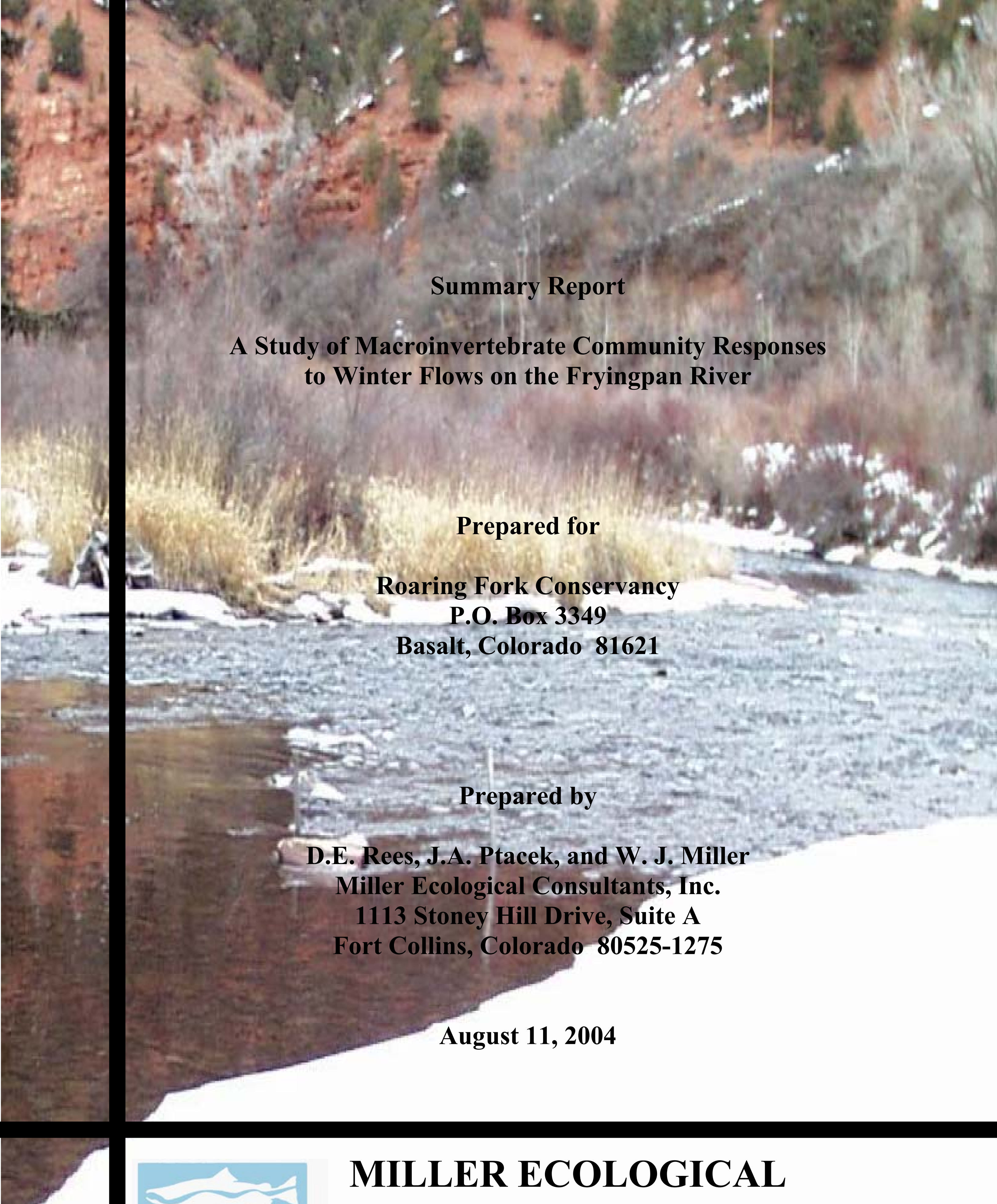

Summary Report

A Study of Macroinvertebrate Community Responses to Winter Flows on the Fryingpan River

Prepared for

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INTRODUCTION

The biological and physical processes that govern the structure and function of benthic macroinvertebrate communities in the Fryingpan River are not entirely understood. However, there is evidence to suggest that the flow regime may be an important physical influence on benthic communities (Rees et al. 2003). For this reason, macroinvertebrate sampling and thermal modeling continued during the fall 2003 and spring 2004 in the Fryingpan River as part of a study to assess the influence of releases from Ruedi Reservoir. Water releases from the impounded reservoir can influence benthic macroinvertebrates and fish communities through regulation of flow and alteration of the thermal regime. It has been hypothesized that erratic changes in discharge have a negative impact on benthic macroinvertebrates (Ptacek et al. 2003); however, it is not clear how the level of discharge during the winter months and the potential formation of anchor ice may influence these communities.

In many ways, the impoundment and physical variables associated with discharge are responsible for the development of an exceptional trout fishery in the Fryingpan River. The purpose of this extended sampling was to evaluate potential impacts associated with low winter flows. This information could be useful when determining management practices that will benefit the trout fishery. Macroinvertebrate monitoring coupled with robust laboratory analysis can provide a great deal of information pertaining to the influence of the flow regime on aquatic conditions.

METHODS

MACROINVERTEBRATE SAMPLING

Benthic macroinvertebrate sampling was conducted during fall (29 October) of 2003, and spring (29 April) of 2004. Two sites on the Fryingpan River (FPR-Res and FPR-TC) were sampled on each occasion. At each location, three samples were taken in riffle habitat using a Hess Sampler with 500 µm mesh to provide quantitative macroinvertebrate data. All samples were taken in areas of similar size substrate and

Figure 1. Satellite image of Fryingpan River study area from Ruedi Reservoir downstream to below Downey Creek (Macroinvertebrates: red, and Thermographs: purple).

Figure 2. Satellite image of Fryingpan River study area from Downey Creek to Basalt (Macroinvertebrates: red, Thermographs: purple).

similar depth to avoid bias that may be directly related to habitat. Depth at each sample location ranged between 24.4 cm and 33.5 cm. Substrate within the Hess Sampler was thoroughly disturbed and individual rocks were scrubbed by hand to dislodge all benthic organisms. Benthic macroinvertebrates were preserved in ethanol and transported to the lab where they were sorted, enumerated and identified to the lowest practical taxonomic level (Merritt and Cummins 1996; Ward et al. 2002).

Identification to the "lowest practical taxonomic level" means that all specimens were identified down to the level that is permitted by the available morphological characteristics. Early life stages of many species lack certain anatomical characteristics that allow the specimen to be identified to the genus or species level. In these cases the "lowest practical taxonomic level" may mean only the family level; however, if the available characteristics are consistent with a species that has been previously confirmed during this study then the individual may be included as a member of that taxa. In these cases the species name is provided in parentheses.

As a means of QA/QC, qualified personnel inspected each sample after sorting and a minimum of 20% of all identified taxa were reviewed. Dr. Boris Kondratieff (Professor of Entomology at Colorado State University) confirmed identifications in all cases where the identification of a specimen was difficult or questionable.

In instances where proper identification was possible, the Orders Ephemeroptera, Plecoptera, and Trichoptera were identified to genus (and many down to the species level). Most specimens of other Orders, including Diptera, were identified to the genus level; however, members of the family Chironomidae were only identified to subfamily or tribe. Further identification would require mounting of head capsules – an expensive and time-consuming process. Data collected were used in various indices recommended by the Rapid Bioassessment Protocols (Plafkin et al. 1989) to provide information regarding macroinvertebrate community structure, function, and general aquatic conditions.

Indices used included Shannon-Weaver diversity (diversity) and evenness (evenness), Family Biotic Index (FBI), EPT index, taxa richness (richness), and description of functional feeding groups. Diversity and evenness values were used to detect changes in macroinvertebrate community structure. In unpolluted waters diversity values typically range from near 3.0 to 4.0. In polluted waters this value is generally less than 1.0. The evenness value ranges between 0.0 and 1.0. Values lower than 0.3 are generally considered indicative of organic pollution (Ward et al. 2002).

The Hilsenhoff Family Biotic Index (FBI) is often used in macroinvertebrate studies as a means of detecting organic enrichment. In this study it was useful for monitoring differences between the sites that may not be attributed to discharge. Because the FBI requires modification for use in many areas, the number indicating a certain water quality rating will vary among regions. Comparison of the values produced within a given system should, however, provide information regarding difference in sites based on nutrient enrichment. Values for the FBI range from 0.0 to 10.0, and increase as water quality decreases (Plafkin et al. 1989).

The Ephemeroptera, Plecoptera, Trichoptera (EPT) index will be employed to assist in the analysis of the data. It is a direct measure of taxa richness among species that are typically considered more sensitive to pollution or other perturbations. This measurement is simply given as the total number of identified taxa in the orders Ephemeroptera, Plecoptera and Trichoptera found at each station.

Taxa richness was also reported for each sampling event during the study. This measurement is reported as the total number of different taxa collected on each date from each sampling location. It is similar to the EPT index, except that it includes all different identifiable benthic macroinvertebrate species. It is useful for describing differences in habitat complexity or aquatic conditions between rivers or site locations.

Benthic macroinvertebrate production at each site was estimated by measuring macroinvertebrate density and biomass. Density was reported as the mean number of macroinvertebrates/m^2 found at each location. Densities were compared among sites for each sampling occasion. Biomass values were obtained by drying the benthic macroinvertebrates from each sample in an oven at 100° C for 24-hours or until all water content had evaporated. Biomass was reported as the mean dry weight of macroinvertebrates per square meter at each site location. Biomass values provide information in terms of weight of macroinvertebrates produced by habitat at each site. Density and biomass provide a means of measuring and comparing productivity at each sampling location.

Separating invertebrate taxa into functional guilds based on food acquisition provided a measurement of macroinvertebrate community function. Aquatic macroinvertebrates were categorized according to feeding strategy to determine the relative proportion of various groups. The proportion of certain functional feeding groups in the macroinvertebrate community can provide insight to various types of stress in river systems (Ward et al. 2002)

THERMAL REGIME

To describe the winter thermal regime in the Fryingpan River we used Stowaway® Tidbit® temperature loggers (accuracy ±0.2^{o}C) encased in a small (10 cm) section of pvc pipe for protection. We surveyed water temperatures at the following four locations in the Fryingpan River: downstream of Ruedi Dam at the USGS gaging station (Gaging Station), Pruessing Property (Pruessing Site), Roy Palm Property (Palm Site), and upstream of the confluence with the Roaring Fork River behind Taylor Creek Fly Shop (Fly Shop Site). At each site, capsules were placed in the river and attached to a permanent object by aircraft cable. Holes were drilled in each capsule to ensure adequate circulation of stream water. Each thermograph was set to record hourly water temperatures and was downloaded using a Stowaway® Optic Shuttle. Capsules were placed in inconspicuous mid-channel locations near the stream bottom at a depth where anchor ice is likely to form.

Thermal data was downloaded and input into a computer spreadsheet. We limited the thermal analysis to the months of December, January, and February, which are the months where anchor ice would typically occur. For analysis purposes, we defined an anchor ice event/occurrence as any hourly observation with a water temperature less than 32.3°F (0.2°C).

RESULTS

FALL 2003

Macroinvertebrate sampling and analyses was conducted at sites on the Fryingpan River in the fall of 2003 and spring 2004. Population densities and species lists were developed for each sampling site (Appendix A). In general, results of fall 2003 were similar to results from previous years; however, some slight differences were observed (Table 1). Diversity, evenness, and FBI values indicated that conditions had improved slightly in the fall of 2003. There was an increase in density at FPR-RES (Figure 3), and an increase in biomass at FPR-TC (Figure 4). The reason for the inconsistency between these metrics was due to changes in the abundance of specific taxa in each community. The number of small mayflies (*Baetis tricaudatus*) at FPR-RES increased during the fall of 2003, while the density of some of the larger macroinvertebrates declined. This resulted in a slight increase in densities and a slight decrease in biomass at FPR-RES in the fall of 2003. The opposite effect of this process occurred at site FPR-TC. A slight variation in community structure was also reflected in the function analysis (Figure 5). Functional groups exhibited similar composition during all fall sampling events at both sites, with slight variation occurring mostly in the scraper and collector-filterer groups at FPR-TC.

The differences in metrics observed during three years of fall sampling may be well within the range of natural variation that occurs at these sites. Changes in metric values would not be considered substantial, or suggest that a major community altering event had recently occurred (Table 1). It is important to note the yearly similarities among fall samples because it suggests that changes in macroinvertebrate communities in spring samples are the result of events that occur during winter months.

Table 1. Metrics and comparative values for macroinvertebrate samples collected during the fall season from riffle habitat in the Fryingpan River, Colorado.

Fall 2001	Diversity	Evenness	FBI	EPT	Taxa Richness	Density (#/m^2)	Biomass (g/m^2)
FPR-RES	2.29	0.453	5.86	19	33	16,509	1.3820
FPR-TC	3.76	0.701	4.76	23	41	10,318	2.4338
Fall 2002							
FPR-RES	2.34	0.478	6.62	14	30	28,220	2.0104
FPR-TC	3.35	0.639	5.27	19	38	17,530	2.4856
Fall 2003							
FPR-RES	2.49	0.508	6.35	14	30	31,665	1.8435
FPR-TC	3.39	0.656	5.04	18	36	15,792	3.2179

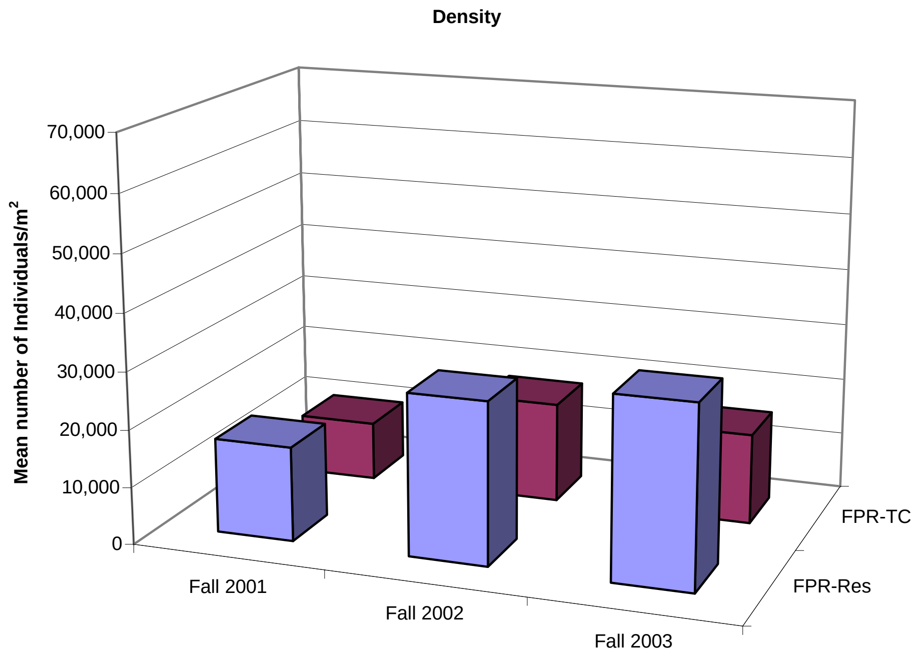


Figure 3. Density values obtained from fall sampling at sites on the Fryingpan River, Colorado.

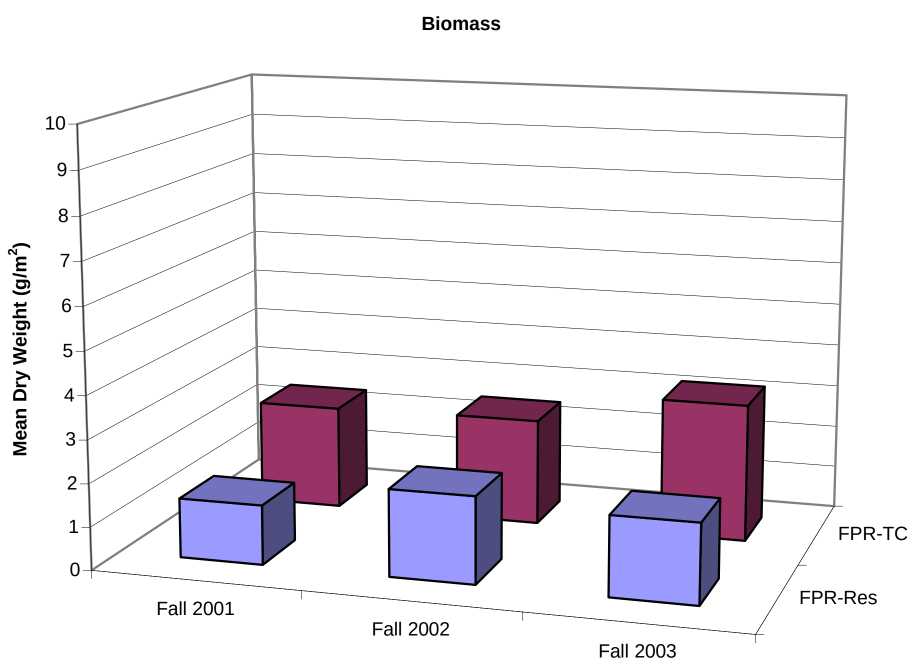
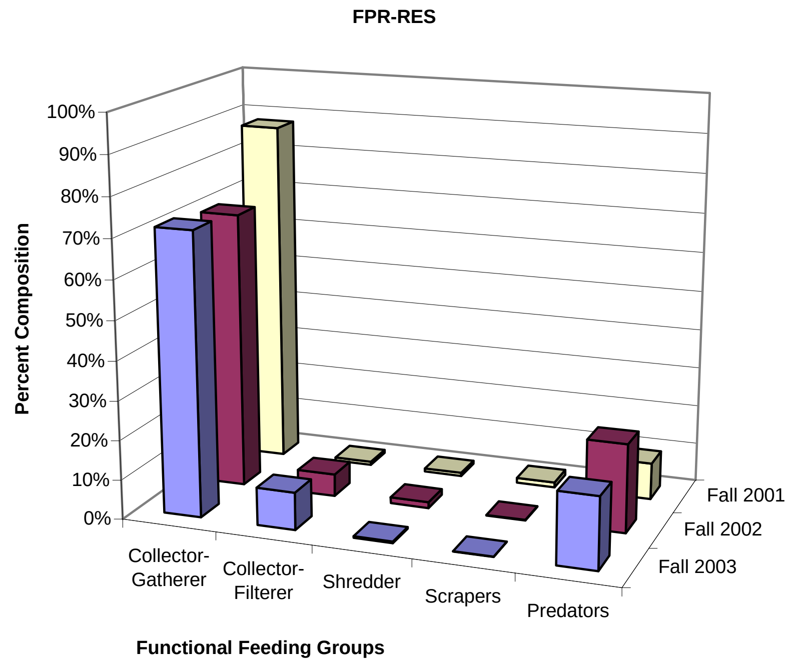


Figure 4. Biomass estimates obtained from fall sampling at sites on the Fryingpan River, Colorado.



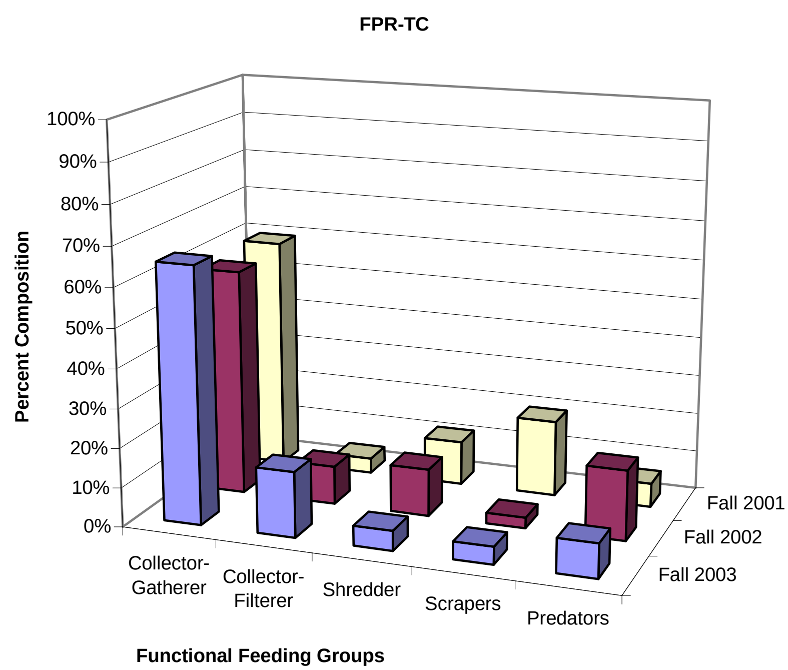


Figure 5. Functional feeding groups at site FPR-RES (top) and FPR-TC (bottom) during fall sampling on the Fryingpan River, Colorado.

SPRING 2004

Evaluation of data collected during spring 2004 indicated that benthic macroinvertebrate communities at both sites had at least partially recovered from conditions existing in 2003 (Table 2). In general, macroinvertebrate communities exhibited an increase in density and biomass at both sites (Figure 6 and Figure 7), while the changes to community composition were mostly site dependant.

The greatest influence on metric values at FPR- RES during the spring of 2004 resulted from a large increase in the density of mayflies, and the presence of additional EPT taxa (mostly caddisflies) that were not accounted for in the spring of 2003. Results of applied metrics indicated that there was a 31% increase in density and a 33% increase biomass at FPR-RES, while EPT and taxa richness values achieved values that were similar to those reported during 2001 and 2002 (Table 2). Other metrics and the composition of benthic macroinvertebrates based on function have remained relatively consistent at this site (Figure 8). The metrics that remained relatively unaffected (diversity, evenness, FBI and functional feeding groups) are often more sensitive to pollution-related disturbance. These metrics have always indicated some disturbance at FPR-RES that was thought to be an influence of Ruedi Dam.

The applied metrics for site FPR-TC were also influenced by higher densities of macroinvertebrates, but community composition remained similar to that observed in 2003. In the spring of 2004 a 95% gain in density and a 258% increase in biomass were observed at FPR-TC. This resulted from a general increase in abundance of several species, and was not restricted to a specific taxonomic group. The quantity of EPT taxa and individuals in these groups increased at FPR-TC during 2004, but the number of chironomids exhibited a similar trend. Therefore, EPT and taxa richness values increased to levels that would be expected based on the first two years of this study, but diversity, evenness and FBI values remained similar to those reported in 2003 (Table 2). This suggests that the macroinvertebrate community at FPR-TC is still not balanced despite the increase of sensitive taxa. The distribution of functional feeding groups reaffirms these results by depicting an allocation of species (based on function) that was similar to what was reported in 2003 (Figure 8).

Several of the species that increased in abundance at FPR-TC in the spring 2004 were caddisflies. This is noteworthy because caddisflies are large-bodied insects that contributed substantially to the increase in the mean biomass observed at this site. Caddisflies may be sensitive to anchor ice formation, but are known to be sensitive to rapid changes in discharge. The increase of caddisflies may signify a reduction in rapid flow changes.

Table 2. Metrics and comparative values for macroinvertebrate samples collected during the spring season from riffle habitat in the Fryingpan River, Colorado.

Spring 2001	**Diversity**	**Evenness**	**FBI**	**EPT**	**Taxa Richness**	**Density (#/m^2)**	**Biomass (g/m^2)**
FPR-RES	2.03	0.406	5.72	17	32	36,770	7.4108
FPR-TC	3.71	0.707	3.97	21	38	18,366	8.7948
Spring 2002							
FPR-RES	2.37	0.471	6.06	20	33	62,996	9.2919
FPR-TC	3.66	0.683	4.86	22	41	21,458	4.3774
Spring 2003							
FPR-RES	2.03	0.470	5.90	9	20	25,198	4.3867
FPR-TC	1.93	0.386	5.66	18	32	20,970	2.0629
Spring 2004							
FPR-RES	2.11	0.430	5.50	16	30	33,191	5.8627
FPR-TC	2.11	0.398	5.64	20	39	40,909	7.3951

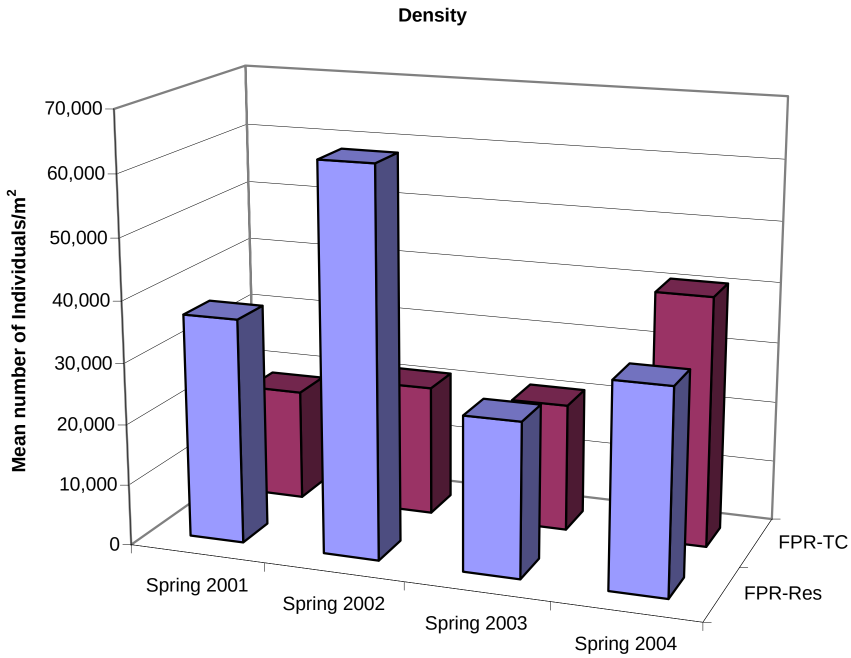


Figure 6. Density values obtained from spring sampling at sites on the Fryingpan River, Colorado.

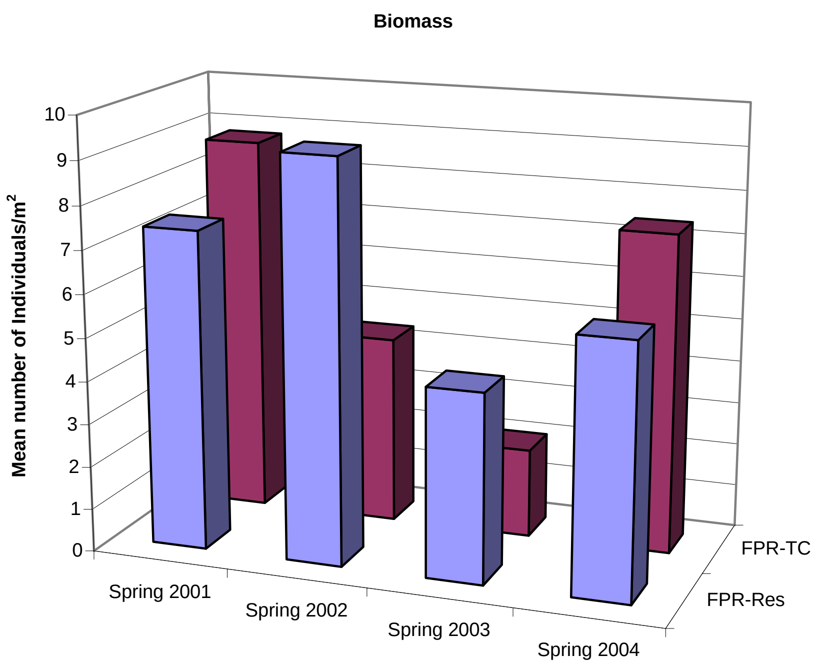
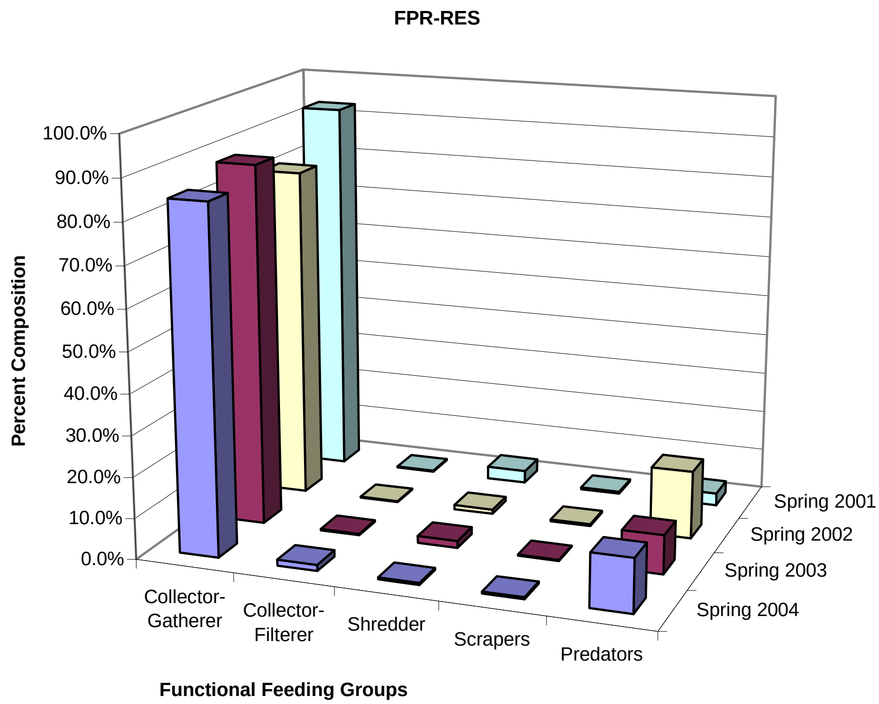


Figure 7. Biomass estimates obtained from spring sampling at sites on the Fryingpan River, Colorado.



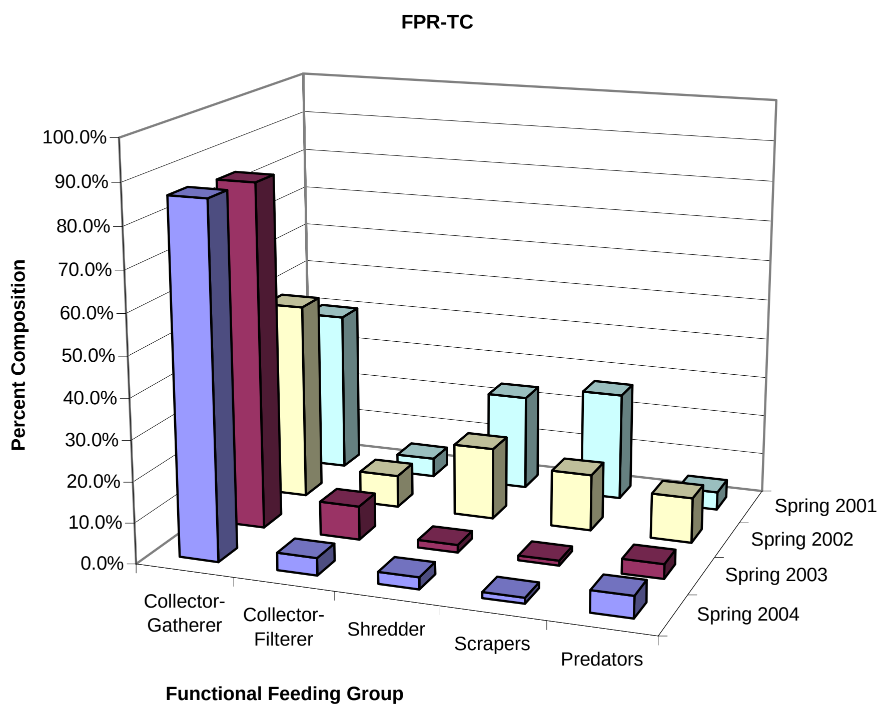


Figure 8. Functional feeding groups at site FPR-RES (top) and FPR-TC (bottom) during spring sampling on the Fryingpan River, Colorado.

DISCUSSION

Aquatic macroinvertebrate communities were evaluated as a means to elucidate the relationships between winter base flows, anchor ice and macroinvertebrates community structure. The results provide a description of the composition of existing macroinvertebrate communities at the time and location of sampling. The mechanisms that influence the community assemblages are numerous and include variables not directly related to flow manipulations (biological interactions, air temperature, etc.). However, the direct and indirect effects of the flow regime resulting from the regulated discharge in the Fryingpan River appear to influence benthic macroinvertebrate communities.

The magnitude of discharge may be the most important factor that influences macroinvertebrates during the winter months. In the winter of 2002-2003 base flows were recorded at an average 40.8 cfs below Ruedi Dam from December through February (Figure 9). Metrics used to describe benthic macroinvertebrate communities in the spring indicated that conditions had declined at both sites. It was hypothesized that benthic communities in the spring of 2003 were responding to physical processes associated with lower discharge (Rees et al. 2003). During the winter of 2003-2004 the mean discharge was approximately 85.2 cfs and some apparent recovery of macroinvertebrate communities was observed at both sites on the Fryingpan River.

Results of metric values from site FPR-RES are likely influenced primarily by discharge because water temperature does not allow anchor ice formation at this site. The mean daily water temperature below the dam was slightly lower during the early portion of the 2002-2003 winter, but water temperature during the coldest months has been similar during each winter season of this study (Figure 10).

Although macroinvertebrate impact and recovery seem to be associated with the magnitude of discharge at both sites on the Fryingpan River, the data suggests that the community at FPR-TC is also influenced by some indirect effects of discharge.

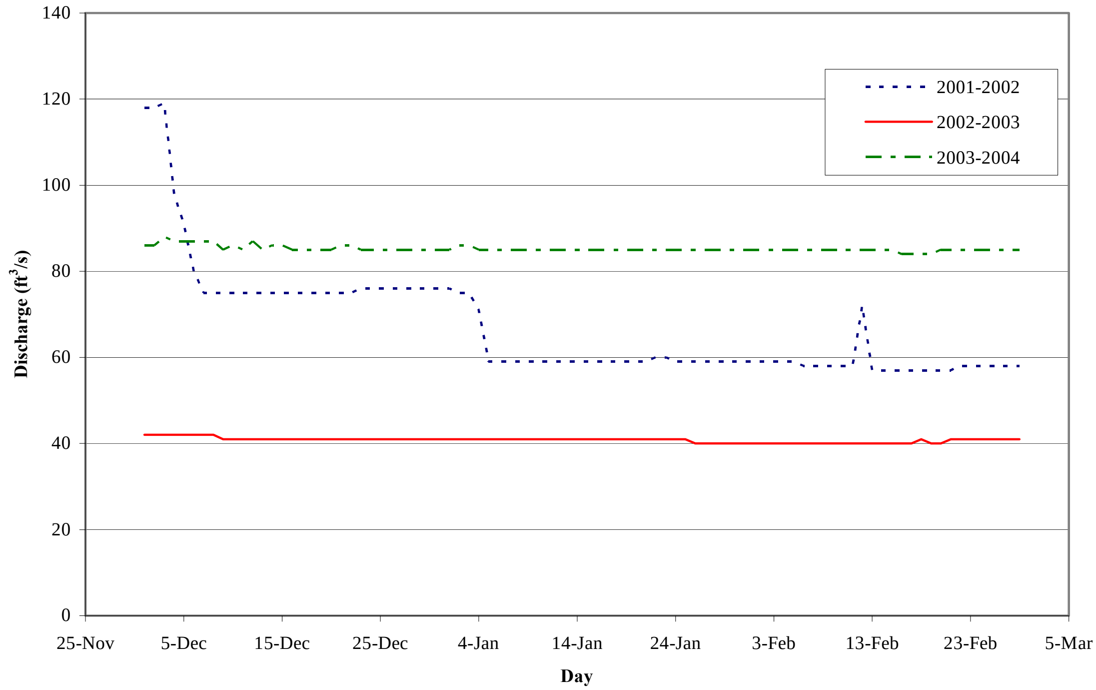


Figure 9. Winter discharge (December-February) for the Fryingpan River below Ruedi Reservoir, Colorado.

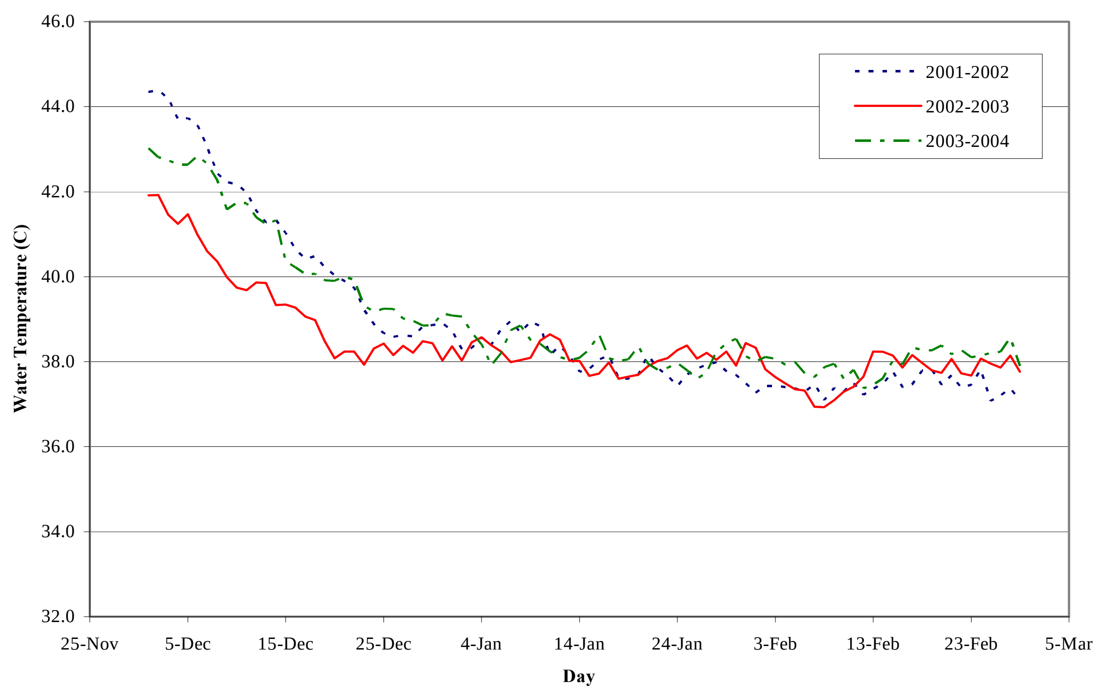


Figure 10. Winter water temperatures for Fryingpan River below Ruedi Reservoir, Colorado.

The formation and frequency of occurrence of anchor ice at FPR-TC appears to be a contributing influence on macroinvertebrate community structure and function.

The responses of metric values to the low flows in the winter of 2002-2003 were noticeably different between sites. At FPR-TC densities of EPT taxa were reduced while chironomid densities increased. This was thought to be a result of combined affects from low flows and anchor ice formation (Rees et al. 2003). Decreases observed in the density of EPT taxa may have been the result of a scouring process that resulted from anchor ice formation. Many of the EPT taxa use microhabitat (surface areas) that would be susceptible to this scouring process, whereas the habitat used by most chironomids (subsurface) provides better protection.

The results of sampling in 2004 after higher winter flows indicated that densities of many EPT taxa had recovered but chironomid numbers had increased as well. This recent data suggests that two or more concurrent winters with higher flows may be necessary to achieve an optimum balance in the macroinvertebrate community at FPR-TC.

Because anchor ice is known to have a negative impact on aquatic biota it is important to identify causes and areas of potential formation. Thermograph data from January 2004 (the coldest month of that winter) at the Pruessing Site (located between the dam and Taylor Creek confluence) suggested that anchor ice formation did not occur between the dam and this location at a discharge of 85 cfs (Figure 11). Thermograph data from December 2003, January 2004, and February 2004 identified periods of anchor ice formation immediately upstream of the FPR-TC site (Figures 12-14). Thermograph data from the Fryingpan River in Basalt indicated an increased frequency and duration of anchor ice formation (Figures 15-17). The frequency of occurrence and duration of anchor ice formation seems to increase with distance downstream.

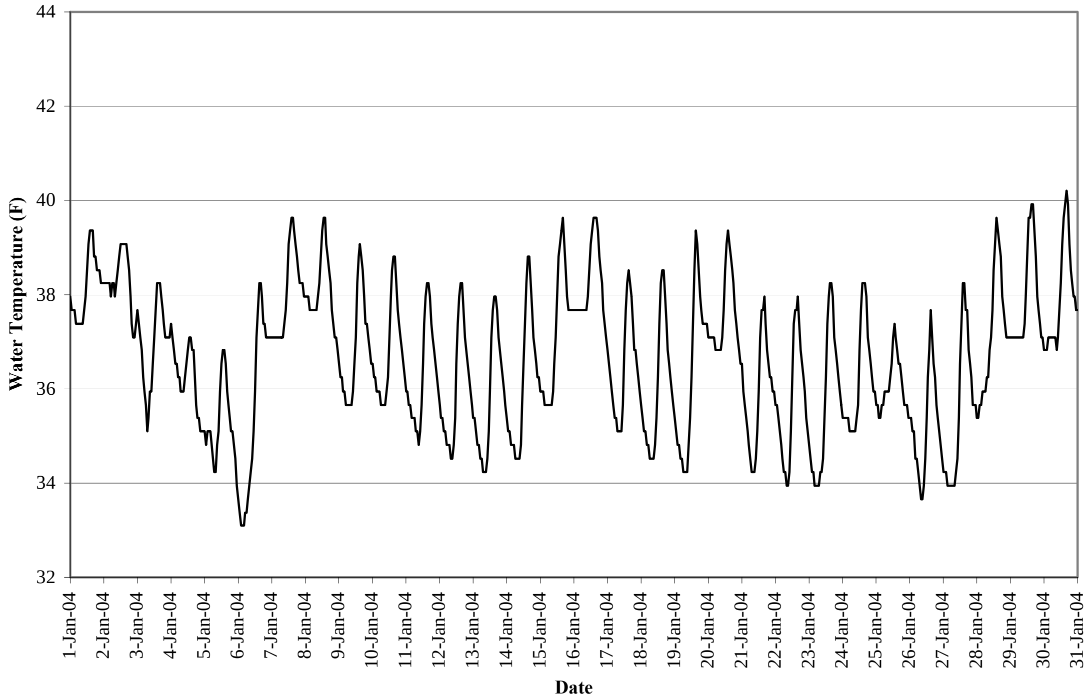


Figure 11. Hourly water temperatures during January 2004 on the Fryingpan River, Pruessing Site.

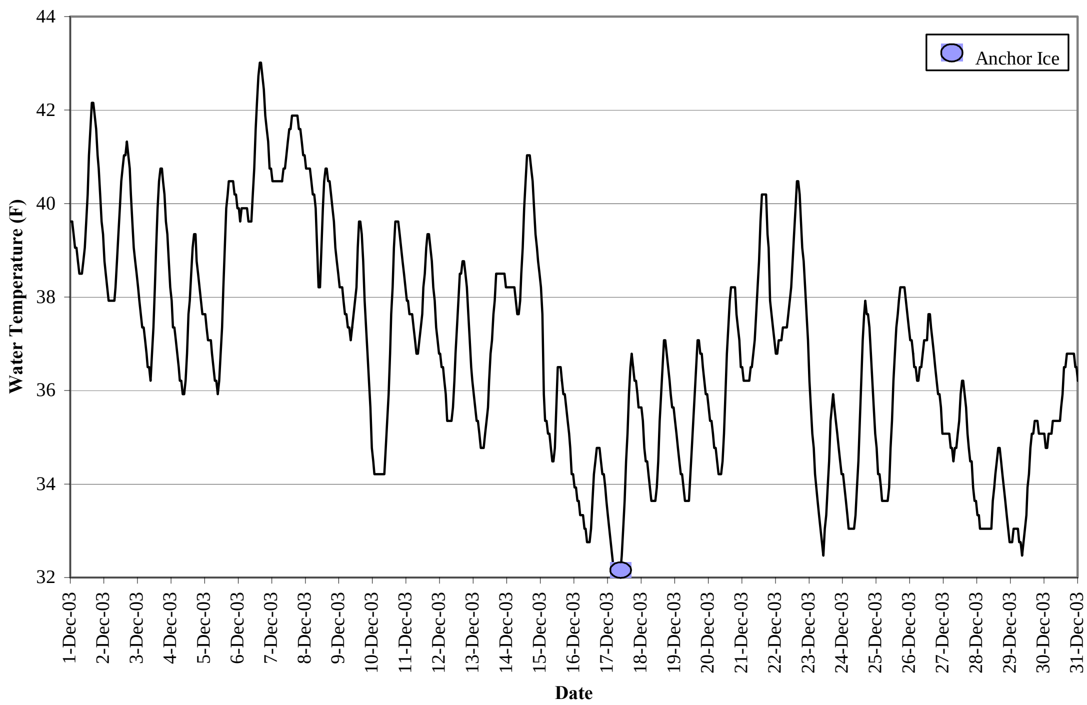


Figure 12. Hourly water temperatures during December 2003 at Palm Site.

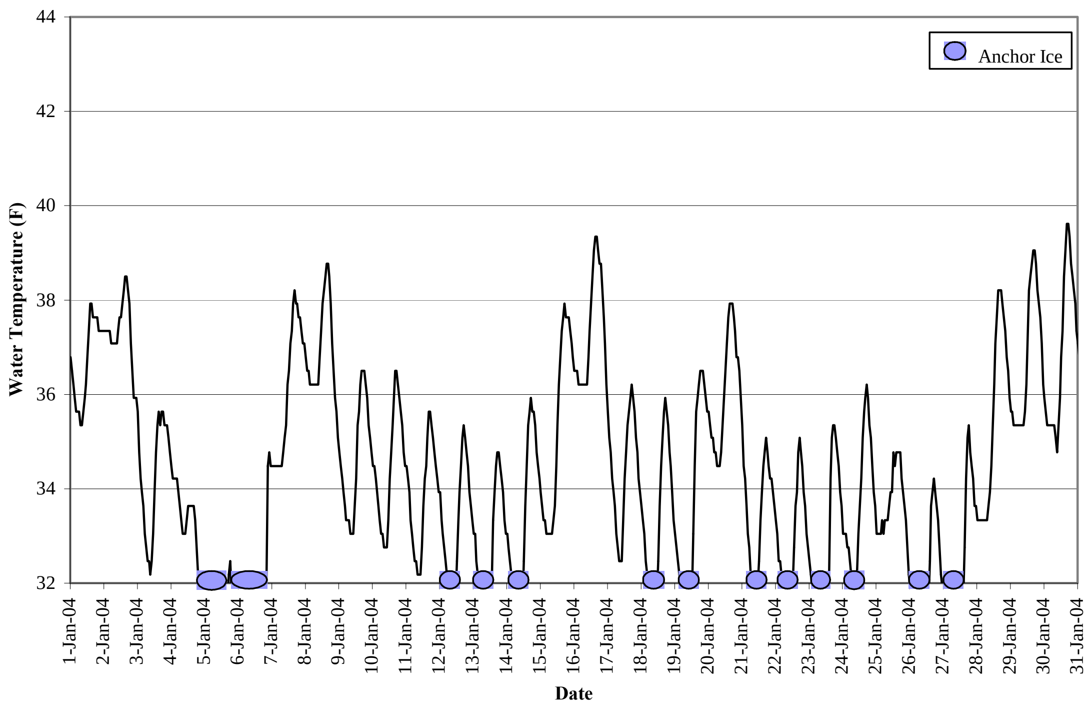


Figure 13. Hourly water temperatures during January 2004 at Palm Site.

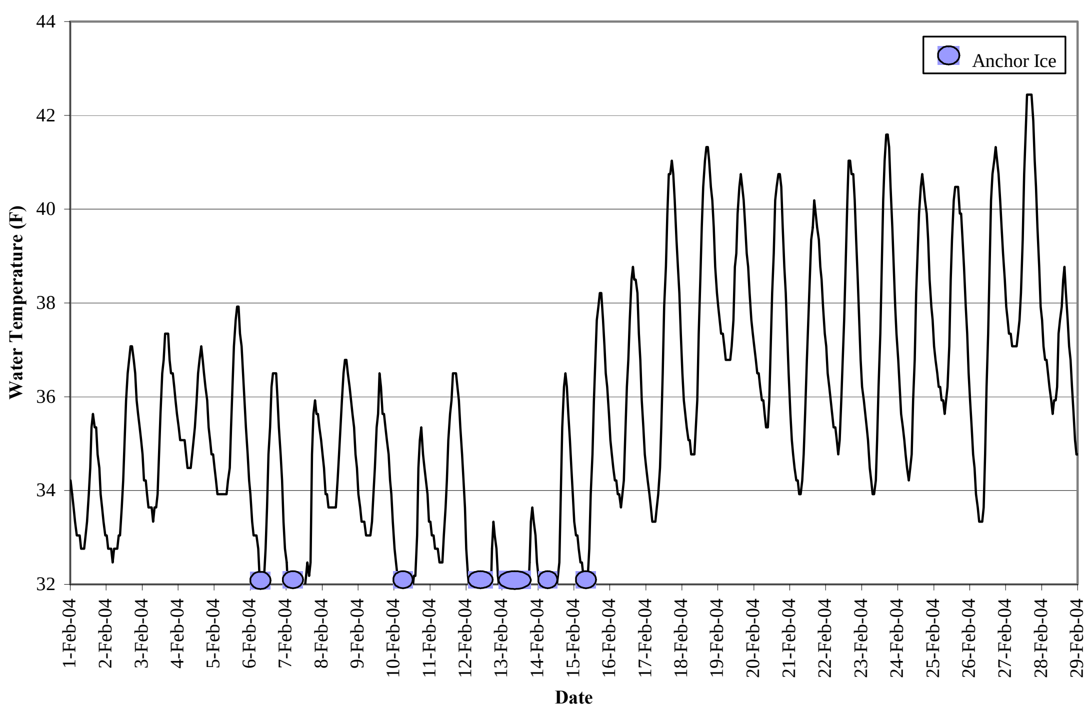


Figure 14. Hourly water temperatures during February 2004 at Palm Site.

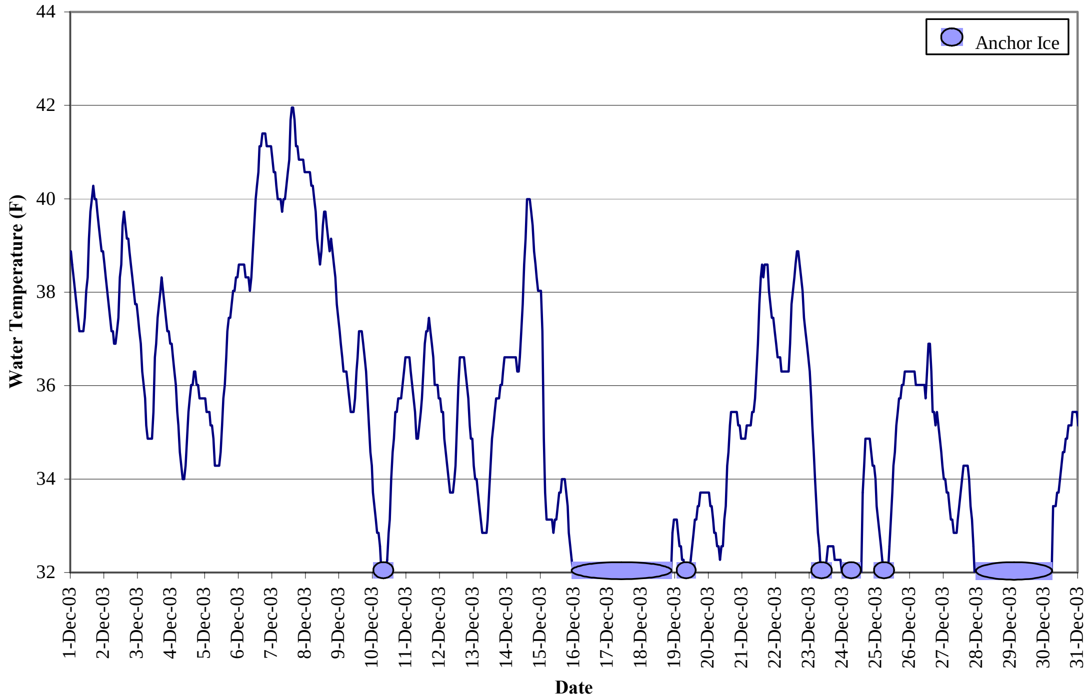


Figure 15. Hourly water temperatures during December 2003 on the Fryingpan River, at Basalt.

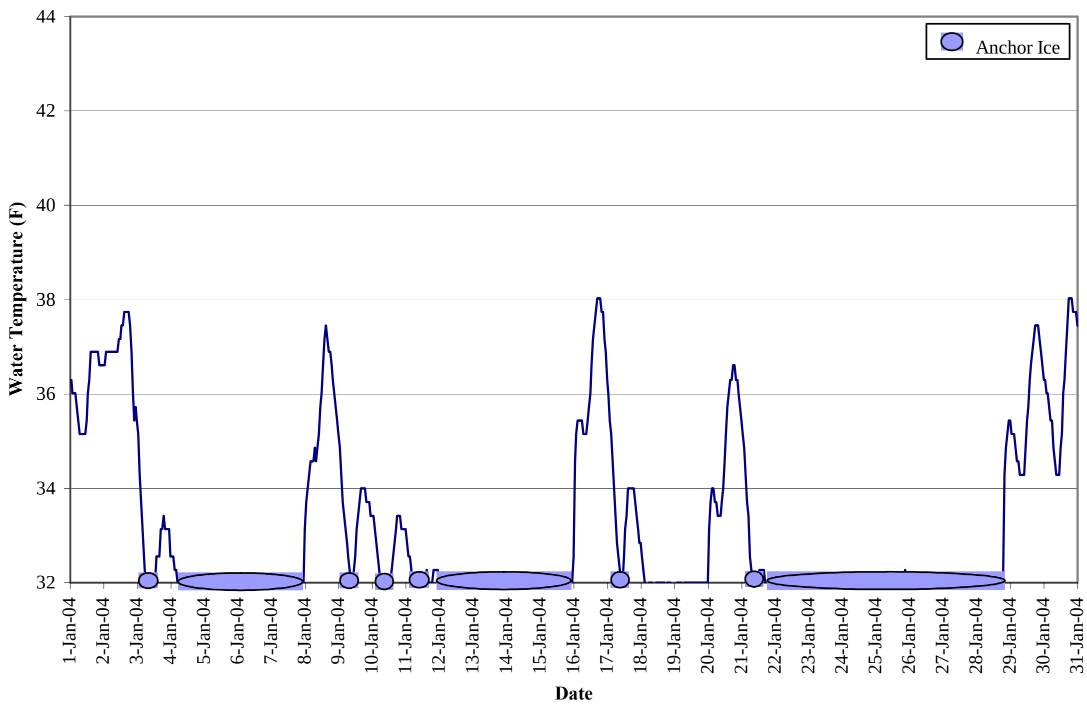


Figure 16. Hourly water temperatures during January 2004 on the Fryingpan River, at Basalt.

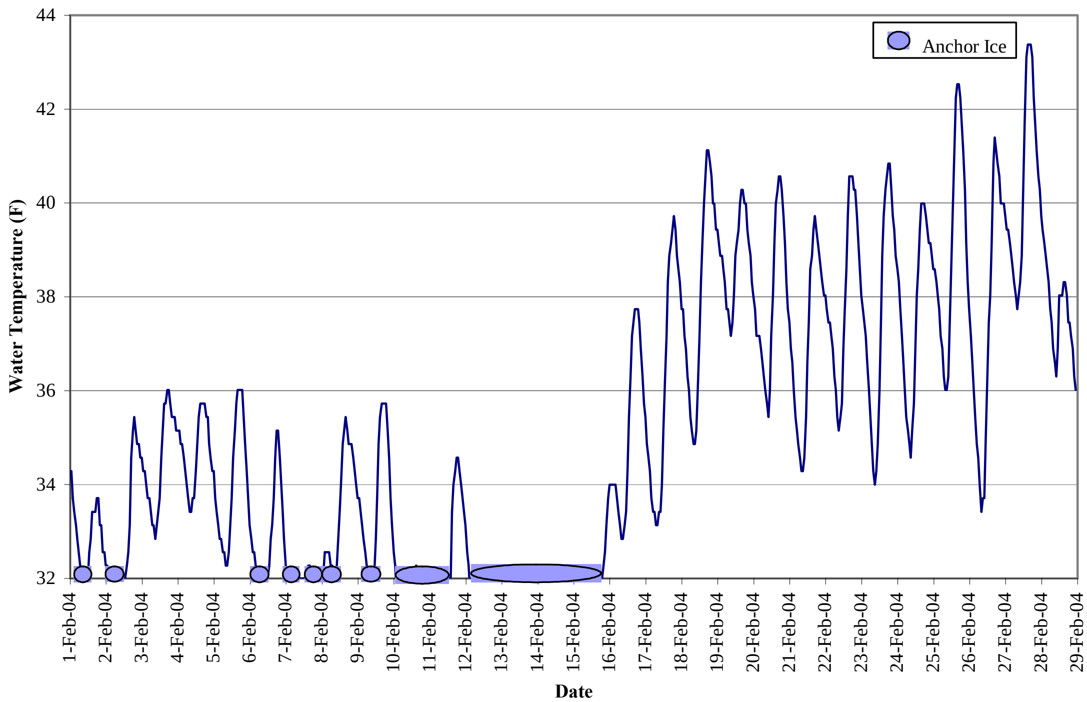


Figure 17. Hourly water temperatures during February 2004 on the Fryingpan River, at Basalt.

Results of this study suggest that magnitude of discharge and air temperature work together to influence anchor ice formation. Thermograph data from two consecutive winter seasons at the Palm site (immediately upstream of FPR-TC) indicated that anchor ice formation at this location was much less frequent during the winter of 2003-2004 compared to the previous winter (Table 3). The average length of an anchor ice occurrence was also much less in 2003-2004. In 2003-2004, each event averaged 10.7 hours compared to 25.7 hours during the 2002-2003 winter. It is possible that the magnitude of the effect of anchor ice formation on the macroinvertebrate community may be amplified as the length of the event increases.

The available data suggests that air temperatures were similar in the study area during both winters (Table 4), but discharge was quite different (Figure 9). The lower discharge at site FPR-TC in 2002-2003 was much more conducive to the formation of anchor ice than the higher flows during the following winter. This results in the location where anchor ice first appears to be further upstream in years with lower flows than those years with higher winter flows. In addition to an increase the length of river susceptible to anchor ice formation, the magnitude of the event also increases with low flows.

The available data suggest that anchor ice was at least partially responsible for the degraded condition of the macroinvertebrate community at FPR-TC during the spring of 2003. To alleviate anchor ice related stress to the macroinvertebrate community, an effort should be made to avoid low wintertime releases out of Ruedi Reservoir.

Table 3. Number of anchor ice occurrences (hourly water temperature less than 0.2°C) during winters (December-February) of 2002-2003 and 2003-2004 at Palm Site.

Month	Year	
	2002-2003	2003-2004
December	229	6
January	214	164
February	200	86

Table 4. Average monthly air temperature (°F) recorded at Aspen, Colorado (Station: Aspen 1 SW, Coop ID: 050372).

Month/Year	Average Max Temperature (°F)	Average Min Temperature (°F)	Count of days with Min Temperature ≤ 5°F
December 01	35.2	8.2	13
January 02	35	8.6	10
February 02	37	5.2	12
December 02	36.5	12.6	6
January 03	40.8	16.3	0
February 03	36.8	12.3	5
December 03	36.6	12.3	7
January 04	36.5	8.8	8
February 04	37.4	10.2	8

RECOMMENDATIONS

Questions for future studies include:

- What are the impacts to benthic macroinvertebrates in lower reaches of the Fryingpan River (near Basalt)?

- There is a need to further evaluate the specific relationship between anchor ice formation, discharge and air temperature at site FPR-TC (or other locations in the Fryingpan River)?

- In a winter with average air temperatures and cloud cover, what is the discharge that would be necessary to maintain high densities of macroinvertebrates.

- What is the time required for recovery that can be expected after impact to macroinvertebrate communities?

To answer the preceding questions, macroinvertebrate sampling and air and water temperature monitoring should continue in the spring and fall for at least the next year. Ideally, it would be good to compare sampling before and after winters with different base lows and different air temperature patterns. Sites for temperature monitoring and macroinvertebrate sampling should at least include FPR-TC, and could be expanded to the lower river. Water quality data (collected frequently) from this reach of the Fryingpan River would also be useful.

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APPENDIX A

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Table 1. Macroinvertebrate data collected from the Fryingpan River at site FPR-RES on 29 October 2003.

Fryingpan River										
FPR-RES		Sample			Mean	ni*LOGni	Count			FBI
29 Oct. 03	1	2	3							
Acentrella insignificans	2	3	2		2.33	0.86	1	4		0.0034
Baetis (flavistriga)										
Baetis (tricaudatus)	641	600	501		580.67	1604.92	1	4		0.8441
Drunella grandis	1	1	2		1.33	0.17	1	1		0.0005
Drunella coloradensis										
Drunella doddsi		4	1		1.67	0.37	1	1		0.0006
Ephemerella sp.	10	12			7.33	6.35	1	1		0.0027
Cinygmula sp.										
Epeorus longimanus	1				0.33	-0.16	1	4		0.0005
Rhithrogena sp.										
Paraleptophlebia sp.	1	1	1		1.00	0.00	1	2		0.0007
Tricorythodes minutus	2	1			1.00	0.00	1	4		0.0015
Caenis sp.										
Pteronarcella badia										
Capnia sp.										
Zapada sp.	3				1.00	0.00	1	2		0.0007
Paraperla frontalis										
Sweltsa sp.										
Triznaka signata										
Claassenia sabulosa										
Hesperoperla pacifica										
Skwala americana										
Isoperla fulva										
Isoperla sp. 2										
Brachycentrus americanus	2				0.67	-0.12	1	1		0.0002
Brachycentrus occidentalis										
Agapetus boulderensis										
Culoptila sp.										
Glossosoma sp.										
Arctopsyche grandis			1		0.33	-0.16	1	4		0.0005
Hydropsyche cockerelli										
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)										
Hydroptila sp.	13	2	6		7.00	5.92	1	1		0.0025
Ochrotrichia sp.										
Lepidostoma sp.	1				0.33	-0.16	1	4		0.0005
Ceraclea sp.										
Oecetis sp.										
Dolophilodes aequalis										
Rhyacophila brunnea										
Rhyacophila coloradensis		1	1		0.67	-0.12	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	698	1278	997		991.00	2969.11	1	6		2.1609
Tanypodinae										
Tanytarsini	31	39	17		29.00	42.41	1	6		0.0632
Chironomini										
Diamesinae	54	19	16		29.67	43.68	1	6		0.0647
Simulium sp.	400	175	112		229.00	540.40	1	6		0.4993
Protanyderus margarita										
Chelifera sp.										
Clinocera sp.		1	1		0.67	-0.12	1	6		0.0015
Hemerodromia sp.										
Antocha sp.	13	35	23		23.67	32.52	1	3		0.0258
Dicranota sp.										
Hexatoma sp.										
Tipula sp.	1				0.33	-0.16	1	3		0.0004
Atherix pachypus										
Pericoma sp.										
Optioservus sp.		1			0.33	-0.16	1	4		0.0005
Heterlimnius corpulentus	13	8	7		9.33	9.05	1	4		0.0136
Zaitzevia parvula										
Microcylloepus sp.										
Narpus concolor										
Hydracarina sp.	7	8	4		6.33	5.08	1	8		0.0184
Gammarus sp.	4	3	3		3.33	1.74	1	4		0.0048
Physa sp.			1		0.33	-0.16	1	8		0.0010
Pisidium sp.	4	2	4		3.33	1.74	1	8		0.0097
Dugesia sp.										
Polycelis coronata	296	659	499		484.67	1301.54	1	8		1.4091
Oligochaeta	201	567	222		330.00	831.11	1	10		1.1993
Nematoda	6	3	6		5.00	3.49	1	10		0.0182
Totals	2405.0	3423.0	2427.0		2751.67	7399.16	30			
										6.35
Shannon Weaver Diversity						2.49				
Shannon Weaver Evenness						0.508				

Table 2. Macroinvertebrate data collected from the Fryingpan River at site FPR-TC on 29 October 2003.

Fryingpan River										
FPR-TC		Sample			Mean	ni*LOGni	Count			FBI
29 Oct. 03	1	2	3							
Acentrella insignificans	7	9	5		7.00	5.92	1	4		0.0204
Baetis (flavistriga)										
Baetis (tricaudatus)	332	552	369		417.67	1094.63	1	4		1.2174
Drunella grandis	12	11	6		9.67	9.52	1	1		0.0070
Drunella coloradensis										
Drunella doddsi			1		0.33	-0.16	1	1		0.0002
Ephemerella sp.	34	37	25		32.00	48.16	1	1		0.0233
Cinygmula sp.	22	44	21		29.00	42.41	1	4		0.0845
Epeorus longimanus										
Rhithrogena sp.										
Paraleptophlebia sp.	59	39	23		40.33	64.76	1	2		0.0588
Tricorythodes minutus										
Caenis sp.										
Pteronarcella badia										
Capnia sp.										
Zapada sp.		1	1		0.67	-0.12	1	2		0.0010
Paraperla frontalis										
Sweltsa sp.										
Triznaka signata										
Claassenia sabulosa										
Hesperoperla pacifica	1	2	1		1.33	0.17	1	1		0.0010
Skwala americana		1			0.33	-0.16	1	2		0.0005
Isoperla fulva		7	1		2.67	1.14	1	2		0.0039
Isoperla sp. 2										
Brachycentrus americanus	36	48	35		39.67	63.40	1	1		0.0289
Brachycentrus occidentalis										
Agapetus boulderensis										
Culoptila sp.										
Glossosoma sp.										
Arctopsyche grandis	13	35	21		23.00	31.32	1	4		0.0670
Hydropsyche cockerelli										
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)	1	3	2		2.00	0.60	1	4		0.0058
Hydroptila sp.										
Ochrotrichia sp.		1			0.33	-0.16	1	1		0.0002
Lepidostoma sp.	43	59	9		37.00	58.02	1	4		0.1078
Ceraclea sp.										
Oecetis sp.										
Dolophilodes aequalis										
Rhyacophila brunnea	1	2	3		2.00	0.60	1	0		0.0000
Rhyacophila coloradensis										
Neothremma alicia										
Oligophlebodes minuta	30	16	10		18.67	23.73	1	4		0.0544
Orthocladiinae	239	410	234		294.33	726.66	1	6		1.2869
Tanypodinae	4	2	3		3.00	1.43	1	6		0.0131
Tanytarsini		6	2		2.67	1.14	1	6		0.0117
Chironomini										
Diamesinae	6	9	5		6.67	5.49	1	6		0.0291
Simulium sp.	14	164	188		122.00	254.54	1	6		0.5334
Protanyderus margarita										
Chelifera sp.		3	1		1.33	0.17	1	6		0.0058
Clinocera sp.	1	2	1		1.33	0.17	1	6		0.0058
Hemerodromia sp.										
Antocha sp.	20	29	20		23.00	31.32	1	3		0.0503
Dicranota sp.		2	1		1.00	0.00	1	3		0.0022
Hexatoma sp.										
Tipula sp.										
Atherix pachypus										
Pericoma sp.	1	1			0.67	-0.12	1	10		0.0049
Optioservus sp.	3	5	2		3.33	1.74	1	4		0.0097
Heterlimnius corpulentus	48	61	35		48.00	80.70	1	4		0.1399
Zaitzevia parvula										
Microcylloepus sp.										
Narpus concolor										
Hydracarina sp.	1	12	3		5.33	3.88	1	8		0.0311
Gammarus sp.	1				0.33	-0.16	1	4		0.0010
Physa sp.										
Pisidium sp.	21	53	44		39.33	62.73	1	8		0.2293
Dugesia sp.										
Polycelis coronata	41	142	106		96.33	191.10	1	8		0.5616
Oligochaeta	17	101	51		56.33	98.63	1	10		0.4105
Nematoda	3	3	5		3.67	2.07	1	10		0.0267
Totals	1011.0	1872.0	1234.0		1372.33	2905.28	36			
										5.04
Shannon Weaver Diversity						3.39				
Shannon Weaver Evenness						0.656				

Table 3. Macroinvertebrate data collected from the Fryingpan River at site FPR-RES on 29 April 2004.

Fryingpan River										
FPR-RES		Sample			Mean	ni*LOGni	Count			FBI
29 Apr. 04	1	2	3							
Acentrella insignificans	5				1.67	0.37	1	4		0.0023
Baetis (flavistriga)										
Baetis (tricaudatus)	843	1044	1462		1116.33	3402.35	1	4		1.5481
Drunella grandis		2	1		1.00	0.00	1	1		0.0003
Drunella coloradensis			1		0.33	-0.16	1	1		0.0001
Drunella doddsi	2	4	1		2.33	0.86	1	1		0.0008
Ephemerella sp.	9	14	14		12.33	13.46	1	1		0.0043
Serratella tibialis										
Cinygmula sp.	16	9	9		11.33	11.95	1	4		0.0157
Epeorus longimanus	8	8	6		7.33	6.35	1	4		0.0102
Rhithrogena sp.										
Paraleptophlebia sp.	1	1	4		2.00	0.60	1	2		0.0014
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa										
Zapada sp.	1				0.33	-0.16	1	2		0.0002
Triznaka signata										
Sweltsa sp.										
Claassenia sabulosa										
Hesperoperla pacifica										
Isoperla fulva										
Isoperla sp. 2										
Skwala americana										
Brachycentrus americanus		1			0.33	-0.16	1	1		0.0001
Brachycentrus occidentalis										
Micrasema bactro										
Culoptila sp.										
Glossosoma sp.		2	1		1.00	0.00	1	0		0.0000
Arctopsyche grandis										
Hydropsyche cockerelli										
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*										
Hydroptila sp.		1	1		0.67	-0.12	1	1		0.0002
Lepidostoma sp.			1		0.33	-0.16	1	4		0.0005
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea		2	3		1.67	0.37	1	0		0.0000
Rhyacophila coloradensis			2		0.67	-0.12	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	512	764	1832		1036.00	3123.91	1	6		2.1551
Tanypodinae										
Tanytarsini		3			1.00	0.00	1	6		0.0021
Chironomini			1		0.33	-0.16	1	8		0.0009
Diamesinae	90	232	312		211.33	491.34	1	6		0.4396
Simulium sp.	23	55	48		42.00	68.18	1	6		0.0874
Chelifera sp.										
Clinocera sp.										
Hemerodromia sp.										
Oreogeton sp.										
Tipula sp.										
Antocha sp.	1	7	11		6.33	5.08	1	3		0.0066
Dicranota sp.										
Hexatoma sp.										
Atherix pachypus										
Pericoma sp.										
Optioservus sp.		1			0.33	-0.16	1	4		0.0005
Heterlimnius corpulentus	2	2	2		2.00	0.60	1	4		0.0028
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	2	8	11		7.00	5.92	1	8		0.0194
Gammarus sp.		1	1		0.67	-0.12	1	4		0.0009
Physa sp.										
Planorbidae										
Pisidium sp.	1				0.33	-0.16	1	8		0.0009
Dugesia sp.										
Polycelis coronata	477	351	257		361.67	925.25	1	8		1.0031
Oligochaeta	37	71	51		53.00	91.39	1	10		0.1838
Nematoda		4	4		2.67	1.14	1	10		0.0092
Totals	2030.0	2587.0	4036.0		2884.33	8147.64	30			
										5.50
Shannon Weaver Diversity						2.11				
Shannon Weaver Evenness						0.430				

Table 4. Macroinvertebrate data collected from the Fryingpan River at site FPR-TC on 29 April 2004.

Fryingpan River										
FPR-TC		Sample			Mean	ni*LOGni	Count			FBI
29 Apr. 04	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	22	15	16		17.67	22.03	1	4		0.0199
Baetis (tricaudatus)	307	179	479		321.67	806.55	1	4		0.3619
Drunella grandis	9	5	23		12.33	13.46	1	1		0.0035
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	16	13	27		18.67	23.73	1	1		0.0053
Serratella tibialis	33	12	35		26.67	38.03	1	1		0.0075
Cinygmula sp.	35	19	7		20.33	26.60	1	4		0.0229
Epeorus longimanus	15	14	8		12.33	13.46	1	4		0.0139
Rhithrogena sp.										
Paraleptophlebia sp.	69	27	65		53.67	92.83	1	2		0.0302
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa		1			0.33	-0.16	1	2		0.0002
Zapada sp.										
Triznaka signata										
Sweltsa sp.										
Claassenia sabulosa										
Hesperoperla pacifica	3	2	2		2.33	0.86	1	1		0.0007
Isoperla fulva		1	2		1.00	0.00	1	2		0.0006
Isoperla sp. 2										
Skwala americana										
Brachycentrus americanus	48	33	78		53.00	91.39	1	1		0.0149
Brachycentrus occidentalis										
Micrasema bactro										
Culoptila sp.										
Glossosoma sp.		4			1.33	0.17	1	0		0.0000
Arctopsyche grandis	10	12	22		14.67	17.11	1	4		0.0165
Hydropsyche cockerelli	1				0.33	-0.16	1	4		0.0004
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*		1			0.33	-0.16	1	4		0.0004
Hydroptila sp.										
Lepidostoma sp.	128	37	90		85.00	164.00	1	4		0.0956
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea	6	1	4		3.67	2.07	1	0		0.0000
Rhyacophila coloradensis			1		0.33	-0.16	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta	15	10	11		12.00	12.95	1	4		0.0135
Orthocladiinae	2209	2378	2666		2417.67	8179.92	1	6		4.0805
Tanypodinae	39	9	22		23.33	31.92	1	6		0.0394
Tanytarsini	71	10	27		36.00	56.03	1	6		0.0608
Chironomini		11			3.67	2.07	1	8		0.0083
Diamesinae	2	1	4		2.33	0.86	1	6		0.0039
Simulium sp.	1	1			0.67	-0.12	1	6		0.0011
Chelifera sp.	7		1		2.67	1.14	1	6		0.0045
Clinocera sp.										
Hemerodromia sp.										
Oreogeton sp.			3		1.00	0.00	1	6		0.0017
Tipula sp.										
Antocha sp.	24	49	86		53.00	91.39	1	3		0.0447
Dicranota sp.	1		1		0.67	-0.12	1	3		0.0006
Hexatoma sp.										
Atherix pachypus		3			1.00	0.00	1	2		0.0006
Pericoma sp.		1			0.33	-0.16	1	10		0.0009
Optioservus sp.	3	4	5		4.00	2.41	1	4		0.0045
Heterlimnius corpulentus	86	41	44		57.00	100.08	1	4		0.0641
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	7	8	19		11.33	11.95	1	8		0.0255
Gammarus sp.										
Physa sp.										
Planorbidae										
Pisidium sp.	68	32	36		45.33	75.09	1	8		0.1020
Dugesia sp.										
Polycelis coronata	184	80	157		140.33	301.32	1	8		0.3158
Oligochaeta	99	98	91		96.00	190.30	1	10		0.2700
Nematoda	2		1		1.00	0.00	1	10		0.0028
Totals	3520.0	3112.0	4033.0		3555.00	10368.65	39			
										5.64
Shannon Weaver Diversity						2.11				
Shannon Weaver Evenness						0.399				