an increasing temperature. The average shade showed no trend and the concentration of nitrates and nitrites was below detection.

Table 2: Physical and chemical results within streams found using the general linear model. Significant results with a P-value<0.05 are in bold face type.

Stream	Source	Degrees of freedom	F-ratio	P-value
Robinson	Velocity	1	1.752	0.234
Robinson	June Conductivity	1	5.170	0.063
Robinson	April Conductivity	1	0.675	0.443
Robinson	Temperature	1	1.143	0.326
Robinson	Average shade	1	0.412	0.544
Robinson	Width	1	1.319	0.295
Robinson	Bank full width	1	0.281	0.615
Black Hole	Velocity	1	1.752	0.234
Black Hole	**June Conductivity**	**1**	**42.209**	**0.000**
Black Hole	**April Conductivity**	**1**	**10.667**	**0.017**
Black Hole	Temperature	1	4.071	0.090
Black Hole	**Average shade**	**1**	**10.531**	**0.018**
Black Hole	Width	1	0.889	0.380
Black Hole	Bank full width	1	-	-
Turner Brook	Velocity	1	0.069	0.822
Turner Brook	June Conductivity	1	1.599	0.253
Turner Brook	April Conductivity	1	1.5	0.267
Turner Brook	**Temperature**	**1**	**2067.222**	**0.000**
Turner Brook	**Average shade**	**1**	**12.405**	**0.012**
Turner Brook	Width	1	2.331	0.178
Turner Brook	Bank full width	1	1.5	0.267
Wheaton	Velocity	1	2.066	0.201
Wheaton	**June Conductivity**	**1**	**12.700**	**0.012**
Wheaton	**April Conductivity**	**1**	**96.000**	**0.000**
Wheaton	**Temperature**	**1**	**25.296**	**0.002**
Wheaton	Average shade	1	2.346	0.177
Wheaton	Width	1	0.176	0.689
Wheaton	Bank full width	1	-	-

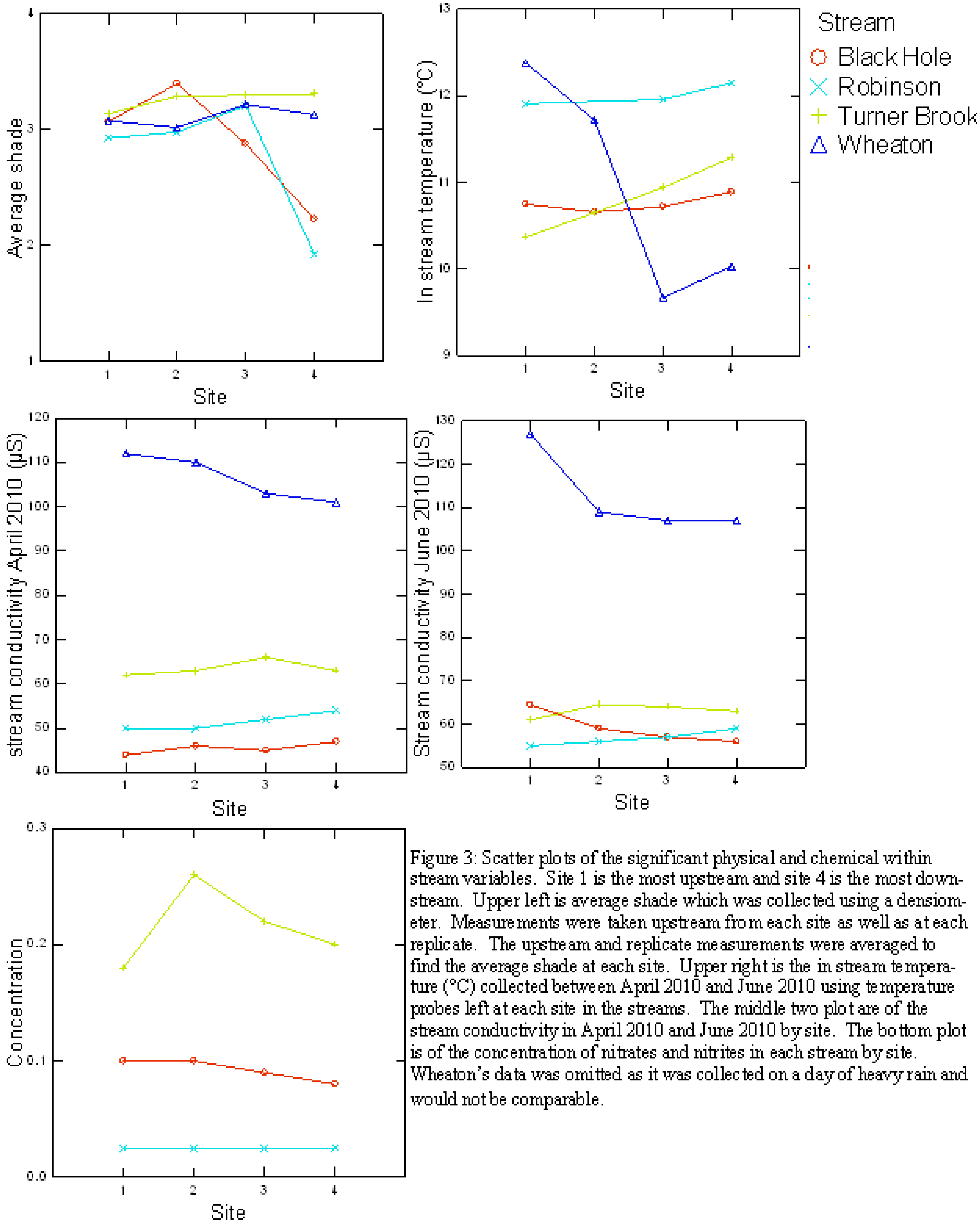


Figure 3: Scatter plots of the significant physical and chemical within stream variables. Site 1 is the most upstream and site 4 is the most downstream. Upper left is average shade which was collected using a densiometer. Measurements were taken upstream from each site as well as at each replicate. The upstream and replicate measurements were averaged to find the average shade at each site. Upper right is the in stream temperature (°C) collected between April 2010 and June 2010 using temperature probes left at each site in the streams. The middle two plot are of the stream conductivity in April 2010 and June 2010 by site. The bottom plot is of the concentration of nitrates and nitrites in each stream by site. Wheaton's data was omitted as it was collected on a day of heavy rain and would not be comparable.

Invertebrate results

The streams differed significantly on several invertebrate variables. Wheaton had the highest densities of EPT, Ephemeroptera, Plecoptera, *R. vibox*, *S. naica*,and *I. montana* (Figures 4 & 5). It had the highest proportion of *I. montana* and larger 4th and 5th instars of *R. fuscula* (Figure 5 & 6). Wheaton had the lowest density and proportion of *R. minor* as there were none present in the Wheaton samples (Figure 5). Turner Brook had the lowest proportion of *I. montana* and the highest proportion of *R. fuscula* (Figure 5). Black Hole Brook had the smallest proportion and density of *R. vibox* and *S. naica* while having the highest density¸ proportion and *R. minor* (Figures 6 & 7). Robinson had the lowest densities of EPT, Ephemeroptera, Plecoptera, Tricoptera, and *I. montana* (Figure 4 & 5). It had the lowest proportion of *I. montana* and larger 4th and 5th instar *R. fuscula* (Figure 5 & 6).

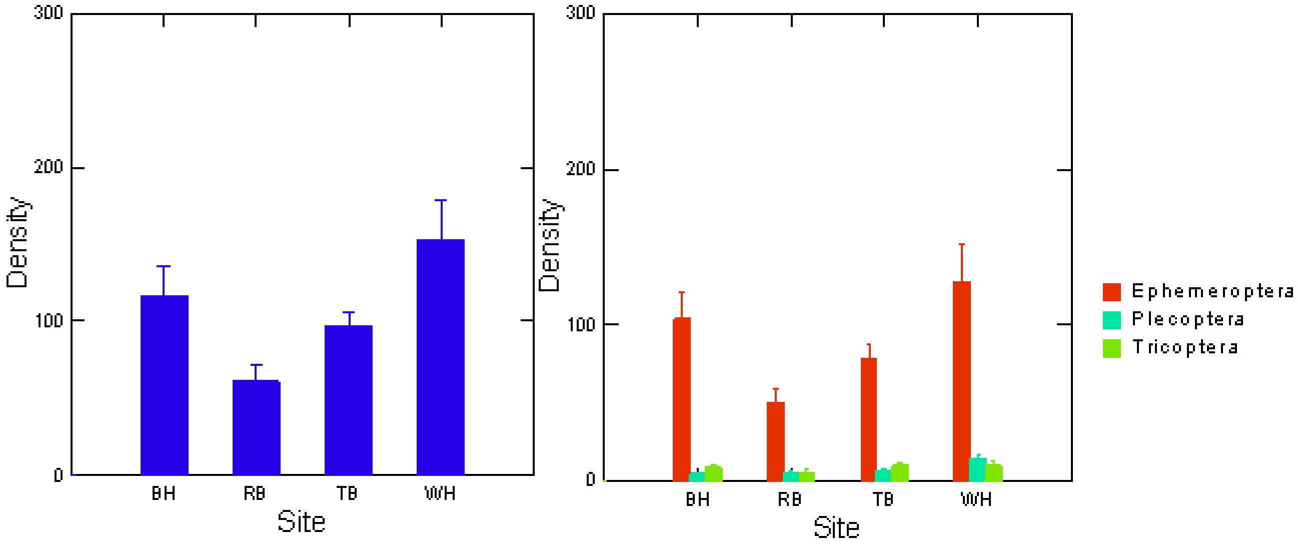


Figure 4: Bar graphs of the densities of the three invertebrate orders; Ephemeroptera, Tricoptera and Plecoptera. Left graph is density of all three orders while the right graph has the three orders separated. BH is Black Hole Brook, RB is Robinson, TB is Turner Brook, WH is Wheaton. Standard error bar is included.

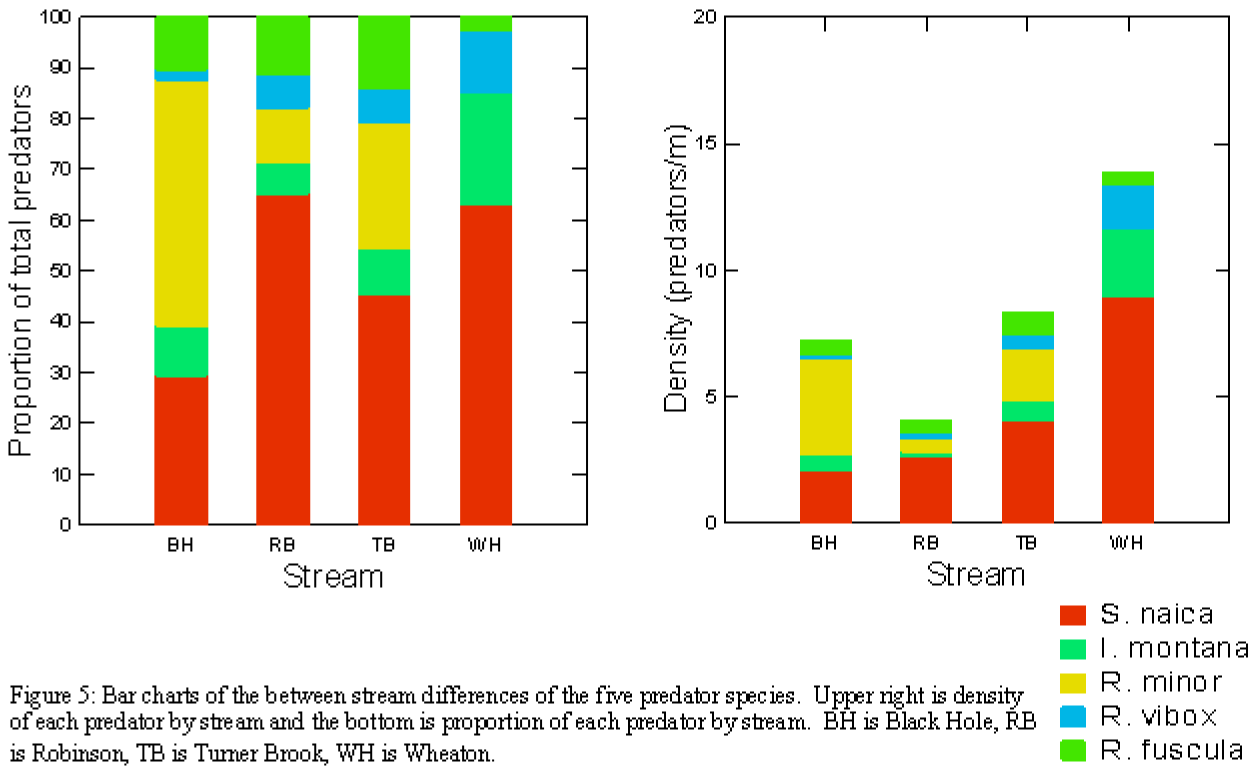


Figure 5: Bar charts of the between stream differences of the five predator species. Upper right is density of each predator by stream and the bottom is proportion of each predator by stream. BH is Black Hole, RB is Robinson, TB is Turner Brook, WH is Wheaton.

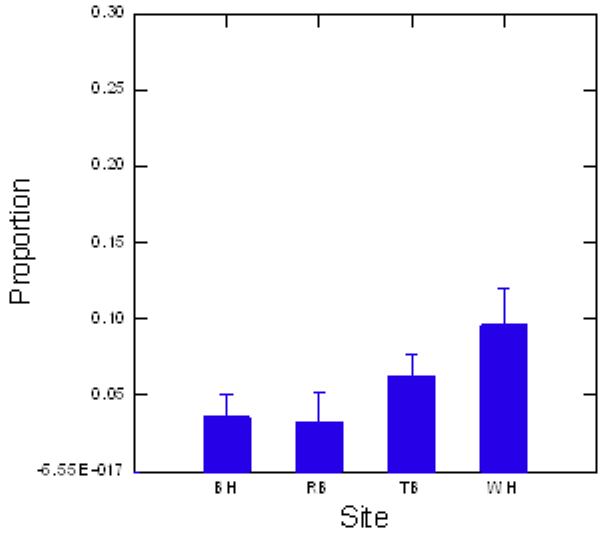


Figure 6: Bar chart of the proportions of 4th and 5th instar *R. fuscula* between streams of the total number of the five predators. With a standard error bar included. BH is Black Hole, RB is Robinson, TB is Turner Brook and WH is Wheaton.

Some of the streams showed downstream trends in some of the invertebrate variables. Wheaton showed no upstream or downstream trends. Turner Brook showed a downstream decrease in the number of larger 4th and 5th instar *R. minor* (Figure 14). Black Hole had a decreasing downstream trend in the density of Tricoptera, *R. minor* as well as the 5 selected predators (Figure 7, 8 &11). The total number of *R. minor* in Black Hole also decreased (Figure 9). Robinson had decreasing number of *R. minor*as well as the density (Figure 9 & 11). It also had a downstream decreasing density of the selected five predators (Figure 8). The proportions of 4th and 5th instar *R. minor* and 5th and 6th instar *S. naica* decreased downstream in Robinson (Figure 10& 12).

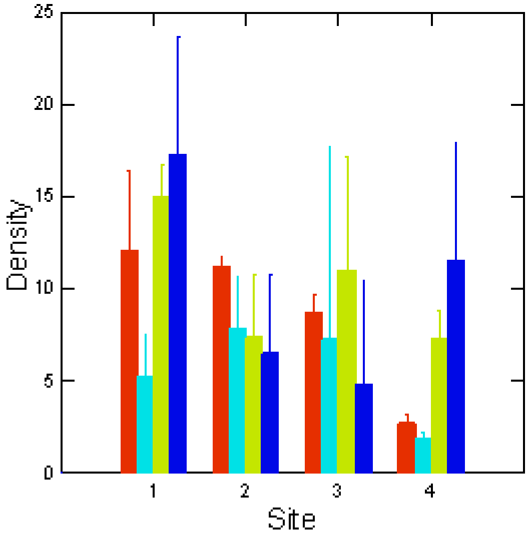


Figure 7: Bar graphs of the density of Tricoptera in each stream by site with a standard error bar included. Site 1 is the most upstream and site 4 is the most downstream.

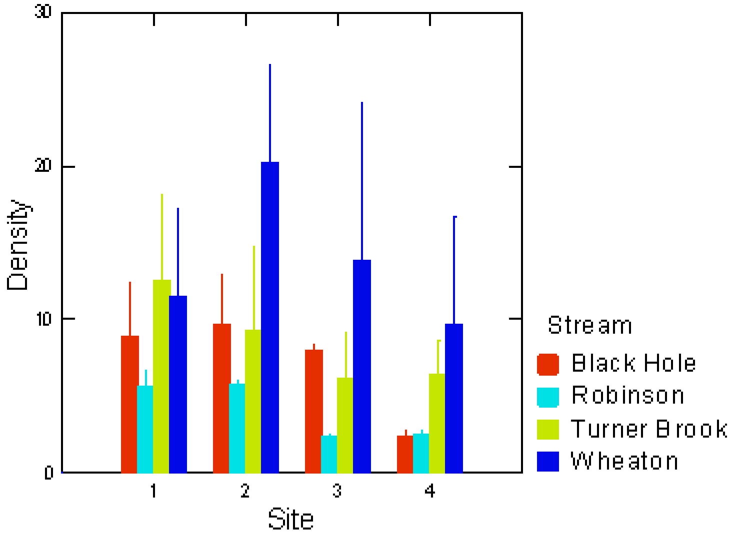


Figure 8: Bar graph of the density of the five selected predator species in each stream by site. A standard error bar is included. The five species are *R. minor*, *R. vibox*, *R. fuscula*, *S. naica* and *I. montana*. Site 1 is the most upstream and site 4 is the most downstream site. See the

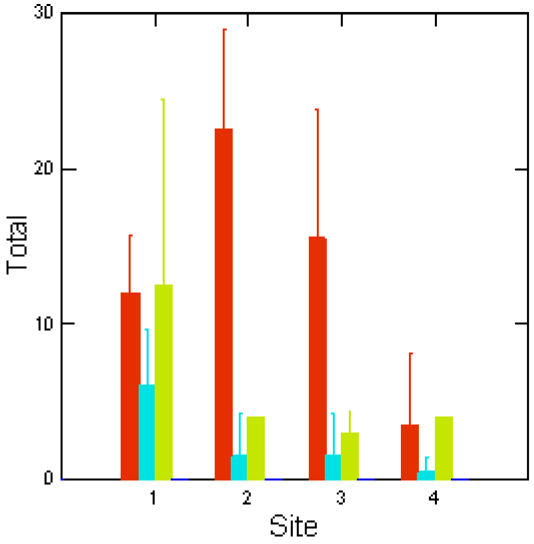


Figure 9: Bar graph of the total number of *R. minor* by site in each stream. A standard error bar is included. Site 1 is the most upstream site and site 4 is the most downstream. See legend to the right

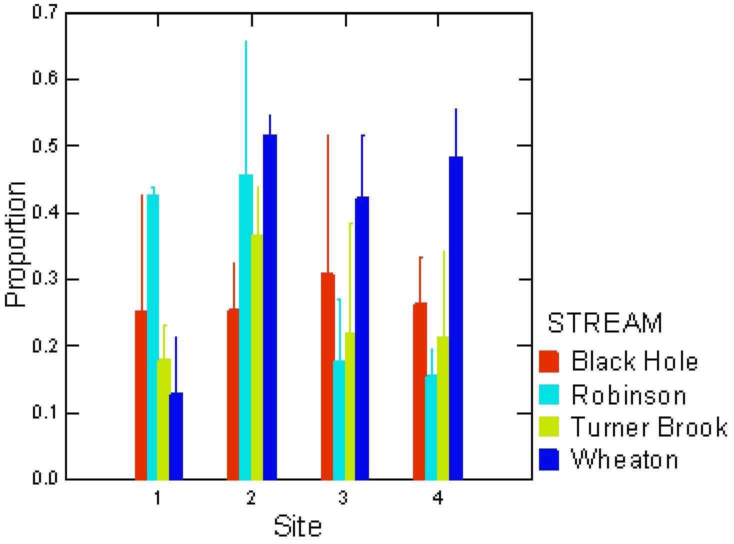


Figure 10: Bar graph of the proportion of instars 5 and 6 of *S. naica* of the total number of predators in each stream by site. A standard error bar is included. Site 1 is the most upstream and site 4 is the most

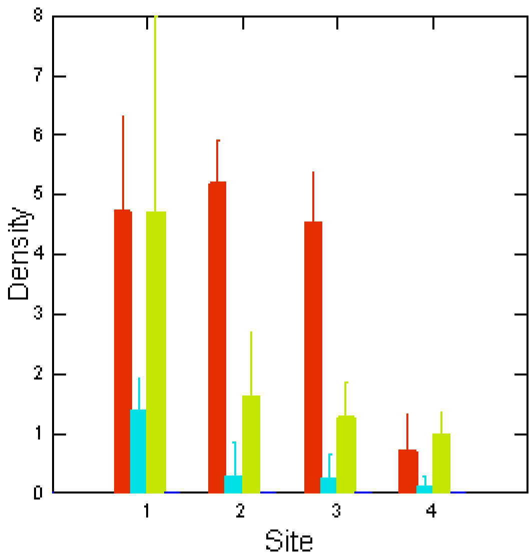


Figure 11: Bar graph of the density of *R. minor* per metre by site at each stream. A standard error bar is included. Site 1 is the most upstream and site 4 is the most downstream.

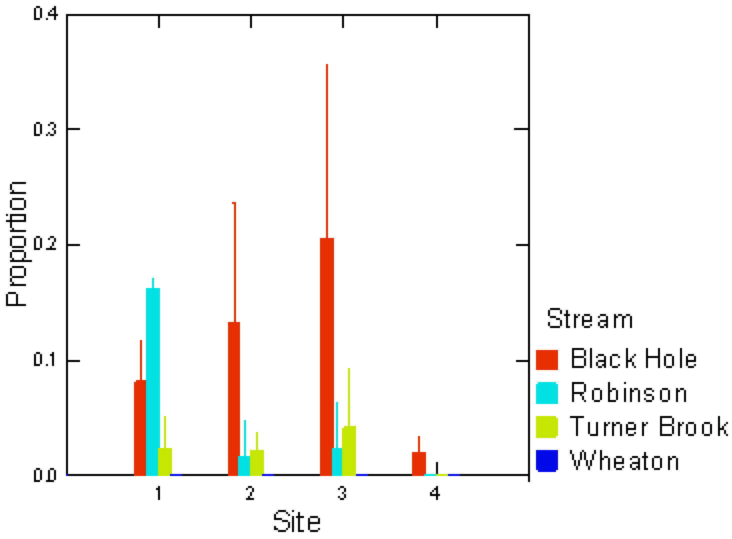


Figure 12: Bar graph of the proportion of instar 4 and 5 of *R. minor* of the total number of predators in each stream by site. A standard error bar is included. Site 1 is the most upstream and site 4 is the most downstream. See legend to the right.

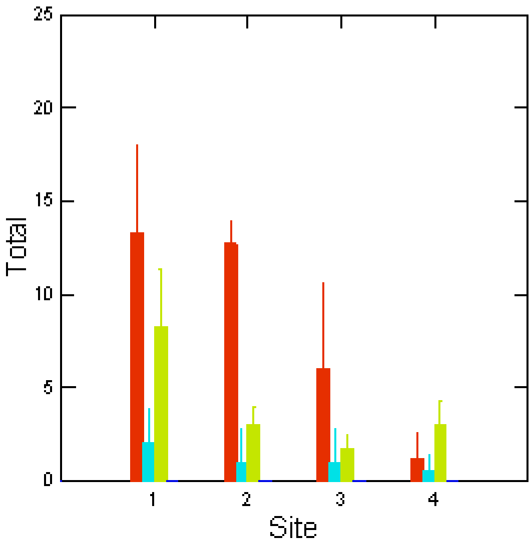


Figure 13:Bar graph of the total number of 4th and 5th instar *R. minor* in each stream by site. A standard error bar is included. Site 1 is the most upstream and site 4 is the most downstream.

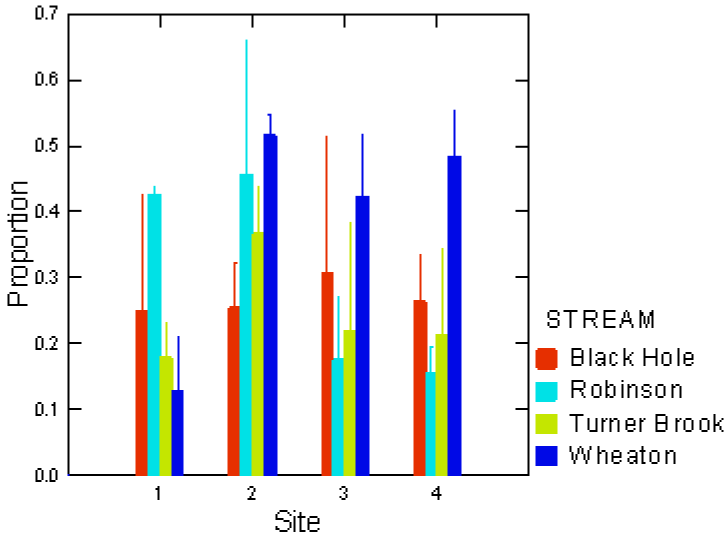


Figure 14: Bar graph of the proportion of instars 5 and 6 of *S. naica* of the total number of predators in each stream by site. A standard error bar is included. Site 1 is the most upstream and site 4 is the most downstream.

Table 3: General linear results for between and within stream invertebrate variables. ANOVAs run at the same time are outlined in black. Results in bold were significant with P-values < 0.05. Variables found to have no significant stream, site or interaction effects are found in appendix A for the sake of space.

Dependant	Source	Degrees of freedom	F-ratio	P-Value
Density of Ephemeroptra, Tricoptera and Plecoptera	**Stream**	**3**	**5.374**	**0.005**
Density of Ephemeroptra, Tricoptera and Plecoptera	**site**	**1**	**4.569**	**0.042**
Density of Ephemeroptra, Tricoptera and Plecoptera	interaction	3	2.210	0.111
Density of Ephemeroptra	**Stream**	**3**	**5.034**	**0.007**
Density of Ephemeroptra	Site	1	3.527	0.072
Density of Ephemeroptra	Interaction	3	2.247	0.107
Density of Tricoptera	Stream	3	0.824	0.493
Density of Tricoptera	**Site**	**1**	**7.603**	**0.011**
Density of Tricoptera	Interaction	3	0.309	0.819
Total *R. vibox*	Stream	3	1.531	0.222
Total *R. vibox*	Site	1	3.393	0.073
Total *R. vibox*	Interaction	3	1.393	0.260
Total *R. minor*	**Stream**	**3**	**11.777**	**0.000**
Total *R. minor*	**Site**	**1**	**18.010**	**0.000**
Total *R. minor*	**Interaction**	**3**	**3.854**	**0.017**
Total *R. minor* instars 1-3	Stream	3	2.613	0.065
Total *R. minor* instars 1-3	**Site**	**1**	**5.217**	**0.028**
Total *R. minor* instars 1-3	Interaction	3	0.994	0.429
Total *R. minor* instars 4,5	**Stream**	**3**	**15.134**	**0.000**
Total *R. minor* instars 4,5	**Site**	**1**	**17.929**	**0.000**
Total *R. minor* instars 4,5	**Interaction**	**3**	**5.952**	**0.002**
Total *I. montana* instars 6,7	Stream	3	2.511	0.073
Total *I. montana* instars 6,7	Site	1	0.246	0.623
Total *I. montana* instars 6,7	Interaction	3	0.831	0.485
Proportion of *R. minor* of the predators	**Stream**	**2**	**6.246**	**0.006**
Proportion of *R. minor* of the predators	Site	1	0.043	0.837
Proportion of *R. minor* of the predators	**Interaction**	**2**	**5.660**	**0.009**
Proportion of *R. fuscula* instars 4,5of the predators	**Stream**	**3**	**5.196**	**0.005**
Proportion of *R. fuscula* instars 4,5of the predators	Site	1	2.713	0.110
Proportion of *R. fuscula* instars 4,5of the predators	Interaction	3	2.187	0.111
Proportion of *S. naica* instars 5,6of the predators	Stream	3	2.754	0.057
Proportion of *S. naica* instars 5,6of the predators	Site	1	4.060	0.051
Proportion of *S. naica* instars 5,6 of the predators	Interaction	3	2.353	0.088
Total *R. vibox*	Site	1	3.206	0.081
Total *R. vibox*	**Stream**	**3**	**4.294**	**0.010**
Total *I. montana*	Site	1	0.003	0.959
Total *I. montana*	Stream	3	2.431	0.079

Table 3: continued

Dependant	Source	Degrees of freedom	F-ratio	P-Value
Total S. naica	Site	1	0.237	0.629
Total S. naica	**Stream**	**3**	**3.037**	**0.040**
Proportion of *R. vibox* instar 5of the predators	Site	1	0.084	0.775
Proportion of *R. vibox* instar 5of the predators	Stream	3	2.778	0.065
Proportion of *R. fuscula* instars 4,5of the predators	**Site**	**1**	**4.663**	**0.038**
Proportion of *R. fuscula* instars 4,5of the predators	**Stream**	**3**	**18.681**	**0.000**
Proportion of *S. naica* instars 5,6 of the predators	Site	1	3.777	0.059
Proportion of *S. naica* instars 5,6of the predators	**Stream**	**3**	**4.554**	**0.008**
Density of S. naica	**Stream**	**3**	**13.856**	**0.000**
Density of S. naica	**Site**	**3**	**4.605**	**0.016**
Density of S. naica	Interaction	9	2.13	0.086
Density of I. montana	**Stream**	**3**	**22.595**	**0.000**
Density of I. montana	**Site**	**3**	**5.078**	**0.011**
Density of I. montana	**Interaction**	**9**	**4.957**	**0.002**
Density of R. minor	**Stream**	**3**	**25.655**	**0.000**
Density of R. minor	**Site**	**3**	**7.487**	**0.002**
Density of R. minor	**interaction**	**9**	**3.082**	**0.022**
Density of R. vibox	**Stream**	**3**	**3.786**	**0.030**
Density of R. vibox	Site	3	0.648	0.595
Density of R. vibox	interaction	9	0.188	0.993
Density of predators	**Stream**	**3**	**10.28**	**0.000**
Density of predators	**Site**	**3**	**4.719**	**0.022**
Density of predators	Interaction	9	0.933	0.522

Table 4: Significant site effects from the table above were tested in each stream to find trends. Significant results with a P-value of < 0.05 are highlighted in bold face. No *R. minor*variables were tested for Wheaton as none were present in the samples.

Stream	Variable	Source	Degrees of freedom	F-ratio	P-value
Wheaton	Density of Ephemeroptera, Tricoptera and Plecoptera	Site	1	5.458	0.058
Wheaton	Density of Tricoptera	Site	1	0.928	0.372
Wheaton	Density of S. naica	Site	1	0.035	0.858
Wheaton	Density of I. montana	Site	1	4.342	0.082
Wheaton	Density of five selected predators	Site	1	0.342	0.580
Wheaton	Proportion of S. naica instars 5,6 of the predators	Site	1	1.580	0.255
Wheaton	Proportion of I. montana instars 4,5 of the predators	Site	1	0.604	0.472
Turner Brook	Density of Ephemeroptera, Tricoptera and Plecoptera	Site	1	0.210	0.663
Turner Brook	Density of Tricoptera	Site	1	1.090	0.337
Turner Brook	Total Number of R. minor	Site	1	3.235	0.122
Turner Brook	Density of S. naica	Site	1	1.416	0.279
Turner Brook	Density of I. montana	Site	1	0.213	0.661
Turner Brook	Density of R. minor	Site	1	5.169	0.063
Turner Brook	Density of five selected predators	Site	1	3.996	0.093
Turner Brook	**Total R. minor instars 4,5**	**Site**	**1**	**5.414**	**0.037**
Turner Brook	Proportion of R. minor instars 4,5 of the predators	Site	1	0.110	0.746
Turner Brook	Proportion of S. naica instars 5,6 of the predators	Site	1	0.294	0.598
Turner Brook	Proportion of I. montana instars 4,5 of the predators	Site	1	4.116	0.070
Black Hole	Density of Ephemeroptera, Tricoptera and Plecoptera	Site	1	0.815	0.401
Black Hole	**Density of Tricoptera**	**Site**	**1**	**20.977**	**0.004**
Black Hole	Total Number of R. minor	Site	1	1.789	0.230
Black Hole	Density of S. naica	Site	1	2.588	0.159
Black Hole	Density of I. montana	Site	1	0.043	0.842
Black Hole	**Density of R. minor**	**Site**	**1**	**7.952**	**0.030**
Black Hole	Density of five selected predators	Site	1	7.768	0.032
Black Hole	**Total R. minor instars 4,5**	**site**	**1**	**26.684**	**0.000**
Black Hole	Proportion of R. minor instars 4,5 of the predators	Site	1	2.598	0.138
Black Hole	Proportion of S. naica instars 5,6 of the predators	Site	1	1.969	0.186
Black Hole	Proportion of I. montana instars 4,5 of the predators	Site	1	4.662	0.059
Black Hole	Proportion of I. montana instars 4,5 of the predators	Site	1	0.534	0.498
Robinson	Density of Ephemeroptera, Tricoptera and Plecoptera	Site	1	0.158	0.705
Robinson	Density of Tricoptera	Site	1	0.653	0.450
Robinson	**Total Number of R. minor**	**Site**	**1**	**6.129**	**0.048**
Robinson	Density of S. naica	Site	1	2.350	0.176
Robinson	Density of I. montana	Site	1	0.102	0.761
Robinson	**Density of R. minor**	**Site**	**1**	**8.715**	**0.026**
Robinson	**Density of five selected predators**	**Site**	**1**	**18.365**	**0.005**
Robinson	Total R. minor instars 4,5	Site	1	1.375	0.285
Robinson	**Proportion of R. minor instars 4,5 of the predators**	**site**	**1**	**28.562**	**0.013**
Robinson	**Proportion of S. naica instars 5,6 of the predators**	**Site**	**1**	**9.228**	**0.023**
Robinson	Proportion of I. montana instars 4,5 of the predators	Site	1	0.534	0.498

Isotope results

The results of a paired t-test (Appendix B) on the predator species showed that site 1 had less C^{13} than site 4 in Turner Brook with a P-value of 0.017. A paired t-test (Appendix C) of the two species of leaves showed no downstream increase with a P-value of 0.486.

Discussion

The four streams differed significantly between and within streams on several measured variables. Differences between streams could be the result of differing amounts of agriculture in the watershed or within a 50 metre buffer of the stream. To restate, the percentages of the watershed devoted to agriculture for each stream was as follows: 37% for Wheaton, 29% for Turner Brook, 9% for Black Hole Brook and 1.9% for Robinson. The percent of a 50 metre stream buffer devoted to agriculture is 22% for Wheaton, 14% for Turner Brook, 11% for Black Hole Brook and 2.7% for Robinson. Based on these numbers it is expected that Wheaton will show the greatest fertilizing effect due to agriculture and Robinson will be the lowest (Gulis *et al.* 2006). Invertebrate differences within streams are expected to correlate with more specific agricultural effects such as canopy cover, conductivity, nutrient inputs or temperature changes as well as declining levels of agricultural input as the sampling sites were located downstream of the agriculture in the watershed.

Between stream discussion

Wheaton had the highest conductivity in both April and June while Robinson had the lowest in June and the second lowest in April (Figure 2). This was expected as the presence of agriculture was highest in Wheaton and it can increase conductivity while Robinson had the least agriculture (Welch, 1977). Black Hole Brook had the lowest conductivity in April but it increased in June, possibly due to increasing agricultural activities in the summer months (Welch, 1977). Turner Brook's conductivity decreased slightly between April and June. June conductivity in Robinson was higher than Aprils but it did not increase as much as Black Hole Brook. Testing water samples from both the spring and summer samples for nutrients could show if ions from runoff were the cause of the differences in the conductivity in Black Hole Brook and Robinson. Robinson was the warmest stream while also having the lowest average shade. This was not an expected result as agriculture can increase the temperature of streams (McTammany *et al.*, 2008). A possible reason for this is that Robinson was on average wider than the other streams this increased temperature is likely due to the lower amount of canopy cover found in wider streams (Vannote *et al.*1980). Black Hole Brook was the coldest stream and did not have the higher average shade nor was it the narrowest. It was only slightly colder than Turner Brook and Wheaton. As the average temperatures are similar, the influence of local weather could be the cause as the streams are located close together. Turner Brook had the highest concentration of nitrates and nitrites and Robinson had the lowest. Robinson was expected to have the lowest while Wheaton was expected to have the highest but the samples from Wheaton were not tested for nutrient content. Based on the results from the other three streams it appears that nitrate and nitrite concentration would increase with percent agriculture. To further support this Wheaton would have to be tested.

Of the significant between stream invertebrate results Wheaton had the highest in all except for those for *R. minor* and the proportion of *R. fuscula* (Figures 4, 5 & 6). That is because *R. minor* were not present in the samples. Wheaton had the lowest proportion of all the instars of *R. fuscula* but the highest proportion of the 4th and 5th instars. Studies have found that smaller instars of *Rhyacophila* are phytophagus while larger instars range from omnivorous to strictly carnivorous depending on species (Céréghino, 2002). Wheaton has the highest conductivity and greatest amount of agriculture in the watershed and this may be fertilizing the stream and increasing many of the totals and densities of stream macroinvertebrates (Gulis *et al.* 2006). The higher agriculture might have caused changes to the streams that *R. minor* and smaller instar *R. fuscula* were sensitive to resulting in lower densities. The only *Rhyacophila* with a higher abundance in Wheaton was *R. vibox* which is likely due to the lack of brook trout in Wheaton because*R. vibox* has been found to be very susceptible to predation from brook trout (Sircom & Walde, 2009). Black Hole Brook had the highest density and proportion of *R. minor* while having the lowest of *R. vibox* and *S. naica*. Black Hole Brook has the 2nd lowest amount of agriculture and the lowest April conductivity and *R. minor* may be sensitive to the higher conductivity found in the other streams. At higher amounts of agriculture inputs things like pesticides can increase in concentration and be detrimental to some species, although no pesticides were detected in this study (Gulis *et al*. 2006). Robinson had the lowest densities of EPT, Ephemeroptera, Plecoptera, Tricoptera, and *I. montana*. As well as lowest proportions of 4th and 5th instar *R. fuscula* and *I. montana*. Robinson had the lowest percent agriculture therefore it is expected to have the lowest fertilizing effect and lower densities of macroinvertebrates. Turner Brook and Black Hole Brook had similar densities of the EPT, Ephemoroptera and of the predators. Although Turner Brook has more agriculture in the whole watershed than Black Hole Brook, within 50 metre buffer of the stream their numbers are closer; 14% for Turner Brook and 11% for Black Hole Brook. The closer agricultural activity, within the buffer, could be having a stronger influence on the macroinvertebrates.

Within stream discussion

Wheaton showed decreasing conductivity downstream in both April 2010 and June 2010 (Figure 3). If the high conductivity was caused by increases in nutrients this downstream decline could be the result of the organisms in the stream using the nutrients. The water from Wheaton was not tested for nutrients because it was collected on a rainy day and wouldn't be comparable so it is not possible to determine which nutrients could have been causing the higher conductivity without resampling. Wheaton also had a decreasing downstream temperature which is not expected since the narrower upstream should be receiving less light due to thicker canopy cover (Vannote *et al,*. 1980). As Wheaton had the second highest average shade and no upstream downstream trend any openings in the canopy were not within the sample area. More canopy cover measurements upstream would be needed to determine if this is the case. Wheaton showed no trends in invertebrate results.

Temperature and average shade increased downstreamin Turner Brook (Figure 3). An increase in temperature downstream is expected when the stream increases in width and therefore decreases in average shade (Vannote *et al*., 1980). The average shade increased a small amount downstream (Figure 3) and there was no trend in width. It is possible that there were not enough samples collected to show that the stream width or average shade was changing downstream. It is also possible the agricultural inputs were increasing the temperature (Young *et al.,* 2008). Although the conductivity in April and June 2010 did not show a significant upstream downstream trend they both increased then decreased (Figure 3). Also the concentration of nitrites and nitrates followed a similar increase in decrease as the June conductivity. The increase in both conductivity and nutrient concentrations was between site 1 and site 2 and there could be a source of runoff between those two sites causing these results.

The total number of larger instars of *R. minor* decreased downstream and so does temperature and average shade (Figure 3 & 13). It is unlikely to be either of these as *R. minor* is present in streams with higher temperatures and with similar levels of shade. It could be due to factors not measured in this study such as habitat or prey availability.

The conductivity in Black Hole Brook increased downstream in April 2010 and decreased downstream in June 2010 (Figure 3). The values for June were also higher so this increase in conductivity and change in downstream trend could be due to an increase in agriculture in the watershed or possibly a clear cutting event as there were other recent clear cuts in the area. The decrease in April 2010 was very small (Figure 3) and it was the lowest conductivity for that sampling period. The influence of agriculture might have been very small at that time and increased in June. The June water samples also showed a small amount of nitrates and nitrites that decreased downstream (Figure 3) and might have been the cause of the decreasing conductivity as they are ions. The decrease in nutrients could be because of organisms in the stream absorbing them. The average shade was found to decrease downstream while the average width did not, this might be because of the small number of width samples taken. Measuring the stream width more often may have shown an increasing downstream trend. The density of Tricoptera, the five predators and *R. minor* decreased downstream (Figures 7, 8 &11). This could be due to the decreasing fertilizing effect from the upstream agriculture. The total number of larger instars of *R. minor* decreased downstream as well, likely for the same reason as the overall decrease in *R. minor* in Turner Brook.

Robinson showed no significant trends in any of the chemical and physical variables. It did however show decreasing total and density of *R. minor* as well as a decreasing proportion of the larger instars of *R. minor* and *S.naica* downstream (Figures 9, 10, 11 & 12). Site 4, the most downstream site, was very close to the ocean and the decreases could be caused by the changes in habitat that, although weren't measured in this study, visibly changed like increases in substrate size.

Isotope discussion

The isotope data from Turner Brook showed that $C^{13}$was more depleted upstream in site 1 than downstream in site 4. All the species had a similar increase except for *I. montana* which had a larger increase. This increase downstream could be the results of a change in the source of carbon as the leaf species did not change. The concentration of nitrates and nitrites as well as the June conductivity in Turner Brook increased at site 2 than started to decrease but site 4's concentration and June conductivity was still higher than that of site 1 (Figure 3). This could mean that the effect of agriculture was stronger at site 4 due to agricultural inputs entering the stream at site 2, therefore increasing the growth of algae and the ratio of C^{13} (France *et al.* 1996).

Conclusion

The streams with higher percentages of agriculture showed evidence of fertilizing effects from agriculture such as higher densities of invertebrate species as well as changes in the stream chemistry. There were also some upstream downstream trends in invertebrate community composition that could have been caused by the agriculture upstream from the sample sites. The carbon isotope data showed a possible diet shift in five predator species between site 1 and site 4 of Turner Brook. Also based on the closeness of Turner Brook and Black Holes densities and the percent agriculture it is possible that the agriculture within the 50 metre buffer is very influential on the stream and is overshadowing the effects over the whole watershed. Evidence of agricultural impacts on the macroinvertebrates in the streams is apparent. Future studies could explore the changes in macroinvertebrate community composition as well as the impacts of those changes on brook trout in the streams.

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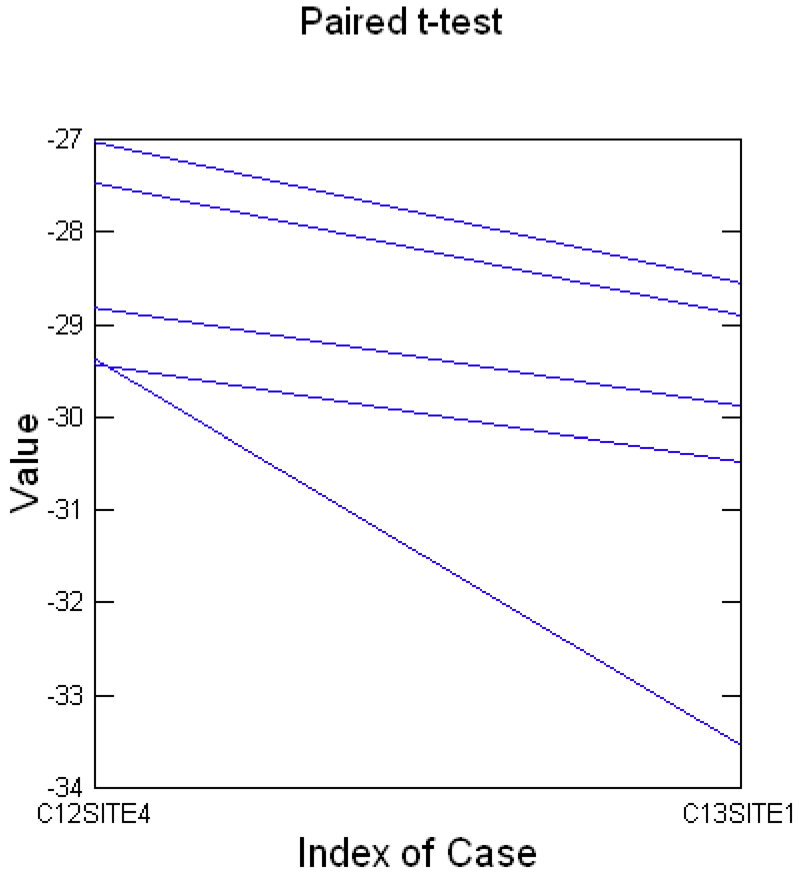
Appendix A: Invertebrate results found using the general linear model found not to be significant. ANOVAs run together are all in one box.

Dependant	Source	Degrees of freedom	F-ratio	P-Value
Total Ephemeroptera, Tricoptera and Plecoptera	Stream	3	0.799	0.506
Total Ephemeroptera, Tricoptera and Plecoptera	Site	1	0.002	0.961
Total Ephemeroptera, Tricoptera and Plecoptera	interaction	3	0.363	0.780
Density of Plecoptera	Stream	3	2.214	0.110
Density of Plecoptera	Site	1	2.139	0.156
Density of Plecoptera	Interaction	3	0.250	0.860
Total R. fuscula	Stream	3	0.517	0.673
Total R. fuscula	Site	1	0.392	0.535
Total R. fuscula	Interaction	3	0.086	0.967
Total I. montana	Stream	3	1.407	0.256
Total I. montana	Site	1	0.000	0.999
Total I. montana	Interaction	3	0.387	0.763
Total S. naica	Stream	3	0.202	0.894
Total S. naica	Site	1	0.830	0.830
Total S. naica	Interaction	3	0.751	0.529
Total R. viboxinstar 4	Stream	3	2.218	0.102
Total R. viboxinstar 4	Site	1	1.732	0.196
Total R. viboxinstar 4	Interaction	3	0.793	0.506
Total R. viboxinstar 5	Stream	3	0.871	0.465
Total R. viboxinstar 5	Site	1	1.203	0.280
Total R. viboxinstar 5	Interaction	3	0.537	0.660
Total R. fusculainstars 1-3	Stream	3	0.523	0.669
Total R. fusculainstars 1-3	Site	1	1.631	0.209
Total R. fusculainstars 1-3	Interaction	3	0.126	0.944
Total R. fusculainstars 4,5	Stream	3	1.734	0.176
Total R. fusculainstars 4,5	Site	1	0.059	0.809
Total R. fusculainstars 4,5	Interaction	3	0.538	0.659

Total I. montana instars 1-3	Stream	3	1.582	0.210
Total I. montana instars 1-3	Site	1	0.423	0.519
Total I. montana instars 1-3	Interaction	3	0.769	0.519
Total I. montana instars 4,5	Stream	3	0.981	0.412
Total I. montana instars 4,5	Site	1	0.502	0.483
Total I. montana instars 4,5	Interaction	3	0.655	0.585
Total S. naicainstars 1-4	Stream	3	1.418	0.252
Total S. naicainstars 1-4	Site	1	1.431	0.239
Total S. naicainstars 1-4	Interaction	3	0.505	0.681
Total S. naicainstars 5,6	Stream	3	0.832	0.484
Total S. naicainstars 5,6	Site	1	1.644	0.208
Total S. naicainstars 5,6	Interaction	3	1.839	0.157
proportion of R. vibox of the predators	Stream	3	0.552	0.653
proportion of R. vibox of the predators	Site	1	0.009	0.924
proportion of R. vibox of the predators	Interaction	3	0.269	0.847
Proportion of I. montanainstars 4,5of the predators	Stream	3	1.492	0.236
Proportion of I. montanainstars 4,5of the predators	Site	1	0.114	0.738
Proportion of I. montanainstars 4,5of the predators	Interaction	3	0.901	0.452
Proportion of I. montana instars 6,7 of the predators	Site	1	0.004	0.948
Proportion of I. montana instars 6,7 of the predators	Stream	3	2.610	0.067
Total R. fuscula	Site	1	0.286	0.596
Total R. fuscula	Stream	3	1.441	0.245
Density of R. fuscula	Stream	3	0.623	0.61
Density of R. fuscula	Site	3	0.353	0.787
Density of R. fuscula	Interaction	9	0.560	0.811

Appendix B: Paired one tail T-test of the Isotope data from Turner Brook for the five predator species. H_o Mean site 1<Mean site 4.

Mean C13SITE1	-30.27
Mean C12SITE4	-28.424
Mean Difference	-1.846
95.00% Confidence Bound	-0.591
Standard Deviation of Difference	1.316
t	-3.136
degrees of freedom	4
p-value	0.017



Appendix C: One tailed paired t-test of the leaf species in site 1 and 4. H_o Mean site 1<Mean site 4.

Mean SITE1	-30.205
Mean SITE4	-30.185
Mean Difference	-0.02
95.00% Confidence Bound	2.884
Standard Deviation of Difference	0.651
t	-0.043
df	1
p-value	0.486