Biological survey of selected stream sites on Mount Mansfield

James L. Carrien, Anna B. Heidorn, Erin A. Magoon,
Holly A. Peters and E. Perry Thomas
Sterling College
Craftsbury Common, VT

We report results in three related parts: Part I describes our efforts to develop a low-impact method for sampling subalpine streams, Part II is Anna Heidorn's exploration of diatoms as biological indicators on Mt. Mansfield, and Part III describes Erin Magoon's use of macroinvertebrates to assess water quality in West Branch and Ranch Brook.

Ultimately, we hope to use traditional and modified-Surber samplers (described in Part I) to conduct annual surveys of macroinvertebrate fauna in subalpine streams of the West Branch and Ranch Brook watersheds. Fieldwork will be conducted during early October to enable comparison with ongoing macroinvertebrate monitoring conducted by the Vermont Department of Environmental Conservation (2001).

Part I: Comparison of conventional and innovative methods for sampling macroinvertebrates in subalpine streams of Mt. Mansfield, Vermont

Abstract

Kicknet and Surber methods were compared in a third-order reach of Ranch Brook on the east slope of Mt. Mansfield. A newly developed method, using a modified Surber sampler, was compared with the traditional Surber in a second-order reach of Nettle Brook on the west slope. The modified Surber is similar in design to the original, but samples 1/9th the surface area (100 cm^2 vs. 900 cm^2). We found no differences ($p > .05$) between diversity estimates in either comparison. For example,. in Ranch Brook, the mean total for these organisms was 52.0 (± 8.7) with the traditional Surber and 51.4 (± 8.9) with the kicknet. In Nettle Brook, the mean total number of Ephemeroptera, Plecoptera, and Trichoptera was 6.7 (SE ± 2.3) with the traditional Surber and 4.7 (± 3.3) with the modified Surber There were, however, significant differences ($p < .05$) between density estimates in both comparisons. We consider implications of these results as we design a low-impact monitoring plan for subalpine streams on Mt. Mansfield.

Introduction

Our challenge is to develop methods for biological monitoring of first-order and second-order streams on Mt. Mansfield, in conjunction with chemical sampling by the U.S. Geological Survey. Our methods need to be comparable to those recommended by the Environmental Protection Agency (Plafkin et al. 1989) and the USGS (Moulton et al. 2000), but appropriately scaled for these headwater ecosystems.
Both USGS and EPA methods entail use of a kicknet to disturb an area of stream at least

1 m^2. The standard Surber sampler has a 900 cm^2 opening and a square frame of equal size which delineates the area of substrate to be disturbed. Kicknet and Surber sampler methods were compared in a third-order stream. A newly developed method, using a modified Surber sampler, was compared with the regular Surber in a second-order stream. The modified Surber has the same proportions as the original, but a 100 cm^2 opening.

Methods

The kicknet/Surber comparison was conducted 28 Nov 00 in Ranch Brook, just below the USGS gauging station. The Surber/modified Surber comparison was conducted 26 Feb 00 in Nettle Brook, also just below the USGS. gauging station (Shanley 1997). We followed field protocols described by Moulton et al. (2000) for kicknet sampling and by Karr and Chu (1999) for Surber sampling. Five replicate samples were collected with for the each sampler in the kicknet/Surber comparison; three replicate samples with each sampler in the Surber/modified Surber comparison. Samples were paired according to substrate and location in the stream.

In the laboratory, samples were transferred into vials filled with 70% EtOH for preservation. For the purpose of these comparisons, organisms were identified to order. Number of individuals present per order was compared between samplers, as an indication of whether the two samplers would provide comparable measures of diversity. Density was calculated as individuals/m^2. While the kicknet method is not typically used to measure density, we estimated the area sampled as 1 m^2 to facilitate comparison. Data were analyzed using paired t-tests (GraphPad 1998).

Results

There were interesting parallels across the two comparisons (Tables 1 and 2). We found no significant difference ($p > .05$) between raw numbers of individuals in either the kicknet/Surber or traditional/modified Surber comparison; however, density estimates were significantly different in all comparisons ($p < .05$).

Table 1. Comparison of kicknet and Surber samplers, including mean #/sample, mean density and corresponding standard error values. Density is reported as # individuals/m^2.

	Kicknet				**Surber**			
Order	**Mean #/Sample**	**SE**	**Mean Density**	**SE**	**Mean #/Sample**	**SE**	**Mean Density**	**SE**
Ephemeroptera	15.6	2.0	15.6	2.0	5.6	2.9	62	32
Plecoptera	23.4	5.9	23.4	5.9	32.0	5.5	352	60
Trichoptera	12.4	2.6	12.4	2.6	14.4	2.0	158	22
Diptera	47.0	11	47.0	11	22.8	3.3	251	36

Table 2: Comparison of conventional and modified Surber samplers, including mean #/sample, mean density and corresponding standard error values. Density is reported as # individuals/m^2.

	Conventional Surber				Modified Surber			
Order	**Mean #/Sample**	**SE**	**Mean Density**	**SE**	**Mean #/Sample**	**SE**	**Mean Density**	**SE**
Ephemeroptera	0	0	0	0	0.33	0.33	33	33
Plecoptera	2.3	1.5	26	16	0.7	0.3	67	33
Trichoptera	4.3	1.7	48	19	3.7	3.2	370	320
Diptera	5.7	2.4	63	27	5.7	4.7	570	470
Coleoptera	5.0	2.3	56	26	4.7	4.2	470	420
Odonata	0.33	0.33	3.7	3.7	0.33	0.33	33	33

Discussion

These comparisons support the use of low-impact sampling methods to characterize macroinvertebrate diversity in subalpine streams on Mt. Mansfield. While the modified Surber sampler needs further testing to determine whether our results can be replicated, we hope it will prove a useful tool. In general, use of a Surber-style sampler is consistant with methods used by other researchers for quantitative sampling of macroinvertebrates in second-order streams (Merritt and Cummins 1984, Kobuszewsi and Perry 1993).

References

GraphPad. 1998. InStat version 3.0 for Windows. GraphPad Software, San Diego, CA.

Gryska, A.D., W.A. Hubert, and K.G. Gerow. 1998. Relative abundance and lengths of Kendall Warm Springs dace captured from different habitats in a specially designed trap. Transactions of the American Fisheries Society 127:309-315.

Hauer, F.R. and G.A. Lamberti. 1996. Methods in stream ecology. Academic Press, San Diego, CA.

Karr, J.R. and E.W. Chu. 1999. Restoring life in running waters: better biological monitoring. Island Press, Washington, DC.

Kobuszewski, D.M. and S.A. Perry. 1993. Aquatic insect community structure in an acidic and a circumneutral stream in the Appalachian mountains of West Virginia. Journal of Freshwater Ecology 8:37-45.

Merrit, R.W. and K.W. Cummins. 1984. An introduction to the aquatic insects of North America, 2nd Edition. Kendall/ Hunt Publishing, Dubuque, IA.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthc macroinvertebrates and fish. U.S. Environmental Protection Agency, Washington, DC. 6-4 through 6-15

Shanley, J. 1997. Flow monitoring at Nettle Brook. VForEM (VMC) Newsletter, May/June.

Terrel, C.R. and P.B. Perfetti. 1996. Water quality indicators guide: surface waters. Kendall/Hunt, Dubuque, Iowa.

Vermont Department of Environmental Conservation. 2001. Aquatic macroinvertebrate monitoring at the Vermont Monitoring Cooperative Research Site Underhill, Vermont. In Wilmot, S.H., J. Supple, J. Rosovsky & P. Girton (Editors). Vermont Monitoring Cooperative: Annual Report for 1998. VMC Ann. Rep. No. 8, pp 163. Vermont Department of Forests, Parks and Recreation, 103 South Main St., Waterbury, VT 05671.

Part II: Diversity of Diatoms in streams as indicators of water quality: a pilot study

Abstract

Diatoms from three streams in northern Vermont were collected and compared to see if there was a difference in colonization rates between streams. Eighteen rocks were sampled every two weeks, six at each stream. The findings between the three sites were not significantly different. There was no correlation between human impacts on the stream and the population diversity on the rocks. This pilot study provides a basis upon which to develop long-term diatom monitoring

Introduction

Diatoms are single celled microscopic algae in the class Bacillariophyceae. Diatoms have characteristic siliceous cell walls composed of two halves that fit together like a lid on a box. The seam of the two halves, form what is known as a frustule. Pennate diatoms can be found in both freshwater and saline environments but are most common in freshwater systems. They range in shape from a pie wedge, to cigar shape, to orange-section shape. Diatoms can be solitary or grow in small colonies.

There have been many studies dealing with water quality monitoring using biological indexes. Diatoms have been described as ideal biological monitors (Stoermer and Smol 1999). They are large in number, ecologically sensitive, abundant in places where water is at least occasionally present, and leave their remains preserved in the sediments of most lakes, many areas of the oceans, and in other aquatic environments. This study was done as a pilot to determine feasibility of diatom studies on Mt. Mansfield, including the best techniques for data collecting and processing and analysis.

Methods

Artificial Substrata Preparation and Placement
During the design of the experiment many different substrates were considered. Historically glass slides were used as artificial substrata but studies showed more textured surfaces promoted diatom colonization. Drain plates for terra cotta pots were considered but a rougher texture was recommended (Clifford 1992). Gneiss stones approximately 0.5 lbs. in weight were chosen for this study. Numbers 1-18 were carved into each. For preparation, the stones were soaked in tap water for an hour, scrubbed with 70% ethanol alcohol, rinsed in tap water again, and then soaked in distilled water over night. There were 18 total, 6 for each stream.

Each stream had two sites with three stones placed at each site. At each site, two of the three stones were placed at either shore and one was placed in the middle of the stream. The sites were made above and below a man-made landmark. The first six were placed in Whitney Brook in Craftsbury, Vermont above and below the Creek Road bridge. Site one was about 1/4 mile above the bridge. Rocks numbered 1-3 were placed there. Site two was located 3/10 of a mile below the bridge adjacent to a dairy farm where rocks numbered 4-6 were placed. Site one and two at Wild Branch in Eden, Vermont, were above and below the bridge on Collinsville Road. Numbers 7-9 were placed 1/4 mile above the bridge where a skidder trail crossed the stream, 10-12 were placed 10 meters below the bridge. For Nettle Brook, a headwater stream on Mount Mansfield, near Underhill, Vermont, a USGS weir separated sites one and two. Site one was about 20 meters below the weir and site two was about 10 meters above. Rocks 13-15 were placed at site one and 16-18 at site two.

Collection

The rocks were placed in Whitney Brook and Wild Branch on June 8, 2000, and Nettle Brook on June 9, 2000. From then data were collected every two weeks. The data collection included scraping periphyton growth from the rocks into labeled Whirl-pacs, and measuring temperature, dissolved oxygen levels, stream flow and pH of the stream. The Whirl-pacs were then refrigerated or frozen until processing. The collection dates were June 22-23, July 7-8, and July 20-21.

Processing

In the lab, wet mount slides were made for each sample. Notes were made of each different species of diatom observed. Some quality specimens were mounted on permanent slides. Samples were then filtered using the gravity filter method with tiered coffee filters. The filter paper was dried for 24 hours, and then weighed.

Analysis

The data were analyzed using repeated measures ANOVA and correlation with *InStat* software (GraphPad 1998).

Results

There was no significant difference among species number or dry mass across time in any of the streams. Variation among means was not significantly greater than expected by chance. The populations on the rocks in Whitney Brook and Nettle Brook showed no obvious increasing or decreasing trends in diversity over time. Wild Branch did however show an increasing trend in diatom population overall. In Nettle Brook rocks 14 and 15 had the same increase throughout the testing period. No significant correlation could be found when the dry weight and population diversity were compared for each sample.

Discussion

There were many problems with this study in the field, lab, and in the design. Some of the samples were lost due to faulty collection bags. Sometimes the sample rocks were covered by silt after a spate so no colonization was possible. In the lab, some samples were kept refrigerated for too long and so there was the variable of the loss of diatoms by microscopic zooplankton.

Only a very small portion of each sample was examined, leaving the possibility for many species to go unnoticed. A total population count was not recorded therefore an accurate measure of population diversity could not be established. The dried samples contained a lot of non-organic material and general periphyton, so the dry weight measurement did not represent the mass of the diatoms in the sample accurately.

Despite these problems, the data that were collected are relevant unto themselves and since the measurements were taken consistently the measurements can be compared to each other. This study, as a pilot, opened the doors for future use of diatoms in local water quality monitoring by preparing future monitors with an idea of what diatom collection and processing entails.

It also shows the feasibility for future studies to contain diatom collection and processing in their analysis of stream water quality. There are exciting possibilities for combining diatom and macroinvertebrate analyses in future water quality studies.

References

Clifford, Casey, and Saffran. 1992. Short-term colonization of rough and smooth tiles by benthic macroinvertebrates and algae (chlorophyll a) in two streams. Journal of North American Benthological Society **11**(3):304-15.

Fryer. 1987. Quantitative and qualitative: numbers and reality in the study of living organisms. Freshwater Biology **17**:177-89.

Round, F.E. 1991. Diatoms in river-water monitoring studies. Journal of Applied Phycology **3**:129-45.

Stevenson, Jan, etal. 1996. Using diatoms as indicators of ecological conditions in lotic systems: a regional assessment. Journal of North American Benthological Society **15**:481-95.

Stoermer, Eugene, and Smol, John. 1999. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, UK.

Part III: Biological assessment: a comparison of two streams in relation to the Stowe Mountain Company expansion project

Abstract

The main focus of this study is to compare macroinvertebrate community composition between two streams on Mount Mansfield: West Branch, above and below current ski-area development, and Ranch Brook in a relatively pristine watershed. We found significant differences in the densities of some invertebrate taxa – trends suggesting a need for continued quantitative monitoring.

Introduction

Of all the potential biological indicators that have been considered for use in assessing quality of freshwater monitoring (e.g. fish or zooplankton), benthic macroinvertebrates are most often recommended (Hauer 1996). The Vermont Department of Environmental Conservation (2001) has sampled in this upper watershed area, as have other agencies, using well-established methods for qualitative analysis.

In the samples we collected we are looking at a direct comparison of two streams on Mount Mansfield, the West Branch and Ranch Brook. West Branch is directly impacted as it flows along the base of Stowe Ski Area and Vermont State Highway 108. Ranch Brook is essentially a reference stream, located in an adjacent watershed where little deforestation exists.

Erosion of undisturbed watersheds usually releases small amounts of particulate material, whereas certain farming, forestry or mining practices, dredging, industrial or construction activities often result in the introduction of substantial amounts of such solids (Wiederholm 1984). As cited by Anguiar (2002), Waters (1995) describes sedimentation as the principal cause of environmental impairment in headwater streams and as a significant threat to aquatic life in streams.

Impacts of sedimentation on aquatic insects can be direct, such as when food collection or respiration is obstructed, or indirect, such as when critical resources are depleted (Wiederholm 1984). Examples of resource limitation include reduction of light penetration/plant growth, smothering of hard surfaces, and filling in of important interstices within the substrate.

In the *Stowe Mountain Resort 2000: A Community Plan for the Future of the Mountain*, the Stowe Mountain Company submitted a plan to the District Environmental Commission for restoration of state conservation flow in the West Branch of the Little River. The plan was due by December 1999 as required by an Act 250 Permit condition issued in 1991. The existing resort cannot economically support the required changes without adjustment to the present facilities. The overview of the expansion includes the following:

1.) Enhanced snowmaking and water quality
2.) On mountain improvements including:
    a.) Expanded base lodge
    b.) New trails on both Mt. Mansfield and Spruce peak
    c.) New Lifts
3.) The creation of a hamlet size settlement at the foot of Spruce Peak
4.) An 18 hole golf course (this has been sized down)
5.) State Campground
6.) Smuggler's Notch Scenic By-way initiatives

The plan is to allow the resort to meet world-class criteria and still be sensitive to the surrounding environment. Stowe has been noted as a tourist town much longer than the resort has been there

Today Route 108, the Mountain Road carries 690,000 tourists and commuters a year through the notch. When even more visitors to the mountain there will be an increase in management concerns. The Mt. Company feels the pressure to compete with other high-class resorts and many facilities need of improvement on the mountain. A planning committee was set up to include the interests of individuals, agencies and organizations, hence the title "Community" Plan.

In the Plan's section on Hydrology and water Quality (section 7, pg 70) there is a computer model that is used to predict the best measures for site design that can be assessed to develop a watershed prospective. The outcome will be a set of recommended measures to ensure that the entire project will provide for sufficient control and treatment of storm water from the resort property, and to ensure the removal of sediment and other contaminants before reaching the West Branch. The Conservation Law Foundation, showing the need for field-tests of water and soil, criticized the town's use of computer models. This was in reference to the proposed sewer line extension to reach up the Mountain Resort (Stowe Reporter, 1999).

In another article in the same April 1999 issue, it is stated how the ski area has made several changes to its original plan in response to several concerns about impacts on wildlife habitat, hiking trails, wetlands, and local streams. It was also noted that "the storm water system is expected to actually improve the river's quality," referring to the Little River which the West Branch flows to. Another factor to consider is the water used for snowmaking is currently taken from a pond of the West Branch. The intake is operated in accordance with the current permits, yet it does not meet the "February Median Flow" (FMF) standard applied by the Vermont Agency of Natural Resources for new or expanded snowmaking systems. At one point the only feasible option for a new source of water was to put in a six-mile pipeline from the ski area to the Waterbury reservoir, which is currently used by Green Mountain Power for hydroelectric purposes. Other more reasonable sources are being investigated.

Once the snowmaking systems expansion is in place, the resort will be required to measure all water use from the source and on the West Branch. The data will be reported to the Agency of Natural Resources on a monthly basis. The report suggests that the best measurement of the effectiveness of the storm water treatment and control measures would be by monitoring the "in-stream biologic conditions in the West Branch over a period of years."

Methods

There are several popular methods of water quality testing that are suggested for use in conjunction with macroinvertebrate sampling (Plafkin, et al.1989). Chemical testing, for instance, can be very helpful in giving an accurate reading of what is in the water at the moment of sampling. It should not be used alone, because reading the current chemical levels will not detect pollution problems that are no longer present and yet may still have an effect on life in the water (Hauer 1996). This is why we look to biological indicators such as macroinvertebrates, which can reveal indications of various impacts whereas chemical measures look only at one impact (Karr and Chu 1999). Macroinvertebrate communities are good indicators of localized conditions because many have limited migration patterns and most species have a complex life cycle of a year or more. Their sensitive life stages respond quickly to stress. Sampling is easy and inexpensive, and most states already have background macroinvertebrate data. (Plafkin et al. 1989).

Thirteen orders of aquatic insects occur in North America (Merritt 1996) but only five of these are composed strictly of aquatic species (i.e., species that have at least one life history stage that is aquatic.) These are damselflies and dragonflies (Odonata), the stoneflies (Plecoptera), the mayflies, (Ephemoptera), the caddisflies (Tricoptera), and the hellgrammites (Megaloptera). While the remaining eight orders have primarily terrestrial inhabitants, several exhibit high species richness in aquatic habitats. Examples are beetles, (Coleoptera) and true flies (Diptera) (Hauer and Resh 1996).

It is necessary to be cautious of concluding that because a pollution tolerant species is in the stream, that you can automatically conclude it is "clean water". It may just be due to habitat conditions (Hauer 1996). Similarly, detecting the absence of sensitive species does not necessarily mean that the water is polluted. Such species may have been eliminated by a recent flood or draught and not have had time to recover (Terrel 1996).

This is why it is important to assess the physical habitat in and around the channel. Using a field guide such as Water Quality Indicators Guide (Terrel 1996) gives adequate steps to take for assessing the watershed. It also provides scoring sheets of what to look for with certain non-point source pollution. This includes physical characterizations such as the six measurements mentioned in Resh (1996): mean stream width; mean stream depth, current velocity, discharge, gradient, air and water temperature.

Materials and Field Collection Processes

Using the procedure described by Hauer (1996), we chose to sample in riffles taking five replicates at each site. On Ranch Brook we had one site and did a set five of replicates, and on the West Branch we had two sites, we took a set directly below the ski area and one in a primarily unaffected area beside the road, higher in the watershed. At this site should not have been affected too much by runoff from the ski area. (Parking lots, ski trails.)Starting at the bottom of a riffle and working our way up, we used a Surber sampler (Surber, 1937) designed for taking samples in small streams with depths up to <30 cm, and substrata containing gravel or small cobble.

Once the sample is taken it is emptied into a bucket, here we check to see what organisms we have gathered and pick out most of the large organic debris and rock. Pouring the sample into a 500μm sieve strains the sample from the water. Now the macroinvertebrates and any remaining material are put into a whirlpack. They are labeled, and filled with one part 95% ethanol alcohol and two parts water to preserve the organisms. At each site the habitat was assessed and we measured stream width, depth and velocity.

In the Lab

Sorting involves the separation of the benthic macroinvertebrates from the substrata, organic matter and other unwanted material. A sample's contents are emptied into a plastic tub with lines as grids for marking which section has been completed. Larger organisms are easier to see and can be picked out with tweezers or a pipet. To scan for smaller organisms a hand held magnified glass can be used, good lighting is absolutely necessary. The organisms are separated to order, or for the less experienced, to similar categories. Again they are placed in ethyl alcohol to be preserved Later the samples where enumerated and identified to order, some to family, using dissecting microscopes.

Results

No noticeable differences among locations were evident when comparing the overall percentage distribution curves from each of the samples. Although in general, there was a trend toward higher densities Ranch Brook than West Branch across all taxa. Ephemoptera and Diptera densities were significantly different (P value greater than 0.05.) in Ranch Brook as compared to West Branch sites. (See fig. 1 for Graph of The Mean and Standard Error of Taxa). The total organism count for the five replicates of each sample is as follows:

Plecoptera

West Branch Site 1-	27
West Branch Site 2-	34
Ranch Brook Site 3-	177

Percent EPT is a measurement of the sensitive types of organisms as compared to the total number per sample. EPT stands for the three more common sensitive orders of Ephemeroptera, Plecoptera, and Diptera.

The %EPT (individuals) :

West Branch Site 1-	89%
West Branch Site 2-	91%
Ranch Brook Site 3-	80%

While sampling, it was noticeable that the amount of sediment in the first site on West Branch was the heaviest. The second site above the ski area there was somewhat more cobble, and in Ranch Brook considerably less sediment than the previous two. In the two West Branch sites there were not many large macroinvertebrates. Within the first sample on Ranch, there was the largest of the Plecoptera, and a small salamander we release back to the stream. In general there is a trend toward higher density in Ranch Brook than West Branch across all taxa.

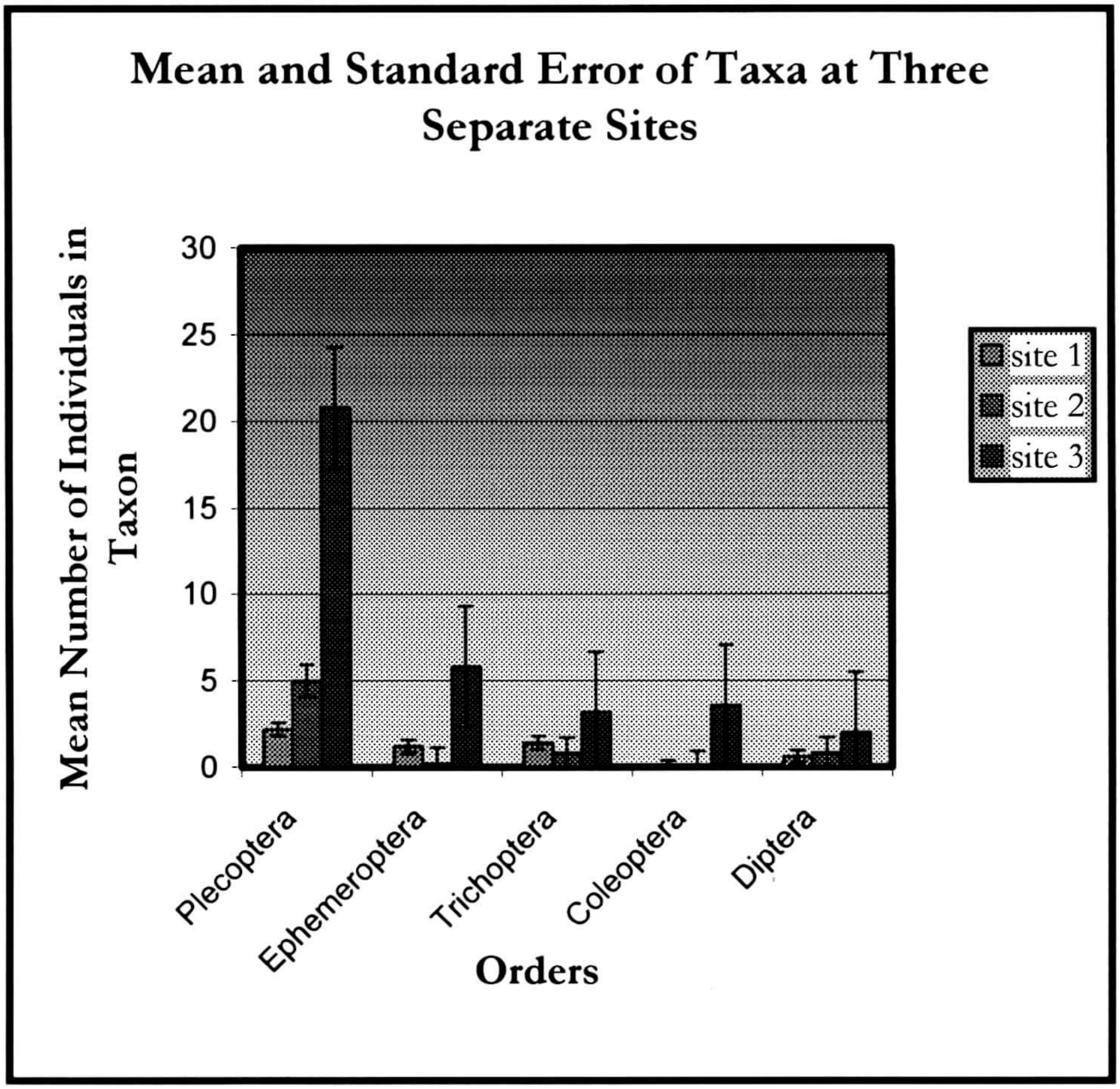

Figure1. Comparison of orders across three sites. Sites 1 and 2 are West Branch, site 3 is Ranch Brook.

Discussion and Conclusions

Based on initial analysis there appear to be greater ~~percentages~~ number of pollution intolerant taxa (Ephemoptera, plecoptera and Trichoptera) in the Ranch Brook site as compared to West Branch. Interestingly, there does not appear to be a difference in diversity between the two West Branch sites- above and below the Stowe Ski Area. It should be noted that comparing % differences between ratios might compound the variability (Plafkin, 1989).

Some metrics suggest including a percent comparison of the chronomidae to the EPT%. I believe the lack of this taxon in our samples was due to our sorting methods, it was not recognized that some of the organisms could be so small. This also may account for why our overall samples were smaller than average. Results from data collected by VT ANR showed a much higher total organism count for individual samples. Their method of sampling differed slightly from ours, using a kick-net sampler, whereas we used the Surber sampler.

A 100-organism subsample is recommended as a time saving sorting procedure for use with the riffle sample. A pilot study (results in Plafkin1989), indicated that although a 100-organism subsample is sufficient, a 200-300 organism subsample may be preferred. This indicates that overall our samples were small, when the largest sample size from all five replicates within the sample was 177.

Acknowledgements

This work was funded by a grant from the Vermont Monitoring Cooperative to Perry Thomas and by the Federal Work College Program at Sterling College. Sarah Deck, Jared Fitzpatrick, Colin Shank, and other Sterling College students conducted field and laboratory work. We thank Heather Bauman for her help with the statistics portion of the diatom study.

References

Anguiar, F.C., M.T. Ferreria, and p. Pinto. 2002. Relative Influence of Environmental variables on Macroinvertebrate Assemblages from an Iberian Basin. Journal of the North American Benthological Society. 21(1):43-53.

Hauer, F. Richard, and Vincent H. Resh. 1996 Benthic Macroinvertebrates. Pgs. 339-369 in R.F. Hauer, 1996. Methods in Stream Ecology. Academic Press, San Diego.

Karr, James R. and Ellen W. Chu. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington D.C.

Merrit,Richard W. and Kenneth W. Cummins. 1984. An Introduction to the Aqulatic

Insects of North America, Second Edition. Dubuque, Iowa: Kendall/Hunt Publishing Co.

Plafkin, James L., Micheal T. Barbour, Kimberly D. Porter, Sharon K. Gross, and Robert M. Hughs. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency Washington D.C.

Stowe Mountain Resort A community Plan for the Future of the Mountain. Stowe Mountain Resort 2000 Community Planning.

Vermont Department of Environmental Conservation. 2001. Aquatic macroinvertebrate monitoring at the Vermont Monitoring Cooperative Research Site Underhill, Vermont. In Wilmot, S.H., J. Supple, J. Rosovsky & P. Girton (Editors). Vermont Monitoring Cooperative: Annual Report for 1998. VMC Ann. Rep. No. 8, pp 163. Vermont Department of Forests, Parks and Recreation, 103 South Main St., Waterbury, VT 05671.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects and Control. American Fisheries Society. Bethesda, Maryland.

Wiederholm, T.1984. Responses of Aquatic Insects to Environmental Pollution. In: Resh, V.H.; Rosenberg, D.M., eds. The Ecology of Aquatic Insects. New York: Praeger Publishers: 508-557.