Colonization of Benthic Macroinvertebrates following construction of Fluvial Geomorphologic Structures

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ABSTRACT

In order to limit large scale erosion and large bed load movement on Big Bear Creek, Lycoming County, PA, members of the Dunwoody Club designed a habitat restoration project partially funded by the Pennsylvania Department of Environmental Protection. The project employed the Rosgen-style of fluvial geomorphology, a relatively new and unexamined practice on the East Coast. Construction of the 171 structures over a 1.8 mile stretch of stream required large machinery to alter the steam bed, causing large-scale substrate disruption. This study's focus was to determine the impact that substrate disruption had on the benthic macroinvertebrate community and determine a timeframe for complete return to prior levels. Immediately following construction (Fall 2000), densities ranged from 1 organism/meter^2 to 57 org/m^2 and by February 27, 2001 densities had reached between 630 org/m^2 and 1818 org/m^2. It was determined that benthos densities returned to prior levels rapidly. In addition, densities after construction far surpassed previous levels. Along with the invertebrate sampling, fish community and physiochemical conditions of the stream were monitored.

INTRODUCTION

The logging industry that was present across much of the east coast in the late 1800's and early 1900's left an indelible mark on the environment. Entire mountain ranges were stripped of trees, rivers and streams were dammed, and towns and cities sprang up on their banks. With the cities and the increasing populations, agriculture began to boom in the fertile river valleys. In the never-ending search to optimize production and real estate, people moved closer to the river, eventually impacting the ecologically fragile and important riparian zones. The amount of erosion and sedimentation increased and over time, streams and rivers were left in unstable conditions. Once this occurred, their instability persisted until the system could naturally right itself, a process that is still taking place. Since this time, however, the effects of the stream instability was severe; greater amounts of erosion, lower water levels, and more extreme and frequent floods occurred.

This was the case at Big Bear Creek, Lycoming County, Pennsylvania. Improper land usage techniques, including large-scale logging, have left Big Bear Creek in an unstable condition. The timbering that took place at the start of the 20th century has caused today's instability. Over the years the erosion increased, worsening sedimentation and eventually leading to more erosion during high water events. High water events caused large bed load movement due to the water's force. The vast majority of the cobble and gravel component of the substrate was being washed downstream and or deposited in sizable gravel bars throughout the stream's in channel and at its confluence with Loyalsock Creek, leaving boulders as the primary substrate of the stream (Worobec 2000).

The Dunwoody Club owns a majority of the reach of Big Bear Creek used in the study. The Sunbury Grouse Hunters Club and a few private citizens own other small parcels along its length. Big Bear Creek is a fourth order, freestone tributary of Loyalsock Creek flowing through parts of the Tiadaghton State Forest and the Sunbury Grouse Club lands in northern Lycoming County near Barbours, PA. The Dunwoody Club first purchased the land in 1887 and has held exclusive fishing rights to the stream since this time. The watershed that contributes to the flows of Big Bear Creek encompasses 17 squares miles of land that is 80% forested. The Dunwoody Club owns a majority of the watershed (Worobec 2000).

informal fishing records have been kept. Over this time, there has been a significant decline in the catches recorded by the club's members over the entire stream's length. These declines facilitated the clubs annual stocking program beginning in 1927. This temporarily quelled the population problems and until 1972, Big Bear Creek was a world-class fishery (Worobec 2000).

A series of events beginning in 1972 led to the further demise of Big Bear Creek. The first was the flood that occurring in the wake of Hurricane Agnes. The mounting stream instability and the fact that the forest was unable to adequately distribute the precipitation caused heavy flooding and large-scale erosion. A second flood caused by Hurricane Eloise in 1976 caused even more erosion since the stream had little time to recuperate following the flooding in 1972. In 1980, a private landowner downstream built a dam for aesthetic purposes, impeding fish migration and causing aggradation behind the dam and extending upstream. The flood during the winter of 1996 also added to the already unstable stream and banks. In 1996, a dam on the grounds of the club was removed for safety reasons and this suddenly added 100 years of accumulated sediment into the system. All of these factors together contributed to the gradual widening and shallowing of the stream, greatly concerning the members of the club (Worobec 2000).

It was determined that a restoration project might save the stream. A Rosgen-style fluvial geomorphologic project was decided upon based on a number of stream criteria. Rosgen's Applied River Morphology(1996) was used as a guide even though no previous projects of this nature had been done on the east coast. These projects do have a history in the west and have been quite successful in the western part of the United States. Rosgen's guidelines follow specific mathematical parameters determined by the topography and characteristics inherent to every stream. Historically, stream improvement structures (e.g. wing dams, deflectors, etc.) were built facing downstream, forcing the water towards the center of the stream and away for trouble areas. However, these conventional structures can cause problems during high water events. As the water volume increases, the water swirls behind the structure and gouges out the banks downstream of the structure, curing one problem area but at the same time creating another. The Rosgen method consists of upstream facing structures that "pull" the water to the correct channel by means of the water's own force. It works on the principle that water flows over any object at a right angle. By utilizing calculus-derived formulas, it returns the stream to its natural course by simply positioning the structures properly and letting nature take care of the rest. The structures create a slack water area near the banks where the sediment load is caused to fall out of suspension and deposit along the shore where it can build up the banks and keep the channel open. As the banks build and vegetation begins to grow, the erosion diminishes and alleviates the amount of sediment entering the stream. In essence, the stream is healing itself (Worobec 2000).

The construction project on Big Bear Creek began in 1996. At this time, the club members built 14 log structures following the Rosgen technique. Although at the time they were not aware of the fact, the majority of the structures were built incorrectly but were still functioning to some degree. In October 1999, after receiving a Growing Greener Grant from the Pennsylvania Department of Environmental Protection, 4000 additional feet of stream were restored including 38 boulder structures comprised of truncated cross veins and J-hook veins. The autumn of 2000 brought more construction on Big Bear Creek. The construction occurring during the month of October and when it was completed, 171 structures had been built covering a distance of 1.8 miles of stream in all. In the fall of 2001, a final project is scheduled to complete the final reach of stream to its confluence with Loyalsock Creek but is currently undergoing some opposition by a few land owners (Worobec 2000).

In order to construct Rosgen-style structures, it is necessary to use large machinery to place boulders, causing severe disruption to the streambed and surrounding banks. The large bulldozers, front-end loaders, and cranes drive directly on the streambed causing large-scale substrate disruption, the habitat of benthic macroinvertebrates. The equipment left the entire reach of stream disrupted; all existing substrate had been crushed and periphyton colonies were scraped free of the rocks by the machinery. The fragile nature of the macroinvertebrate community is widely known, raising the question as to whether construction procedures would be beneficial. The macroinvetebrates are a very fragile population and any seemingly small impact can have a large effect on the macroinvertebrate community. Their fragility makes them an efficient means of assessing pollution events because they are the first to be effected by an event as well as the first to recover when conditions are suitable. They are also a major contributor to the food web and a primary component of the trout's diet so their presence is of utmost importance to the club and the project. I hypothesized that disruption due to construction would have a major negative impact on the macroinvertebrate densities, resulting in a time period where the densities would be below their historical levels.

METHODS

In accordance with Lycoming College's contract for biomonitoring of Big Bear Creek under the Growing Greener Grant, several tests were run on a monthly basis. Three different criteria were included in the testing: Physical/ Chemical Water Assessment, Benthic Macroinverterbrate Collection, and Fish Collection.

The physiochemical samples were taken monthly at the three sites used for the study as well as a fourth reference site. The water was collected using grab samples in 500-mL containers. These were then stored on ice for processing upon return to the lab. Once at the lab, the samples were then tested for Nitrate Nitrogen, Nitrite Nitrogen, Orthophosphorus, Conductivity, pH, and Alkalinity levels. The nitrate, nitrite, and phosphorus tests were run using HACH 2000 and 4000 spectrophotometers and using Low Range(LR) assessments. The pH and alkalinity were analyzed using a Corning 440 pH meter. For Alkalinity, the sample was titrated to pH 4.0 using 0.20 molar H_2SO_4 and calculated using the formula $\{vol\ H_2SO_4 \times 10 = alk\}$.. Conductivity was measured using a Hanna Instruments HI 9635 Microprocessor Conductivity/TDS meter. Field analyses were also taken at each site upon obtaining the grab sample. Temperature(^oC) and Dissolved Oxygen levels were analyzed using a YSI 55 DO meter.

The second aspect of the contracted monthly biomonitoring was fish collection, survey and tagging by means of electrofishing. The electrofishing was done using a Smith-Root 15A Electrofisher sending a pulse DC signal at 1000 volts and a frequency of 60 Hz. The electrofishing was done over a 100-meter stretch of stream with blocking nets set at either end to prevent fish from escaping the survey area. A crew of 5 or 6 students would participate in the collection with one student wearing the backpack electrofishing unit and carrying the anode probe while the rat-tail cathode followed behind to complete the circuit. The other members of the crew would carry nets to retrieve the fish and buckets to store the fish in until the time came for their processing. Once the pass was completed all the fish were identified to species level and counted. Trout over 10 cm in length were measured (cm), weighed (oz), and selected fish were tagged and scale samples were taken. The age of the scales was then determined in the lab using a compound microscope. The tagged fish are used for marked/ recapture studies to get and estimate of growth rates and age distribution in Big Bear Creek. This is data in continuation of a project monitoring the effects of the cessation of stocking upon the wild trout populations of Big Bear Creek begun in the Fall of 1999 by Jud Kratzer.

The third component of the monitoring was collection of benthic macroinvertebrates. Due to the fact that it was the primary focus of this study, the sample frequency and protocol were changed to meet the need for significant amounts of data necessary to conduct an adequate survey. In order to test the effects of substrate disruption on the macroinvertebrate community, three study sites and a new reference were established. The first site of study was site 2 (Appendix A, Figure 1). This site was previously a reference site and no construction had taken place here until the Fall 2000. For reference, the historical data for this site collected by Jud Kratzer would be used and compared to the data taken during corresponding times for the present year. A second site, site 16, was also used in the same manner (Appendix A, Figure 1). It was previously a reference site and the historical data would be used for comparison. Site 19 was a new site specific to the construction in the Fall 2000 (Appendix A, Figure 1). This third site was to be used in terms of a control to certify that the progression of the other sites was characteristic. No existing data was present for this site so data collected could not be compared to historical data. Instead, information was gathered for current analysis and to be used for reference for future experimentation. A new reference site was also created this year to create a backlog of data for next year when this site will be incorporated into the construction (Appendix A, Figure 1). This site is located approximately 100 meters upstream from the confluence of Big Bear Creek with Loyalsock Creek. This site was designated NDS for New Down Stream reference point and samples were taken here monthly when access was available, since this unrestored section of stream had a tendency to freeze over.

The protocol for macroinvertebrate sampling was changed to fit the more intensive surveying. Samples were taken at each site beginning one week following construction at that site and continuing weekly until February 27, 2001. The samples were collected by using a series of 2 D-Frame Net kicks at each site. Each kick lasted for 2 to 3 minutes in duration. The sample was then taken to shore and the bulk of organic debris was placed in a container. The net was then rinsed in a bucket of water and the net picked thoroughly to remove all macroinvertebrates. The contents of the bucket were then sieved using a 0.05 mm screen and condensed and placed into the container mentioned previously. The samples were then preserved in 10% Formalin solution because of its capacity to prolong the integrity of the macroinvertebrates as compared to 97% Ethanol. Once at the lab, the samples were floated in magnesium sulfate ($MgSO_4$) solution to separate organic debris from macroinvertebrates. The entire sample was picked void of macroinvertebrates instead of a 100-organism sub sample because interest was taken in a record of all taxa present and it is possible to miss a number of taxa at that point with conventional means. The macroinvertebrate sample was then placed in a 96 in^2 gridded enamel pan and a random 100-organism sub sample was chosen and its contents identified. The macroinvertebrates were identified to generic level using dissecting microscope and 3 different dichotomous keys (Peckarsky et al 1990, Stewark and Stark 1988, Wiggins 1977). After sub sample was identified, a scan was done to include all taxa not covered in the sub sample. These were signified with an "S" and were not added into the density counts.

Diversity indices were used as part of the analysis of the macroinvertebrate community of Big Bear Creek. Four calculations were done on the data. Taxa Richness and Biotic Index (Plafkin et al 1989) were calculated for Sites 2 and 16. The calculations compared historical data to data taken following construction. The Shannon-Wiener and Simpson Indices (Zimmerman 1993) were also utilized. These were calculated for the first week and fifth weeks following construction and the final collection date(2/27/01) at Site 2, 16, and 19.

The data was entered into Microsoft Excel for database storing as well as graphical analysis of the data.

RESULTS

The raw data for the benthic macroinvertebrate densities can be found in Appendix B, Table 1-3. Table 1 indicates the taxa present as well at the densities of macroinvertebrates at Site 2. It breaks down each of the weekly samples and gives populations of each of the taxa present, number of organisms that comprise the sub-sample, and grids necessary to arrive at a 100-organism sub-sample. Densities ranged from 57 org/m^2 following construction to peak at 972 org/m^2 18 weeks after construction (2/06/01). Table 2 includes the taxa present as well as the densities of macroinvertebrates at Site 16. Table 2 breaks down each of the weekly samples and gives populations of each of the taxa present, number of organisms that comprise the sub-sample, and grids necessary to arrive at a 100-organism sub-sample. Densities at Site 16 ranged from 57 org/m^2 following construction to 1818 org/m^2 16 weeks after construction (2/06/01). Table 3 shows the taxa present as well as densities of macroinvertebrates at Site 19. The composition of Table 3 is similar to previously mentioned tables but applies to Site 19. Densities at this site ranged from 1 org/m^2 after construction to 630 org/m^2 on 2/27/01, 17 weeks after construction.

Graphical analysis of the benthic macroinvertebrate data can be found in Appendix B, Figures 7-10. Figure 7a is a density curve showing the colonization at Site 2 beginning with the first week after construction and culminating on February 27, 2001. Comparison of data collected following construction this year and data collected prior to construction by Kratzer shows similar densities in the beginning but as high as an 8-fold increase by the end of the study period (Appendix B, 7b). Taxa composition shows that there was a dominance of Ephemeroptera in the samples collected (Appendix B, Figure

7c). Figure 8a is a density curve showing the colonization at Site 16 beginning with the first week after construction and culminating on February 27, 2001. Comparison of data collected following construction this year and data collected prior to construction by Kratzer shows similar densities in the beginning but as high as an 10 fold increase by the end of the study period (Appendix B, 8b). Taxa composition shows that there was dominance of Ephemeroptera in the samples collected (Appendix B, Figure 8c). Figure 9a is a density curve showing the colonization at Site 19 beginning with the first week after construction and culminating on February 27, 2001. Taxa composition shows that there was dominance of Ephemeroptera in the samples collected(Appendix B, Figure 9c). Graphical analysis shows that the increase in densities was greatest at Site 16 but the more uniform colonization increases occurred at Site 19 (Appendix B, Figure 10).

Diversity index calculations had little variation. Taxa Richness calculations at Site 2 for the sample collected following construction had diversities of 93%, 171% , and 120% of reference (Appendix B, Table 4). Taxa Richness calculations for Site 16 yielded 100%, 78.95%, and 100% of reference (Table 4). The Biotic Index for Site 2 ranged from 1.892 to 2.2 (Table 4). At Site 16, significant difference occurred between the sample following the first week of construction and its comparison date, 1.561 and 2.762, respectively (Table 4). The remaining comparisons at Site 16 were 1/12/00 to 1/9/01 and 3/6/00 and 2/27/01, resulting in 2.114 to 2.462 and 2.453 to 2.456, respectively (Table 4). The Simpson Index calculations for Site 2 resulted in 0.922 for the first week following construction, 0.828 for the fifth week following construction, and 0.743 for the final collection date (Table 4). The Simpson Index calculations for the first, fifth, and final weeks following construction were 0.834, 0.785, and 0.694, respectively(Table 4). The

Simpson Index for the fifth and final weeks following construction were 0.805 and 0.736, respectively(Table 4). The Shannon-Wiener indices for Site 2 for the first, fifth, and final weeks following construction were 3.636, 3.322, and 2.584, respectively (Table 4). At Site 19, these indices yielded scores for the first, fifth, and final weeks of 3.636, 3.322, and 2.584, respectively (Table 4). Shannon-Wiener index calculations at Site 19 for the fifth and final weeks following construction were 2.058 and 2.574, respectively (Table 4).

Appendix C is the compilation of fish data collected during the Summer and Fall of 2000. Table 5 is a list of all tagged trout and their pertinent data. During this time 26 trout were tagged, identified, measured, and 12 of these trout were also aged. Ages ranged between 1 and 5 years of age. Graphical analysis of the populations of the fish and their placement into specific size classes over the past 2 years has shown that there has been a shift in the dominant size class of trout making up the stream (Appendix C, Figure 11).

Appendix D is material pertaining to the physiochemical data taken from Big Bear Creek beginning in August 2000 and ending March 2001. Table 6 shows the physiochemical data for the four sites monitored monthly. Little fluctuation in the parameters occurred over the course of the study. Missing data from winter months due to ice over (primarily NDS).

DISCUSSION

The construction of the Rosgen-style fluvial geomorphologic structures had a sizable impact on the benthic macroinvertebrate community of Big Bear Creek. The construction had impact on the densities of macroinvertebrates at all sites for a period of time following completion of the project but this time frame was brief.

At Site 2, the two weeks following construction had density levels of 57 and 33 organisms/ meter^2 respectively (Appendix B, Table 1) but by the third week, a density of 104 org/m^2 had been reached (Appendix B, Table 1). Based on historical data, this is the average density of macroinvertebrates found in Big Bear Creek (Kratzer 2000). The major climb in densities came in the fourth week (Appendix B, Figure 7a) and on December 5, 2000 and again February 5, 2001 (Appendix B, Figure 7a). Densities at Site 2 following construction were higher for all dates after October 31, 2000 as compared to historical data collected during similar times and by similar means during last year's survey (Kratzer 2000)(Appendix B, Figure 7b). The densities found after construction were as high as 8 times greater than densities calculated prior to construction. Analysis of Taxa Richness shows that at Site 2, values of 171% of reference and 120% of reference were present showing that a diversity increase occurred at this site following construction.

Site 16 exhibited similar trends to Site 2 in terms of density. The first four weeks following construction had densities of 57, 92, 52, and 29 org/m^2, respectively (Appendix B, Table 2). The fifth week following completion of the project seemed to be the pivotal week at this site in terms of density. This sample yielded a density of 294 org/m^2 (Appendix B, Table 2), well above the average gathered in last year's surveys at the same site during a similar time. Kick samples taken the previous year yielded densities of 110 org/m^2 on average (Kratzer 2000)(Appendix B, Figure 8b). The major shift in density numbers occurred between November 28, 2000 and December 5, 2000 (Appendix B, Figure 8a). At this site, the difference in densities between pre- and post-construction data was as high as 10 fold in favor of the post construction data (Appendix B, Figure 8b). Analysis of Taxa Richness showed that no difference in diversity occurred as a result of construction at this site.

Site 19 exhibited the most severe impact upon the macroinvertebrate community following disruption during construction of the structures at that site. Densities of 1, 7, 1, 9 and 113 org/m2 were calculated for the first 5 weeks following construction, respectively (Appendix B, Table 3). The densities of the samples drastically increased following the fifth week after completion (Appendix B, Figure 9a).

The analysis of the diversity indices for the Taxa Richness Index showed that there was an increase in diversity at Site 2 when compared to the historical data. The calculations for the fifth week after construction had a diversity that was 171% of the historical reference data gathered in Kratzer's study. The sample from the final week of collection had a diversity of 120% of the reference (Appendix B, Table 4). This indicates that there has been an increase in diversity at this site following construction. Similar calculations at Site 16 showed no change in diversity following construction. The Biotic Index at Site 16 for the first week following construction (10/31/00) yielded a score of 1.561 while its comparison sample (11/2/99) yielded a score of 2.762 (Appendix B, Table 4). This shows that there is a significant improvement in the biotic index following the construction. The remainder of the calculations showed no other significant differences in terms of diversity. Due to the number of calculations and only two instances resulted in significant differences, it is concluded that little change in diversity resulted from construction.

The major change in densities across all sites seemed to occur following the fifth week after construction was completed on each site (Appendix B, Figure 10). Each of the sites seemed to have a considerable increase in densities and there are a few possible reasons for this occurrence. One possibility may be linked to the return of the periphyton community to the disturbed substrate. Periphyton became readily visible at this time, but no analysis was done on the periphyton community to give accurate measurements of the colonization rates. Periphyton is a major contributor to the diet of the grazing macroinvertebrates and may have facilitated their colonization. The biomass, however, of a benthic algal bloom is a poor predictor of a stream to support grazing (Stevenson et al 1996). The rapid colonization of the periphyton may have corresponded with either time or sunlight patterns. Five weeks may have been the proper time frame to see the return of the periphyton colonies on disrupted substrates such as these. This was also the period of time when the canopy was void of leaves, allowing large amounts of sunlight to reach the stream and enhance the colonization rates of periphyton.

Another possible explanation of the rapid macroinvertebrate return is the act of normal behavioral drift. Normal behavioral drift has the organisms moving to new areas to eliminate competition caused by overpopulation (Smock 1996). A major result of drift is that artificially cleared areas are rapidly colonized from animals from upstream. A study near Philadelphia focused on a channel disruption event occurring in August and by November *Taeniopteryx* were present. At this same site, not long after completion of the construction, *Simulium, Baetis*, and *Stenonema* had recolonized(Hynes 1972). This information is important in that all of these genera are common in Big Bear Creek. Muller studied a 150-m stretch of Skravellbacken, Sweden which had been cleared by a Caterpillar tractor, similar to the construction at Big Bear Creek, and found large-scale colonization of Chironomidae, *Simulium*, Ephemeroptera, Trichoptera, and Plecoptera after 4 days following construction in Autumn and 10 days in Winter(Hynes 1972). This research was only on a 150m stretch while the reach that was disrupted in Big Bear Creek was 1.8 miles so the colonization rates are not likely to be similar.

The most influential factor for the rapid return as well as the increase in density of macroinvertebrates is the change in the substrate that resulted from the construction. Prior to construction, there was a majority of boulder substrate and the riffle- pool regime was not well developed. During construction, the large machinery crushed the boulders by running over the streambed while building the structures, leaving behind more suitable cobble substrate for macroinvertebrate colonization. Prior to restoration, cobble substrate would be transported in high water events and deposited in gravel bars. With the restoration producing a more stable system, the amount of cobble transport has been cut back considerably. This allows the macroinvertebrates to colonize more easily and it is more permanent, allowing populations to grow. The higher percentage of suitable substrate has created a larger area for the macroinvertebrates to colonize and as a result a higher population density.

The effect that the structures have on the substrate and therefore the macroinvertebrates can be seen clearly at Site 19. The structures built at Site 19 are not functioning to full potential. It is uncertain whether there were design problems, construction errors, or whether all the small upstream miscalculations manifest themselves on these structures causing them to not to function properly, but never the less they are not functioning to full potential. This has resulted in less stabilization and less suitable substrate for the macroinvertebrates to inhabit. Boulders still predominate in this area but there is more cobble present than before the construction took place. Site 19 had a peak density around 600 org/m2 while other sites peaked at roughly 1000 org/m2 (Site 2) and more than 1800 org/m2 (Site 16) (Appendix B, Figure 10).

Another aspect noticed about the restored areas as compared to areas that remain unaltered is that the unaltered arêas have a propensity to freeze. Only one sampling effort was aborted on the restored section because of anchor ice while the NDS reference site had shelf ice or anchor ice preventing sample collection for most of the winter months. This is mainly due to the riffle/ run pattern present on the restored section that is missing on the unrestored areas. The unrestored areas are shallow and wide over a great length making them more likely to freeze due to the fact that more surface area is exposed to the colder air temperatures.

Along with the macroinvertebrate study, a continuation of the monitoring in trout populations was done for the effects that the cessation of stocking was having on the wild trout populations of Big Bear Creek. In the past year, there has been a shift in the size class that makes up the largest percentage of the population. Data from 1999 shows that the major size class was the less than 10 cm size class trout (Kratzer 2000)(Appendix C, Figure 11a). During electrofishing outings this season, the majority of the catches fell in the 10-15cm-size class (Appendix C, Figure 11b). The number of specimens used does not allow for definite conclusions, but it appears that there has been a shift in the size class. However, the main factor for this apparent shift may be due to low catches brought about by equipment failure faced in the Fall 2000.

A troubling issue is the lack of recruitment taking place. With the shift in dominant size class, there should not be such a decline in the less than 10-cm size class. This decline could be attributable to the fact that the construction disrupted the breeding behavior because it fell at the same time as spawning and possibly few offspring were produced to fill this void.

The question may be raised as to the means of invertebrate collection methods used with regards to density. In most density-specific research, the common method of collection is a Surber sampler but instead I opted for a D-frame kick net for my sampling tool. A D-frame is the method used by the Pennsylvania Department of Environmental Protection for their stream assessment studies. After extensive use of D-frames and the DEP protocol, this method was used because of comfort with the system as well as the ease of sampling that this method implies. Kratzer's study incorporated both Surber and Kick net samples. The kick samples alone were used for comparison because of the similarities between this method and D-frame kicks. When calculations were completed, the results were checked with the densities calculated with Surber samples and they were comparable with results obtained by the other methods. This alleviated the question as to the accuracy of the D-frame sampling method.

As the study progressed, a few topic areas arose for new studies as well as expansion upon this topic. A main area necessary for a better understanding of macroinvertebrate colonization is the drift behavior. Drift had a great effect on the colonization and therefore a study of drift behavior would greatly enhance interpretation of the present results. Another major influence on the results was periphyton colonization. With construction scheduled for later this year, it would be possible to study periphyton to determine whether there is correlation with macroinvertebrate return. The new construction scheduled would also allow another chance to gather data that would reinforce the conclusions found in this study. Also, to aid in determination of the effects of substrate, another pebble count should be conducted to get an idea of the extent of substrate change as a result of the structures. Since the structures at Site 19 are going to undergo reconstruction, an area of possible study would be to compare the return now to when they are functioning properly and see what kind of differences exist. Continuation of the monitoring will also be conducted for 3 more years so it will be interesting to see what the end result will be for those criteria.

Works Cited

Hauer, F.R., Lambert, G.A. Methods in Stream Ecology. San Diego: Academic Press, 1996.

Hynes, H.B.N. The Ecology of Running Waters. Toronto: U of Toronto Press, 1972.

Kratzer, J. The Effects of Trout Habitat Restoration and the Cessation of Stocking on Big Bear Creek. Lycoming College Honors Project. 2000.

Peckarsky, B.L., Fraissinet, P.R., Penton, M.A., Conklin, D.J. Freshwater Macroinvertebrates of North America. Ithaca: Cornell Univ. Press, 1990.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., Hughes, R.M. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. Environmental Protection Agency. 1989.

Rosgen, D. Applied River Morphology. Pagosa Springs: Wildland Hydrology. 1996.

Stewart, K.W., Stark, B.P. Nymphs of North America stonefly genera(Plecoptera). Thomas Say Foundation Entomological Society of America. 1988.

Stevenson, R.J., Brothwel, M.L., Lowe, R.L. Algal Ecology; Freshwater Benthic Ecosystems. San Diego: Academic Press, 1996.

Wiggins, G.B. Larvae of North America caddisfly genera(Trichoptera). Toronto: U. of Toronto Press, 1977.

Worobec, W. "Growing Greener Grant" 2000.

Zimmerman, M.C. Ecology lab notebook. Lycoming College. 1993

Figure 1: Map of Sites on Big Bear Creek

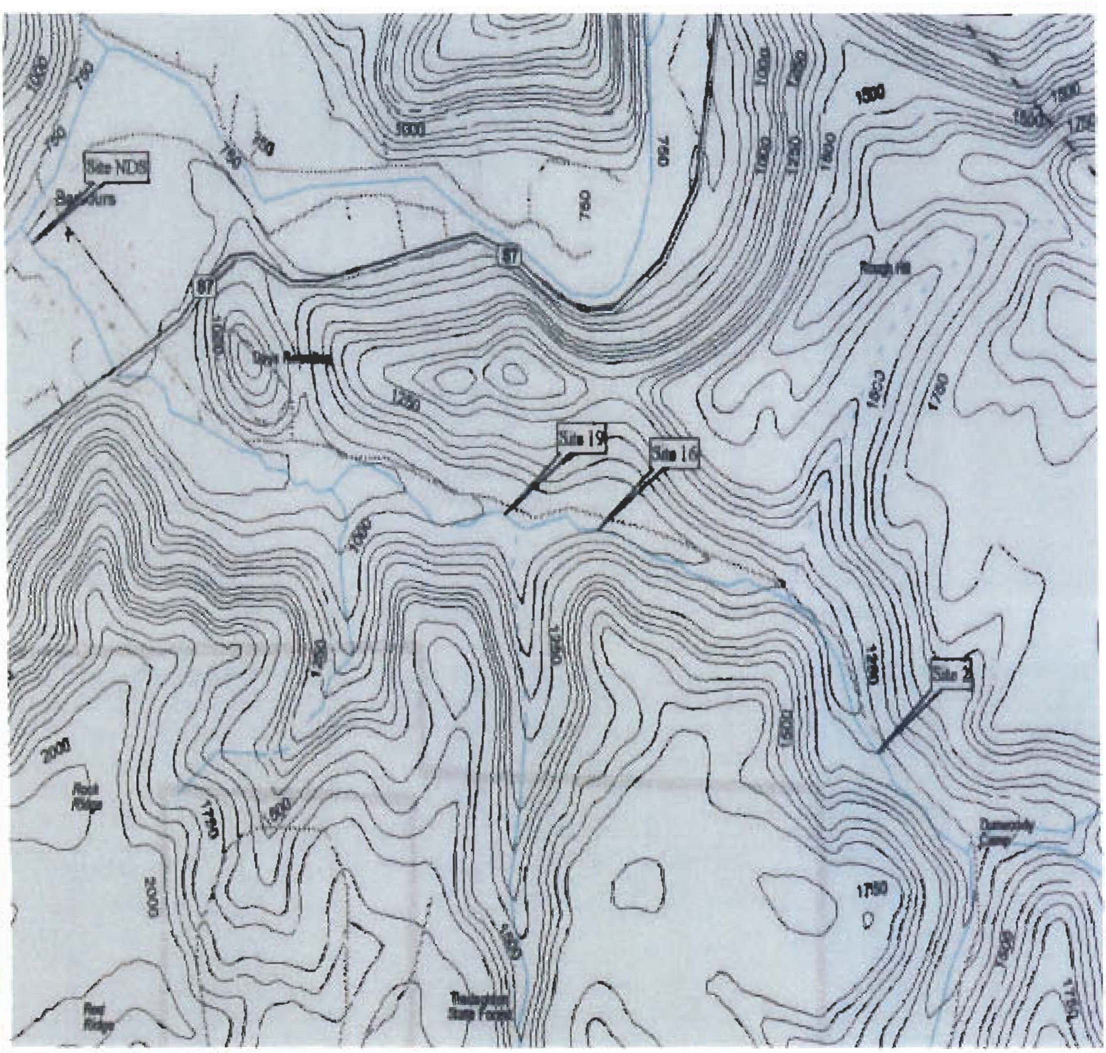


Figure 2: Construction at Big Bear Creek

a) Machinery preparing to build structure near Site 16

b) Building of structures at Site 19

c) Placement of boulders at Site 11

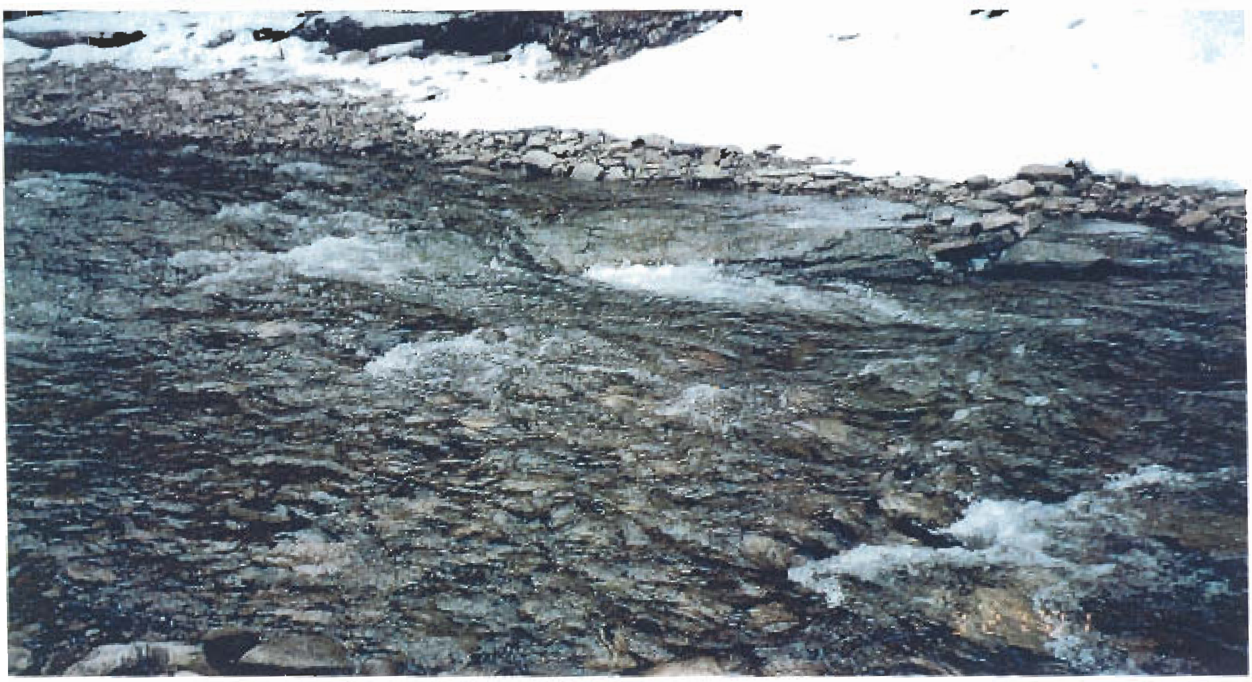
Figure 3: Pictures of Structure at Site 2

a) View looking slightly upstream at J-hook structure at Site 2

b) View looking down on J-hook structure at Site 2

Figure 4: Pictures of Structures from Site 16

a) View from right bank looking slightly upstream at J-hook structure at Site 16



b) view from left bank looking slightly upstream at J-hook structure at Site 16

Figure 5: Pictures of Structures at Site 19

a) view looking upstream at truncated cross vein structure at Site 19

b) view looking downstream on a second truncated cross vein structure at Site 19

Figure 6: Pictures from NDS Reference Site

a) view looking upstream at NDS reference(*notice eroded banks and midstream gravel bar as well as lack of pool water)

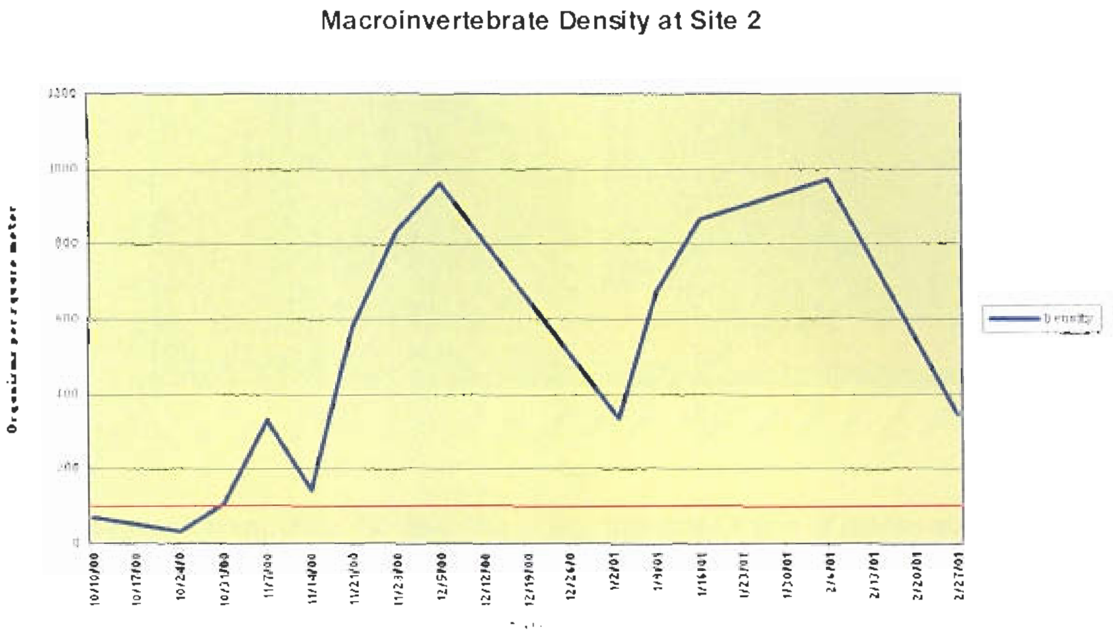
b) view looking downstream at Site NDS to the confluence with Loyalsock Creek(*notice expansive gravel bar and eroded bank on the right)

Appendix B

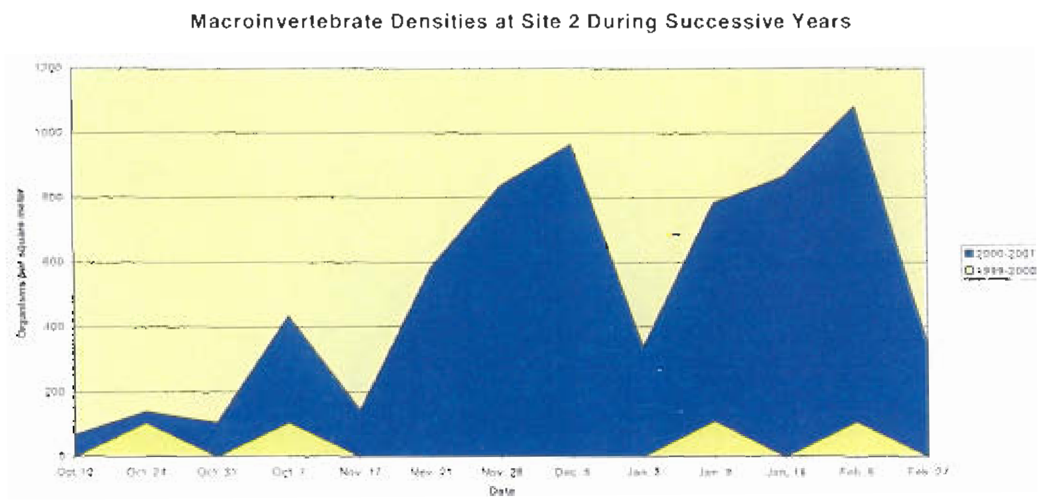
Table 1: Macroinvertebrate Data from Site 2

Taxa	10/10/00	10/24/00	10/31/00	11/7/00	11/14/00	11/21/00	11/28/00	12/6/00	1/3/01	1/9/01	1/16/01	2/6/01	2/27/01
Ephemeroptera													
Baetidae													
Baetis	7	4	9	40	28	29	33	44	18	32	39	22	20
Ephemerellidae													
Dannella												4	5
Ephemerella		6	24	77	30	12	16	6	6	9	8	6	8
Eurylophella		1		1	2							1	
Heptagenlidae													
Epeorus	9	1	48	101	45	44	31	27	53	49	51	37	48
Rhithrogena													
Stenacron		1		2	2								
Stenonema	4	1	1	6	1	1	1	S	1		S		1
Oligoneuridae													
Isonychia													S
Paraleptophlebidae													
Paraleptophlebia			1	2			1	1				S	1
Plecoptera													
Chloroperlidae													
Haploperla	6	2		2	9								
Sweltsa		6	3	18		3	4	2	7	4	5	8	2
Leuctridae													
Leuctra	1			3			S	S	2	S		1	
Nemouridae													
Amphinemoura											1		
Peltoperlidae													
Peltoperla	5	6		2	4	1	2	2	S				S
Perlidae													
Acroneuria				1									
Perlodidae													
Isogenoides	6		5	8	1	S	1	3		2	S	3	
Isoperla			1	1	1	1		3	4	2		1	
Pteronarcidae													
Pteronarcys		1					S				2		S
Taeniopteridae													
Taenionema		1		3	2	10	4	4	11	10	3	2	6
Taeniopteryx		1	1	4	5		1	1			S		
Trichoptera													
Brachycentridae													
Brachycentrus	2		1	2			S	S	1	S	S		1
Glossosomadidae													
Glossosoma				3					S		1		
Hydropsychidae													
Cheumatopsyche	1			3				S	S		1	1	
Hydropsyche	3		2	10			S	S		S		1	
Odontoceridae													
Psilotreta	1	1	5	5	4	S	15	4	3	1	2	1	S
Philopotamidae													
Dolophilodes	4			8	2	1	1	S	2				1
Polycentropidae													
Polycentropus					1								
Rhyacophilidae													
Rhyacophila				2			1					1	1
Coleoptera													
Elmidae													
Optioservus	1			2		1							
Odonata													
Gomphidae													
Lanthus	1			1									
Diptera													
Athericidae													
Atherix		1	1	5	1	4	S	1		1	1	S	1
Chironomidae	5		3	10	4	5		5	2		2		2
Simulidae													
Simulium				1		1	2	4	2	1	3	1	8
Tipulidae													
Antocha				4						1		S	
Hexatoma											S		
Tipula													
Oligochaeta	1												
Turbellaria												S	
TOTAL:	57	33	104	327	142	113	116	107	112	112	120	106	105
Subsample						7 of 24	5 of 24	4 of 24	12 of 24	6 of 24	5 of 24	4 of 24	11of 24
Density						581.14	835.2	963	336	672	864	972	343.632

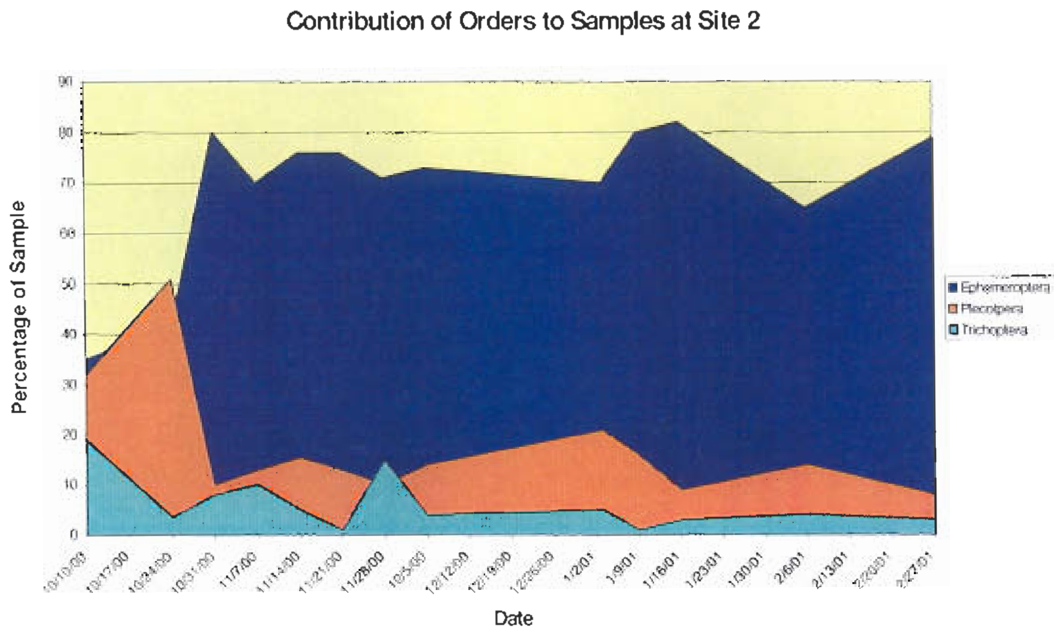
Figure 7 : Graphical Analysis of Macroinvertebrate Data from Site 2



a) Line graph showing the density of macroinvertebrates following construction of J-hook structure at Site 2. Red line signifies average of densities calculated from historical data.



b) Area graph comparing macroinvertebrate densities from data taken prior to construction(1999-2000) and following construction(2000-2001) at Site 2

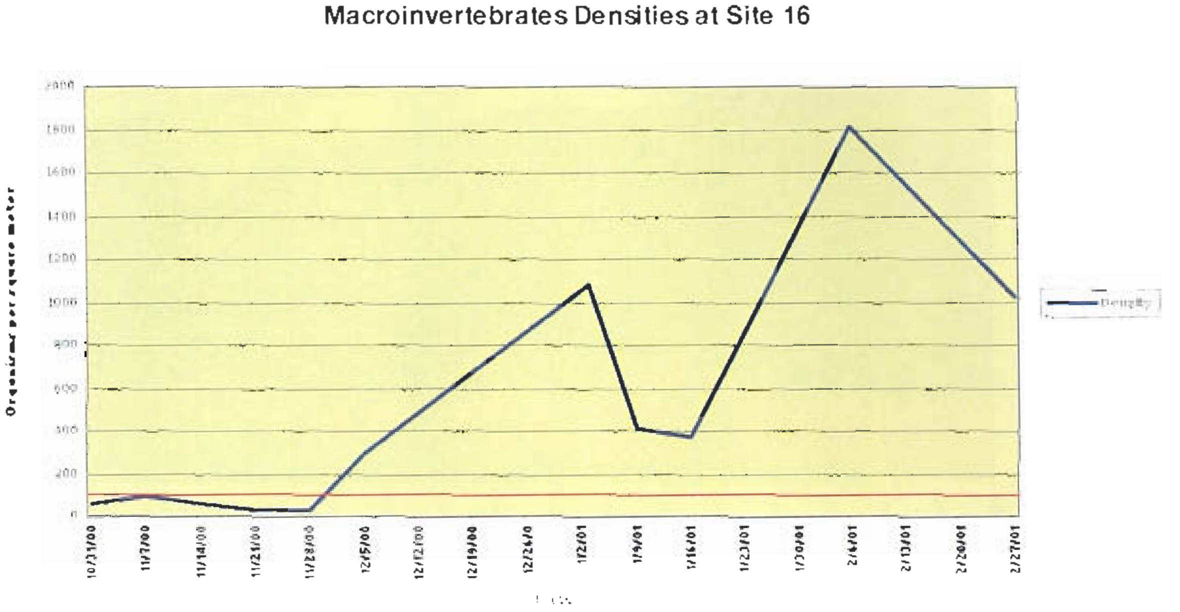


c) Area graph comparing the densities of the different Orders of macroinvertebrates in the samples taken at Site 2

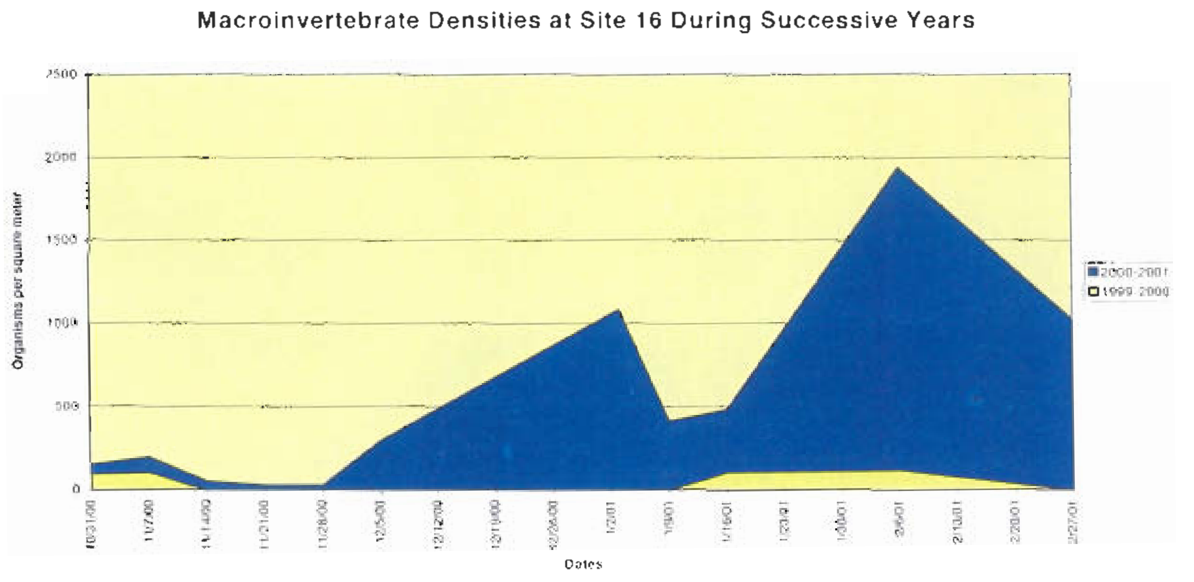
Table 2: Macroinvertebrate Data from Site 16

Taxa	10/31/00	11/7/00	11/14/00	11/21/00	11/28/00	12/5/00	1/3/01	1/9/01	1/16/01	2/6/01	2/27/01
Ephemeroptera											
Baetidae											
Baetis	2	9	5		31	12	23	27	62	29	36
Ephemerellidae											
Dannella										2	1
Ephemerella	5	10	5	1	19	5	1	5	15	S	2
Eurylophella		1									
Heptageniidae											
Epeorus	22	33	22	13	117	53	54	37	71	48	51
Rhithrogena	2	1				S			1		
Stenacron											
Stenonema	1	1					S			S	
Oligoneuridae											
Isonychia											
Paraleptophlebidae											
Paraleptophlebia	3	5	3	1	11	2	1	1	3	2	S
Plecoptera											
Chloroperlidae											
Haploperla	4								1		
Sweltsa		2	2	2	6	1	2	2	3	2	4
Leuctridae											
Leuctra		2						2			1
Nemouridae											
Amphinemoura											
Peltoperlidae											
Peltoperla	1	1	5	2	9	S		S		1	
Perlidae											
Acroneuria											
Perlodidae											
Isogenoides	2		1		1				1	S	S
Isoperla		1			5	1	6	2	4	3	2
Pteronarcidae											
Pteronarcys	1		1							S	S
Taeniopteridae											
Taenionema		4			22	13	13	17	50	10	9
Taeniopteryx	5	5	1	2	7	1		2	1	S	
Trichoptera											
Brachycentridae											
Brachycentrus		1		3	3		2	2	3	S	S
Glossosomadidae											
Glossosoma											
Hydropsychidae											
Cheumatopsyche			1		4				1	S	
Hydropsyche	2	2			3	1		S			
Odontoceridae											
Psilotreta	1	2	4	1	9	4	4		3	1	2
Philopotamidae											
Dolophilodes		1	1	1	3	3					
Polycentropidae											
Polycentropus											
Rhyacophilidae											
Rhyacophilia	1	1									
Coleoptera											
Elmidae											
Optioservus		1				1					
Odonata											
Gomphiidae											
Lanthus											
Diptera											
Athericidae											
Atherix		4		3	1	2	S		1		
Chironomidae	5	4	1		35	11	2	4	1	4	
Simulidae											
Simulium	1				9	10	2	2	15	1	6
Tipulidae											
Antocha								1			
Hexatoma										S	
Tipula		1									
Oligochaeta											
Turbellaria											
TOTAL:	57	92	52	29	294	120	114	104	256	101	114
Subsample						4 of 24	10 of 24	10 of 24		2 of 24	6 of 24
Density						1080	410.4	374.4		1818	1026

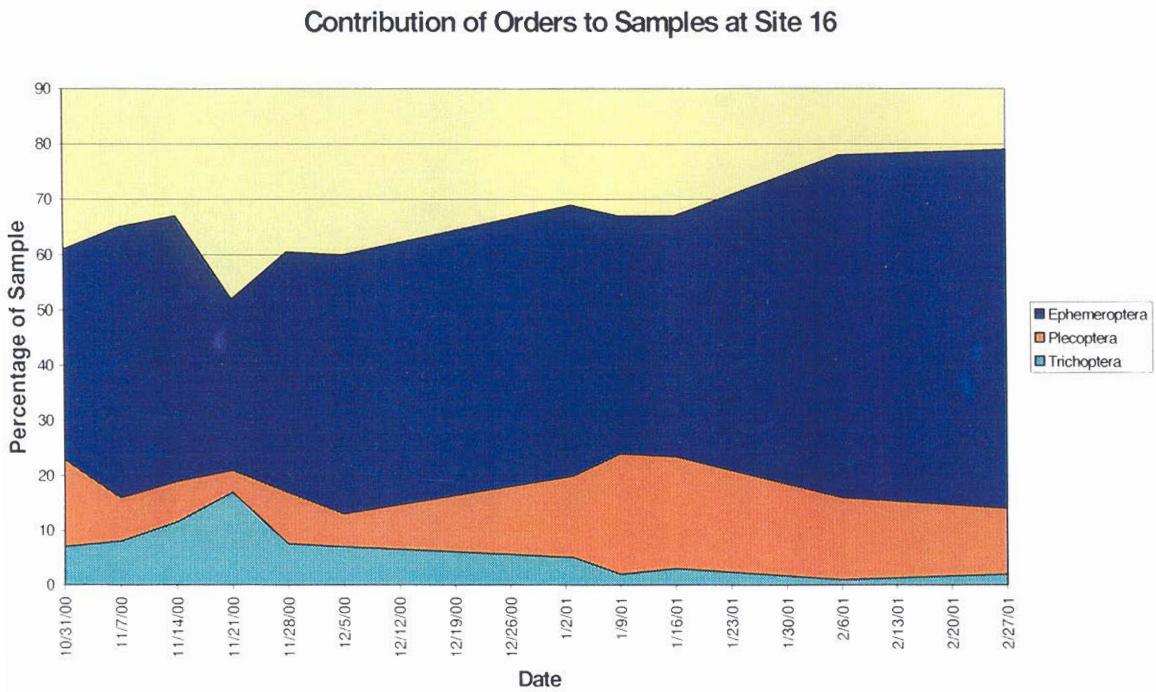
Figure 8: Graphical Analysis of Macroinvertebrates at Site 16



a) Line graph showing density of macroinvertebrates following construction of J-hook structure at Site 16. Red line signifies average densities calculated from historical data.



b) Area graph comparing macroinvertebrate densities from data taken prior to construction(1999-2000) and following construction(2000-2001) at Site 16

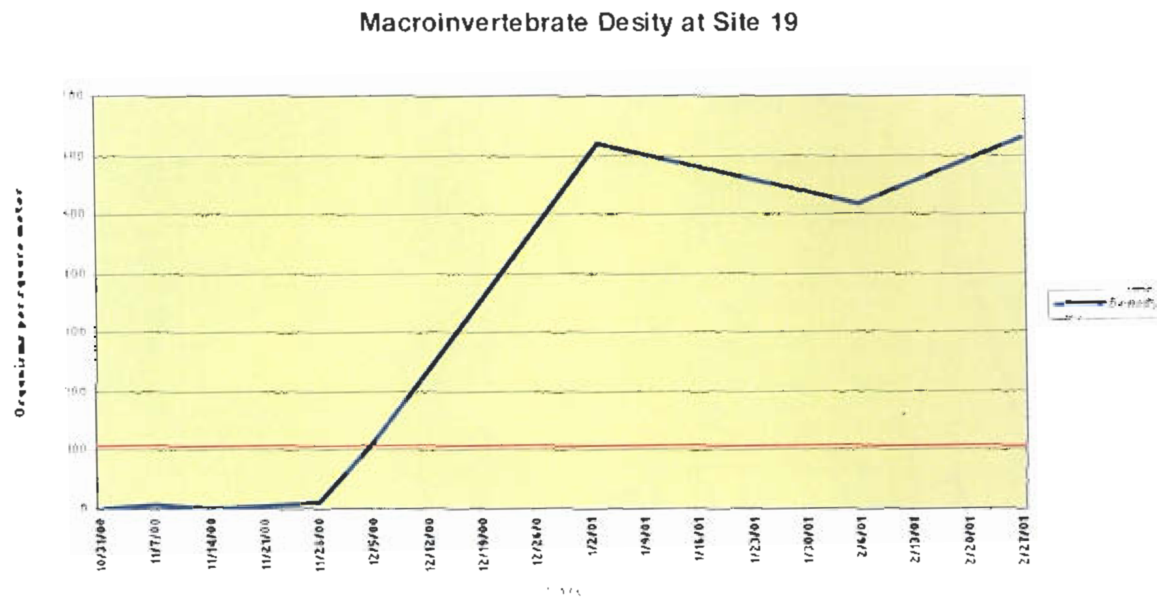


c) Area graph comparing the densities of the different Order of macroinvertebrates in samples taken at Site 16 following construction

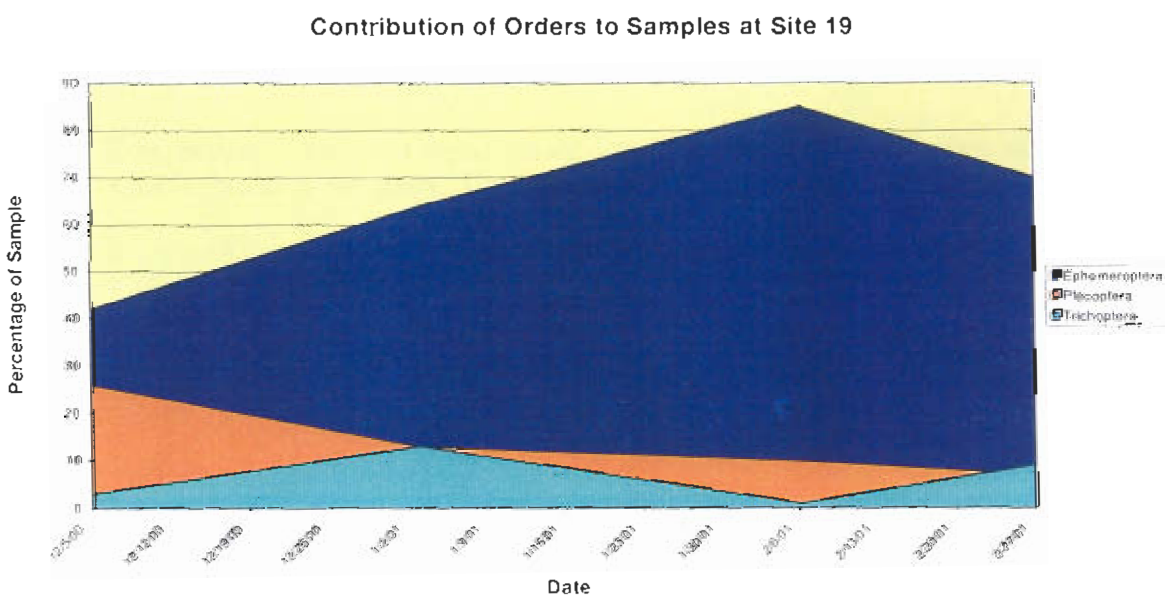
Table 3: Macroinvertebrate Data from Site 19

Taxa	10/31/00	11/7/00	11/14/00	11/28/00	12/5/00	1/3/01	2/6/01	2/27/01
Ephemeroptera								
Baetidae								
Baetis		1			17	13	5	15
Ephemerellidae								
Dannella								
Ephemerella					1	5	4	8
Eurylophella								
Heptageniidae								
Epeorus					27	46	69	50
Rhithrogena								
Stenacron								
Stenonema						S		
Oligoneuridae								
Isonychia								
Paraleptophlebidae								
Paraleptophlebia					2			1
Plecoptera								
Chloroperlidae								
Haploperla								
Sweltsa		2		1	6	1	3	S
Leuctridae								
Leuctra					4			
Nemouridae								
Amphinemoura								
Peltoperlidae								
Peltoperla	1					S		1
Perlidae								
Acroneuria								
Perlodidae								
Isogenoides						1	S	
Isoperla						1	1	2
Pteronarcidae								
Pteronarcys			1					1
Taeniopteridae								
Taenionema				1	19	9	7	3
Taeniopteryx						1		S
Trichoptera								
Brachycentridae								
Brachycentrus						5	S	3
Glossosomadidae								
Glossosoma								
Hydropsychidae								
Cheumatopsyche						1		
Hydropsyche		1			1	S		
Odontoceridae								
Psilotreta					1	7		6
Philopotamidae								
Dolophilodes					1		1	
Polycentropidae								
Polycentropus						S		
Rhyacophilidae								
Rhyacophilia						S		
Coleoptera								
Elmidae								
Optioservus								
Odonata								
Gomphiidae								
Lanthus								
Diptera								
Athericidae								
Atherix		1		1		1		1
Chironomidae		2		4	5	3	2	3
Simulidae								
Simulium				2	29	3	3	11
Tipulidae								
Antocha								
Hexatoma								
Tipula								
Oligochaeta								
Turbellaria								
TOTAL:	1	7	1	9	113	103	115	105
Subsample						6 of 24	6 of 24	6 of 24
Density						618	517.5	630

Figure 9: Graphical Analysis of Macroinvertebrate Data at Site 19

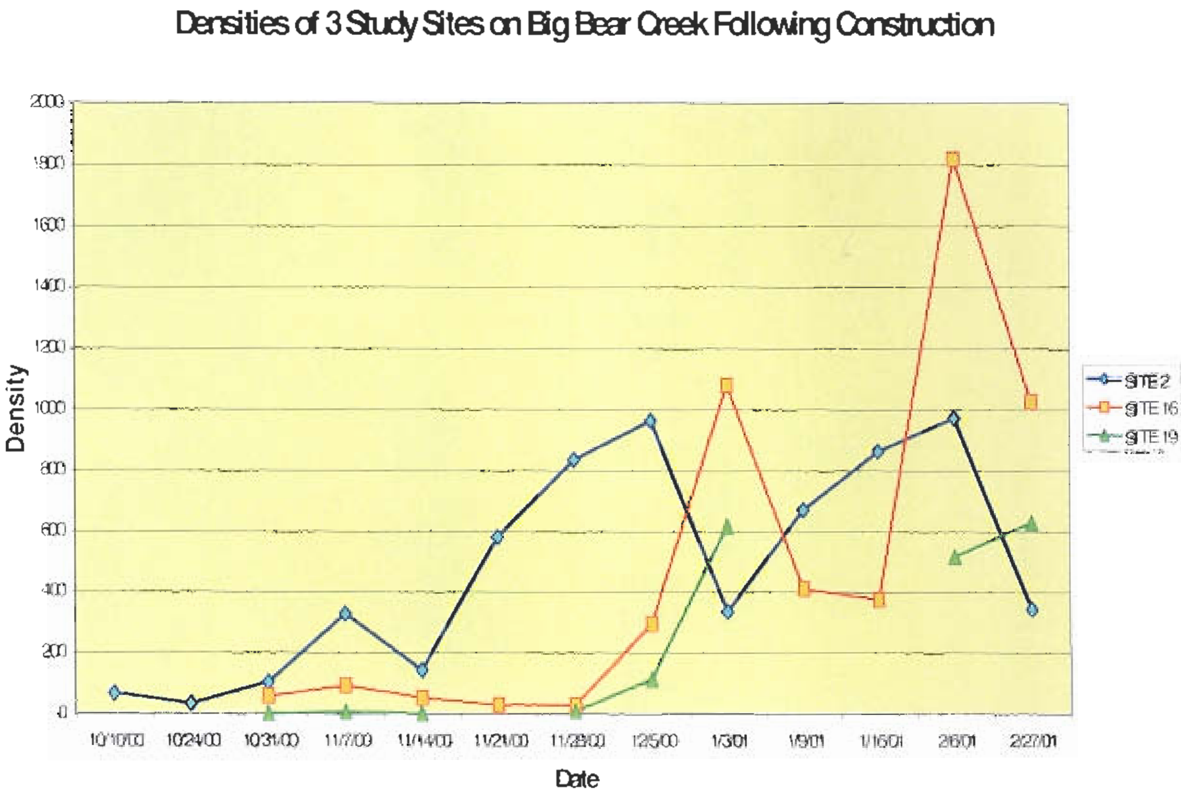


a) Line graph showing the density of macroinvertebrates following construction of truncated cross vein structure at Site 19



b) Area graph comparing the densities of the different Orders of macroinvertebrates in the samples taken at Site 19 following construction

Figure 10: Comparison of Desities of Macroinvertebrates Following Construction



a) Comparison of the macroinvertebrate densities following construction at each of the 3 sites included in the study. Construction ended on 10/10/00 at Site 2 and the week of 10/28/00 for both Sites 16 and 19.

Table 4: Diversity Analysis of Macroinvertebrates in Big Bear Creek

Taxa Richness

	Site 2	Site 16
1st week following construction	93%	100%
5th week following construction	171%	78.95%
Final sample	120%	100%

*comparison with historical data from comparable dates

Biotic Index

Site 2	
10/19/99	1.94
10/24/00	2.2
11/2/99	1.96
11/7/00	1.92
3/6/00	1.892
2/27/01	2.152
Site 16	
11/2/99	2.762
10/31/00	1.561
1/12/00	2.114
1/9/01	2.452
3/6/00	2.453
2/27/01	2.456

*comparison with historical data of comparable dates

Simpson

	Site 2	Site 16	Site 19
1st week following construction	0.922	0.694	
5th week following construction	0.828	0.785	0.805
Final Sample	0.743	0.694	0.736

Shannon-Weiner

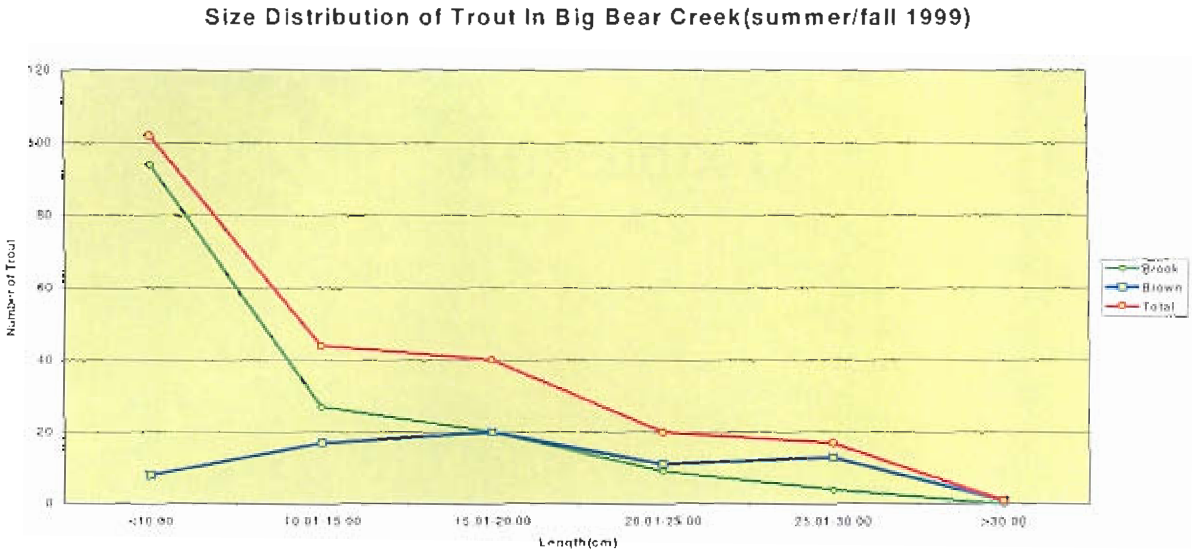
	Site 2	Site 16	Site 19
1st week following construction	3.636	3.208	
5th week following construction	3.322	2.664	2.058
Final Sample	2.584	2.153	2.574

Appendix C

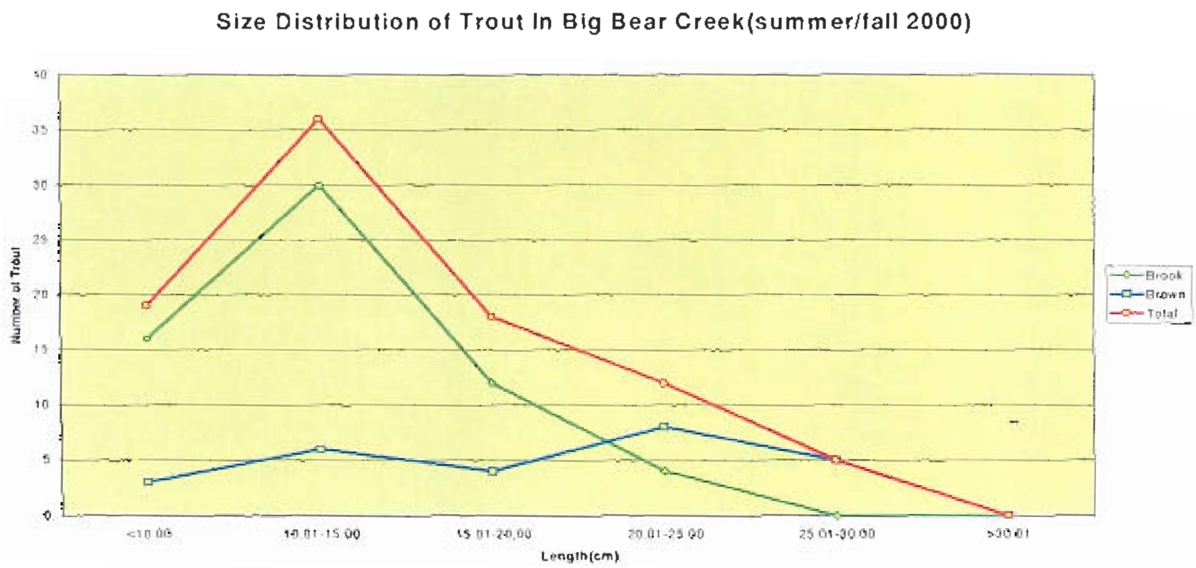
Table 5: Tagged Fish Data from Big Bear Creek
(Summer/ Fall 2000)

TAG#	Species	Length(cm)	Weight(oz)	Age(yrs)	Location
228	Brook	13	1		16
229	Brook	15	2		8
230	Brook	17	2		8
233	Brown	26.5	7	2	11
234	Brown	22	4	4	11
238	Brook	20.5	3	2	11
239	Brown	26	6		2
418	Brown	21	4	3	11
428	Brook	18	3		2
430	Brown	17	2		2
431	Brook	22	5		2
434	Brown	19	4		2
450	Brown	22	3	3	7
451	Brown	12.5	1		16
452	Brook	17.5	2		16
453	Brook	19.5	4		16
454	Brook	17	2		14
455	Brook	23	5		14
456	Brown	24	6	3	9
457	Brown	20	5	2	9
461	Brown	24.5	6	5	7
462	Brown	22	5	4	7
467	Brook	22	4	2	6
472	Brook	15	2	1	11
475	Brown	26	8	3	11
480	Brown	22.5	4		11

Figure 11: Comparison of Size Distributions of Trout in Big Bear Creek



a) comparison of the numbers of trout in various size classes collected during electrofishing sessions during Summer and Fall 1999



b) comparison of the numbers of trout in various size classes collected during electrofishing sessions during Summer and Fall 2000

Appendix D

Table 6: Physical/ Chemical Data from Big Bear Creek

Plunkett's Creek Township, Lycoming County

Site 2

Date	pH	Alkalinity (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho P. (mg/L)	D0 (ppm)	Temp (c)
8/29/00	5.95	0.06	0.5	0.003	NA	9.8	15.2
9/25/00			1.3	0	0.06		
10/31/00	6	3.5	0.7	1	0.07		
11/28/00	6.97	0.01	0.1	1	0		
12/20/00	6.96	0.01	0	0.002	0	14.6	0.4
1/30/01	6.49	0.33	0.8	0.003	0.2	14.2	1.9
2/27/01	5.84	<0.01	0.1	0.003	0.1	14.26	37

Site 16

Date	pH	Alkalinity (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho P (mg/L)	DO (ppm)	Temp (c)
8/29/00	6.06	0.01	0.7	0.0053	NA	9.68	15.6
9/25/00			1.1	0	0.21		
10/31/00	5.79	<.01	1	1	0.04		
11/28/00	6.71	0.03	0.2	1	0		
12/20/00	6.19	0.01	0	0.001	0.01	14.58	0.4
1/30/01	6.45	0.48	0.9	0.01	0.3	14.29	1.3
2/27/01	6.19	0.05	0	0.004	0.1	13	37

Site 19

Date	pH	Alkalinity (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho P (mg/L)	DO (ppm)	Temp (C)
10/31/00	6.79	<.01	0.5	2	0.03		
11/28/00	6.67	0.09	0.2	2	0	12.56	5.3
12/20/00	6.26	0.01	0	0	0	14	0.4
1/30/01	6.49	0.5	0.8	0.002	0.3	14.2	1.2
2/27/01	6.17	0.07	0.01	0.002	0	12.26	37

Site NDS

Date	pH	Alkalinity (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho P (mg/L)	DO (ppm)	Temp (C)
9/25/00			1.2	0	0.16		
11/28/00	6.82	0.11	0.3	2	0	12.36	5.4
12/20/00							
1/30/01							
2/27/01	5.92	<0.01	0	0.006	0.3	11.77	37