ECCLES CREEK BENTHIC INVERTEBRATE MONITORING
JUNE 2003
(Revised)

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INTRODUCTION

In August of 2001 an aquifer tapped by Skyline Mine, near Scofield, Utah, significantly increased the discharge of water from the mine into Eccles Creek. The discharge has maintained the stream at approximately bank full levels since that time. This report summarizes results of monitoring of the benthic invertebrate community in Eccles Creek for spring, 2003 and includes summaries of previous data to maintain the context for comparative purposes. The samples taken in the spring of 2003 represents the fourth sample series taken from the stream within the time period following increased discharge. This project was undertaken for Canyon Fuel Company with the objective of determining the impact of the increased flows on the stream community.

METHODS

Quantitative samples were taken from Eccles Creek on June 12, 2003. The three stations sampled were Eccles Creek, above South Fork (EC2: N 39^0 40.970', W 111.11.579', 8406 feet elevation), Eccles Creek at Whisky Canyon (EC-4: N 39^0 40.908', W 111.10.747', 8234 feet elevation), and Lower Eccles Creek (EC-5: N 39^0 41.001', W 111.10.031', 8074 feet elevation). These three stations have been sampled intermittently since 1979 (Shiozawa 2003). The samples were taken from the same locations sampled in July and October of 2002. Five replicate samples were taken per station. All samples were taken from locations in the stream where rubble or cobble substrates were present to reduce variability. A box sampler with a net mesh of 250 microns was used to collect the samples. The substrate was stirred to a depth of approximately 5 cm. All rocks within the area of the sampler were removed and individually washed to insure quantitative collection of the invertebrates. The samples were concentrated on a screen with a mesh of 64 microns and field preserved in ethyl alcohol. A GPS unit was used to both locate and record the positions of the sample stations.

In the laboratory the samples were sorted in illuminated pans. All invertebrates were removed and identified to the lowest possible taxonomic level using the keys of Merritt and Cummins (1996). Beginning with this sample series we have taken sub-samples from the samples after they were visually sorted. The sorted samples were placed in a volume of 200 ml and five 2 ml subsamples were processed under magnification with a dissecting scope. This was done to improve the accuracy of the sample counts. The mean density per subsample was used to project the total density of organisms remaining in the visually sorted sample, and these projections were added to the total count from the visual sorting. The data were then used to determine the density of taxa per square meter. Mean biomass estimates were also generated so that trends in standing crop could be documented. Analyses included comparisons of the number of taxa and mean densities in the June 2003 samples with those generated from samples taken October 2002, November 24, 2001 (Shiozawa 2002a) and July 2, 2002 (Shiozawa 2002c), and with samples taken in 1979 (Winget 1980) and1992 (Ecosystems Research Institute,1992). These comparisons allow a general evaluation of changes that have occurred since the increased discharge of water

into the stream channel from the mine, and help place the results in perspective relative to other perturbations and baseline conditions.

The community tolerance quotient (CTQ; Winget and Mangum 1979) was used to gain insight into the condition of the stream relative to idealized system predicted from slope, water chemistry, and substrate. Water chemistry for Eccles Creek was provided EarthFax Engineering (2001). The following estimates were used for alkalinity and sulfate levels: Eccles Creek alkalinity recorded levels at 264 mg/l and sulfate estimated at 49 mg/l. The gradient in Eccles Creek it is approximately 3.3%. With its combination of physical properties, it had a predicted community tolerance quotient (CTQp) of 80 (Winget and Mangum 1979). The Biotic Condition Index was used to further interpret the data generated with this procedure.

Diversity was calculated for the stations using the Shannon-Weiner index (Pieliou 1977). This allows a general comparison among sample stations and dates. Diversity indices take the number of taxa and their individual densities into account, generating a single value for each station. The greater the number of species or taxa and generally the more even the distribution of densities between taxa, the higher the index value. Finally, the data were clustered with the UPGMA algorithm using the Bray-Curtis measure of dissimilarity (Poole 1974, Krebs 1989). The NTSYSpc package was utilized to generate the cluster dendrograms (Rolf 2000).

RESULTS AND DISCUSSION

Number of Taxa

A total of eighteen taxa were collected from Eccles Creek in the spring 2003 samples. Of this total number, eleven taxa were found in EC2 , nine in EC5, and nine taxa in EC4 (Table 1). The total number of taxa is less than the 23 taxa collected in October 2002, but is still significantly higher than the five taxa (*Baetis*, *Hydropsyche*, *Pedicia*, chironomids, and ostracods) gathered from Eccles Creek in the 2001 sampling series. In comparison to the October 2002 data, the June 2003 samples maintained or increased in the number of taxa at sites EC2 and EC4, while station EC5 decreased in the number of taxa. These numbers are comparable with data collected in the early 1990s (Ecosystems Research Institute,1992), but are a third to a fourth the number collected in the late 1970s (Winget 1980). If the stream was to recover to the pre-mining level, the number of taxa would be expected to increase substantially. However the sustained high discharge does not favor retention of detritus, and thus it is unlikely that the stream can recover without a reduction in flow. The number of taxa in Eccles Creek between the impacts of the early 1990's and the increased discharge in 2001, is unknown. However, studies in the 1980s documented the impact of the road, (Shiozawa 2002b), so it is reasonable to assume that just prior to the increased discharge of 2001, between 21 to 33 taxa were in the system. This would suggest that a doubling of the number of taxa from the June 2003 samples is a minimum recovery level for taxa.

Table 1. Number of taxa collected from Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003
South Fork tributary above mine, upper site (USF2)			20	11					
South Fork tributary above mine (USF)			12	9	21				
Middle Fork tributary above mine (UMF)			14	18					
Eccles Creek below mine (EC1)			4	2					
Eccles Creek above south Fork (EC2)		42	6		6		6	11	11
South Fork Eccles Creek (SF)	36	35	12						
Eccles Creek below South Fork (EC3)	27	30							
Eccles Creek at Whisky Canyon (EC4)	35	37	7	17	15	6	14	7	9
Lower Eccles Creek (EC5)	38	21	12	13/11	14		6	11	9

Total Density Comparisons

Total mean density (average density of the sample stations shown in Table 2) of invertebrates in the June, 2003 sampling series was 6668 per square meter, considerably higher than obtained in October 2002 when the average per square meter was 1877. This increase is partly due to seasonal changes in community structure. Early instars of many invertebrates can pass through a

250 micron mesh net and chironomids often overwinter in early instars (e.g. Shiozawa and Barnes1977). By June they would have grown to a size that could be more readily collected by the sampler. In addition, beginning with this sample series we initiated subsampling to improve recovery of small invertebrates that are often missed by unaided sorting in the illuminated trays. The increase in specimen recovery is seen with small invertebrates, especially microcrustaceans and early instar chironomids.

Table 2. Total invertebrate densities per square meter for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003
South Fork tributary above mine, upper site (USF2)			1089	528					
South Fork tributary above mine (USF)			1144	216	2455				
Middle Fork tributary above mine (UMF)			1503	3812					
Eccles Creek below mine (EC1)			164	16					
Eccles Creek above south Fork (EC2)		73,181	267		89		3703	1260	6265
South Fork Eccles Creek (SF)	9321	17773	1356						
Eccles Creek below South Fork (EC3)	18,093	23,247							
Eccles Creek at Whisky Canyon (EC4)	11,634	25,273	1719	3928	1419	61	8757	1491	10,351
Lower Eccles Creek (EC5)	18661	2526	2212	4104/ 2863	1468		4927	2879	3387

The total density for June 2003 is also higher than both the July 2002 (Shiozawa 2002c) and the 1990 (Ecosystems Research Institute,1992) estimates, but is are still lower than the values recorded in 1979. As noted in previous reports (Shiozawa 2002c, 2003) the invertebrate densities should increase to 15,000 per square meter, or higher, if total numbers were to approximate the baseline condition. Based upon that measure, the stream has still not recovered, although EC4 appears to be close.

Taxa Specific Densities

While total densities can give a quick picture of the state of the stream system, they can also be misleading if the component taxa are not considered. High densities of relatively few taxa are common in stressed or polluted systems because under such conditions a few tolerant taxa are able to monopolize resources in an environment with reduced predation and competition.

Baetis were absent or rare in the June 2003 sampling series (Table 3). In the July 2002 samples (Shiozawa 2002c) *Baetis* densities were moderate, at 242/m^2 491/m^2 and 200/m^2 in EC2, EC4, and EC5 respectively. The October 2002 samples showed *Baetis* absent at EC2, about the same density at EC4 (400/m^2), and higher at EC5 (1297/m^2). Yet in the June 2003 samples only six *Baetis* per square meter were found at EC4, and none were present at EC2 or EC5. Sampling error and seasonal changes in abundance due to their life cycle could be responsible for this decrease, but those are unlikely given that a progressive decline in *Baetis*, beginning in the downstream station (EC2), appears to have taken place from July of 2002 to June of 2003. It is possible that the initial invasion of this vagrant species has not been sustained with the continual scouring of the stream bed by high flows. The constant and higher temperature of the stream may have also altered (advanced) emergence times such that the mayflies are emerging in mid winter when adult survival is not possible.

The mayfly *Cinygmula* was in moderate densities in the upstream site (EC2*)* with a density of 230/m^2, but rare or absent in the middle(EC4) and lower (EC5) sites. This genus was also absent in the fall 2002 samples, but was in very low densities at stations EC2 and EC4 in July of 2002. *Cinygmula* is characteristic of relatively high quality systems, so its increase in the upstream site may be a positive indicator for that station. It is a scraper-gatherer, feeding on algae and detritus on the surface of rocks. Prior to the construction of the road, this genus reached densities of over 8000 per square meter in late summer, although spring and early summer densities were around 1000 per square meter in the middle and upper reaches of Eccles Creek (Shiozawa 2002b). The numbers collected at EC2 are about a third to a fourth of what we would expect under baseline conditions.

The hydroptilid caddisfly, *Ochrotricha* (a micro-cadddisfly), was abundant in EC4. Densities were high in several samples (these were mostly detected in subsamples). These insects attach to the surface of rocks and woody debris and feed on algae growing on the surface of the substrate. While this taxon is abundant, it is also very small. It was absent from both the upstream (EC2)

and downstream (EC5) sites. Other hydroptilids (*Hydroptila*) were collected at station EC4 in July of 2002. It is not clear why this site has these taxa, while the other sites do not, but they are tolerant to stressful conditions and their feeding behavior, utilizing algae on the surface of rocks means they are not reliant on continual detritus input and deposition.

Table 3. Sample data and invertebrates per square meter.

	Eccles Creek above South Fork (EC2)						Eccles Creek Whisky Canyon (EC4)						Lower Eccles Creek (EC5)					
Taxa	1	2	3	4	5	**#/m²**	1	2	3	4	5	**#/m²**	1	2	3	4	5	**#/m²**
Ephemeroptera: *Baetis*	0	0	0	0	0	**0**	0	0	0	0	1	**6**	0	0	0	0	0	**0**
Ephemeroptera: *Cinygmula*	0	1	2	1	34	**230**	0	0	0	0	1	**6**	0	0	0	0	0	**0**
Plecoptera: *Zapada*	2	0	0	0	0	**12**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: pupae	0	0	0	0	0	**0**	1	0	0	0	0	**6**	0	0	0	0	0	**0**
Trichoptera: *Hydroptila*	0	1	0	0	0	**6**	0	0	0	0	0	**0**	1	0	0	0	5	**36**
Trichoptera: *Ochrotricia*	0	0	0	0	0	**0**	0	30	0	0	127	**951**	0	0	0	0	0	**0**
Trichoptera: *Tinodes*	0	0	0	0	0	**0**	1	0	0	0	0	**6**	0	0	0	0	0	**0**
Trichoptera: *Neothremma*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	1	0	**6**
Coleoptera: *Peltodytes*	0	0	0	0	1	**6**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: Chironomidae larvae	184	225	90	24	117	**3837**	80	127	129	124	702	**7042**	142	25	9	63	161	**2424**
Diptera: Chironomidae pupae	2	8	1	0	5	**97**	4	3	4	8	40	**358**	8	0	0	0	12	**121**
Diptera: Ceratopogonidae	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	1	**6**
Diptera: *Chelifera* (Empididae)	0	1	0	0	1	**12**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Cladocera	45	15	15	16	0	**551**	0	0	0	150	0	**909**	2	0	0	0	93	**576**
Copepoda	15	1	15	31	15	**467**	1	0	1	0	0	**12**	1	0	0	0	2	**18**
Ostracoda	45	0	15	16	1	**467**	0	0	0	0	0	**0**	0	0	0	0	1	**6**
Hydracarina	15	0	0	0	0	**91**	0	0	0	0	0	**0**	0	0	0	0	15	**91**
Oligochaeta	16	50	0	1	6	**442**	3	32	3	3	104	**879**	16	0	0	0	1	**103**
totals	322	293	137	89	175	6265	86	189	133	307	807	10351	162	27	9	64	279	3387

Hydropsyche was not collected in the spring 2003 samples series. This genus was the dominant benthic macroinvertebrate in the October 2002 samples (1030/m^2, 1024/m^2, 1321/m^2 at stations EC2, EC4, and EC5 respectively). This difference could be due to temporal changes (seasonal emergence) or a lack of food for filter feeders because of the high flushing induced by the increased flows. The July 2002 samples had densities of 18/m^2, 1027/m^2, and 494/m^2 at stations EC2, EC4, and EC5 respectively). While lower densities may be characteristic during the early summer, a complete absence of individuals of this genus appears to be unlikely. This implies that other changes in the environment have a role in the disappearance of this group from the stations.

Chironomids were the dominant taxon in the June 2003 samples, being present in densities of 3837, 7042, and 2424 per square meter at stations EC2, EC4, and EC5 respectively (Table 3). Their numbers were almost 700 fold higher than in samples gathered in October 2002 (12/m^2, 12/m^2, and 97/m^2), but were roughly equivalent to the July 2002 densities (3163/m^2, 6121/m^2 and 3545/m^2). This suggests that the chironomid community may be fluctuating from seasonal changes in density. As noted above, many chironomids should have been in early instars during October and could have been missed with the 250 micron mesh net used in sampling. The further refinement in sample processing by subsampling (see methods) of the already sorted sample, should have also increased the overall recovery rate of very small larvae from the June 2003 samples, but this does not appear to have significantly shifted the numbers away from the July 2002 densities.

Oligochaets were moderately abundant at all three sites. Oligochaets are deposit feeders, burrowing into sand and other depositional microhabitats. Their abundance is may be a function of the sand in the stream bed. Cladocera and Ostracada were present in higher numbers than before in sites EC2, EC4, and EC5. This is probably due to the implementation of subsamples in the invertebrate counts. The small size of Cladocera and Ostracada makes it difficult to obtain an accurate count when separating them from debris in the illuminated pans.

Both the total densities of invertebrates in Eccles Creek in June 2003 as compared to 2001 and 2002 and the higher numbers of taxa at each site in 2003 suggest that the stream is undergoing a recovery. But the loss of *Hydropsyche* and *Baetis*, both of which are considered to be tolerant of stressful environments, indicates that serious problems exist. Recovery should include sustained populations of these two taxa, as well as the addition of other, less tolerant, groups. Two aquatic insects that did show higher numbers in the June 2003 samples, *Cinygmula* and *Ochrotricha*, are grazers. The two that were lost from the system feed more heavily on detrital food chains. This suggests that detrital input and/or retention has been compromised. Such changes can be attributed to the higher discharge which generates a continual scouring (erosional) environment in the stream system. As emphasized in previous reports (Shiozawa 2002a, b, c) the community is unlikely to return to the structure that existed in 1979 unless the sustained discharge is eliminated. If and when that occurs, the trajectory of the recovering community should resume towards the 1979 state.

Biomass

Total biomass for each site (Table 4) was determined. Such estimates allow insight into the actual partitioning of energy stored in the living system at different locations and time periods. Both the upper (EC2) and middle (EC4) sites have the highest standing crop, both being about double that in the lowest station (EC5). When compared to the October 2002 samples the June biomass estimates are nearly half of the October 2002 biomass estimates. The lack of tipulids, which are large detritivores, and hydropsychids could be the causal factors. Since tipulids tend to be in highest densities in the fall and winter when maximum coarse detrital material is available, the decline in biomass could be interpreted to be due to seasonal factors. However several more seasons of sampling need to be completed to determine if the patterns suggesting lower detrital retention continue. The decline in biomass between October 2002 and June 2003 while chironomid density increased greatly indicates that densities cannot stand alone. The June samples suggest numbers approaching the baseline states of the 1980s, yet clearly the lower densities of October 2002 included a much higher standing stock of fixed energy. The system has switched from fewer large individuals to many small individuals.

Table 4. Biomass, comparisons October 2002 with June 2003.

	Upper Eccles (EC2)		Middle Eccles (EC4)		Lower Eccles (EC5)	
	Oct 2002	June 2003	Oct 2002	June 2003	Oct 2002	June 2003
Sample 1	0.58 g	0.13 g	0.24 g	0.14 g	0.21 g	0.14 g
Sample 2	0.34 g	0.31 g	0.40 g	0.10 g	0.04 g	0.07 g
Sample 3	0.07 g	0.05 g	0.27 g	0.06 g	0.40 g	0.01 g
Sample 4	0.31 g	0.04 g	0.05 g	0.12 g	0.43 g	0.05 g
Sample 5	0.29 g	0.11 g	0.07 g	0.24 g	0.10 g	0.10 g
total	1.59 g	1.03 g	1.03 g	0.66 g	1.18 g	0.37 g
per m^2	16.06 g/m^2	6.46 g/m^2	10.40 g/m^2	6.67 g/m^2	11.92 g/m^2	3.74 g/m^2

Biotic Condition Index

Community tolerance quotients are a part of the biotic condition index developed by Winget and Mangum (1979). The community tolerance quotients are of two types, the actual community tolerance quotient, CTQa, and the predicted community tolerance quotient, CTQp. The predicted

community tolerance quotient is based on water chemistry, substrate, and gradient, and was determined to be 80 using the directions in Winget and Mangum (1979). CTQa values are a simple arithmetic mean of preassigned index values for the taxa present at a given station. The CTQa indices for the June 2003 samples and an idealized stream, based on a combination of taxa collected from Boardinghouse Creek in November of 2001 and all taxa collected in Eccles Creek from 2001-2003 are given in Table 5.

Table 5. Tolerance quotients.

Eccles Creek, June 2003 Taxa	above South Fork (EC2)	at Whisky Canyon (EC4)	Lower Eccles (EC5)	Ideal stream (species list, including Boarding-house Creek)
Ephemeroptera: Baetidae: Baetis	0	72	0	72
Ephemeroptera: Ephemerellidae: *Drunella sp.*	0	0	0	48
Ephemeroptera: Ephemerellidae: *Drunella dodsei*	0	0	0	4
Ephemeroptera: Ephemerellidae: *Seratella*	0	0	0	48
Ephemeroptera: Ephemerellidae: *Ephemerella*	0	0	0	48
Ephemeroptera: Heptageniidae: *Cinygmula*	21	21	0	21
Ephemeroptera: Leptophlebidae: *Paraleptophlebia*	0	0	0	24
Plecoptera early instar	0	0	0	36
Plecoptera: Nemouridae: *Malenka californica*	0	0	0	36
Plecoptera: Nemouridae: *Zapada*	16	0	0	16
Plecoptera: Perlodidae: *Isoperla*	0	0	0	48
Trichoptera: pupae	0	108	0	108
Trichoptera: Brachycentridae: *Brachycentrus*	0	0	0	24
Trichoptera: Brachycentridae: *Micrasema*	0	0	0	24
Trichoptera: Hydropsychidae: *Arctopsyche*	0	0	0	18
Trichoptera: Hydropsychidae: *Hydropsyche*	0	0	0	108
Trichoptera: Hydroptilidae: *Hydroptila*	108	0	108	108
Trichoptera: Hydroptilidae: *Ochrotricia*	0	108	0	108
Trichoptera: Limnephilidae: *Dicosmecus*	0	0	0	24

Trichoptera: Psychomyiidae: *Tinodes*	0	108	0	108
Trichoptera: Rhyacophilidae: *Rhyacophila*	0	0	0	18
Trichoptera: Uenoidae: *Neothremma alica*	0	0	8	8
Trichoptera: Uenoidae: *Oligoplebodes*	0	0	0	24
Coleoptera: Elmidae: *Optioservus*	0	0	0	108
Coleoptera: Haliplidae: *Peltodytes*	54	0	0	54
Diptera: Ceratopogonidae	0	0	108	108
Diptera: Chironomidae	108	108	108	108
Diptera: Empidae: *Chelifera*	108	0	0	108
Diptera: Simuliidae: *Simulium*	0	0	0	108
Diptera: Tipulidae *Dicranota*	0	0	0	24
Diptera: Tipulidae *Limnophila*	0	0	0	72
Diptera: Tipulidae *Tipula*	0	0	0	36
Diptera: Tipulidae *Pedicea*	0	0	0	72
Diptera: Tipulidae *Antocha*	0	0	0	24
Diptera: Stratiomyidae: *Allognasa*	0	0	0	108
Collembola	0	0	0	108
Hemiptera: Saldidae	0	0	0	108
Acari: Hydracarnia	108	0	108	108
Ostracoda	108	0	108	108
Copepoda	108	108	108	108
Cladocera	108	108	108	108
Mollusca: Spharidae *Sphaerium*	0	0	0	108
Oligochaeta	108	108	108	108
Tricladida Planariidae	0	0	0	108
total	955	849	872	2983
n	11	9	9	45
CTQa	86.8	94.3	96.9	62.2

Generally CTQa values less than 65 represent high quality waters, while those between 65 and 80 represent situations with moderate to high quality water. CTQa values greater than 80 represent low water quality or stressed systems. The June 2003 stations had CTQa values of 86.8, 94.3, and 96.9 at stations EC2, EC4, and EC5 respectively. All are greater than 80, thus indicating water quality problems with Eccles Creek. In October 2002 the sample from Eccles Creek above South Fork (EC2) had a CTQa value of 86.2, slightly lower than the June 2003 value, but both Eccles Creek at Whisky Canyon (EC4) and Lower Eccles Creek (EC5) had values representing moderate to high quality conditions (68.6 and 69.0 respectively). Thus all three stations showed in increase in stress from October 2002 to June of 2003. The downstream sites showed the greatest change in condition, and actually exceeded the upper site in the stress index. These values are comparable to the 93.6 CTQa for the fall of 2001. This indicates that significant problems still exist with Eccles Creek, and confirms the changes detected individual taxa and biomass.

Comparisons of Community Tolerance Quotient and Biotic Comparison Indices

CTQa values for Eccles Creek can be compared from the 1979, 1990 and 2000 time periods. These values detected the impact in the 1990s in three stations below the mine (EC1, EC2 and EC4; Table 6). This impact did not reach the lowest station, EC5. Beginning in 2001 the average CTQa for the stream jumped to 94 and stayed above 70 in 2002, and in June of 2003 it was again 94. The additional inflow has had a more intense impact on the stream than the 1990 detergent spill.

The biotic condition index (BCI) is simply CTQp/CTQa X 100. This measure, according to Winget and Mangum (1979), can be used in conjunction with CTQa to generate a broader interpretation of the state of the stream system. Ideally, if all predictors are accurate, a pristine system will have a BCI of 100 (CTQp = CTQa). BCI values below 100 represent a condition where fewer clean water taxa than predicted are present and thus indicate a reduction in the quality of the habitat. Any BCI value above 100 represents communities whose clean water taxa are in greater abundance than predicted. In 31 of the 37 sample stations presented in this report (Table 6) the BCI was over 100. None of the stations sampled in June 2003 had a BCI value above 100. The BCI values generated in previous studies of Eccles Creek indicates that the CTQp is systematically biased in its prediction of the expected average community tolerance quotient. However that implies that a BCI value less than 90 is a strong indication of a problem in the system.

One additional habitat measure, based on the BCI, can be explored, although the limitation in the BCI itself must be considered in interpreting the data. Winget and Mangum (1979, page 14) classify habitat quality based on the combination of the CTQa and BCI values (Table 7). The table provided on page 14 by Winget and Mangum, 1979 has an error, condition 4 should list the BCI as >70 rather than <70). These habitat quality designations can be used as general BCI generated statements of the condition of the stream in 1979, 1990-91 and 2001-03.

The habitat quality measures for Eccles Creek in 1990-91 do appear to have detected the impact of the mine spill and sedimentation. Streams reaches and tributaries outside of the influence of the mine are rated as high quality habitats while those below (EC1, EC2, and EC4) show signs of impact, being rated as low or high to moderate habitat quality. Additionally, the 2001 and 2002 data showed either high-moderate habitat quality or low habitat quality. Station (EC4), in July of 2002, had high habitat quality, even though the number of taxa and densities indicated that the site was been heavily impacted. Station EC2 in July 2002 and October 2002 had high-moderate habitat quality, yet again the number of taxa and densities are far from the baseline states for both dates. In addition the November 2001 samples, which had a total of just six taxa (Table 1) and a density of 61 per square meter (Table 2), was rated as having high-moderate habitat quality. The June 2003 sample stations all had low habitat quality.

Table 6. CTQa and BCI values for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003
	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI
South Fork tributary above mine, upper site (USF2)			59 /133	53 /151					
South Fork tributary above mine (USF)			49 /163	59 /136	45 /178				
Middle Fork tributary above mine (UMF)			54 /148	49 /163					
Eccles Creek below mine (EC1)			67 /119	108 /74					
Eccles Creek above south Fork (EC2)		65 /123			73 /110		99 /81	86 /93	87 /92
South Fork Eccles Creek (SF)	59 /136	64 /125	55 /145						
Eccles Creek below South Fork (EC3)	65 /123	55 /145							
Eccles Creek at Whisky Canyon (EC4)	62 /127	61 /131	69 /116	70 /114	63 /127	94 /85	52 /154	69 /116	94 /79
Lower Eccles Creek (EC5)	59 /136	74 /108	53 /151	55 /145 57 /140	58 /138		66 /121	69 /116	97 /82
Average	62 /131	64 /126	59 /140	64 /132	60 /138	94 /85	72 /119	75 /108	93 /86

Table 7. Habitat quality based on CTQa and BCI values for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003
South Fork tributary above mine, upper site (USF2)			high	high					
South Fork tributary above mine (USF)			high	high	high				
Middle Fork tributary above mine (UMF)			high	high					
Eccles Creek below mine (EC1)			low	high-mode rate					
Eccles Creek above south Fork (EC2)		low			low		high-moderate	high-moderate	low
South Fork Eccles Creek (SF)	high	high	high						
Eccles Creek below South Fork (EC3)	low	high							
Eccles Creek at Whisky Canyon (EC4)	high	high	low	low	high	high-moderate	high	low	low
Lower Eccles Creek (EC5)	high	low	high	high/ high	high		low	low	low

When interpreting the BCI one must keep in mind that the CTQp values is likely to induce a systematic error into the computation. The interpretation given in Winget and Mangum (1979)

can not be assumed to have consistent properties when compared across streams. Further, the CTQa values are based on the average index from just those taxa that are present, and all taxa are weighted equally, regardless of differences in abundance. A site could conceivably have just a single individual, and nothing else. For example one specimen of *Neothremma* would give the sample a CTQa of 8. One *Neothremma* and 5000 Chironomids would have a CTQa of 58 while 5000 chironomids would have a CTQa of 108. For these reasons the CTQa and BCI values cannot be relied upon as stand alone indicators of stream condition.

Diversity Index

Diversity indices are a way of combing both number of taxa and relative densities into a single measurement. High diversity index values indicate more taxa and a greater number of individuals per taxon. Low diversity values generally reflect a depauperate fauna in both species and somewhat in numbers. The baseline stations (the 1979 samples; Table 8) had diversity values ranging between about 2 to 3. The areas impacted in 1990-91 had diversities values around 1. But in September 1991 the values fell to around 0.5. However in that same sample series, the Upper South Fork had a diversity of 0.7, considerably lower than in the previous year.

Diversity from 2001-2002 was below 1.0 for all sampled stations. In June 2003 EC4 and EC5 were slightly below the July, 2002 levels, and EC2 was above 1.0 for the first time. This appears to be somewhat related to seasonality, and the baseline samples and the 1990-91 samples had obvious seasonal patterns. The continual discharge of water into the stream appears to be keeping diversity low in the two downstream stations. The upstream station, EC2, has shown some improvement in its diversity value, but this likely stems from the increased recovery of microcrustaceans as a result of adding subsampling to the sorting procedure. The diversity levels of June 2003 are still far from the values of 2 or 3 that characterized the baseline data taken in the late 1970s. Thus the diversity indices indicate that the conditions have not changed from the 2002 status at the three sites.

Cluster Analysis

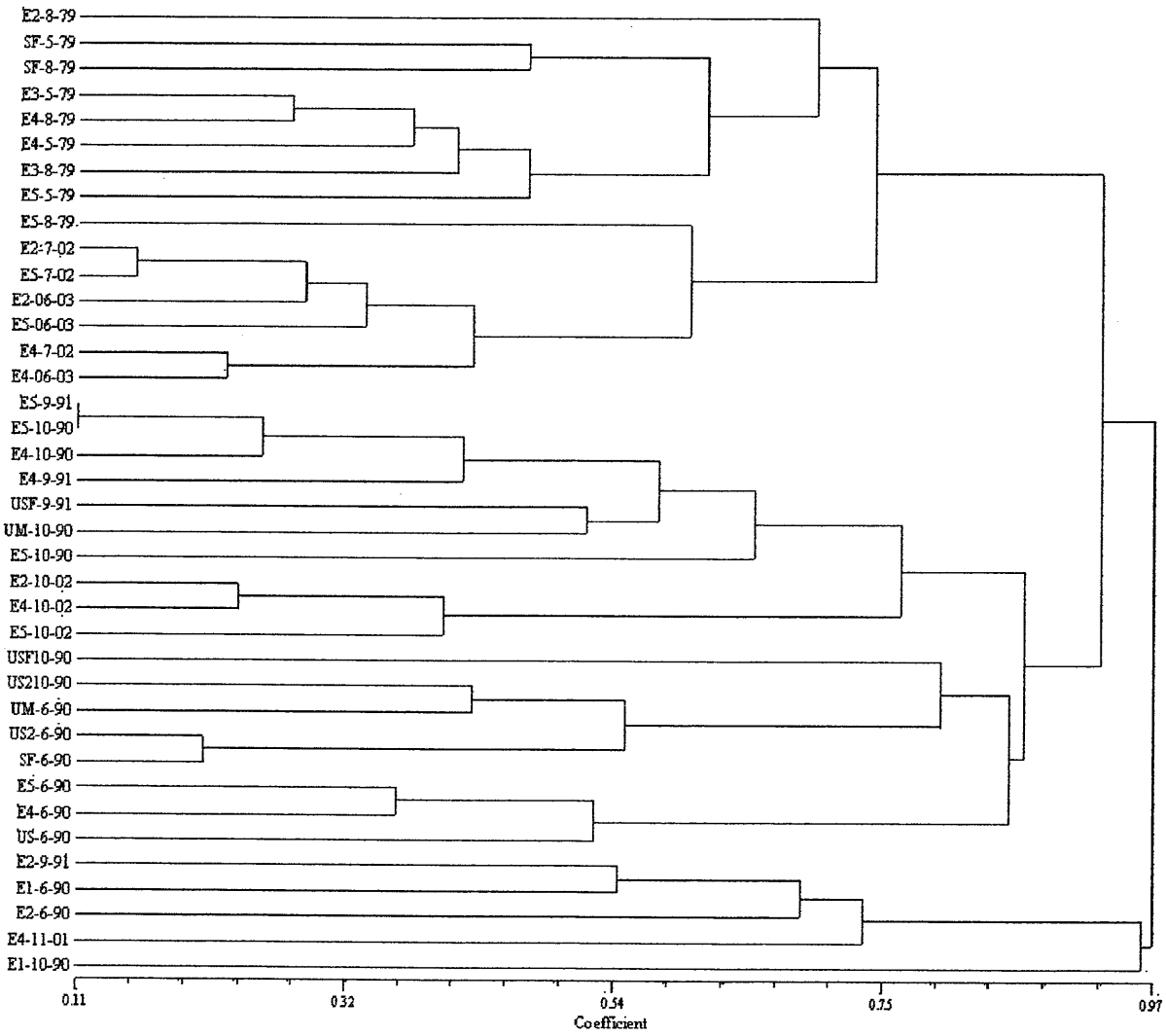
The final analysis utilized in this study was clustering. This is a multivariate approach that generates a visual representation of the relationships among samples. The dissimilarity index utilized in the study considers both quantitative counts of individuals within each taxon and the relative densities of those organisms. The cluster results (Figure 1) separate the majority of the spring-summer samples, including all of the reference samples, into one cluster while the fall samples are part of a second cluster. The exceptions are eight aberrant spring samples in 1990. These are in the fall cluster but show a high dissimilarity to other members of the group. This separate grouping of spring/summer samples and fall samples illustrates very clearly the effect of seasonality on the samples. The October 2002 samples were clearly in the fall cluster and the July 2002 were in the spring-summer cluster.

The Spring 2003 samples were grouped with the July 2002 samples. The June 2003 EC4 site clustered with the July 2002 EC4 site. The July 2002 and June 2003 cluster separate from the baseline stations by about 60% dissimilarity, indicating that while a seasonal signal existed, the samples form Eccles Creek after the input of the discharge water was still very dissimilar to the community that existed during the baseline studies in the late 1970s. Thus the cluster analysis also indicates that the stream is still far from its original condition.

Table 8. Diversity Indices, based on natural logs, for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003
South Fork tributary above mine, upper site (USF2)			1.63	1.9					
South Fork tributary above mine (USF)			1.72	1.9	0.702				
Middle Fork tributary above mine (UMF)			1.66	1.9					
Eccles Creek below mine (EC1)			1.06	0.7					
Eccles Creek above south Fork (EC2)		1.964	1.58		0.400		0.398	0.836	1.314
South Fork Eccles Creek (SF)	3.510	3.322	1.62						
Eccles Creek below South Fork (EC3)	2.450	2.743							
Eccles Creek at Whisky Canyon (EC4)	2.450	3.060	1.22	1.6	0.666	0.757	0.957	0.835	0.955
Lower Eccles Creek (EC5)	2.280	2.590	1.24	1.8/ 1.4	0.416		0.829	0.341	0.789

Figure 1. UPGMA Cluster dendrogram of relationships among invertebrate communities from selected stations and dates in Eccles Creek.



CONCLUSIONS

Eccles Creek in June of 2003 was still showing significant impacts from the increase inflow of water. In fact, this sample period indicated that the stress may have actually increased over what it was in the previous sample periods. This change could be caused by a number of factors associated with the increased inflow, or it could have been induced by an unknown spill into the stream some time between October 2002 and June of 2003. We assume that the change is a chronic response the elevated discharge. The shifts in community structure that we can document show an increase in grazers and a decrease in detritivores. Such shifts reflect a decrease in the availability of detritus to run detrital based food chains. The lack of detritus is one expected outcome when habitats capable of retaining detritus are greatly reduced (Shiozawa 1983). In this case, the discharge has increased the stream level to channel full, and at the channel full level the stream becomes predominantly erosional. This change will increase the flushing rate of detritus from the system, and will also increase the leakage of any coarse particulate matter that is retained on or under rocks. In combination these factors will significantly affect the detrital based food chains in the stream.

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