The Effects of Trout Habitat Restoration and the Cessation of Stocking on Big Bear Creek

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Abstract

The brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) fishery of Big Bear Creek, a tributary of the Loyalsock Creek in Lycoming County, Pennsylvania, has been declining over the past several decades. The construction of 38 boulder structures, in accordance with Rosgen, was completed in October 1999 in order to help the stream deal with a large sediment load from the removal of a 100 year old dam in 1996. The structures are intended to protect the stream banks, narrow and deepen the stream, and provide more trout habitat. Stocking of hatchery-raised trout was ended in 1999 in hopes that wild trout would provide a sufficient fishery within a few years.

This study determined the immediate impacts of habitat construction and will be used as a baseline for the next 4 years of study. No major changes occurred in water chemistry as a result of construction other than a rise in turbidity from 0 to 21 FAU (FAU = NTU), but even the turbidity returned to normal after construction. The density and makeup of the benthic macroinvertebrate community was not significantly impacted by construction. Construction caused a small scale migration of fish away from the disturbed areas, with electrofishing catches of adult and age 0+ trout decreasing by 48% and 45%, respectively, in a site that underwent the construction of 4 structures.

Introduction

Civilizations have always depended on a water source, and this dependence often meant the clustering of villages and cities along river systems. Unfortunately, humans have a tendency to destroy their natural surroundings, and rivers are certainly no exception. Industries have released their toxic pollutants into rivers. Dams have been built to control flooding, but they also block fish migration and change the river's natural flow. Introduced species of fish and plants have severely threatened the existence of many native species. Withdrawal of water for agriculture and industry has reduced the amount of water available for river life, and some rivers, such as the Colorado River, don't even reach the sea anymore. Acid mine drainage and acid rain have fatally lowered the pH in many northeastern US streams. Agriculture, deforestation, and riparian disturbance have increased sediment loads in streams and rivers. These sediment loads can be deposited in rivers, thereby decreasing the availability of fish habitat and killing fry and invertebrates living in the river's substrate. In Pennsylvania alone there are 16,000 stream miles with unnaturally high sediment load problems, making sediment the leading form of water pollution in the state (Worobec 2000).

Big Bear Creek, located in Lycoming County, Pennsylvania, is a fourth order stream surrounded by hemlock-hardwoods forest and is a tributary of the Loyalsock Creek. It has a 17 square mile watershed that is 80% forested. The section of Big Bear Creek under study has been privately owned since 1887. The Dunwoody Club, which owns this stretch, has kept informal fishing records since this time, and they have noticed a decline in trout populations over the years (see Figure A, Appendix I). They began annually stocking catchable trout in 1923 in an attempt to increase the fishery's quality.

The stream provided a world renowned trout fishery until the 1970's. Hurricane Agnes in 1972 and Hurricane Eloise in 1975 caused considerable damage to the stream. In 1980, a downstream landowner constructed a dam that blocked fish migration from the Loyalsock and caused aggradation of the streambed above the dam. Aggradation occurs when sediment is deposited more than it is carried downstream, causing the stream to get shallower and wider, which is less favorable to trout. By raising the streambed height, this dam caused problems upstream.

Sediment load has also plagued Big Bear Creek. In 1996, a 100 year old dam was removed from the Dunwoody Club property, sending 100 years of accumulated sediment down the creek. It will be many years before the stream is able to work this sediment load through, and while it does, the stream will remain shallow and wide. Severe bank erosion has been another problem that has caused the stream to become shallower and wider. There are three slide banks along the stream that contribute to the stream's sediment load, and the flood of January 1996 also harmed the fishery. (Worobec 2000)

The result of all these negative impacts on Big Bear Creek is that trout habitat had become relatively limited. The severe bank erosion, the dam built in 1980, and the dam removed in 1996 caused the stream to erode away at its banks and deposit sediment in its center, making the stream wider and shallower. The floods also contributed to these conditions. The problem is that trout prefer deeper, slower water, especially in winter (Johnson and Dropkin 1996, Cunjak and Power 1986, Baltz et al. 1990).

To correct these habitat problems, Rosgen's Applied River Morphology (1996) was used as a guide. Rosgen's methods have been used successfully in the western United

States (Schmetterling 1998, Ross 1994, Monde 1998), and they are just starting to be used in the eastern United States. Rosgen's book explains the classification of streams based on many mathematical parameters such as entrenchment, width/depth ratio, sinuosity, channel materials, and slope. Based on the stream's classification, several types of habitat improvement structures are suggested, but it is extremely important that these structures don't change any of the aforementioned mathematical parameters. This mathematical and scientific method of habitat improvement ensures that the stream will work with the installed structures rather than against them, as can occur when structures are built without regard to the stream's geomorphology (the study of a stream's characteristics, origin, and development). For example, a log dam built on Big Bear Creek in 1996 was so high above bed height (around 0.5m), that the pool above the dam had become filled in with cobble and smaller debris to the point that the stream was getting wider and shallower above the dam. The dam built in 1980 is causing the same types of problems but on a larger scale because it is around 3m tall. By paying attention to the stream's geomorphology, this type of incorrect habitat "improvement" can be avoided.

Big Bear Creek was classified as a B3 stream based on Rosgen's classification system. In 1996, Dunwoody Club members 14 log single veins, cross veins, and cross weirs were put in place in accordance with Rosgen's techniques. These were the first structures of their kind built in Pennsylvania, and possibly the first in the entire East Coast. In October 1999, 4000 feet of stream were restored with 38 more boulder truncated cross veins (Figure D, Appendix I) and J-hook veins (Figure C, Appendix I). By September 2001, the Dunwoody Club hopes to have built 145 more structures and bypass the dam that was built in 1980 (downstream from Dunwoody property). These structures all work by causing the water's flow to erode the stream bottom instead of the stream banks, making the stream deeper and narrower and forming some slower eddies for trout holding areas and sediment deposition along the banks.

These structures are unique because they "roll" the water in the desired directions based on the fact that water will pass over the structure at a 90 degree angle, rather than "push" the water, like many traditional structures attempt to do (Worobec 2000). Traditional structures, such as wing dams and gabions, push water to the center of the stream under normal flow conditions; however, under flood conditions, water overtops the structure, eroding away at the very bank that was supposed to be protected by the structure (Worobec 2000). Figure B (Appendix I) shows a gabion (a wire basket of rocks) that had caused this phenomenon on Big Bear Creek before being removed in the Fall of 1999. The structures built on Big Bear Creek in October 1999 work the same at all flow levels and are most effective in flood conditions (Worobec 2000).

These structures are only serving to accelerate the natural processes that would occur over many years. The sediment load from the removed dam would eventually work its way through the stream. If the bank erosion continued to be a problem, it would wash away at the bases of trees, causing them to fall into the stream. The trees would alter stream flow, hopefully in ways that cause the stream to become deeper and narrower. With the banks protected from erosion by the fallen trees, riparian vegetation, such as sedges and willows, would be able to take root and provide further stability to the stream's banks. Big Bear Creek has not been able to recover naturally because of the many damaging events that have regularly occurred since the 1970's.

Many studies (Yuskavitch 1999, Carline et al. 1991, Vincent 1983, Thuember 1975) have shown that when stocking is ended on a stream that has sufficient habitat, water quality, and food, wild trout populations are often able to rebound and provide a better fishery than was present when trout were stocked. Stocking has many ill-effects on wild trout populations including dilution of the gene pool (Goodman 1991). Hatchery-raised trout come from a very limited genetic background, and if they manage to breed with the more genetically diverse wild trout, the wild gene pool can be diluted. Also, since hatchery trout are artificially selected for and raised in a hatchery, they are unfamiliar with the social hierarchy of the stream. The stocked trout engage in long, energy-draining disputes with wild trout (Vincent 1983). The wild trout, wanting to conserve energy and avoid competition for food and habitat, will often flee the stocked area (Yuskavitch 1999).

Another problem with stocking is that it becomes addictive because most of the stocked trout are caught or die by the next fishing season. This high mortality is caused by the stocked trout's inability to minimize energy use by using slow water holding areas and lack of experience with natural foods (Mesa 1991, Bachman 1984). With this information in mind, the Dunwoody Club decided to increase the stream's habitat quality and end stocking to bring back a high quality wild trout fishery. Stocking was ended in the spring of 1999.

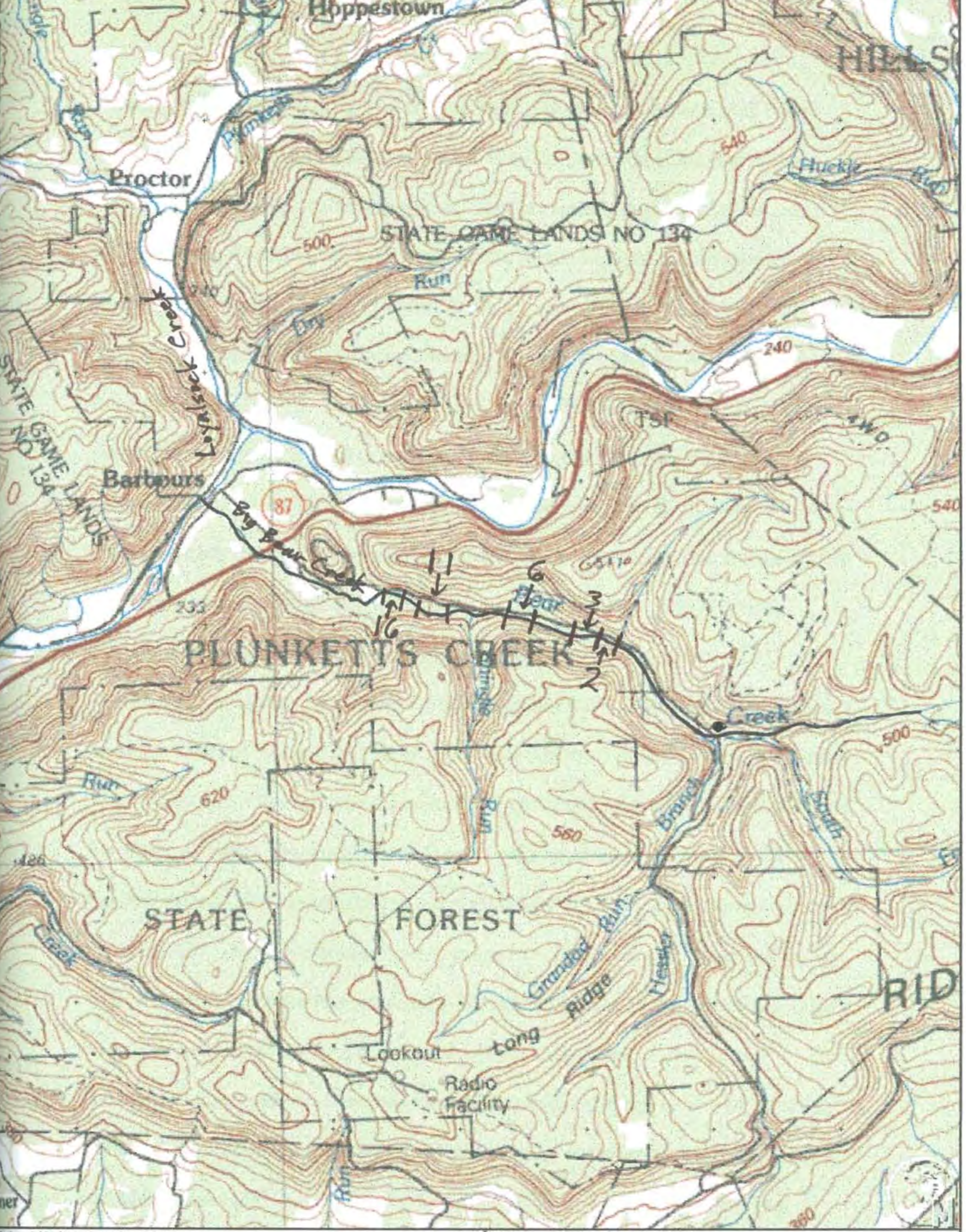
There are two goals for this study. One goal is to determine if the water chemistry, benthic macroinvertebrate community, and fish community are immediately affected by the construction process. Since heavy machinery was driven on the streambed and used to move the boulders into position (see Figure E, Appendix I), it seems possible that construction could cause some immediate negative impacts. The second goal is to provide baseline data in the water chemistry, benthic macroinvertebrate community, and fish community of this stream so that future studies can determine the long term effects of habitat restoration and the cessation of stocking on this stream section. Lycoming College will be studying Big Bear Creek for a five year period.

Methods and Materials

Table A (Appendix I) displays the results of the EPA's Rapid Bioassessment habitat assessment (Plafkin et al. 1989) on sites 2, 3, 6, 11, and 16. This habitat assessment relies on the researcher's interpretation of various habitat parameters in assigning scores from 0 to 20, and so it is very subjective. This method is very insensitive to slight differences in habitat quality that might occur between sites on a single stream, and by this method, none of the sites on Big Bear Creek were very different in terms of habitat quality. The stream's lowest scores occurred in "condition of banks" (highly eroded) and "channel flow status" (large areas of shallow water), which are two of the parameters that habitat restoration on this stream will improve.

Site 2 (refer to map) was the upstream control site because it had no structures built within it. Site 2 is 110m long with 1 pool and 1 run for a total of 35m of pool/run water. The other 75m consists of two riffles. A floating log structure is present at the pool, but it has been there for many years.

The upstream end of site 3 is about 30m downstream from site 2. Site 3 is 160m long, with 4 pools for a total of 50m pool/run water. The other 110m consists of 3 riffles. A log dam (a log perpendicular to the stream) and a wing dam (a structure that forces water into the channel at normal flow) are present at this site. Also, a dead tree was cabled to a



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standing tree and used to protect an eroding bank. These structures were built before there was an appreciation for Rosgen's methods by the Dunwoody Club, and so these structures are inappropriate for this stream. They are actually degrading habitat rather than improving it because they don't maintain the stream's natural geomorphology. No structures were built on site 3 in October 1999.

Site 6 is about 300m downstream from site 3. Site 6 is 67m long, with 6 pools for a total pool/run length of 52m. There are only 15m of riffles. This lack of riffles is mainly due to the two log single veins (a single log running across the stream but not perpendicular to it) that were built in 1996. These structures provide the deepest water of any of the study sites, reaching almost 2m deep at one point. One boulder truncated cross vein (boulders in a U-shape with the rounded end facing upstream) was built at the extreme downstream end of site 6 in October 1999.

Site 11 is about 300m downstream from site 6. Site 11 is 120m long with 5 pools and 1 run for a total of 60m pool/run water. The other 60m are 3 riffles. In 1996, a log cross vein (two logs in a V-shape with the point facing upstream), a log cross weir (a cross vein, but higher above the streambed), and a log dam were constructed on this site. The log dam (described in the introduction) was replaced with a boulder truncated cross vein in October 1999. Another truncated cross vein and two J-hook veins (boulders in the shape of a "J", with the rounded end upstream) were built in October 1999. One of these J-hook veins was constructed just upstream from the bridge that crosses at this site to demonstrate how these structures can prevent the erosion of bridge abutments by rolling water away from the stream bank. Site 11 had the most construction done on it of any of the sites under study.

Site 16 was the downstream control site and is about 500m downstream of site 11. Site 16 has 1 run for 25m, while the other 75m is riffle. No construction was ever done on site 16.

It is important to realize that structures were built at somewhat regular intervals all the way from above site 16 to below site 3. Sites 6 and 11 served as study sites representing the 4000ft of stream that were restored in October 1999.

Physicochemical data was collected at site 2 (the upstream control) and site 16 (the downstream control). Velocity was measured with a Swiffer Model 2100 velocity meter. Also, stream width and depth were measured so that discharge could be calculated. Water temperature and dissolved oxygen were measured on site with a YSI 55 DO meter. Conductivity was measured on site with a Hanna conductivity/TDS meter. Alkalinity and pH were measured in the lab with a Corning pH-meter 440 and Hach sension 2 (sulfuric acid titration for alkalinity). Nitrates, total phosphorus, reactive phosphorus, and aluminum concentrations (in ppm) were all measured in the lab using the Hach DR/4000 spectrophotometer. Physicochemical analyses were conducted roughly once a month from July to November 1999 and also in January, February, and March 2000. Turbidity was determined with the Hach DR/4000 spectrophotometer only once for sites 2 and 16, while construction was occurring.

Benthic macroinvertebrates were sampled at sites 2, 11, and 16. Kick samples were taken for use in the EPA's Rapid Bioassessment Protocol III, RBPIII (Plafkin et al. 1989), using a 100 organism sub sample. The kick sampling schedule was the same as the physicochemical sampling schedule. Sites 2, 11, and 16 before construction served as references for sites 2, 11, and 16 (respectively) after construction and in the winter. The

Community Loss Index, as described in EPA's RBPIII, also stood alone and was used to compare each site after construction to itself before construction and to compare sites 11 and 16 to site 2 on each sampling date.

Kick samples were also used to compare trends in the relative numbers of some of the major invertebrate taxa (e.g. *Baetis*, *Epeorus*, *Hydropsyche*, etc.) and to construct graphs showing the changes in relative numbers of some of the major Ephemeroptera, Trichoptera, and Diptera. Kick samples were also used to compare percentages of invertebrate communities in the various feeding categories (predators, shredders, collecting gatherers, scrapers, and filtering collectors).

A one square foot surber sampler was used to determine invertebrate community density. The average of two surber samples was taken for most sampling dates, and the surber sampling schedule was the same as the physicochemical and kick schedule. A comparison of monthly samples was used to determine the effects of construction-related disturbance. Student's t-testing was also used to determine if there were significant differences in invertebrate density related to construction.

Fish sampling was done with a pulsed-DC Smith-Root Model 15-A Electrofisher set to 1000V and 60Hz. Most sampling was done with a crew of around four or five at random dates from June to November. All fish were collected and counted. Trout over 10cm were measured for length and weight, were tagged, and had scales removed for aging at the lab. Aging was done with a compound microscope. The tags were intended to be used in a mark-recapture population estimate, but recaptures were so spotty that catch per 100m of stream was instead used to compare trout populations in the various sites. To compare catch per 100m, the mean number of fished captured in a site was divided by the site's length (in m) and multiplied by 100. Mark-recapture most likely failed due to the excessive length of time between successive runs and the extremely low conductivity of this stream. Conductivity ranged from 4.5ppm to 52ppm in the Fall, when it should be at least 100ppm for optimum electrofishing efficiency (Reynolds 1983). The conductivity remained constant enough so that a catch-per-unit-effort can be compared rather than making a population size estimate. The tags also provided information on the movement of trout between sites.

Site 2 was electrofished 4 times before construction and once after, site 3 was sampled once before and once after, site 6 was sampled once before and twice after, site 11 was sampled 3 times before and twice after, and site 16 was sampled once before and twice after. Sites 4, 5, 7, 9, and 10 were sampled only once before construction.

The EPA's Rapid Bioassessment Protocol V (Plafkin et al. 1989) was performed using the data obtained through electrofishing. The most important data obtained through electrofishing was a comparison of catch rates of the four fish species present in the various sites before and after construction. Brown trout (*Salmo trutta*), brook trout (*Salvelinis fontinalis*), slimy sculpin (*Cottus cognatus*), and Longnose dace (*Rhinichthys cataractae*) were the 4 species.

Age-length growth curves for brook and brown trout were constructed by plotting the mean length of each year class against the age of that year class. The length of age 0+ trout was estimated at 9cm since lengths were not taken on trout less than 10cm. It was assumed that all trout around 10cm or less were age 0+. This assumption was based on the fact that there was a large number of trout under this 10cm mark and no trout between 10cm and 12cm; therefore, there was a noticeable size gap between age 0+ and age 1+. A plot of numbers of brook and brown trout in various size classes was also constructed.

Results

Tables 1a and 1b show the physicochemical data. Viewing Figure 1 reveals slight increases in almost all of the chemical parameters during October (sampled during construction). Turbidity (not shown in Figure 1) went from 0 to 21 FAU during construction. Figure 1 also shows that after construction was completed, chemical parameter values at both the upstream and downstream sites were very similar. Figure 1 shows large spikes in conductivity and alkalinity in September, which were probably caused by the flood conditions that occurred on the stream during this sampling date.

Table 2 shows the individual metric scores and total scores for RBPIII for the Fall of 1999. Sites 2, 11, and 16 before construction were used as references for sites 2, 11, and 16 after construction, respectively. For this analysis, metric values were derived from an average of all sampling dates before and after construction. The total scores were all very similar for the three sites, and all were categorized as non-impaired following construction. A few of the metrics did show some change. Taxa richness was lower for site 11 (the site that underwent construction), the ratio of scrapers to filtering collectors was much lower for site 11, and community loss was higher for site 11.

Table 3 shows the individual metric scores and total scores for RBPIII for the winter of 2000. Sites 2, 11, and 16 before construction were used as references for sites 2, 11, and 16 from January to March, respectively. Metric values used in the calculations came from the averages of all sampling dates before construction and from the winter. All sites received non-impaired scores for the winter, although the total scores were mostly lower than the fall scores. Site 11's ratio of scrapers to filtering collectors was much lower than that of the other sites, as it was in the fall. Notable metric scores for site 16 include a high EPT (Ephemeroptera, Plecoptera, and Trichoptera) to Chironomidae ratio, a relatively high community loss, and a low ratio of shredders to total.

Table 4 shows Community Loss Index values. Sites 11 and 16 were compared to site 2 for each sampling date. Also, each sampling date at each site was compared to that same site in September. The only possibly significant community loss caused by the construction can be seen in site 11's November sampling, compared with site 2 for that date (0.46) and compared to September's site 11 (0.38). Statistical testing was not used to determine significant difference because the sample sizes were so small (only one per month per site).

Table 5 and Figure 2 show benthic macroinvertebrate density on a monthly basis. It appears as though there were no significant changes in density attributable to construction. If anything, density increased at site 11, even in areas where the machinery had actually disturbed the bottom.

Table 6 displays the values used for t-testing invertebrate density. The mean invertebrate densities of all sampling dates before construction, after construction, and for the winter were compared to each other. Before construction, site 2 had significantly greater invertebrate densities than sites 11 and 16. After construction (October and November) and in the winter (January to March), there was no significant difference in the invertebrate densities among the three sites. Site 2's invertebrate density significantly decreased after construction but significantly increased in the winter. Site 11's density significantly increased after construction and again in the winter. Site 16's density remained unchanged after construction but significantly increased in the winter.

Figures 3a to 3k display comparisons in the percent contributions of some of the major invertebrate taxa to kick samples throughout the study. No sampling was done during December, so December values are actually the average of November and January values. Although the percent contributions peak at different times for some invertebrates at some sites, the general trends are the same for all sites. The only dissimilarity that occurred in October (during construction) was a large drop in *Dolophilodes* at site 16. The high peaks for *Brachycentrus* and Athericidae on site 2 were probably cause by randomly sampling an area with unusually large amounts of these taxa.

Figures 4 and 5 show the average percent contributions of some of the major taxa during the study based on data from all three sites. These figures are included so that future studies can compare invertebrate communities to determine long-term effects of habitat restoration and the cessation of stocking. *Baetis* was the dominant genus from July to September, while *Hydropsyche* was the dominant genus for October and December, and *Epeorus* was dominant from December to March.

Figures 6a, b and c display percentages of invertebrates in the various feeding groups for sites 2, 11, and 16 before construction, after construction, and in the winter. Comparisons of the three sites within the three time periods are more valuable than comparisons of sites with themselves at different time periods because the communities change during the year as food sources change. There are no glaring differences between sites, but there are a few differences worth mentioning. Before construction, site 11 had more scrapers and less filtering collectors than sites 2 and 16. Site 16 had more shredders than the other sites before construction. After construction, all sites had very similar invertebrate communities. In the winter, site 11 had more scrapers than the other sites and less shredders than site 2. Site 16 had more filtering collectors and less shredders than the other sites in the winter.

Table 7 and Figure 7 show the percent changes in electrofishing catch rates before and after construction. Catch rates increased after construction for almost every site. Site 2 had a minor decrease (-24%) in adult trout, probably attributable to random error. Site 11 had decreases in adult trout (-48%), age 0+ trout (-45%), slimy sculpins (-44%), longnose dace (-73%), and total (-45%). Site 16 also had a 73% decrease in longnose dace. Site 3 had the greatest increases in catch rates for adult trout (+800%), slimy sculpins (+336%), and total (+359%). Site 3's age 0+ trout increase of 400% was second only to site 6's 650% increase.

Table 8 shows the individual metric scores and total scores for RBPV. If there was more than one sampling date for a site before or after construction, the metrics were averaged. The total scores all fall within 4 points of each other (44-48), and all sites were categorized as "fair" to "good". Individual metric scores were mostly very similar for all sites, with variation in the species-related metrics mostly due to the presence or absence of longnose dace. Since there were only four species in the stream, the presence or absence of one can have a major impact on species-related metric scores. The lowest metric scores for all sites tended to be "Number of sculpin species" and "Number of intolerant species".

Table 9 shows the first and second capture locations for each recaptured trout. Most of the recaptured fish remained in the original capture site, but one brook trout was tagged at site 6 and recaptured at site 2.

Table 10 shows the average lengths and weights for each year class of trout. There appears to be no major difference in the two species, but the brown trout tend to be slightly larger, as is expected. Figure 8 shows that there is no major difference in growth rate between the two species. Although there was not enough data (year classes) for a von Bertalanffy equation, graphs such as Figure 8 can be used for future growth rate comparisons.

Table 11 and Figure 9 show the number of brook and brown trout in various length categories. The great majority of trout in the stream are young brook trout. In fact, 41% of all trout captured were age 0+ brook trout. The brown trout population was very different, having very few age 0+ fish. Most brown trout were age 2+ (determined from scales) and were 15.5 to 20cm long.

Table 12 and Figures 10 and 11 display the mean numbers of fish caught before and after construction. Figure 10 is a chart of adult trout and age 0+ trout, while Figure 11 is a chart of sculpins and total. Two figures had to be used because the number of sculpins compared to the number of trout is so large that graphing trout with sculpins would make bars representing trout numbers seem insignificant. Also notice how the number of sculpins is the main determinant of total fish since they are so numerous. This data is useful for comparing fish communities at different sites because the numbers are given in fish per 100m.

Discussion

As seen in Tables 1a and 1b and in Figure 1, most of the chemical parameters monitored during the study increased slightly during construction. Turbidity had the greatest increase, from 0 to 21 FAU. These increases occurred due to the streambed disturbance caused by the equipment, but it does not appear that the concentrations increased to high enough levels or stayed at high levels long enough to cause any significant ecological damage. There is a possibility that the longnose dace population, a species sensitive to environmental stress, was harmed by this construction because electrofishing catches of this species declined after construction was completed (-73% at site 11 and -83% at site 16); however, the longnose dace population was very small to begin with, so maybe this decrease in catch was due to random error. All chemical parameters returned to normal after construction.

One possible problem is the low pH and alkalinity of this stream during the winter months. For most of the study, the pH stayed above 6, which should be high enough for most trout populations (Peterson et al. 1982). In January, the alkalinity dropped to zero, and pH fell to 5.44 at site 2 and 5.26 at site 16. The pH remained below 6 for site 2 through to March, while it remained slightly above 6 for site 16 through to March. Although these pH levels are too high to affect adult trout (Leivestad 1982), they may be low enough to affect developing embryos and young fry (Peterson et al. 1982). Peterson et al. (1982), in a literature search, found that pH ranges from 4.5 to 6.5 can inhibit brook trout reproduction and that brown trout reproduction can be inhibited by pH ranges from 4.5 to 5.0. Peterson et al. (1982) noted that different strains of trout show different sensitivities to low pH, so it may be that Big Bear's native brook trout are adapted for life in this low alkalinity stream. Since there were over 11 times as many age 0+ brook trout captured as age 0+ brown trout, it appears as though low pH isn't a major problem since brook trout are supposedly more sensitive. Aluminum concentrations remained low enough (never more than 0.02 ppm) throughout the study so as not to be of concern (Baker 1982, Peterson et al. 1982).

One instance in which this low alkalinity and pH may be a problem is during the snowmelt following a snowy winter. This melt could cause a sharp decrease in pH, depending on the acidity of the snow, due to Big Bear's inability to buffer such a sudden acid load. The Spring is also the time at which trout are most sensitive to low pH since the fall-spawned eggs are hatching (Peterson et al. 1982). In Table 1b, the 2/10 and 2/23 sampling dates occurred on days warm enough to cause significant snowmelt, and it appears that snowmelt did not significantly lower Big Bear's pH. It is possible that the native brook trout have reproduced successfully the past few years only because the past few years saw very little snowfall compared to harsher winters. If the cessation of stocking and trout habitat restoration appear to have failed in bringing back an acceptable wild trout fishery over the next few years, this pH issue may be the culprit.

There seems to have been no major changes in the benthic macroinvertebrate community caused by the construction. The total scores for Rapid Bioassessment Protocol III (Table 2) would suggest that no significant change occurred due to construction because the total scores of site 11, which underwent construction, and site 16, the downstream control site, were very close or identical to the score of the upstream control site. Some of the metrics did vary, however. The ratio of scrapers to filtering collectors decreased at site 11 (-62%) but increased slightly at site 2 (+31%) and increased greatly at site 16 (+219%). The Community Loss Index score was higher for site 11 (0.44) than it was for the control sites (0.13 and 0.17). Also, Table 4 shows a relatively high community loss score for site 11 in November vs. Site 2 in November; however,

Table 4 also shows other high community loss scores that seem to have no explanation relative to construction. It is possible that some of the more sensitive genera were forced to leave the sites that underwent construction due to higher sediment, chemicals, etc., but random error would be a more plausible explanation given the data in Table 4.

Rapid Bioassessment Protocol III suggests that there was no impairment of the stream in the winter (Table 3). Since there was no evidence of impairment immediately following construction, it is most likely that any changes in the invertebrate community were caused by the changing of seasons rather than the effects of construction lasting into the winter. Site 11's ratio of scrapers to filtering collectors remained lower than the pre-construction ratio. A look at Figure 6a may reveal the reason for this decline. Site 11 had a much larger percentage of scrapers to begin with, probably due to the relative lack of shade at this site. The percentages of scrapers at sites 11 and 16 increased after construction, and the scraper percentage decreased at all sites in the winter, so it doesn't appear as though site 11's ratio of scrapers to filtering collectors was influenced by construction. Site 16's immense increase in ratio of EPT to Chironomidae (+1027%) was not as comparatively large as it may appear. Chironomidae numbers were so low for all sites in the winter (see Figure 3k) that only a small decrease in the number of Chironomidae could cause a large increase in EPT to Chironomidae ratio. Site 16's community loss was higher than that of the other sites, but when compared to values in Table 4, it was relatively insignificant. Site 16's decrease in ratio of shredders to total (-77%) is worth discussing. In Figure 6c, it is evident that site 16 had a much lower percentage of shredders in the winter. Plafkin et al. (1989) would suggest the possibility of pollutants on riparian vegetation, but it is apparent that this is not the case on Big Bear Creek. It is most likely that winter kick samples at site 16 occurred in areas with a relative lack of allocthanous material.

Unexpectedly, construction seemed to have no effect on benthic macroinvertebrate density. Table 5 and Figure 2 show that density at site 11 was very comparable to density at sites 2 and 16 after construction. If anything, density increased following construction on site 11. Six surber samples were taken at site 11 immediately following construction at that site. Two samples were taken in areas not directly disturbed by the equipment, while 4 came from disturbed areas. The average density in the undisturbed areas was 29 organisms/ft^2, while the average for disturbed areas was 28.3 organisms/ft^2.

Table 6 shows the data used for student's t-testing invertebrate density. Surber samples for July and September represent the stream before construction, surber samples from October and November represent the stream after construction, and surber samples from January, February, and March represent the stream in winter. Site 11 actually had a significant increase in invertebrate density following construction, and this density was not significantly different from the densities of the other sites after construction. Also, site 16's invertebrate density did not significantly change following construction. The significant increases in density over winter reflect the invertebrates' life cycles. These invertebrates have hatched from their eggs and live as nymphs, naiads, or larvae over the winter before becoming adults in the spring and summer. These results are promising since it appears that the trouts' main food source was not depleted by the construction, which was a possible problem due to the amount of disruption caused by the construction process.

Figures 3a through 3k show that the trends in percent contribution of the most numerous invertebrate taxa are similar for all three sites. There are some differences, but the overall trends are unchanging. The fact that these trends remain the same for all sites, even following construction, suggests that construction had little impact on the stream's invertebrate community. The only change that occurred during construction was a large decrease in *Dolophilodes* at site 16 (see Figure 3i). The fact that *Dolophilodes* did not decrease at site 11 would suggest that site 16's decrease was not caused by *Dolophilodes*' sensitivity to the effects of the construction process. Site 16's *Dolophilodes* population was higher than the other sites before October, so it is possible that site 16's population was a month ahead of the other sites in its life cycle because *Dolophilodes* decreased at sites 2 and 11 in November, much like they had at site 16 a month earlier.

Figures 4 and 5 are for future reference and are not intended to aid in the determination of construction's effects. It is important to realize that these figures are graphs of percent contribution and not graphs of population numbers. An increase in percent contribution could be caused by a decline in other taxa rather than an increase in the taxon in question. But for the most part, increases in these figures can be assumed to correspond to increases in an individual taxon's numbers and not to decreases in other taxa. *Drunella* emerged into adulthood from August to September. It appears as though many *Baetis* and Chironomidae emerged into adults between September and October. *Epeorus*, *Paraleptophlebia*, *Ephemerella*, and *Baetis* were preparing for spring emergences. The large increase in *Brachycentrus* in September was most likely due to randomly sampling an area at site 2 with a large concentration of this genus.

Figures 6a, 6b, and 6c show the percentages of invertebrate communities in the various feeding groups. When considering feeding groups, the communities of sites 11 and 16 were closer to the community of site 2 following construction (Figure 6b) than they were before construction (Figure 6a) or in the winter (Figure 6c). If construction had affected the stream's invertebrate community, the communities of the individual sites should have been most different in the time period following construction. Therefore, feeding group analysis favors the conclusion that construction had no significant impact on the stream's invertebrates.

The percent changes in electrofishing catch show that construction may have had localized effects on the fish community (Table 7 and Figure 7). Of the five electrofished sites, site 11 had by far the greatest amount of disturbance, with four new boulder structures put in place in October 1999. The catch rate responded with a 48% decrease in adult trout, a 45% decrease in age 0+ trout, a 73% decrease in longnose dace, a 44% decrease in slimy sculpins, and a 45% decrease in total fish. These decreases appear to be significant since all other sites had increased catches of all categories except for site 16's longnose dace and site 2's adult trout. Site 2's adult trout only decreased 24%, which can probably be attributed to random error since no construction occurred there. Site 11's decrease in adult trout was twice as great as site 2's, so it follows that site 11's decrease was significant in comparison.

Site 6 was the next most disturbed site, but it only had one boulder structure built at its downstream end; therefore, the number of fish caught there increased. Site 6 had the greatest increase in age 0+ trout of any site at 650%.

Site 3 had the most significant increases, with an 800% increase in adult trout, a 400% increase in age 0+ trout, a 336% increase in slimy sculpins, and a 359% total increase. Site 3 was upstream of all construction and had no construction done on itself, so it seems that as the construction proceeded in an upstream direction, as it did in this case, the fish were forced upstream to avoid the commotion. More evidence for this behavior is the fact that a brook trout tagged at site 6 in early October was recaptured at site 2 in November (see Table 9). This fish had to overcome many obstacles to travel this roughly 500m. One of the greatest obstacles was a log dam that created a waterfall almost a half meter high.

Given these findings, the construction seems to have had no significant impact on the stream's fish community as a whole, but localized areas that underwent construction did have a decrease in fish. As time goes by, the displaced fish will find their ways back to the new habitat created by the construction, and there should be no lasting negative effect on the stream's fish community.

The EPA's Rapid Bioassessment Protocol V (Table 8) was of little value in assessing habitat restoration's effects on Big Bear Creek. This stream only had four fish species in it, and only three species were really common (longnose dace were rare). This low diversity was probably the most important reason why this protocol was ineffective on this stream. Big Bear's low diversity may be due to its relative lack of productivity, which is typical of small freestone streams. Also, the dam built in 1980 blocks the upstream movement of fish from the Loyalsock Creek, further lowering diversity. Protocol V is probably better suited for comparing different streams, instead of the same stream directly following an event. Big Bear Creek received low scores for number of sculpin species because there were large numbers of only one species (slimy sculpin), probably not because of sedimentation. The stream also received low scores for number of intolerant species (only longnose dace are considered intolerant), which is probably not caused by environmental degradation because trout are able to naturally survive and reproduce in the stream.

The data displayed in Table 10 and Figure 8 will not be addressed in this study, but data from future years can be compared to it. There were not enough year classes for any true analysis such as with the von Bertalanffy growth equation (Cailliet et al. 1986). This lack of year classes is probably due to stocking of similar ages and the fact that most of these stocked trout died off anyway (Yuskavitch 1999). Lycoming College will be studying this stream for the next four years, and only then can any conclusions be made about the effects of non-stocking on Big Bear Creek.

Although there was no way to easily distinguish wild and stocked trout, Table 11 and Figure 9 provide evidence for which trout species is more wild. The large number of age 0+ brook trout (less than 10cm) suggests that a wild population has been naturally reproducing in the stream, while the brown trout population is made up mostly of older, stocked trout that have failed to reproduce to any great extent, as evidenced by the very small numbers of age 0+ brown trout. More evidence for the natural reproduction of brook trout was the discovery of sac fry in an early April kick sample. Stocking tends to have the greatest effect on adult wild trout because catchable-sized stocked trout compete with catchable-sized wild trout for habitat and food, forcing these adult wild trout to flee the stocked area (Yuskavitch 1999). The age structure of Big Bear Creek reflects this behavior in that there are very low numbers of catchable-sized brook trout compared to the large numbers of age 0+ brook trout.

Table 12 and Figures 10 and 11 can be used to compare the fish communities of different sites because they display the mean numbers of fish caught per 100m of stream. The two control sites and site 6 were all fairly similar before construction, while site 11 had larger numbers of all fish categories than any other site. Site 11 most likely had the highest numbers before construction because it had the greatest total pool/run length, 60m (vs. 35m for site 2, 50m for site 3, 52m for site 6, and 25m for site 16). Site 3 had much smaller numbers of all categories, but these numbers can't be explained by pool/run length. Site 3 was only electrofished once before construction, so it is possible that some error occurred that day or that there was just a local area of low fish numbers. After construction, site 11's numbers were very similar to the control site numbers, while sites 3 and 6 had large increases. The results of this analysis resemble those of the percent change in catch rate analysis (Table 7 and Figure 7) in that both show a movement of fish away from construction.

Although far too soon to make any conclusions, it appears as though the elimination of stocking will aid the wild trout fishery of Big Bear Creek. Of all trout captured via electrofishing, 41% were age 0+ brook trout, and since electrofishing is less efficient at capturing small fish (Buttiker 1992, Anderson 1995), the proportion of young fish is probably even greater. This type of population structure is typically found when stocking of catchable trout occurs on top of a naturally reproducing trout population (Yuskavitch 1999). In the absence of stocking, these wild brook trout should be able to dominate the stream because water quality, food, and now habitat should be sufficient to sustain a healthy, wild population. Vincent (1983) found that after 4 years of non-stocking on the Madison River, Montana, brown trout increased 162% in number and 133% in biomass, while rainbow trout had an 8-fold increase in number and 11-fold increase in biomass. Carline et al. (1991) showed that the elimination of stocking and no-harvest regulations boosted the brown trout population in Spring Creek, Pennsylvania. Also, Thuember (1975) observed that the number of wild brook trout nearly doubled when stocking was ended in the North Branch of the Pike River and K.C. Creek, Wisconsin.

It is apparent that the structures will provide sufficient habitat for Big Bear's trout. Just by visually comparing the stream before and after the installation of structures, the stream appears to have gone from just water running through a forest to what looks like an excellent trout stream. Before the habitat structures, the stream was mainly just riffles, with a few pools here and there. The structures have provided a diversity of depth and current speeds, which are needed for trout to flourish. Rosgen's methods have been used with success in the Western United States (Schmetterling 1998, Ross 1994, Monde 1998), and Big Bear Creek's restoration looks as if it will make Rosgen's methods a success in the East. When the next four years of study are completed, a more substantial conclusion on the habitat restoration's effectiveness will be made.

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Table 1a. 1999 Physicochemical data. The 10/5 samples were taken during habitat construction.

site	2	7	11	14	2	16	2	16	2	16	2	16
date	7/31	7/31	7/31	7/31	9/2	9/2	9/14	9/14	10/5	10/5	11/2	11/2
velocity (m/s)	0.36	0.28	0.23	0.56	0.23	0.3	0.68	0.3	0.72	0.6	0.37	0.71
discharge (m3/sec)	0.14		0.21		0.013	0.005	1.01	0.76	1.9	1.7	0.41	2.03
temperature (C)	14.2	13.5	15.7	13.9	12.8	14.5	14.3	14.9	9.9	10.2	9.8	9.8
TDS	4.1	7.4	8.3	9.5								
conductivity (ppm)	5.9	10.4	11.4	13.9	51.5	52	28.8	28.7	12.1	37.4	4.5	10.8
turbidity (FAU or NTU)									0	21		
DO (ppm)	10.15	9.56	9.6	7.73	10	8.81	11.57	9.53	10.89	12.49	9.4	9.08
pH	6.6		6.3		6.8	7.1			6.2	6.4	6.6	6.2
alkalinity (ppm CaCO3)	6		5		13	20			3.2	4.5	1	7
nitrate as NO3 (ppm)	0.7		0.7		0.7	0.7	1.7	1.8	1	1.3	1.4	1.8
total phosphorus (ppm)	0.57		0.57		0.58	0.77	0.037	0.37	0.48	0.48	0.015	0.49
reactive phosphorus (ppm)	0.12		0.12		0.12	0.17	0.4	0.026	0.025	0.025	0.44	0.021
aluminum (ppm)									0.019	0.007	0.004	0.003

Table 1b. 2000 Physicochemical data.

site	2	16	2	16	2	16	2	16	2	16
date	1/12	1/12	2/2	2/2	2/10	2/10	2/23	2/23	3/6	3/6
velocity (m/s)										
discharge (m3/sec)										
temperature (C)	4.2	3.8	0.9	0.3					4.9	4.9
TDS										
conductivity (ppm)			0	0					2.8	0
turbidity (FAU or NTU)										
DO (ppm)	15.3	14.4	15.82	15.72					13.2	13.28
pH	5.4	5.3	5.4	5.5	6	6.4	5.8	6	5.7	6.1
alkalinity (ppm CaCO3)	0	0	0	27	6.2	7.1	0	0	0	0
nitrate as NO3 (ppm)	1.9	1.5	1.9	1.6					0.2	0.2
total phosphorus (ppm)	0.4	0.38	0.38	0.43					0.5	0.42
reactive phosphorus (ppm)	0.1	0.072	0.237	0.066					0.111	0.066
aluminum (ppm)	0.009	0.009	0.000	0.003	0.003	0.000			0.01	0.000

Figure 1. Water Chemistry Results: No significant changes resulted from the construction, which occurred during the October sampling date. The only significant change was an increase in turbidity from 0 to 21 FAU (not shown below). The September sampling date occurred during flood conditions.

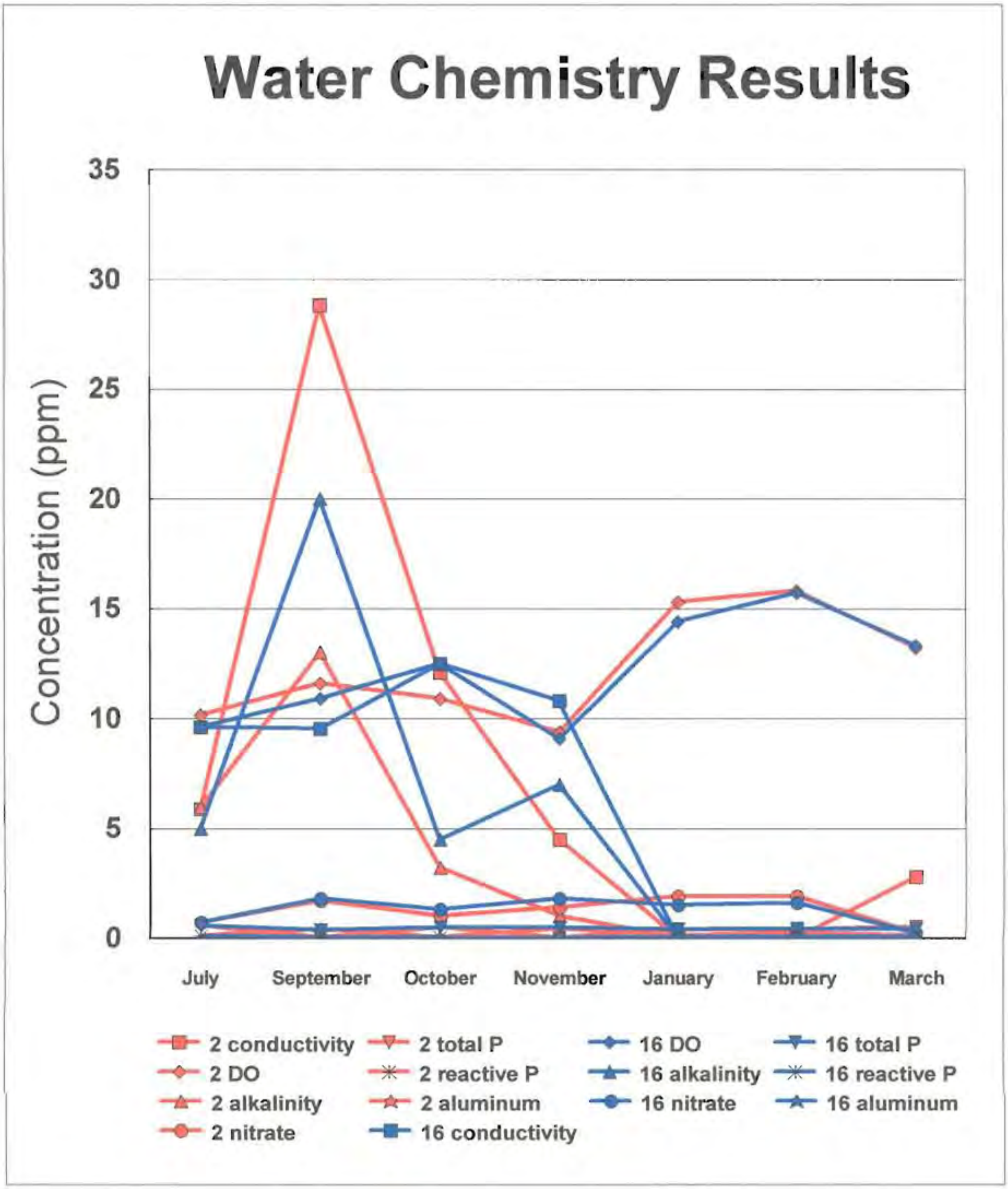


Table 2. The results of EPA's Rapid Bioassessment Protocol III. Metric scores (given after percentage) can have values of 0, 3, or 6, with 6 being the highest environmental quality. All three sites were categorized as non-impaired following construction. Taxa. Rich.= Taxa richness, FBI = Hilsenhoff Family Biotic Index, SC/FC= Ratio of scrapers to filtering collectors, EPT/C= Ratio of Ephemeroptera, Plecoptera, and Trichoptera to Chironomidae, % Dom.= % contribution of dominant family, EPT= Ephemeroptera, Plecoptera, and Trichoptera Index, Com. Loss= Community Loss Index, and SH/Total= Ratio of shredders to total.

	Taxa Rich.	FBI	SC/FC	EPT/C	% Dom.	EPT	Com. Loss	SH/Total	Total
Site 2	123%-6	136%-6	131%-6	279%-6	54%-0	85%-4	0.13-6	500%-6	40
Site 11	91%-6	114%-6	38%-4	363%-6	114%-0	100%-6	0.44-6	275%-6	40
Site 16	103%-6	110%-6	319%-6	568%-6	171%-0	97%-6	0.17-6	192%-6	42

Table 3. The results of EPA's Rapid Bioassessment Protocol III for the winter following construction.

	Taxa Rich.	FBI	SC/FC	EPT/C	% Dom.	EPT	Com. Loss	SH/Total	Total
Site 2	130%-6	144%-6	378%-6	624%-6	87%-0	93%-4	0.06-6	85%-6	42
Site 11	98%-6	179%-6	33%-4	134%-6	217%-0	100%-6	0.06-6	100%-6	39
Site 16	94%-6	162%-6	375%-6	1127%-6	200%-0	105%-6	0.13-6	23%-0	36

Table 4. Community Loss Index. Sites across the top of the table are reference sites. (2-7/31= Site 2 on 7/31)

	2-7/13	2-7/31	2-9/2	2-9/14	2-10/19	2-11/2	11-9/14	16-9/2
11-7/13	1						0.67	
11-7/31		0.47					0.26	
11-9/14				0.2				
11-10/20					0.11		0.06	
11-11/9						0.46	0.38	
16-7/31	0.75							0.16
16-9/2			0.2					
16-10/5					0.28			0.17
16-11/2						0.12		0.17
2-7/13				0.26				
2-7/31				0.24				
2-9/2				0.5				
2-10/19				0.2				
2-11/2				0.06				

Table 5. Benthic macroinvertebrate density in organisms per square foot. Each density is the average of two, one square foot samples unless marked with a *, which denotes the average of 4 samples. Oct. Dist.= sample was taken in an area disturbed by the equipment.

	July	Sept.	Oct.	Oct. Dist.	Nov.
Site 2	23.5	66.8*	27		26
Site 11	28.3*	10.5	29	28.3*	31.5
Site 16		25	48.5		22.5

Figure 2. Graph of Table 5.

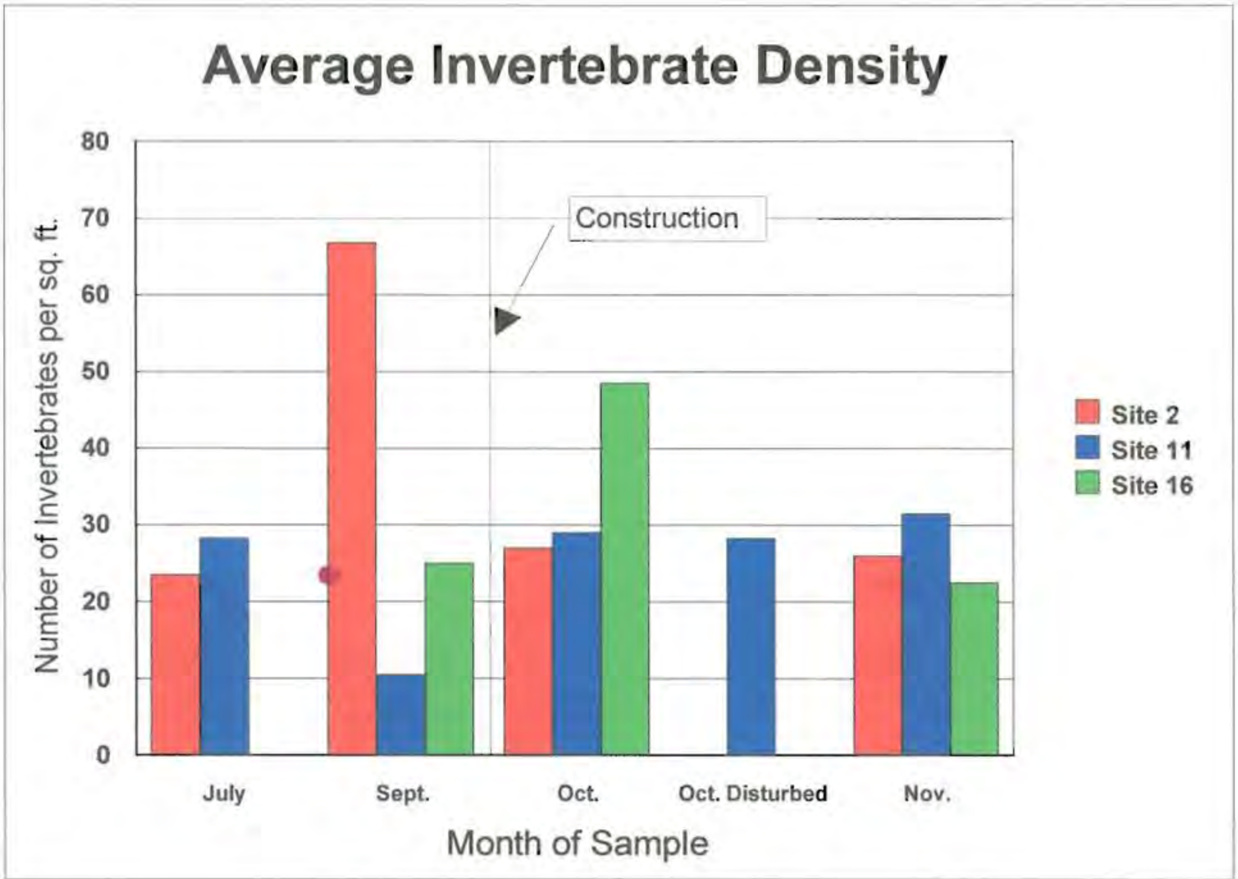


Table 6. Mean, standard deviation, and sample size for benthic macroinvertebrate density in organisms per square foot. (x+sd, n)

	Before	After	Winter
Site 2	52.2+24.6, 6	26.5+0.3, 4	95.0+43.2, 6
Site 11	11.0+0.6, 4	29.1+6.4, 8	79.3+35.2, 6
Site 16	25.0+0.7, 2	24.3+2.0, 4	92.8+41.1, 6

Figure 3a. Percent contribution of Baetis, a collecting gatherer mayfly, to kick sample taxa over time.

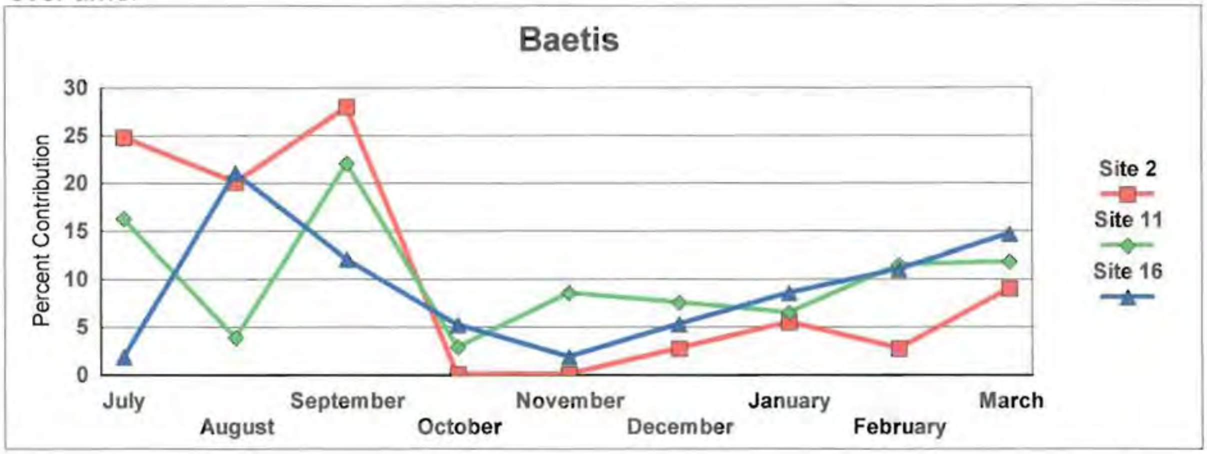


Figure 3b. Percent contribution of Drunella, a scraper mayfly, to kick sample taxa over time.

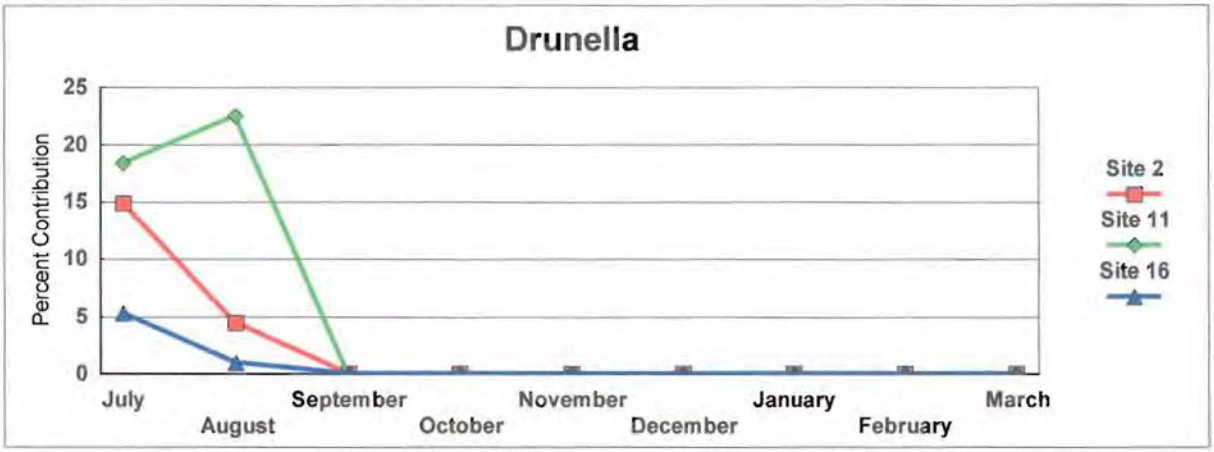


Figure 3c. Percent contribution of Ephemerella, a collecting gatherer mayfly, to kick sample taxa over time.

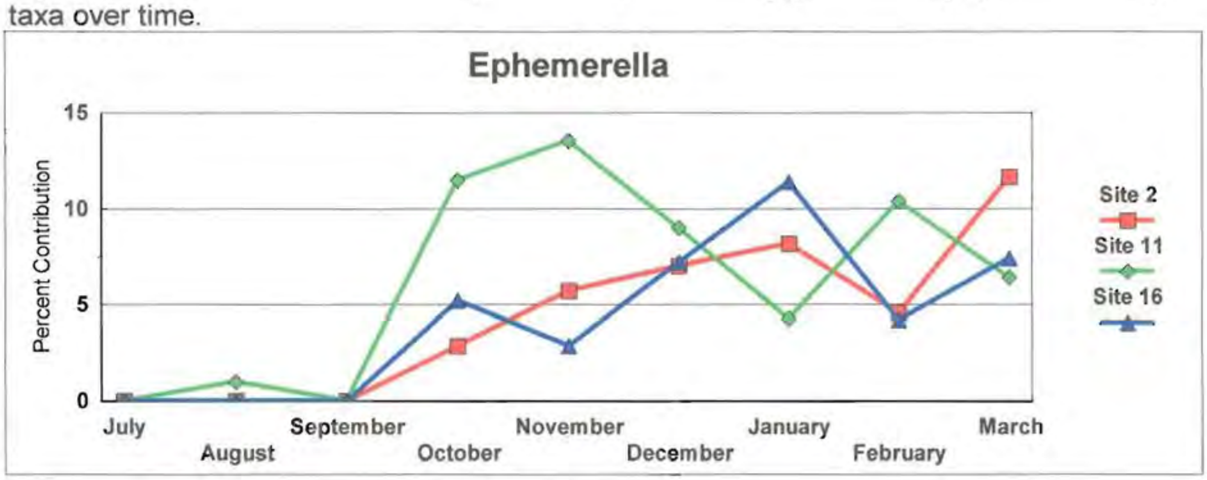


Figure 3d. Percent contribution of Epeorus, a collecting gatherer mayfly, to kick sample taxa over time.

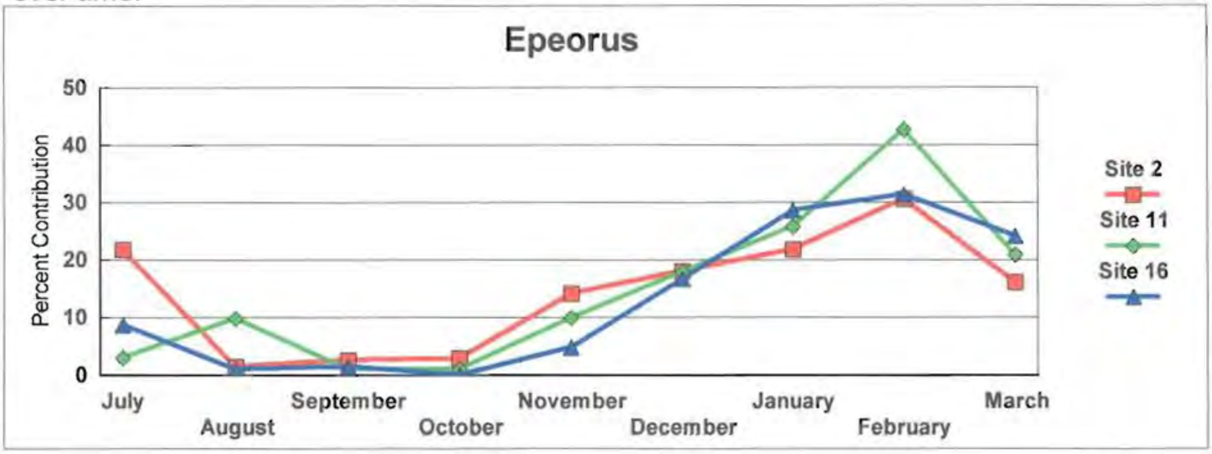


Figure 3e. Percent contribution of Stenonema, a scraper mayfly, to kick sample taxa over time.

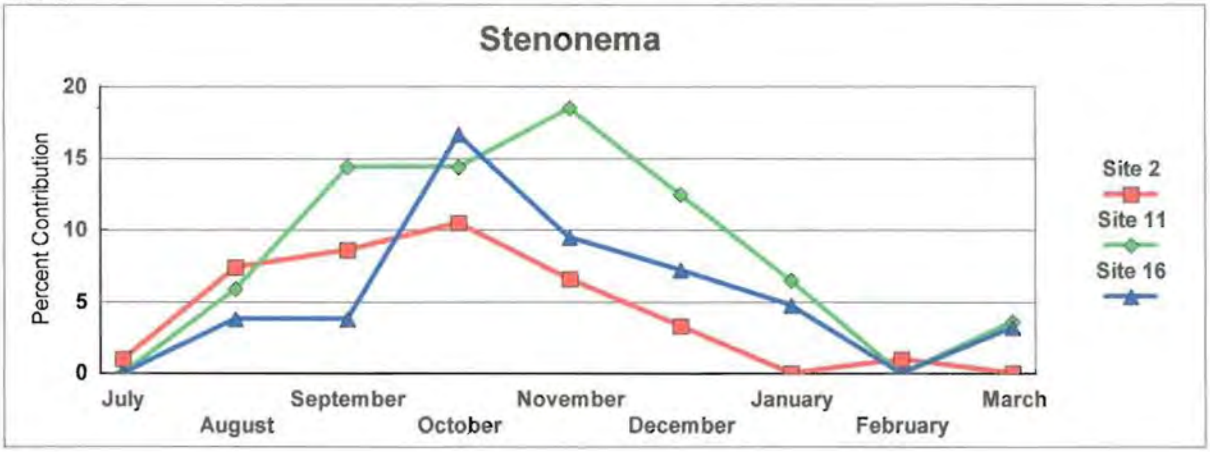


Figure 3f. Percent contribution of Paraleptophlebia, a collecting gatherer mayfly, to kick sample taxa over time.

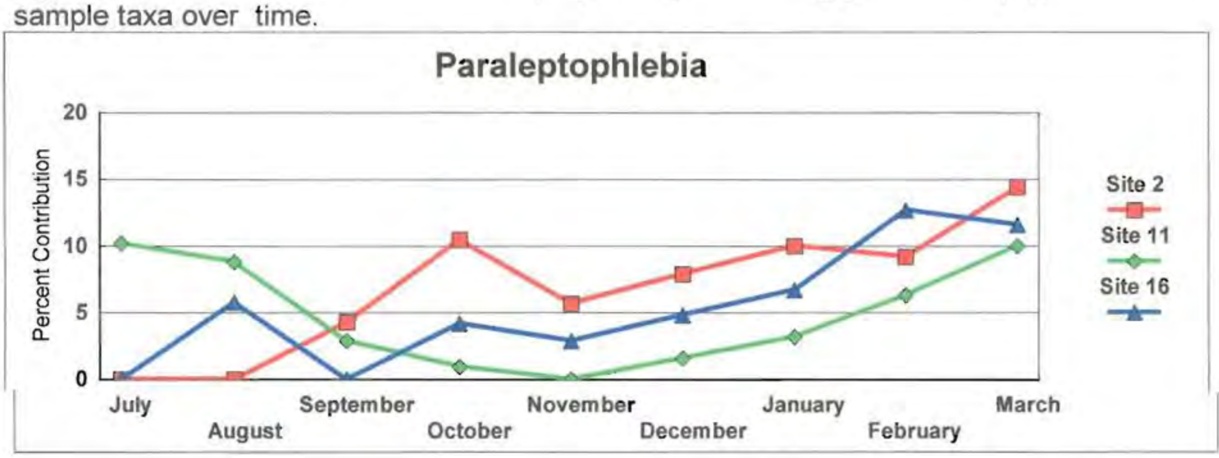


Figure 3g. Percent contribution of Brachycentrus, a filtering collector caddis, to kick sample taxa over time.

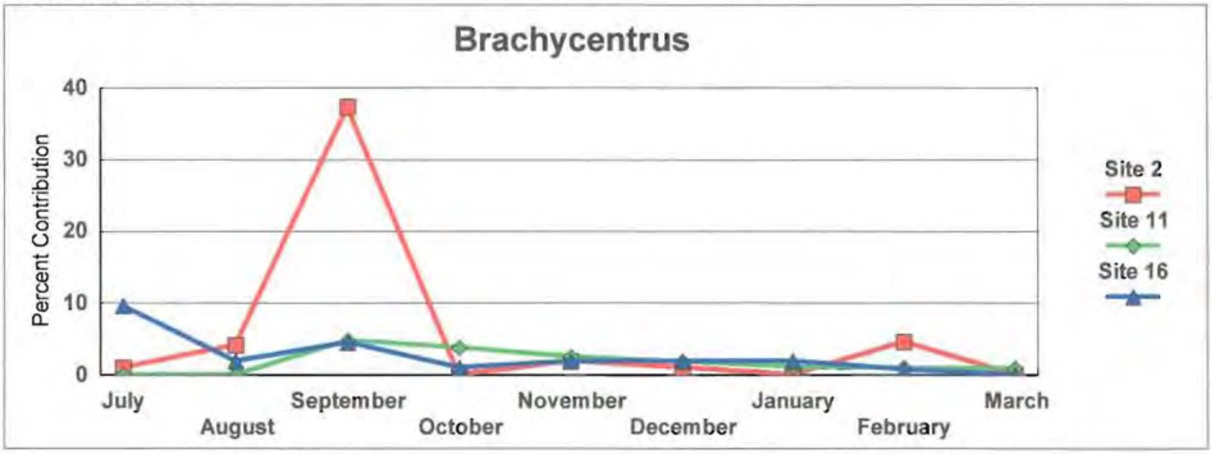


Figure 3h. Percent contribution of Hydropsyche, a filtering collector caddis, to kick sample taxa over time.

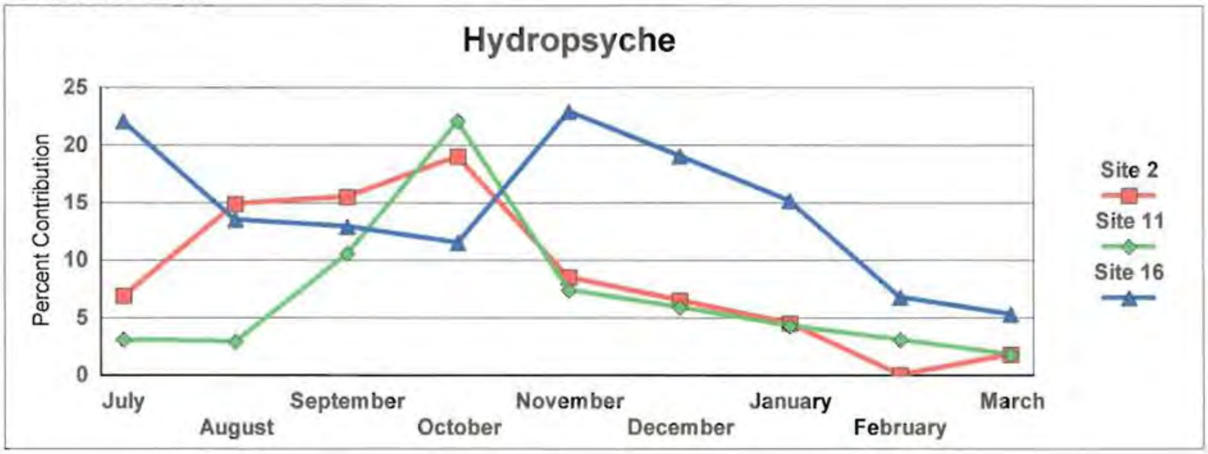


Figure 3i. Percent contribution of Dolophilodes, a filtering collector caddis, to kick sample taxa over time.

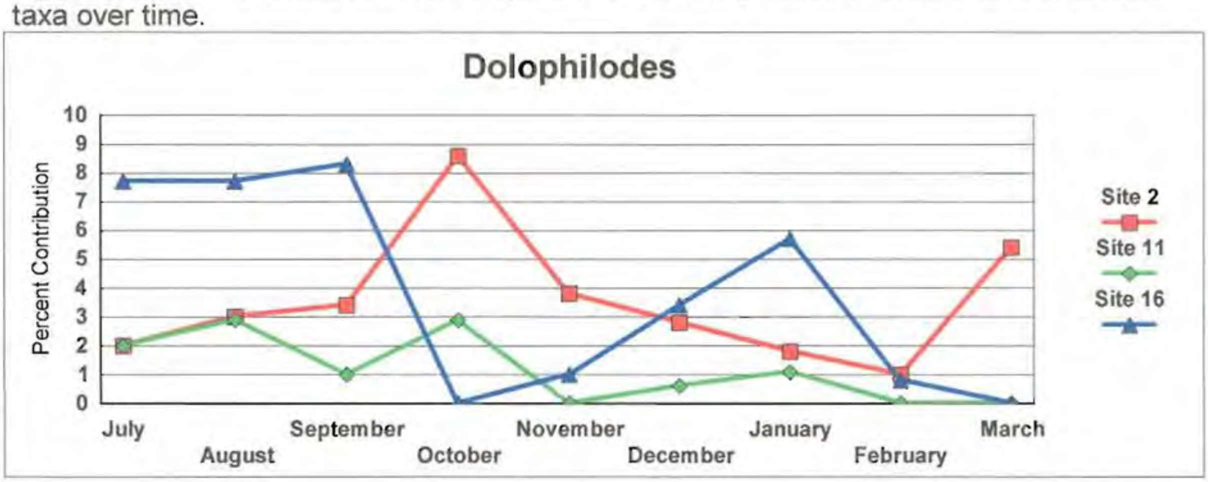


Figure 3j. Percent contribution of Athericidae, a predatory dipteran, to kick sample taxa over time.

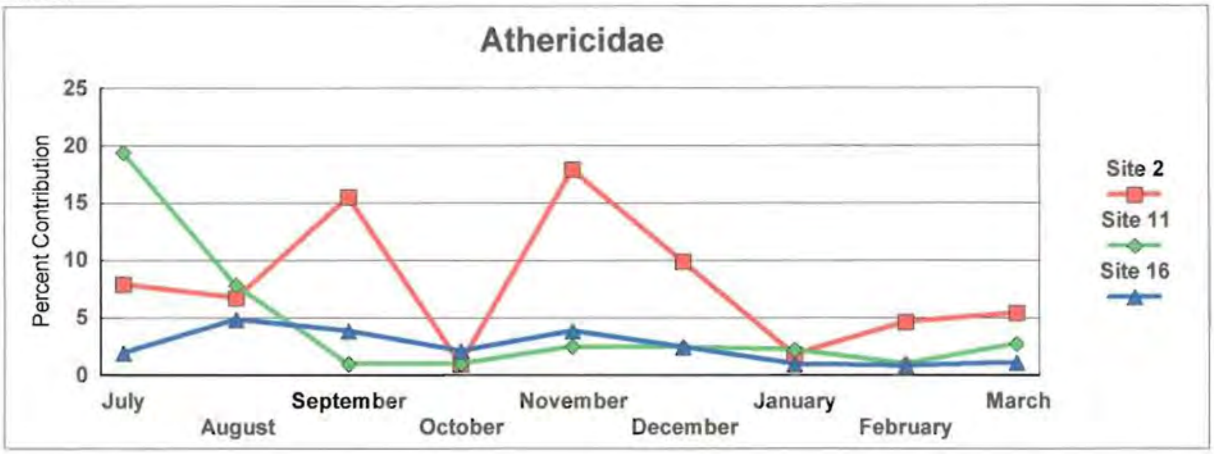


Figure 3k. Percent contribution of Chironomidae (midges) to kick sample taxa over time.

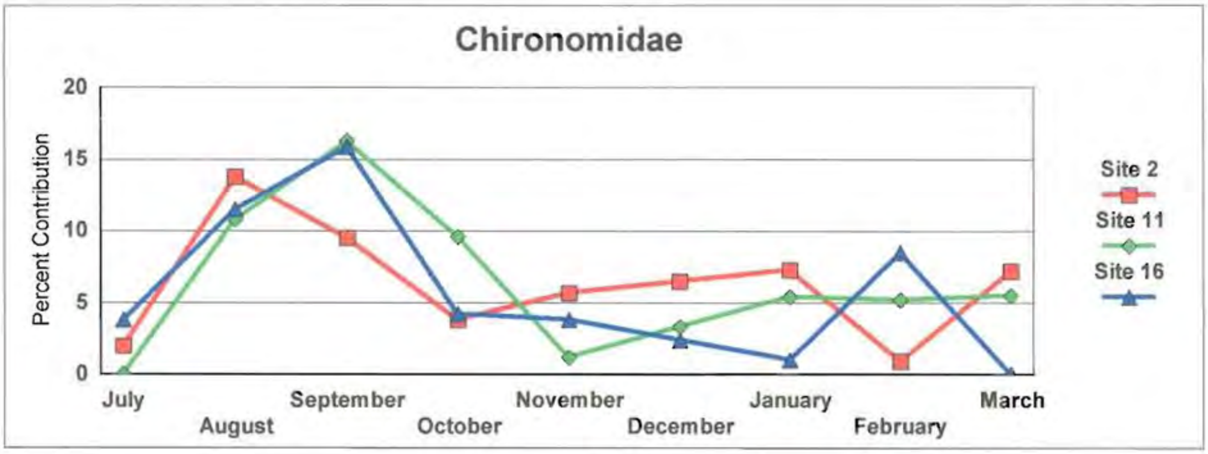


Figure 4. Average percent contributions of major Ephemeroptera taxa to kick samples for Big Bear Creek over time. This graph shows the average percent contribution of sites 2, 11, and 16.

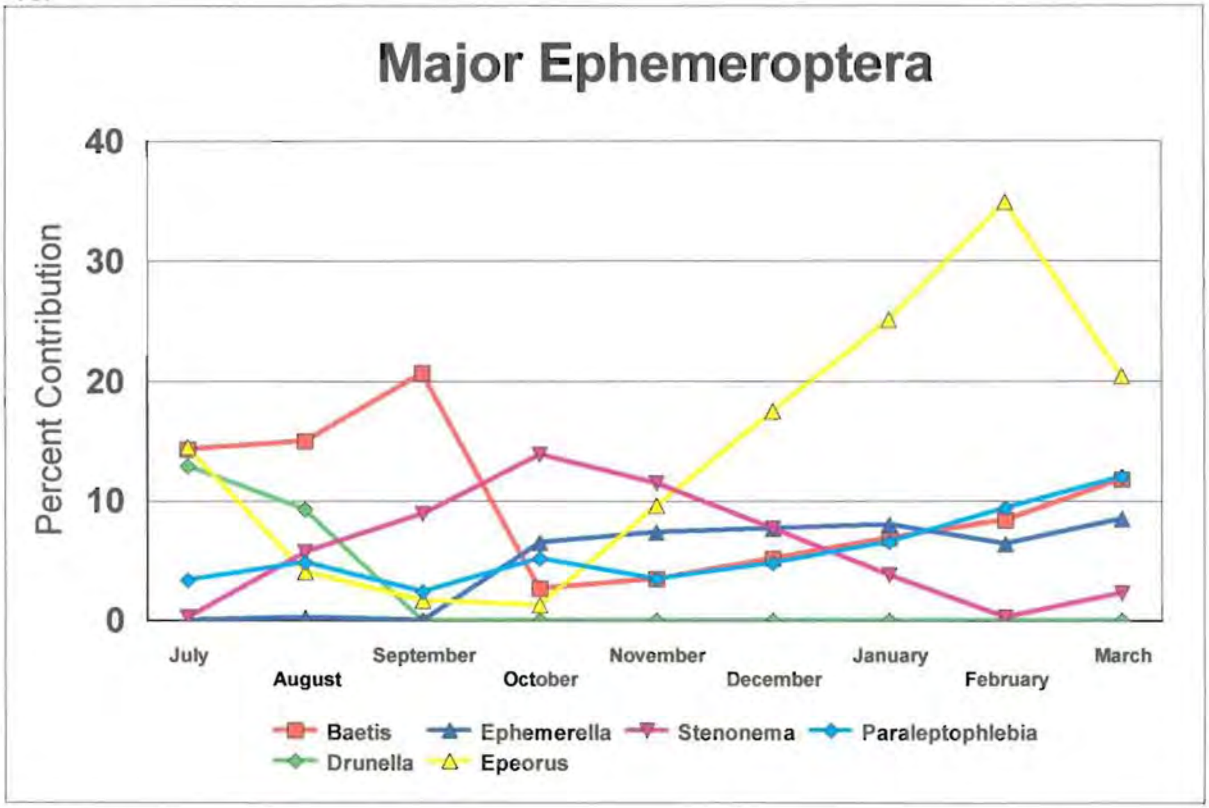


Figure 5. Average percent contributions of major Trichoptera and Diptera taxa to kick samples for Big Bear Creek over time. This graph shows the average percent contribution of sites 2, 11, and 16.

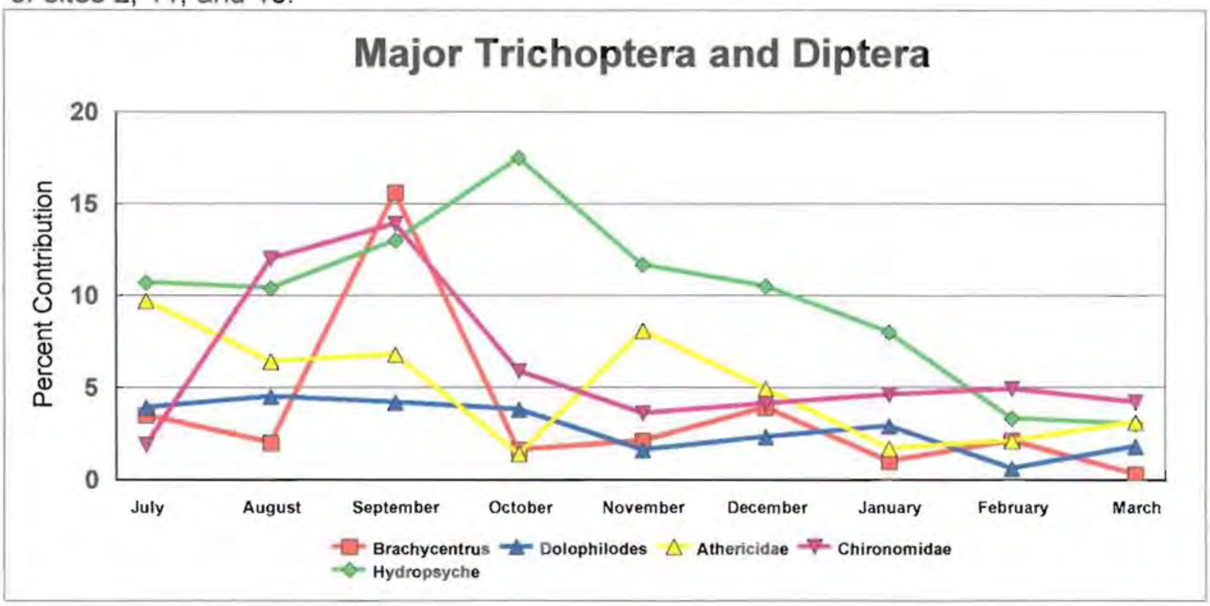


Figure 6a. Percentages of the invertebrate communities in the various feeding groups for sites 2, 11, and 16 before construction (July to September).

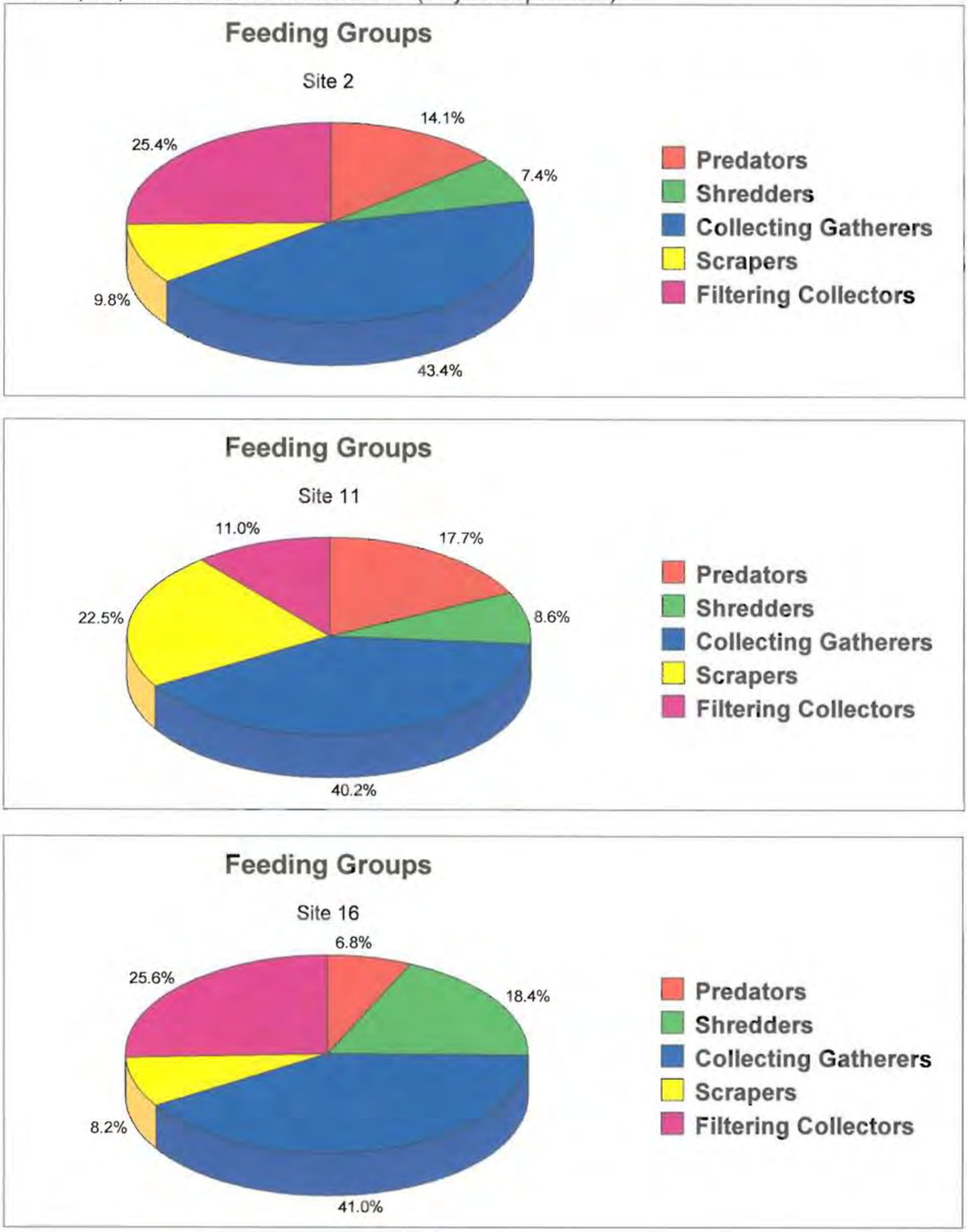
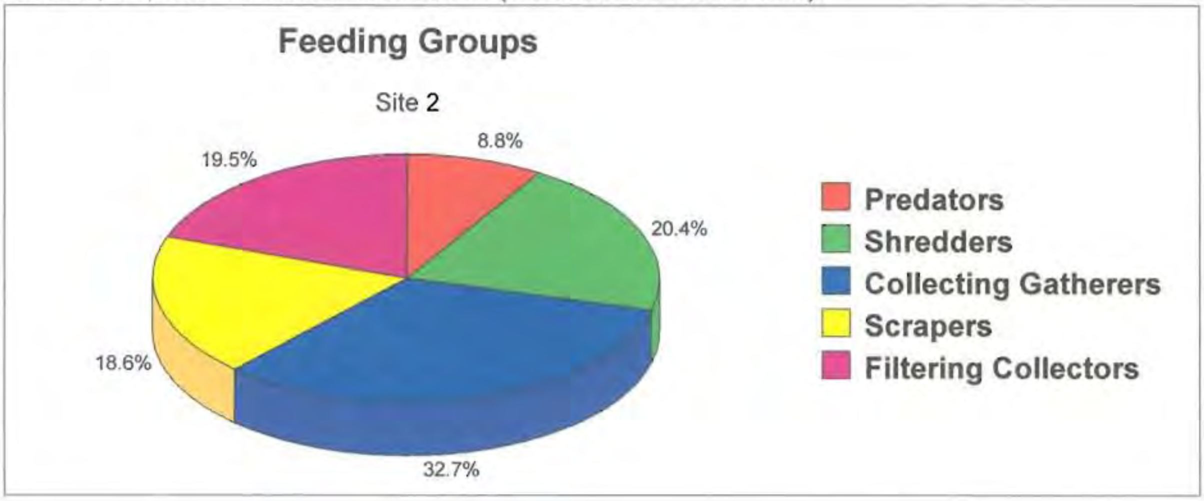
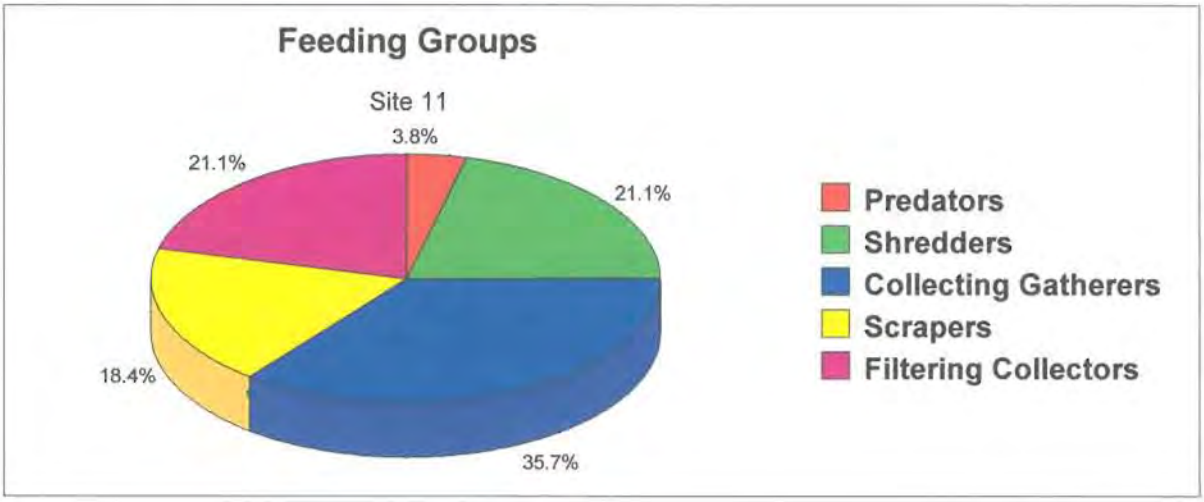


Figure 6b. Percentages of the invertebrate communities in the various feeding groups for sites 2, 11, and 16 after construction (October and November).





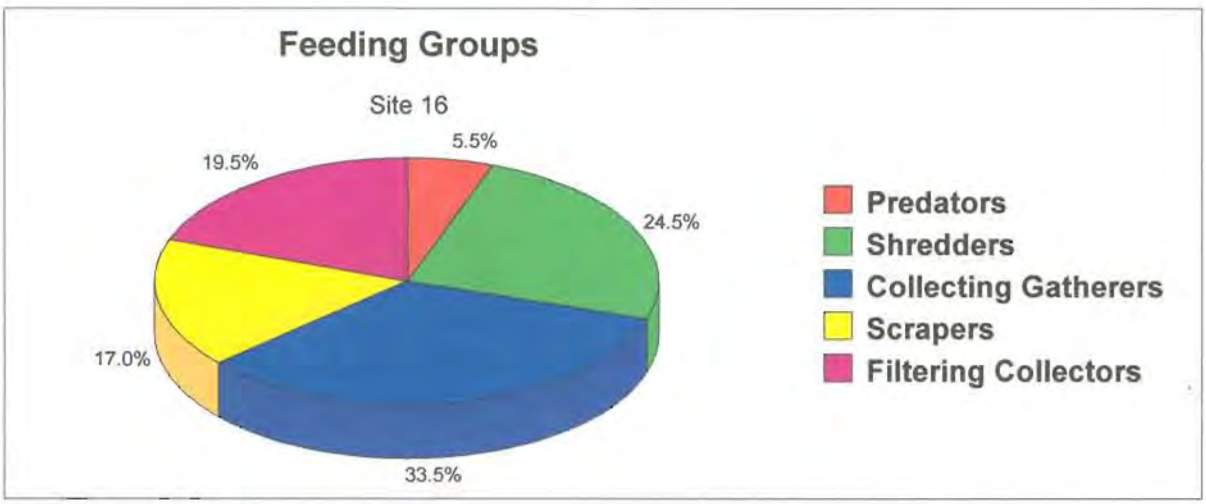
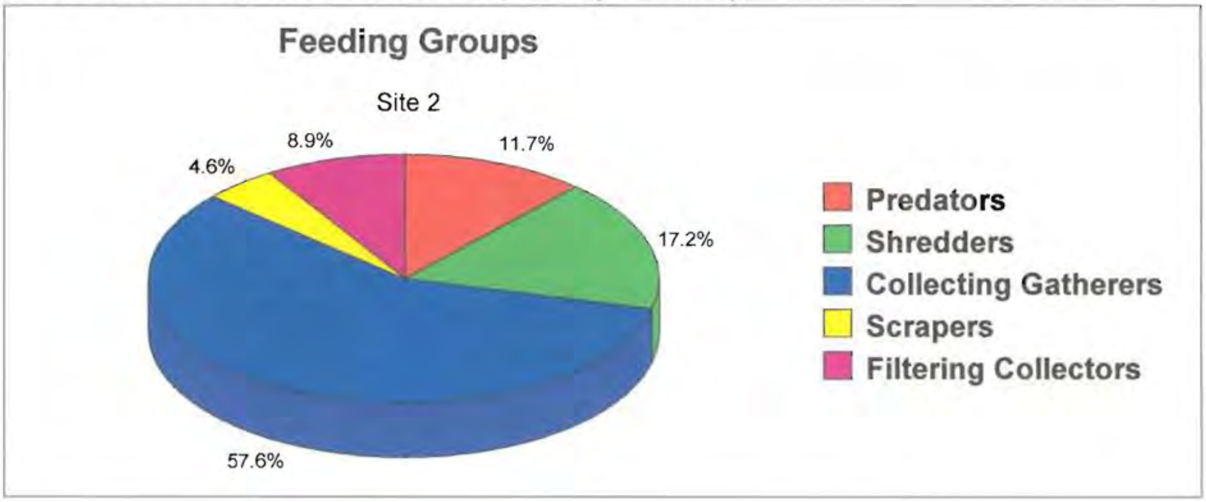
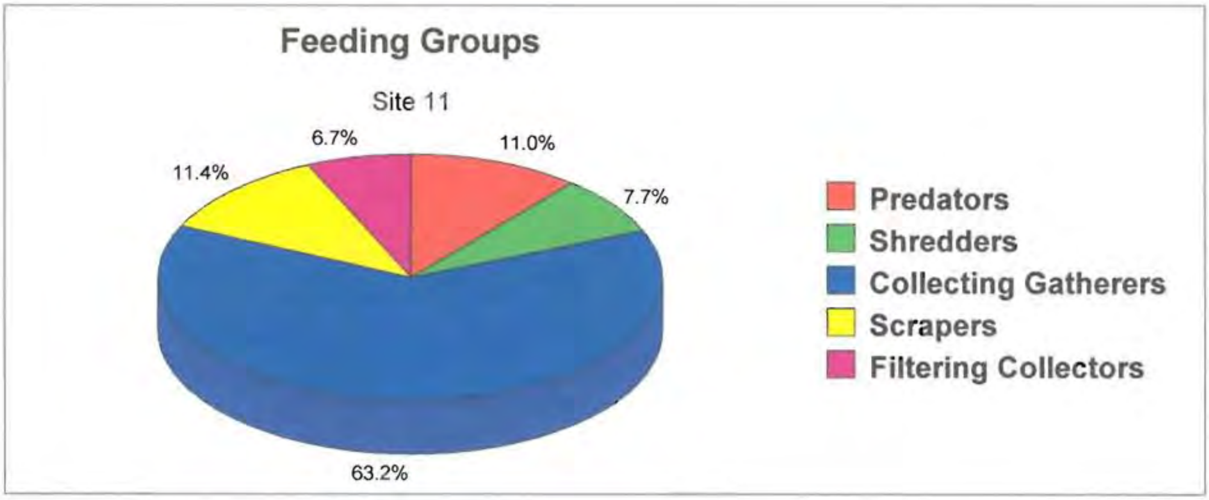


Figure 6c. Percentages of the invertebrate communities in the various feeding groups for sites 2, 11, and 16 after construction (January to March).





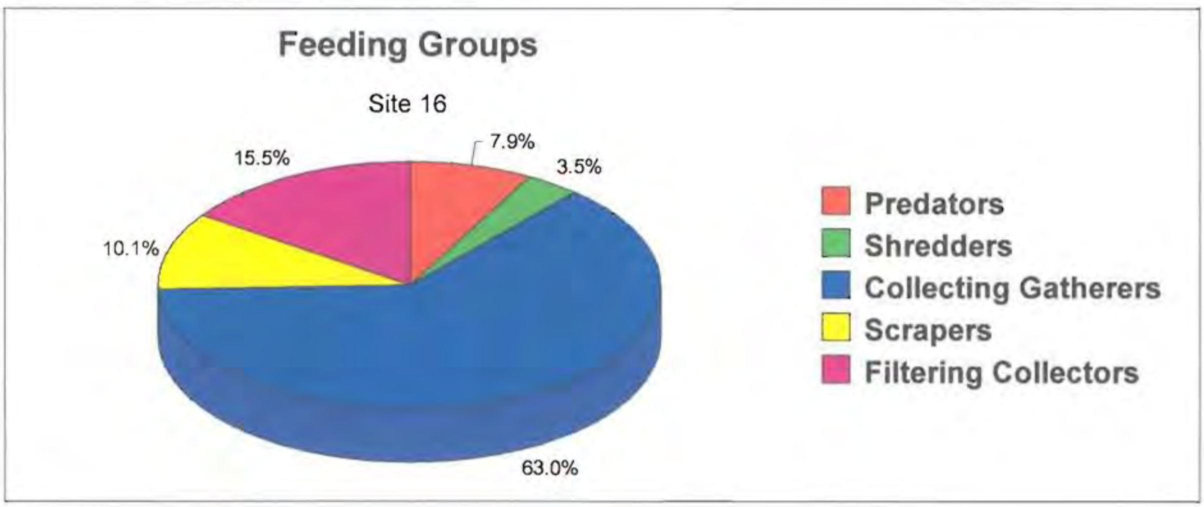


Table 7. Percent changes in fish caught by electrofishing. The values given represent the percent change in catch after construction.

	Site 2	Site 3	Site 6	Site 11	Site 16
Adult Trout	-24%	+800%	+83%	-48%	+17%
Age 0+ Trout	+65%	+400%	+650%	-45%	+83%
Slimy Sculpin	+20%	+336%	+7%	-44%	+40%
Longnose Dace				-73%	-83%
Total	+19%	+359%	+3%	-45%	+32%

Figure 7. Graph of Table 7.

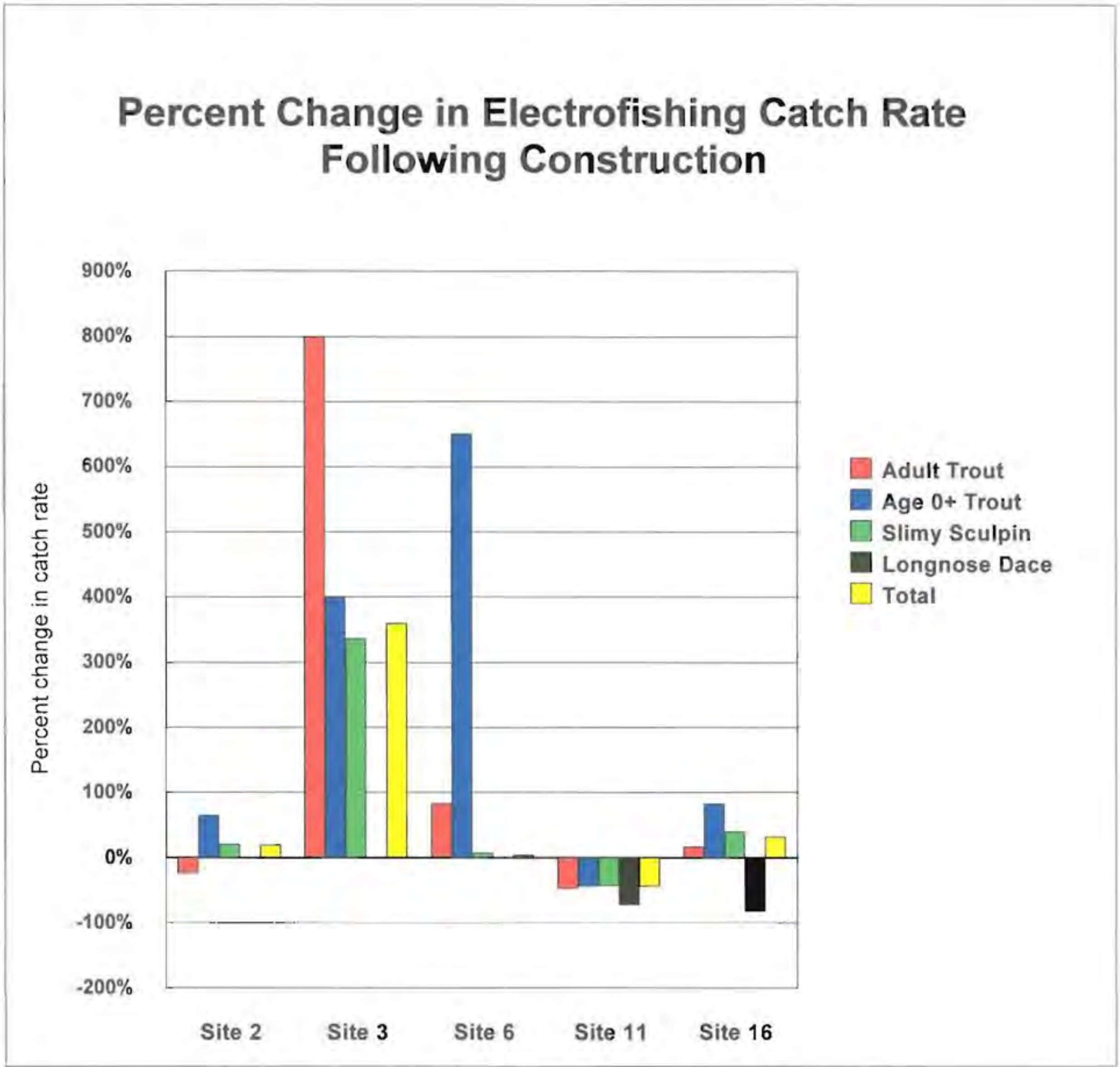


Table 8. The metric scores and total scores for EPA's Rapid Bioassessment Protocol V. Metric scores (given after percentage) can be 1, 3, or 5, with 5 being the highest environmental quality. All sites were categorized on the border between fair and good before and after construction.
b= before construction, a= after construction

	2b	2a	3b	3a	6b	6a	11b	11a	16b	16a
Total number of native species	80%-5	67%-3	100%-5	67%-3	67%-3	67%-3	75%-5	75%-5	75%-5	75%-5
Number of sculpin species	20%-1	33%-3	50%-3	33%-3	33%-3	33%-3	25%-1	25%-1	25%-1	25%-1
Number of salmonid species	40%-3	67%-3	50%-3	67%-3	67%-3	67%-3	50%-3	50%-3	50%-3	50%-3
Number of adult trout species	40%-3	67%-3	50%-3	67%-3	67%-3	67%-3	50%-3	50%-3	50%-3	50%-3
Number of intolerant species	20%-1	0%-1	0%-1	0%-1	0%-1	0%-1	25%-1	25%-1	25%-1	25%-1
Number of tolerant individuals	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5
Number of yearling individuals	5%-5	8%-5	10%-5	11%-5	2%-5	13%-5	5%-5	5%-5	8%-5	11%-5
Number of insectivorous individuals	87%-5	87%-5	86%-5	82%-5	91%-5	77%-5	90%-5	90%-5	84%-5	82%-5
Number of catchable salmonids	8%-5	5%-3	3%-3	7%-5	7%-5	10%-5	5%-3	5%-3	8%-5	7%-5
Number of individuals in sample	84%-5	5	22%-1	5	79%-5	5	5	55%-3	76%-5	5
Number of simple lithophil individuals	13%-5	13%-5	14%-5	18%-5	9%-5	22%-5	10%-5	10%-5	16%-5	18%-5
Number of diseased individuals	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5	0%-5
Total	48	46	44	48	48	48	46	44	48	48

Table 9. Mark-recapture record for 11/4/99 and 11/18/99. The fish were tagged at the site along the side and recaptured at the site along the top. The date of the first capture is given. *= recaptured at different site

		Recapture Site				
	Date of Recapture	11/4	11/4	11/18	11/18	4/2
		Site 2	Site 6	Site 6	Site 16	Site 11
Mark Site	Site 2	9/23				
	Site 6	10/7*				
	Site 6		8/5			
	Site 6			8/5		
	Site 6			10/7		
	Site 6			11/4		
	Site 6			11/4		
	Site 11					10/28
	Site 16				10/28	

Table 10. Average lengths and weights of Big Bear Creek's fish age classes. The data is given in the form x±sd. Mean lengths of age 0+ trout are estimated, since all trout around 10cm or less were not weighed, measured, tagged, or scaled. It was assumed that these trout were age 0+. Also note that there was only one age 3+ trout captured.

	Brook Trout		Brown Trout	
Age (years)	Length (cm)	Weight (g)	Length (cm)	Weight (g)
0+	9		9	
1+	16.2±2.2	48.2±22.7	17.7±2.2	53.9±19.8
2+	23.3±2.9	131.1±81.4	23.7±3.5	144.0±57.0
3+			26	170

Figure 8. Graph of Table 10.

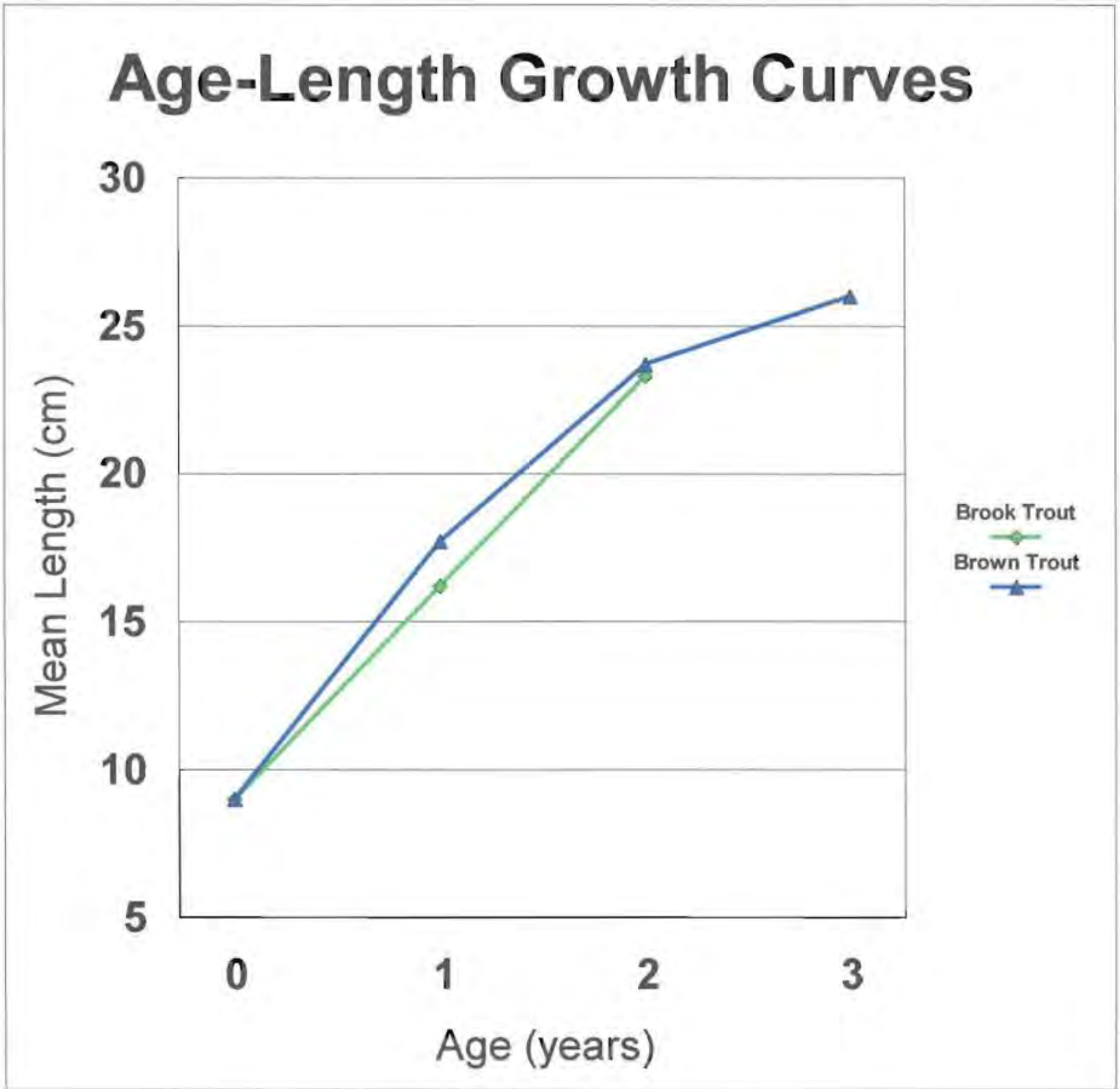


Table 11. Numbers of brook and brown trout in various size categories. These numbers represent the total numbers of trout caught in each category via electrofishing before and after construction.

Lengh (cm)	Brook Trout	Brown Trout
<10	94	8
10-15	28	17
15.5-20	20	20
20.5-25	9	11
25.5-30	4	13
>30	0	1

Figure 9. Graph of Table 11.

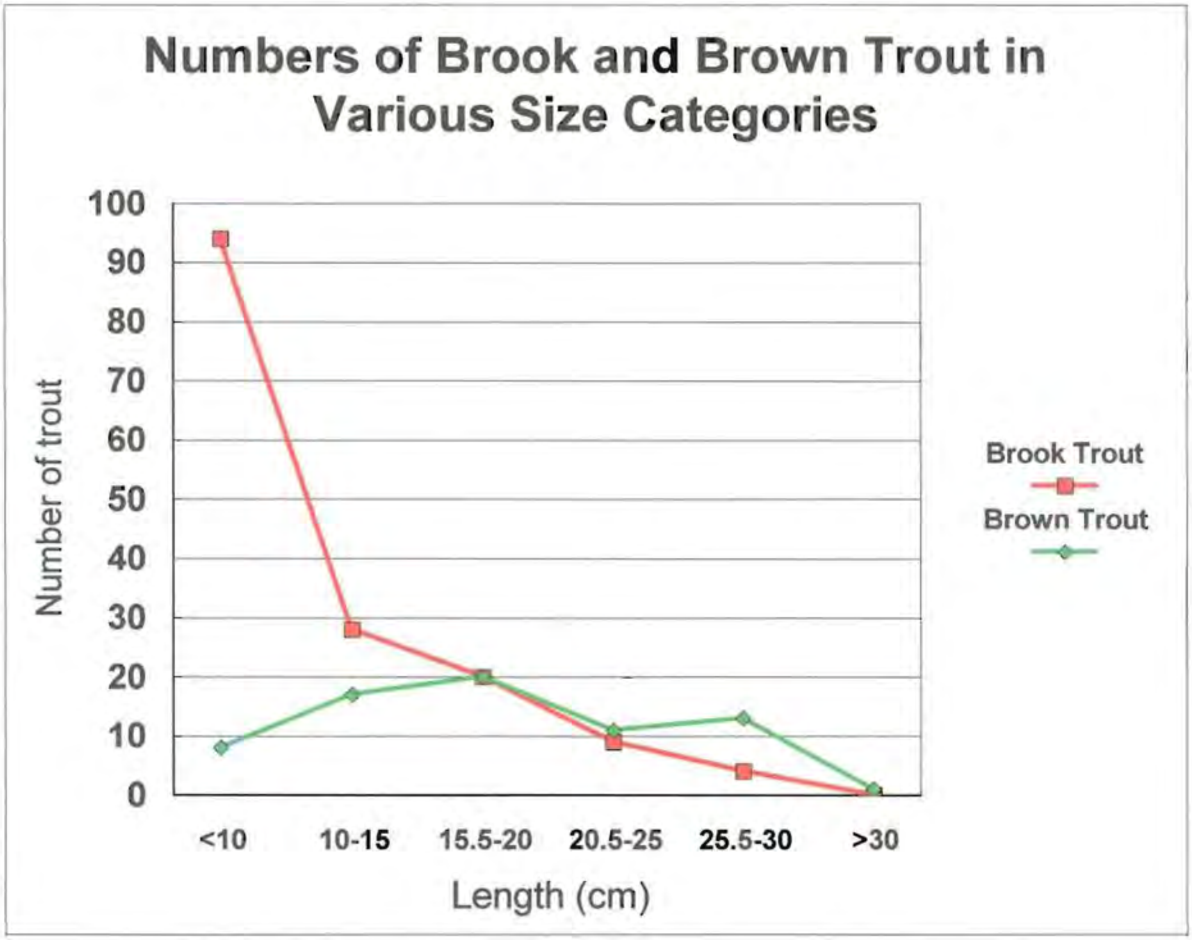


Table 12. Mean numbers of fish captured per 100m of stream before and after construction. The letter "b" after the site number signifies before construction, while the "a" means after.

	2-b	2-a	3-b	3-a	6-b	6-a	11-b	11-a	16-b	16-a
Adult trout	4.2	4.1	0.6	5.6	4.5	8.2	6.2	3.3	3	3.5
Age 0+ trout	3	5	1.9	9.4	1.5	11.2	6.1	3.3	3	5.5
Sculpins	47	56.8	15.6	68.1	61.1	65.6	104.4	58.8	29	40.5
Dace	0.3	0	0	0	0	0	3.1	0.4	3	0.5
Total	54.8	65	18.1	83.1	67.1	84.9	119.8	65.8	38	50

Figure 10. Chart of Table 12 data for adult and age 0+ trout.

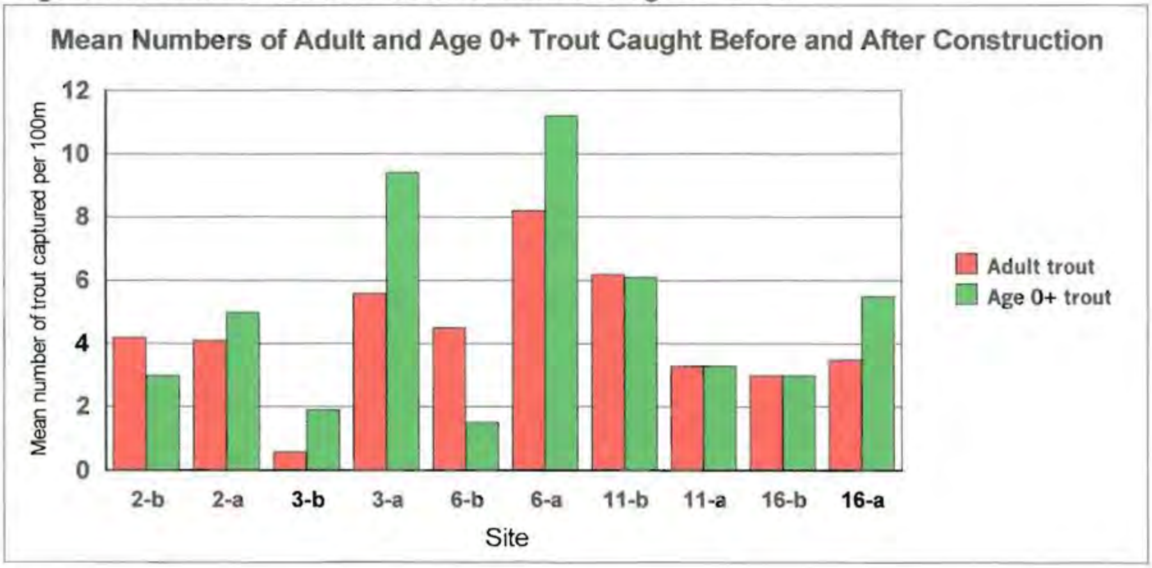
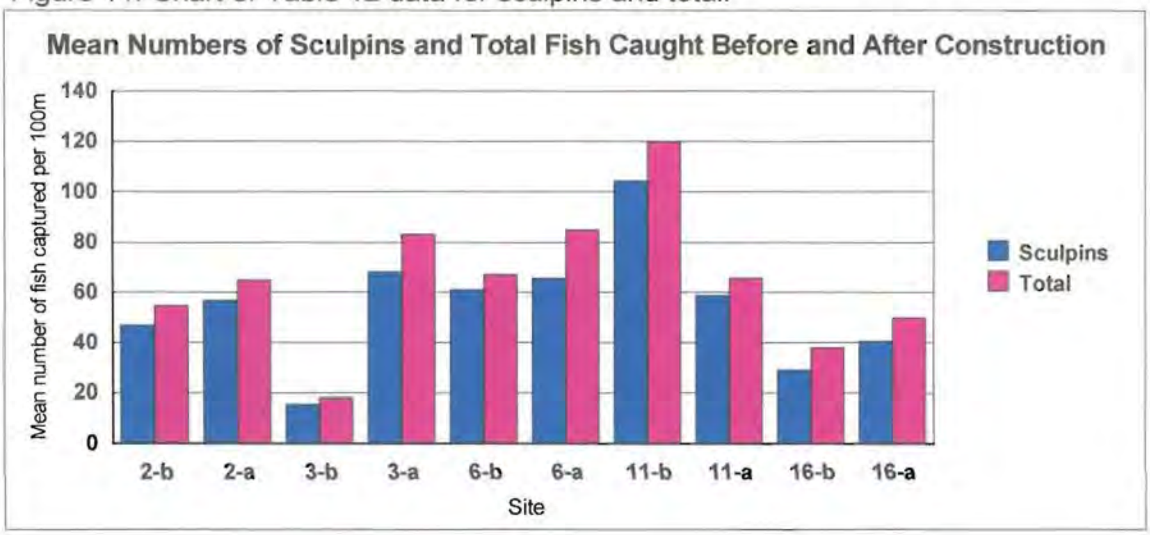


Figure 11. Chart of Table 12 data for sculpins and total.



Appendix I

Figure A. Dunwoody Club Trout Catch 1903-1930. Catchable trout were stocked in 1906, 1908, 1913, 1915, and 1918. Fry were stocked in 1921, and annual stocking of catchable trout began in 1923.

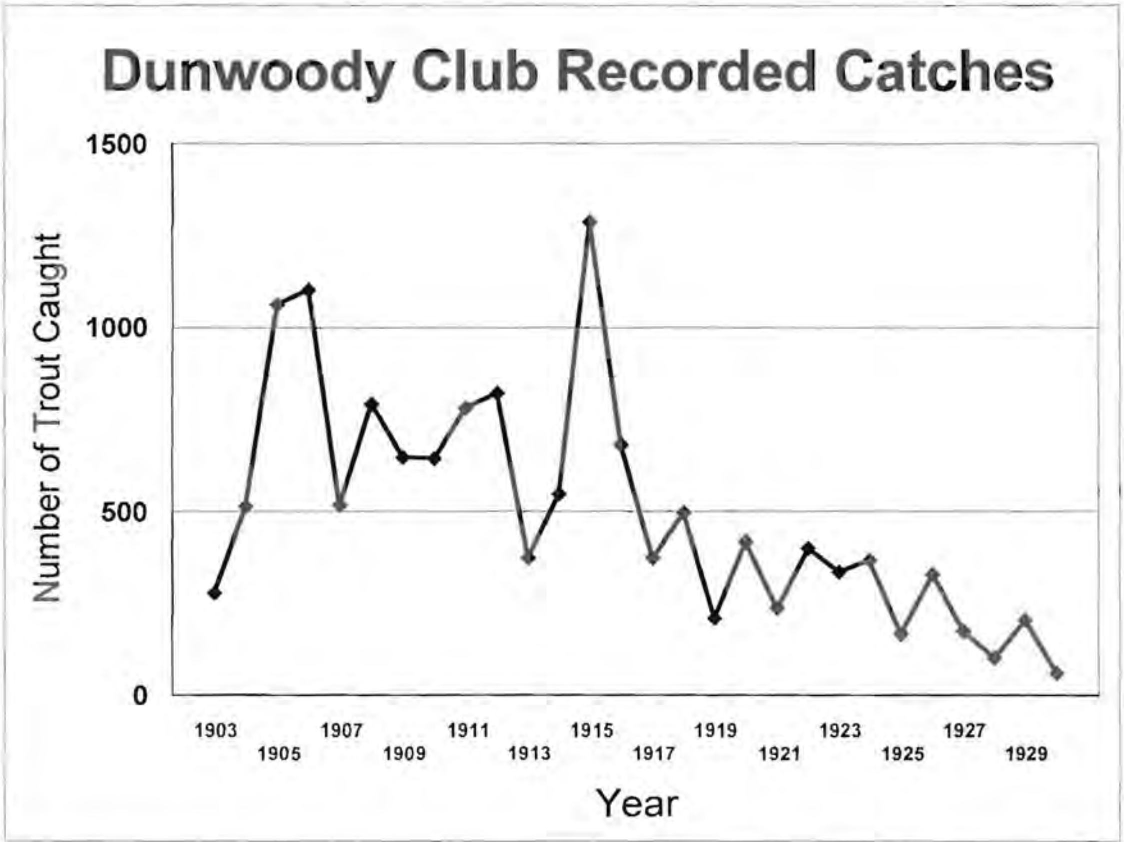


Table A. Habitat assessment results for five sites on Big Bear Creek in September 1999. The scores for each parameter range from 0 to 20, with 20 being the best habitat.

Habitat Parameter	Site 2	Site 3	Site 6	Site 11	Site 16
Instream Cover	18	20	20	20	17
Epifaunal Substrate	20	20	20	17	20
Embeddedness	20	17	17	18	19
Velocity/Depth Regimes	14	19	18	20	9
Channel Alteration	20	20	20	14	20
Sediment Deposition	20	17	15	17	10
Frequency of Riffles	19	20	20	18	20
Channel Flow Status	7	8	12	13	7
Condition of Banks	2	2	6	10	7
Bank Vegetative Protection	19	11	19	11	17
Grazing or Other Disruptive Pressure	20	20	20	15	20
Riparian Vegetative Zone Width	20	20	20	14	20

Figure B. An example of inappropriate practice. The gabions have caused severe bank erosion at times of high water.

Figure C. A J-hook vein provides erosion control and some great trout habitat.

Figure D. A truncated cross vein rolls water to the center of the stream, protecting the banks.

Figure E. The stream bottom was disturbed by the construction process.

Appendix II

Benthic Macroinvertebrate Raw Data - surber, kick, and CPOM samples

Feeding Groups:

- P = predator
- SH = shredder
- CG = collecting gatherer
- SC = scraper
- FC = filtering collector

Big Bear Creek Benthic Macroinvertebrates - July to September 1999 - Site 2

date		7/13	7/13	7/31	7/31	9/2	9/2	9/2	9/14	9/14
s=surber, k=kick, c=CPOM		s	k	s	k	s	k	c	s	k
Nematoda			2							
Annelida										
Oligocheata				1						1
Decapoda										
Cambaridae						1				
Plecoptera										
Chloroperlidae	P	1			7	3				
Leuctridae										
Leuctra	SH				2	3			2	12
Peltoperlidae	SH					2	4	30	2	1
Perlidae										
Paragnetina	P									
Perlesta	P									
Phasganophora	P									
Perlodidae										
Isogenoides	P									
Isoperla	P						18	2		
Pteronarcidae										
Pteronarcys	SH		7	1	3					
Ephemeroptera										
Baetidae										
Baetis	CG	1	25	2	17	16	37	2	13	30
Ephemerellidae										
Drunella	SC		15	3	12			1		
Ephemerella	CG									
Seratella	CG				4					
Heptageniidae										
Cinygmula	SC				1					
Epeorus	CG		22	8	3	2	1		3	3
Heptagenia	SC			2						1
Stenonema	SC		1	1	7	24	13		22	10
Leptophlebiidae										
Paraleptophlebia	CG									5
Tricorythidae										
Odonata										
Gomphidae										
Lanthus	P		1			1				
Libellulidae	P									

date		7/13	7/13	7/31	7/31	9/2	9/2	9/2	9/14	9/14
s=surber, k=kick, c=CPOM		s	k	s	k	s	k	c	s	k
Megaloptera										
Corydalidae										
Nigronia	P									
Trichoptera										
Brachycentridae										
Brachycentrus	FC	6	1	6	9	30	2	45	40	1
Glossosomatidae										
Glossosoma	SC									
Hydropsychidae										
Hydropsyche	FC		7	3	9	20	31	6	4	18
Lepidostomatidae										
Lepidostoma	SH		1		2					
Leptoceridae										
Setodes	CG	4			4	6	2		2	
Philopotamiidae										
Chimarra	FC		1	1	1					
Dolophilodes	FC		2			12	8		2	4
Phryganeidae	SH									1
Rhyacophilidae										
Rhyacophila	P		3	9	1	2		1	5	
Coleoptera										
Elmidae										
Optioservus	SC								1	
Promoresia	SC									
Stenelmis	SC		1				1			
Ptilodactylidae										
Anchytarsus	SH						1			
Curulonidae										
Diptera										
Athericidae	P		8	6	18	2			2	18
Ceratopogonidae	P									
Chironomidae	CG		2	1	15	33	22	18	8	11
Empipidae	P		1	2						
Simulidae										
Simulium	FC		2		9		1	2		
Tabanidae	P					1				
Tipulidae										
Hexatoma	P				3					
Tipula	SH			1	1				1	
Total		12	101	48	128	158	141	107	107	116

Big Bear Creek Benthic Macroinvertebrates - October 1999 to March 2000 - Site 2

date		10/5	10/19	11/2	11/2	1/12	2/2	3/6
s=surber, k=kick, c=CPOM		s	k	s	k	k	k	k
Nematoda								
Annelida								
Oligocheata								
Decapoda								
Cambaridae								
Plecoptera								
Chloroperlidae	P							
Leuctridae								
Leuctra	SH	1	21	4	16	8	23	14
Peltoperlidae	SH		1	4	1	2	2	
Perlidae								
Paragnetina	P							
Perlesta	P							
Phasganophora	P							
Perlodidae								
Isogenoides	P					8	3	3
Isoperla	P					1	3	3
Pteronarcidae								
Pteronarcys	SH			2		1		
Ephemeroptera								
Baetidae								
Baetis	CG	6	1		1	6	3	10
Ephemerellidae								
Drunella	SC							
Ephemerella	CG		3	6	7	9	5	13
Seratella	CG							
Heptageniidae								
Cinygmula	SC	1						
Epeorus	CG	1	3	15	15	24	33	18
Heptagenia	SC	2			2	4	5	4
Stenonema	SC	15	11	3	7		1	
Leptophlebiidae								
Paraleptophlebia	CG		11	3	6	11	10	16
Odonata								
Gomphidae								
Lanthus	P							
Libellulidae	P							

date		10/5	10/19	11/2	11/2	1/12	2/2	3/6
s=surber, k=kick, c=CPOM		s	k	s	k	k	k	k
Megaloptera								
Corydalidae								
Nigronia	P							
Trichoptera								
Brachycentridae								
Brachycentrus	FC	10		5	2		5	
Glossosomatidae								
Glossosoma	SC							
Hydropsychidae								
Hydropsyche	FC	4	20	2	9	5		2
Lepidostomatidae								
Lepidostoma	SH							
Leptoceridae								
Setodes	CG	9	12	7	7	10	2	1
Philopotamiidae								
Chimarra	FC							
Dolophilodes	FC	1	9		4	2	1	6
Phryganeidae	SH		2		1	1		
Rhyacophilidae								
Rhyacophila	P						4	
Coleoptera								
Elmidae								
Optioservus	SC		2		2	1		
Promoresia	SC							
Stenelmis	SC							
Ptilodactylidae								
Anchytarsus	SH							
Curulonidae								
Diptera								
Athericidae	P	1	1		19	2	5	6
Ceratopogonidae	P							
Chironomidae	CG	2	4	1	6	8	1	8
Empipidae	P							
Simulidae								
Prosimulium	FC					5	2	1
Simulium	FC							
Tabanidae	P							
Tipulidae								
Hexatoma	P							
Tipula	SH		4		1	2		3
Total		53	105	52	106	110	108	111

Big Bear Creek Benthic Macroinvertebrates - 1999 - Site 11

date		7/13	7/31	7/31	9/14	9/14	10/20	10/20	10/20	10/20	11/9
s=surber, k=kick, c=CPOM		k	s	k	s	k	s	s	s	k	s
Nematoda											
Annelida											
Oligocheata											
Decapoda											
Cambaridae											
Plecoptera											
Chloroperlidae	P	17	1	9	1	4	3		5	2	1
Leuctridae											
Leuctra	SH					12				12	10
Peltoperlidae	SH					2			2		1
Perlidae											
Paragnetina	P			1						1	
Perlesta	P			1							
Phasganophora	P										1
Perlodidae											
Isogenoides	P	1					5	3	4		
Isoperla	P			1							
Pteronarcidae											
Pteronarcys	SH	3									2
Ephemeroptera											
Baetidae											
Baetis	CG	16	1	4		23	3	3	2	3	
Ephemerellidae											
Drunella	SC	18	9	23	1						
Ephemerella	CG			1						12	6
Seratella	CG										
Heptageniidae											
Cinygmula	SC				1						
Epeorus	CG	3	1	10		1		2	3	1	3
Heptagenia	SC	3	1	1	1		6	11	2		
Stenonema	SC			6	12	15				15	5
Leptophlebiidae											
Paraleptophlebia	CG	10		9	1	3				1	
Odonata											
Gomphidae											
Lanthus	P										
Libellulidae	P										

date		7/13	7/31	7/31	9/14	9/14	10/20	10/20	10/20	10/20	11/9
s=surber, k=kick, c=CPOM		k	s	k	s	k	s	s	s	k	s
Megaloptera											
Corydalidae											
Nigronia	P			5		1				1	
Trichoptera											
Brachycentridae											
Brachycentrus	FC		5			5	12	20	3	4	5
Glossosomatidae											
Glossosoma	SC										
Hydropsychidae											
Hydropsyche	FC	3	1	3		11	7	14	4	23	6
Lepidostomatidae											
Lepidostoma	SH						12	6	3		
Leptoceridae											
Setodes	CG					5				7	17
Philopotamiidae											
Chimarra	FC										
Dolophilodes	FC	2		3		1	2			3	
Phryganeidae	SH					3				3	
Rhyacophilidae											
Rhyacophila	P	3		6							
Coleoptera											
Elmidae											
Optioservus	SC			2				2			
Promoresia	SC									4	
Stenelmis	SC										
Ptilodactylidae											
Anchytarsus	SH										
Curulonidae											
Diptera											
Athericidae	P	19	3	8	2	1	3	4		1	
Ceratopogonidae	P										
Chironomidae	CG		1	11	2	17	2	1	1	10	5
Empipidae	P										
Simulidae											
Simulium	FC										
Tabanidae	P										
Tipulidae											
Hexatoma	P										
Tipula	SH			1						1	1
Total		98	23	102	21	104	59	73	40	104	63

Big Bear Creek Benthic Macroinvertebrates - 2000 - Site 11

date		1/12	2/2	3/6
s=surber, k=kick, c=CPOM		k	k	k
Nematoda				
Annelida				
Oligocheata				
Decapoda				
Cambaridae				
Plecoptera				
Chloroperlidae	P			
Leuctridae				
Leuctra	SH	6	2	4
Peltoperlidae	SH	1		
Perlidae				
Paragnetina	P			
Perlesta	P			
Phasganophora	P			
Perlodidae				
Isogenoides	P	10	4	3
Isoperla	P	7	1	1
Pteronarcidae				
Pteronarcys	SH			
Ephemeroptera				
Baetidae				
Baetis	CG	6	11	13
Ephemerellidae				
Drunella	SC			
Ephemerella	CG	4	10	7
Seratella	CG			
Heptageniidae				
Cinygmula	SC			
Epeorus	CG	24	41	23
Heptagenia	SC	2	3	19
Stenonema	SC	6		4
Leptophlebiidae				
Paraleptophlebia	CG	3	6	11
Odonata				
Gomphidae				
Lanthus	P			
Libellulidae	P			

date		1/12	2/2	3/6
s=surber, k=kick, c=CPOM		k	k	k
Megaloptera				
Corydalidae				
Nigronia	P			1
Trichoptera				
Brachycentridae				
Brachycentrus	FC	1	1	1
Glossosomatidae				
Glossosoma	SC			
Hydropsychidae				
Hydropsyche	FC	4	3	2
Lepidostomatidae				
Lepidostoma	SH			
Leptoceridae				
Setodes	CG	8	2	4
Philopotamiidae				
Chimarra	FC			
Dolophilodes	FC	1		
Phryganeidae	SH		1	2
Rhyacophilidae				
Rhyacophila	P			
Coleoptera				
Elmidae				
Optioservus	SC			
Promoresia	SC			
Stenelmis	SC			
Ptilodactylidae				
Anchytarsus	SH			
Curulonidae				
Diptera				
Athericidae	P	2	1	3
Ceratopogonidae	P			
Chironomidae	CG	5	5	6
Empipidae	P			
Simulidae				
Prosimulium	FC		1	6
Simulium	FC			
Tabanidae	P			
Tipulidae				
Hexatoma	P			
Tipula	SH	3	4	
Total		93	96	110

Big Bear Creek Benthic Macroinvertebrates - 1999 - Site 16

date		7/31	7/31	9/2	9/2	9/2	10/5	10/5	11/2	11/2
s=surber, k=kick, c=CPOM		s	k	s	k	c	s	k	s	k
Nematoda							1			
Annelida										
Oligocheata		1					2	1		
Decapoda										
Cambaridae										
Plecoptera										
Chloroperlidae	P	1	5	1				2		
Leuctridae										
Leuctra	SH	2	11		28	4	1	22	3	21
Peltoperlidae	SH	36	2	1		17			1	
Perlidae										
Paragnetina	P							2	2	1
Perlesta	P									
Phasganophora	P									
Perlodidae										
Isogenoides	P									
Isoperla	P	1								
Pteronarcidae										
Pteronarcys	SH							1		
Ephemeroptera										
Baetidae										
Baetis	CG	4	22	5	16	4	3	5		2
Ephemerellidae										
Drunella	SC	11	1							
Ephemerella	CG						2	5	1	3
Seratella	CG	1								
Heptageniidae										
Cinygmula	SC		2	3	3			1		
Epeorus	CG	18	1	2	2					5
Heptagenia	SC	1	1	3	1					4
Stenonema	SC		4	1	5		6	16	6	10
Leptophlebiidae										
Paraleptophlebia	CG		6					4		3
Odonata										
Gomphidae										
Lanthus	P									
Libellulidae	P			1						

date		7/31	7/31	9/2	9/2	9/2	10/5	10/5	11/2	11/2
s=surber, k=kick, c=CPOM		s	k	s	k	c	s	k	s	k
Megaloptera										
Corydalidae										
Nigronia	P		1				1		2	
Trichoptera										
Brachycentridae										
Brachycentrus	FC	20	2	6	6	9	7	1	11	2
Glossosomatidae										
Glossosoma	SC									
Hydropsychidae										
Hydropsyche	FC	46	14	3	17	51	24	11	10	24
Lepidostomatidae										
Lepidostoma	SH									
Leptoceridae										
Setodes	CG		4	1	12		3	16	5	12
Philopotamiidae										
Chimarra	FC									
Dolophilodes	FC	16	8	2	11		4			1
Phryganeidae	SH			1		1		2	1	2
Rhyacophilidae										
Rhyacophila	P	8	1	2						
Coleoptera										
Elmidae										
Optioservus	SC				2				2	3
Promoresia	SC					1				
Stenelmis	SC									
Ptilodactylidae										
Anchytarsus	SH	1	1	1						
Curulonidae			1							
Diptera										
Athericidae	P	4	5	1	5	5	1	2		4
Ceratopogonidae	P									
Chironomidae	CG	8	12	15	21	11	2	4	1	8
Empipidae	P									
Simulidae										
Simulium	FC	28		1	2	1				
Tabanidae	P									
Tipulidae										
Hexatoma	P									
Tipula	SH	1			1		1	1		
Total		208	104	50	132	104	58	96	45	105

Big Bear Creek Benthic Macroinvertebrates - 2000 - Site 16

date		1/12	2/2	3/6
s=surber, k=kick, c=CPOM		k	k	k
Nematoda				
Annelida				
Oligocheata		1		
Decapoda				
Cambaridae				
Plecoptera				
Chloroperlidae	P			
Leuctridae				
Leuctra	SH	2	5	3
Peltoperlidae	SH	1		
Perlidae				
Paragnetina	P		1	
Perlesta	P			
Phasganophora	P			
Perlodidae				
Isogenoides	P	2	4	3
Isoperla	P	2	7	1
Pteronarcidae				
Pteronarcys	SH			
Ephemeroptera				
Baetidae				
Baetis	CG	9	13	14
Ephemerellidae				
Drunella	SC			
Ephemerella	CG	12	5	7
Seratella	CG			
Heptageniidae				
Cinygmula	SC			
Epeorus	CG	30	37	23
Heptagenia	SC	1	4	19
Stenonema	SC	5		3
Leptophlebiidae				
Paraleptophlebia	CG	7	15	11
Odonata				
Gomphidae				
Lanthus	P			
Libellulidae	P			

date		1/12	2/2	3/6
s=surber, k=kick, c=CPOM		k	k	k
Megaloptera				
Corydalidae				
Nigronia	P	2		
Trichoptera				
Brachycentridae				
Brachycentrus	FC	2	1	
Glossosomatidae				
Glossosoma	SC			
Hydropsychidae				
Hydropsyche	FC	16	8	5
Lepidostomatidae				
Lepidostoma	SH			
Leptoceridae				
Setodes	CG	2	1	3
Philopotamiidae				
Chimarra	FC			
Dolophilodes	FC	6	1	
Phryganeidae	SH			
Rhyacophilidae				
Rhyacophila	P			
Coleoptera				
Elmidae				
Optioservus	SC			
Promoresia	SC			
Stenelmis	SC			
Ptilodactylidae				
Anchytarsus	SH			
Curulonidae				
Diptera				
Athericidae	P	1	1	1
Ceratopogonidae	P			
Chironomidae	CG	1	10	
Empipidae	P			
Simulidae				
Prosimulium	FC	3	5	2
Simulium	FC			
Tabanidae	P			
Tipulidae				
Hexatoma	P			
Tipula	SH			
Total		105	118	95

Appendix III

Fish Raw Data - electrofishing catches before and after construction

Big Bear Creek Fish Data

Before Construction

site	2	11	2	11	16	2	3	4	5	7	9	10	2	11	2	3	6
date	6/23	6/23	7/31	7/31	7/31	8/5	8/5	8/5	8/5	8/5	8/5	8/5	9/23	9/23	10/7	10/7	10/7
Brown trout																	
<10cm			1	3							1						
10-15cm		2				4					1	1	3		1		
15.5-20cm	1	1	1	3	1	2	1				1		1	1			
20.5-25cm	1	1	1			1		1					1				1
25.5-30cm	1	3					1	1	3								1
>30cm										1							
Brook trout																	
<10cm	2	4	4	6	3				1	1			3	9	1	3	1
10-15cm	2	1	1	3	1		2	2	2	1	4	1			1		
15.5-20cm		1		3	1			3				1		1			
20.5-25cm		1	1				1			1	1						1
>25cm		1				1										1	
Slimy sculpin	36	54	60	105	29								59	217	22	25	41
Longnose dace		1	1	5	3									5			
Green darter	1																

Big Bear Creek Fish Data

After Construction

site	11	16	2	3	6	6	11	16
date	10/28	10/28	11/4	11/4	11/4	11/18	11/18	11/18
Brown trout								
<10cm	2							1
10-15cm		1	1	1				2
15.5-20cm	4	1					1	1
20.5-25cm				1	2	1		
25.5-30cm					1	1		1
>30cm								
Brook trout								
<10cm	2	4	10	15	6	9	4	6
10-15cm	2		1	2	1			1
15.5-20cm			2	4	2	1	1	
20.5-25cm			1		1	1		
>25cm				1				
Slimy sculpin	76	52	103	109	36	52	65	29
Longnose dace							1	1