0052

Canyon Fuel Company, LLC.
Sufco Mine
A Subsidiary of Arch Western Bituminous Group, LLC.

Michael L. Davis
Environmental Engineer
397 South 800 West
Salina, UT 84654
(435) 286-4421 - Office
(435) 286-4499 - Fax

November 12, 2007

Coal Regulatory Program
Attn.: Pam Grubaugh-Littig
Utah Division of Oil, Gas and Mining
1594 West North Temple, Suite 1210
P. O. Box 145801
Salt Lake City, Utah 84114-5801

Incoming
C/041/0002 OK

Re: 2006 Annual Report Macroinvertibrate Study, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

Dear Ms. Grubaugh-Littig:

Please replace the macroinvertibrate explanation page in the Sufco Mine 2006 Annual Report, Appendix B, with the enclosed macroinvertibrate study report. This study report 'An Assessment of the Macroinvertebrates of Box Canyon, Sevier County, Utah, October 2006' was recently completed by our consultant.

If you have any questions please give me a call at (435) 286-4421.

Sincerely,
CANYON FUEL COMPANY, LLC
SUFCO Mine

Michael L Davis

Michael L. Davis,
Environmental Engineer

Enclosures

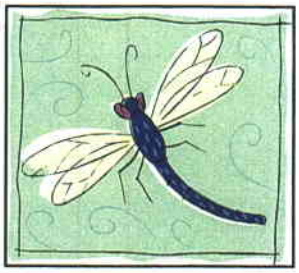
cc: Division of Oil, Gas and Mining – Price Field Office

SUFPUB:\GOVT2007\DOGM CORR\Pam Grubaugh-Littig.ltr 111207.doc

File in:
C/041/0002, 2007, Incoming
Refer to:
❑ Confidential
❑ Shelf
☒ Expandable
Date 11-12-07 For additional information

RECEIVED
NOV 15 2007
DIV. OF OIL, GAS & MINING

AN ASSESSMENT OF THE MACROINVERTEBRATES OF BOX CANYON, SEVIER COUNTY, UTAH, OCTOBER, 2006



File in:
☐ Confidential
☐ Shelf
☒ Expandable
Refer to Record No 0052 Date 11-12-07
In C/041/0002, 2007, Incoming
For additional information

Prepared by

MT. NEBO SCIENTIFIC, INC.
330 E. 400 S., Suite 6
Springville, UT 84663
(801) 489-6937

by

Dennis K. Shiozawa, Ph.D.

for

CANYON FUEL COMPANY, LLC.
397 S. 800 W.
Salina, UT 84654

October, 2007

TABLE OF CONTENTS

INTRODUCTION 1

METHODS 1

RESULTS AND DISCUSSION 3

- Water Chemistry 3
- Invertebrate Taxa 5
- Biomass 10
- Diversity Indices 11
- Biotic Condition Index 11
- Community Tolerance Quotient and Biotic Condition Indices 14
- Cluster Analyses 14
- Canonical Correspondence Analysis 16

CONCLUSIONS 28

LITERATURE CITED 30

Introduction

This is the final series of the aquatic invertebrate monitoring in the Box Canyon drainage on the southeastern Wasatch Plateau, Sevier County, Utah. This system is a tributary to Muddy Creek and the Fremont River of the Colorado River drainage. Box Canyon Creek heads at an elevation of approximately 2,600 meters above sea level. Mining induced subsidence occurred under the East Fork of Box Canyon in the late fall of 2003. Baseline samples of the invertebrate communities in the East Fork of Box Canyon were collected prior to subsidence on October 20, 2003. At the same time, the main stem of Box Canyon Creek (which we will designate as the Main Fork Box Canyon) was sampled to establish a control where no subsidence was expected. A second set of samples, post subsidence, was collected on October 3, 2004; a third sample series was taken on October 8, 2005; and the final set of samples was taken on September 29 and September 30, 2006. The results from this final sampling effort are covered in this report.

Methods

The control reach in the Main Fork of Box Canyon has been discussed previously (Shiozawa and Kauwe, 2006). Its lower gradient and retention of organic matter resulted in it supporting a different community than that found in the East Fork of Box Canyon. During the 2006 sampling period, the streambed at the Main Fork Box Canyon was again retaining a high volume of leaf litter.

The East Fork of Box Canyon streambed consisted predominantly of a mobile sand bottom with sections of exposed bedrock. Short plunge pools developed where the stream had downcut through Castlegate sandstone to shales at the top of the underlying Blackhawk formation. The plunge pools had bedrock or sand bottoms, but at the outflow of the larger plunge pools, gravel and rubble had accumulated. These were deposited during high flow events as the water exiting the plunge pools slowed (turbulence diminished) below the fall velocity for coarse particles. Since sand continued to be transported during lower flows, the outflow riffles became embedded in a sand matrix.

Just prior to the fall 2006 sampling period, a significant flash flood occurred in the East Fork of Box Canyon. The markers for many of the sampling stations had been removed by the high water, and shrubs and trees had been scoured. Several large debris and boulder dams had formed. The sample stations were located with their GPS coordinates, but most sites were barely recognizable. The magnitude of the flood event was apparent upstream of the stations as well. Evidence also existed in the Main Fork of Box Canyon of a high water event. However, its lower gradient resulted in much less erosion from the increase in water level. This station did not appear to be modified in any significant way.

Sampling was focused on the small riffles near the plunge pool sites. However, at several stations, the sampling sites had to be adjusted to the nearest riffle habitat, because the flood had scoured the area below the pools. Sampling in the East Fork of Box Canyon began in the downstream most station (Site 1). We progressively sampled upstream (Table 1).

Table 1. Sampling station locations

	Station	Station Code	Zone	East	North
Main Fork of Box Creek	Site 1	SBXM01	Z12S	E 0469490	N 4316829
East Fork of Box Creek	Site 1	SEFM01	Z12S	E 0471321	N 4317506
East Fork of Box Creek	Site 2	SEFM02	Z12S		
East Fork of Box Creek	Site 3	SEFM03	Z12S	E 0471336	N 4317420
East Fork of Box Creek	Site 4	SEFM04	Z12S	E 0471333	N4317378

Conductivity, pH, alkalinity, and hardness were measured to characterize the stations. Three benthic samples were taken at each site. Since the data are being used to monitor changes in the stream over time, each site in the East Fork of Box Canyon is being treated as a replicate. The individual samples taken from within each site are, therefore, subsamples which give estimates of the density at the individual site (Jordan, et al., 1999). Thus, the samples were bulked together in the field. A modified Surber-type sampler based on the dimensions of the box sampler developed by Shiozawa (1986) with a net mesh of 250 microns was used to collect the samples. The substrate was stirred to a depth of approximately five 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 2006. Previously, they had been marked with plastic flagging.

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). We took subsamples from the samples after they were visually sorted. The remaining sample material was placed in a beaker with a total volume of 200 ml, and five 2 ml subsamples were removed and processed under magnification with a dissecting microscope. The mean density per subsample was used to estimate the total density of organisms remaining in the sample after it had been visually sorted. 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, mean densities, and biomass. These allow a general evaluation of changes that have occurred since the subsidence occurred in late 2003. The community tolerance quotient (CTQ; Winget and Mangum, 1979) was used to gain insight into the condition of the stream relative to an idealized system predicted from slope, water chemistry, and substrate. 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.

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). As a final analysis, the entire data set was examined with an ordination technique, detrended correspondence analysis (Braak and Smilauer, 2002). This procedure is used mainly as an exploratory method so that general trends in the sampling stations can be graphically appraised.

Results and Discussion

Water Chemistry

In 2006, conductivity levels in both the Main Fork of Box Canyon and the East Fork of Box Canyon had fallen by 5% to 40%. The Main Fork of Box Canyon Creek station underwent the greatest decline. In the fall of 2005, the Main Fork of Box Canyon Creek conductivity had increased substantially from 202 uS/cm in 2004 to 412 uS/cm in 2005. In the 2006 sample, conductivity at that station had declined to 240 uS/cm. The East Fork stations also declined in conductivity generally below levels measured in 2004 and 2005 but still higher than the conductivity readings from 2003 (Table 2). These shifts may be related to changes in annual precipitation rates.

Alkalinity in the Main Fork remained lower than that in the East Fork and was the same as recorded in 2005. The East Fork alkalinity readings at all stations were120 mg/l. This value was the lowest that had been recorded in the East Fork ranging from 25% to 50% lower than in previous years (Table 2). This may be a function of the flood event which would be expected to have altered the relative influences between surface and deeper waters.

Hardness data from all stations in 2006 were very close to the 2005 measurements. Hardness in the Main Fork was much lower than those measurements taken at the East Fork sites. As with the previous sample periods, alkalinity was less than hardness indicating that anions other than just carbonates were present (Boyd, 1990). It is probable that the difference is made up by sulfate ions in the two streams. Assuming that the majority of the missing anions were sulfates and that the these were largely tied to divalent cations, the 2006 Main Fork sulfate levels were probably in the range of about 80 mg/l, identical with 2005, and similar to 2003 when the estimate was 86 mg/l. The East Fork sulfate levels were between 80 to 100 mg/l in 2006 as compared with 40 to 60 mg/l in 2005. The East Fork stations had approximately 40 mg/l in 2003, but in 2004, the sulfate levels varied from about 40 mg/l in the upstream station (Site 4) to 0 mg/l in the downstream most station (Site 1). The excess alkalinity noted in 2005 at Station 2 (when alkalinity exceeded hardness by 60 mg/l) did not occur in 2006.

The pH readings, which had stayed relatively consistent throughout the study period, showed increases in both the Main Fork and East Fork. The Main Fork of Box Canyon pH increased to 8.13 from a pH of 7.3 in 2005. It was still more acidic than the East Fork sites. The East Fork sites were slightly more basic than they had been in previous sampling periods.

Table 2. Water chemistry

Box Canyon Water Chemistry		**Conductivity (uS/cm)**	**pH**	**Alkalinity mg/L $CaCO_3$**	**Hardness mg/L $CaCO_3$**
Main Fork Box Canyon	October, 2003	170	7.83	34	120
	October, 2004	202	7.76	80	120
	October, 2005	412	7.3	60	140
	September, 2006	**240**	**8.13**	**60**	**140**
East Fork Box Canyon Site 1	October, 2003	300	8.52	154	188
	October, 2004	260	8.28	240	240
	October, 2005	463	8.42	200	260
	September, 2006	**390**	**8.73**	**120**	**240**
East Fork Box Canyon Site 2	October, 2003	270	8.39	137	188
	October, 2004	435	8.31	220	240
	October ,2005	432	8.3	260	200
	September, 2006	**390**	**8.4**	**120**	**200**
East Fork Box Canyon Site 3	October, 2003	290	8.43	137	171
	October, 2004	445	8.06	240	260
	October, 2005	426	8.3	180	220
	September, 2006	**370**	**8.42**	**120**	**200**
East Fork Box Canyon Site 4	October, 2003	280	8.44	154	188
	October, 2004	466	7.94	200	240
	October, 2005	405	8.4	160	220
	September, 2006	**390**	**8.53**	**120**	**220**

Invertebrate Taxa

The Main Fork of Box Canyon had 20 taxa and 19,290 organisms per square meter in 2006 (Table 3). The number of taxa was three less than were collected in 2005 and four less than in 2004 but was five more than in 2003. The total density estimate for the Main Fork of Box Canyon in 2006 was close to the 2003 value of 20,633 per square meter but was a decrease of over 30% from the previous year. The difference between the 2005 and 2006 densities were associated with decreasing numbers of ceratopogonids and the absence of *Baetis*, early instar stoneflies, and copepods. Midges also decreased. *Simulium* showed a significant increase. This group can be highly vagrant and may have moved into the sample station with the increased discharge associated with the rains that generated the flash flood in the East Fork of Box Canyon.

Station 1 of the East Fork of Box Canyon retained the same number of taxa as in the 2005 sampling period, but the density was almost double that recorded in 2005. The difference was due to an increase in chironomids and simuliids. *Baetis* decreased at this station. The middle two of the four East Fork of Box Canyon stations had increased number of taxa in 2006 while the upstream most station, Station 4, decreased from 16 taxa in 2005 to 12 in 2006. The densities of invertebrates at these three stations increased substantially over the 2005 estimates. The greatest increase occurred at Station 2 where the 2006 density was 4.2 times higher than in 2005. The other stations had increases from 1.6 to 2.4 times the 2005 level. These increases were mainly driven by increased densities of chironomids and simuliids. Both taxa can respond quickly to spates. In Station 1, the downstream most station, the stonefly, *Zapada*, did not change density substantially. *Zapada* was in low densities in Station 2 and absent in the stations above that. Its distribution reflects the impact of the flooding which would have scoured much of the leaf debris on which it depends. Both Stations 2 and 3 also had significant increases in *Baetis*.

The increase in both *Baetis* and plecopteran recorded in the Main Fork of Box Canyon in 2005 was reversed in 2006. Chironomid density increased to about 70% of the total invertebrate density. But ceratopogonid larvae decreased significantly in density to just 30 per square meter. In 2004, this group numbered 347 per square meter and increased to 1,141 per square meter in 2005. Simuliids increased in numbers from none in 2003 and 2004, to ten in 2005, and 2,485 per square meter in 2006. This taxon made up almost 13% of the invertebrates collected. Oligochaete numbers were roughly the same as in previous sampling periods still showing densities that appear to be within the long-term range for that taxonomic group. Ostracods declined from the 2005 numbers but still made up over 2% of the total invertebrate density.

In 2005, chironomids comprised just 2% to 4% of the total density at Stations 1 through 4, respectively in the East Fork of Box Canyon. In 2004, they made up 23%, 48%, 44%, and 55% of the total organisms. In the 2006 samples, chironomids made up 71%, 15%, 41%, and 79% of the organisms, making that taxon the dominant in Stations 1 and 4, and co-dominant with *Baetis* (at 45%) in Station 3. In Station 2, *Baetis* dominated with 38% of the density, and Simuliidae comprised 34%, as the second most abundant taxon. Oligochaetes, a dominant taxon in 2005, were rare in 2006, likely due to the flood, since this group would have little refuge from scouring flows over the shallow bedrock.

Table 3. Summary of densities per square meter and total taxa for Box Canyon, 2003-2004

	Main Fork Box Canyon				East Fork Box Canyon Site 1				East Fork Box Canyon Site 2				East Fork Box Canyon Site 3				East Fork Box Canyon Site 4			
	Fall 03	Fall 04	Fall 05	Fall 06	Fall 03	Fall 04	Fall 05	Fall 06	Fall 03	Fall 04	Fall 05	Fall 06	Fall 03	Fall 04	Fall 05	Fall 06	Fall 03	Fall 04	Fall 05	Fall 06
Ephemeroptera: *Baetis*	20	20	939	0	3313	364	10029	2727	2010	1949	5181	15180	2242	0	2555	14271	3333	1828	525	0
Ephemeroptera: *Cinygmula*			40				40									61		20		
Ephemeroptera: early instar										313										
Plecoptera: *Alloperla*						20				162										
Plecoptera: early instar		646	6818		414	2212	1020		1353	1919	1111		51	323	2394			1879	5808	
Plecoptera: *Hesperoperla pacifica*														10						
Plecoptera: *Malenka californica*	10					61				51			798	949			444	414		
Plecoptera: *Paraperla*	191	10										61	2515				1485			
Plecoptera: *Zapada*		10	152		152	152	273	212	172	374	525	61	61	293	1252				848	
Trichoptera: *Brachycentrus*					10				10											
Trichoptera: *Dicosmoecus*	263																10			
Trichoptera: Early Instar			20																	
Trichoptera: *Hesperophylax*		202	293	61		91		515		10	20			91	192	61		40	242	30
Trichoptera: *Hydropsyche*				61	30			1061	172				1353							

Trichoptera: *Lepidostoma*										10										
Trichoptera: *Limnephilus*									10											
Trichoptera: *Neothremma alicia*		10																		
Trichoptera: *Oligophlebodes*											71									
Trichoptera: *Psychomyia flavida*					10				646											
Trichoptera: pupae		10	10																	
Trichoptera: *Rhyacophila*							20	30			10		20		30				10	
Coleoptera: Dytiscidae (larvae)		293	121					30		10		30				30		20	10	
Coleoptera: Dytiscidae (adult)						20		30												1121
Coleoptera: Dryopidae *Helichus*		111	121	90				970											10	
Coleoptera: *Heterlimnius* (larvae)	10	1131				10								10					1515	
Coleoptera: *Heterlimnius* (adult)	20	10																		
Coleoptera: *Hydrophilidae*			10																	
Coleoptera: *Optioservus* (larvae)		51		10																
Coleoptera: *Optioservus* (adult)	525			10								30								
Diptera: *Atherix*		20																		
Diptera: *Caloparyphus*			10	10						10						939				

Diptera: Ceratopogonidae	10	374	1141	30				90	40			909				30	10		10	
Diptera: *Chelifera*					30				61									10		
Diptera: Chironomidae (larvae)	16089	18544	15100	13443	2636	1293	333	22816	2656	5787	323	5939	2030	3394	768	13029	1182	9292	253	23422
Diptera: Chironomidae (pupae)	10	20	10	758		303		970	40			121		40	10	939	40	434		909
Diptera: *Dicranota*		71	111	61		20	61	152		111	51			91	101	30		475	222	61
Diptera: *Dixa*		10			10					10										
Diptera: *Hexatoma*		10					10													
Diptera: *Limnophora*												61		10		121		20		212
Diptera: *Limnophila*		20	10	343			616	30			303	30		10	364				20	939
Diptera: *Pedicia*		20												10				30		
Diptera: *Pericoma*	10		20	343		61		61	10	40		30		20	30		10	10		
Diptera: *Ptychoptera*							10													
Diptera: Nr. Rhabdomastix							10													
Diptera: Scleroprocta tetonica		10					20	30												
Diptera: *Simulium* (pupae)				20							10	30			20					
Diptera: *Simulium* (larvae)			10	2485	1010	40	182	2212	5848	343	172	13293	1889	20	444	2182	1000	808	81	939
Diptera: *Tipula*	61	20	20	20	91	30	10	121	232	343			71	323	10	30	91	394	30	30
Crustacea: Copepoda	303		3030		535	303		909					0	606				303		
Crustacea: Isopoda																				909

Crustacea: Ostracoda	1687	12686	919	606		303	313				10			616	313		10	1212		
Arachnida: Hydracarina	20	1525	10	303					10	303		1818		303					303	
Mollusca: *Sphaerium*	30	91	30																	
Annelida: Haplotaxidae							20													
Annelida: Oligochaeta	1303	636	869	677		303	2929				1353	667	606	576	9858	61	1343	434	2475	30
Planaria		10	40	10			1172			30	152	121		10	1566	91		20	152	909
Collembola			30	10						10								10		
Culicidae			30																	
Hemiptera	71																			
Nematoda										303										
Total	20633	36572	29914	19290	8242	5585	17068	31936	13271	12090	9292	39442	11635	7706	19907	31906	8959	17655	12514	29512
Total taxa	15	24	23	20	12	15	17	17	14	17	12	17	11	18	13	15	11	18	16	12

Biomass

Biomass in the Main Fork of Box Canyon (Table 4) fell in 2006 but was still greater than the 2004 level. Station 1 of the East Fork of Box Canyon had about the same biomass as in 2004 and was about two and a half times greater than the previous year. Stations 2 and 3 were also close to their 2004 levels. Station 2 was higher than it was in 2005 while station 3 had less biomass than in 2005. Station 4 had the lowest biomass recorded for this location. This reflects the increased impact of the flood in the upstream stations. As was concluded in 2005, it appears that high fluctuations in biomass are to be expected in this system, a response to the flashy nature of these streams.

Table 4. Biomass comparisons for October, 2003-September, 2006

Box Canyon Fall Biomass		**g/m²**
Main Fork Box Canyon	October, 2003	24.12 g/m²
	October, 2004	11.07 g/m²
	October, 2005	56.27 g/m²
	September, 2006	**16.22 g/m²**
East Fork Box Canyon Site 1	October, 2003	3.54 g/m²
	October 2004	16.03 g/m²
	October, 2005	6.77 g
	September, 2006	**17.12 g/m²**
East Fork Box Canyon Site 2	October, 2003	14.30 g/m²
	October, 2004	6.13 g/m²
	October, 2005	4.49 g/m²
	September, 2006	**7.68 g/m²**
East Fork Box Canyon Site 3	October, 2003	8.87 g/m²
	October, 2004	7.04 g/m²
	October, 2005	15.87 g/m²
	September, 2006	**9.34 g/m²**
East Fork Box Canyon Site 4	October, 2003	13.95 g/m²
	October, 2004	23.26 g/m²
	October, 2005	28.62 g/m²
	September, 2006	**11.81 g/m²**

Diversity Indices

The diversity index for the Main Fork of Box Canyon decreased from 1.325 in 2005 to 1.023 in 2006 (Table 5). The East Fork of Box Canyon stations also showed a general decrease in diversity. Only Station 2 of the East Fork of Box Canyon increased its diversity value above the 2005 levels. The other stations decreased as would be expected following the flash flood. The magnitude of the 2006 flood was likely much greater than the usual spate in this system since tree clumps were uprooted and boulders moved. Given the magnitude of the flood, the decline in mean East Fork diversity from about 1.7 to 1.5 to 1.1 is not surprising. Interestingly, Station 2 had a higher diversity in 2006 than it had in 2004 or 2005, but the other three stations had their lowest recorded diversities in 2006.

Table 5. Diversity indices based on natural logs for Box Canyon, October; 2003-October, 2005

	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4	East Fork Box Canyon - mean index
Oct 2003	0.897	1.505	1.614	1.929	1.713	1.690
Oct 2004	1.237	2.059	1.337	1.852	1.553	1.700
Oct 2005	1.325	1.278	1.280	1.509	1.881	1.487
Sept 2006	**1.023**	**1.034**	**1.492**	**1.110**	**0.787**	**1.106**

Biotic Condition Index

The actual Community Tolerance Quotient (CTQa) was determined from the presence-absence of taxa (Table 6). The individual taxa are assigned a tolerance quotient value which is lower for those taxa that require high water quality (Winget and Mangum, 1979). The CTQa is simply the mean of the individual tolerance quotients for the taxa at a given site. Thus, the lower the CTQa value, the better the water quality. The lowest CTQa value for the 2006 samples was again the East Fork of Box Canyon Station 1 which had a CTQa value of 72.24 (compared with 70.29 in 2005). The next lowest was Station 4 with a CTQa value of 80 (compared with 76.75 in 2005) followed by Station 2 with a CTQa of 82.57 (72.83 in 2005), and Station 3 with a CTQa of 83.77 (70.92 in 2005). The Main Fork of Box Canyon again had the highest CTQa of 89.29 (81.70 in 2005). The Main Fork Station is retaining its clear difference from the East Fork stations, and its higher stress rating is supported by the low diversity that station has had since sampling began in 2003 (Table 5, Table 7).

Within the East Fork of Box Canyon, Station 3 was the most stressed followed closely by stations 2 and 4. While Station 1, the downstream most site, is the least stressed (has the fewest stress indicator taxa). These values do not correspond with the diversity indices (Table 5), where the upstream most site, Station 4, has the lowest diversity, and Station 2 had the highest diversity (Table 5). The downstream most station, Station 1, had the second lowest diversity, yet it had the best

Table 6. Tolerance quotients for Box Canyon; Fall, 2005

Box Canyon Tolerance Quotients	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4	Ideal Stream
Ephemeroptera: Baetidae: *Baetis spp.*		72	72	72		72
Ephemeroptera: Heptageniidae: *Cinygmula*				21		21
Plecoptera: Chloroperlidae: *Alloperla*						24
Plecoptera: Chloroperlidae: *Paraperla*			24			24
Plecoptera: Nemouridae: *Malenka californica*						36
Plecoptera: Nemouridae: *Zapada*		16	16			16
Plecoptera: Perlidae: *Hepseroperla pacifica*						18
Trichoptera: Brachycentridae: *Brachycentrus*						24
Trichoptera: Hydropsychidae: *Hydropsyche*	108	108				108
Trichoptera: Lepidostomatidae: *Lepidostoma*						18
Trichoptera: Limnephilidae: *Dicosmoecus*						24
Trichoptera: Limnephilidae: *Hesperophylax*	108	108		108	108	108
Trichoptera: Limnephilidae: *Limnephilus*						108
Trichoptera: Psychomyidae: *Psychomyia*						108
Trichoptera: Rhyacophilidae: *Rhyacophila*		18				18
Trichoptera: Uenoidae: *Neothremma alicia*						8
Trichoptera: Uenoidae: *Oligophlebodes*						24
Coleoptera: Dryopidae: *Helichus*	54	54				54
Coleoptera: Dytiscidae		72	72	72	72	72
Coleoptera: Elmidae: *Heterlimnius*					108	108
Coleoptera: Hydrophilidae						72
Coleoptera: Elmidae: *Optioservus*	108		108			108
Diptera: Athericidae: *Atherix*						24
Diptera: Ceratopogonidae	108	108	108	108		108
Diptera: Chironomidae	108	108	108	108	108	108
Diptera: Dixidae: *Dixa*						108

Diptera: Empimidae: *Chelifera*						108
Diptera: Muscidae: *Limnophora*			108	108	108	108
Diptera: Psychodidae: *Pericoma*	36	36	36			36
Dipter: Ptychopteridae: *Ptychoptera*						108
Diptera: Simuliidae: *Simulium*	108	108	108	108	108	108
Diptera: Stratiomyidae: *Caloparyphus*	108			108		108
Diptera: Tipulidae: *Dicranota*	24	24		24	24	24
Diptera: Tipulidae: *Hexatoma*						36
Diptera: Tipulidae: *Limnophila*	72	72	72		72	72
Diptera: Tipulidae: *Pedicia*						72
Diptera: Tipulidae: *Nr. Rhabdomastix*						72
Diptera: Tipulidae: *Scleroprocta tetonica*		72				72
Diptera: Tipulidae: *Tipula*	36	36		36	36	36
Copepoda		108				108
Ostracoda	108					108
Acari: Hydracarina	108		108			108
Mollusca: Gastropoda: *Sphaerium*						108
Tricladida: Planariidae	108		108	108	108	108
Annelida: Haplotaxidae		108				108
Annelida: Oligochaeta	108		108	108	108	108
Collembola	108					108
Culicidae						108
Nematoda						108
Total	**1518**	**1228**	**1156**	**1089**	**960**	**3561**
n	**17**	**17**	**14**	**13**	**12**	**49**
CTQa	**89.294**	**72.235**	**82.571**	**83.769**	**80**	**72.7**

CTQa for the 2006 sampling series. The discrepancy, as in 2005, reflects the difference between an approach that weighs each taxon equally (the CTQa method) with one that considers the relative abundances of each taxon. The limitations of the CTQa approach has been discussed in previous reports.

Community Tolerance Quotient and Biotic Condition Indices

The CTQa index can be adjusted to a value corrected for various physical factors associated with the stream system. The adjustment is made with a predicted community tolerance quotient (CTQp). The CTQp values are estimated from a combination of gradient, substrate, and water chemistry in accordance with a key provided by Winget and Mangum (1979). One of the chemical factors that is important, sulfate, was not measured in this study so it must be estimated (see Shiozawa, 2004). The estimates were 40 mg/l for the East Fork of Box Canyon and 80 mg/l for the Main Fork of Box Canyon. The gradients of both sites, estimated from topographical maps, are less than 1.2%. The Main Fork of Box Canyon was a gravel-rubble substrate, while the stations on the East Fork were sorted gravels or rubble substrates. The estimated CTQp for the Main Fork of Box Canyon was 51 while the East Fork Stations had a CTQp of 53.

The Biotic Condition Index is the ratio of CTQp/CTQa expressed as a percent. This ratio effectively reverses the reading of the relationships so that instead of low values being indicative of higher quality waters, high BCI values indicate better water quality. The ideal is a BCI of 100 or higher, meaning that the station meets or exceeds the predicted level. The BCI for 2006 in the Main Fork of Box Canyon (Table 7) was 57.12, the lowest in the four-year sample period. The four-year average is 62.24. This station does not meet, nor has it met, the ideal predicted by the physical parameters used by Winget and Mangum (1979). The BCI in the East Fork of Box Canyon (Table 7) ranged from 63.27 to 73.37. Station 1 was almost equal to its four-year average, but Stations 2, 3, and 4 were lower than the average over that same period. The patterns indicate the same trends noted for the CTQa above.

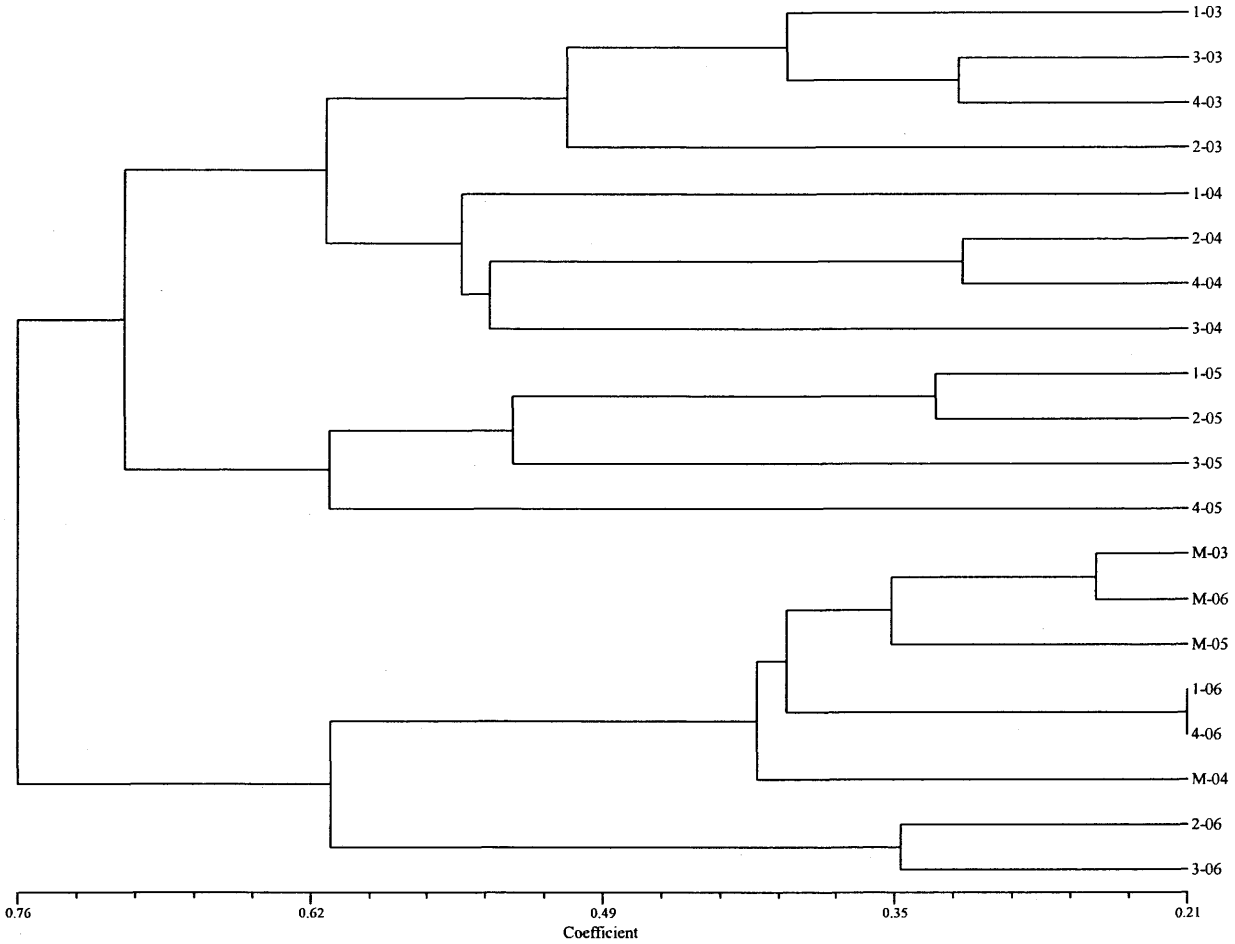
Table 7. CTQa and BCI values for Box Canyon; October, 2003-September, 2006

	Main Fork	East Fork Site 1	East Fork Site 2	East Fork Site 3	East Fork Site 4
	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI
October, 2003	84.8/ 60.14	78.33/ 67.66	85.57/ 61.94	60.91/ 87.01	76.36/ 69.41
October, 2004	73.62/ 69.27	69.25/ 76.53	70.7/ 74.96	75.05/ 70.62	78.16/ 67.81
October, 2005	81.70/ 62.42	70.29/ 75.4	72.83/ 72.77	70.92/ 74.73	76.75/ 69.06
September, 2006	**89.29/ 57.12**	**72.24/ 73.37**	**82.57/64.19**	**83.77/ 63.27**	**80.00/ 66.25**
Average	82.35/62.24	72.53/73.24	77.92/68.46	72.66/73.91	77.82/68.13

Cluster Analysis

The data were run in a cluster analysis using the Bray-Curtis dissimilarity index (Poole, 1974; Krebs, 1989) with the unweighted pairs group averaging algorithm (UPGMA) (NTSYS; Rolf, 2000). The analysis (Figure 1) resulted in two main clusters separating at a dissimilarity level of 0.73. One cluster consisted of three years of the Main Fork of Box Canyon samples plus the 2006 samples

Figure 1. Cluster dendrogram for the Box Canyon samples. Main Fork of Box Canyon samples are designated with M, and the four East Fork Stations are designated with the station number.



from the East Fork of Box Canyon. The other included the 2003, 2004, and 2005 East Fork of Box Canyon samples. Within the latter cluster, the sites clustered by year. The 2003 and 2004 samples formed one subcluster, and the 2005 samples formed a second subcluster. These two subclusters separated at a dissimilarity level of approximately 0.73. The 2003 and 2004 samples separated from one another at a dissimilarity level of about 0.62. The 2005 invertebrate communities in the East Fork of Box Canyon were more divergent from the same communities in 2003 and 2004. The upstream most site, Station 4, was more divergent from the other 2005 East Fork Box Canyon sample sites than were the 2003 stations from the 2004 stations.

The inclusion of the 2006 East Fork of Box Canyon stations with the Main Fork of Box Canyon station is likely a result of the flood that took place in the East Fork of Box Canyon in 2006. The flood rearranged the stream bed, and many of the sites had more sand embedding the rubble. Within the Main Fork Box - East Fork Box cluster, Stations 1 and 4 fell within a subcluster containing the Main Fork station samples while the 2006 East Fork of Box Canyon Stations 2 and 3 were separated from the Main Fork subcluster at a dissimilarity of approximately 0.62, essentially the same level of dissimilarity that separated the 2005 East Fork of Box Canyon samples from the 2003 and 2004 series. This difference likely represents the fact that the latter stations have higher numbers of *Baetis* and lower numbers of chironomids than do Stations 1 and 4.

Canonical Correspondence Analysis

The final technique applied to the data set was correspondence analysis (Braak and Smilauer, 2002). The analysis was run on the full data set. This procedure allows the generation of a graphical view of relationships among the stations sampled since 2003 along with the corresponding invertebrates that determine the positioning of the sampled stations.

It has always been apparent that the habitat in the East Fork of Box Canyon differs from that in the Main Fork. The water tends to flow more rapidly in the East Fork of Box Canyon since the stream channel has a greater gradient and a higher discharge than the Main Fork of Box Canyon. The Main Fork of Box Canyon has sand in much of the channel. Sand tends to embed the rubble substrates in that system. It also tends to slow or reduce water infiltration and can induce anoxic conditions in the hyporheic zone (that region under the stream bed which still has flowing water) under conditions of high organic loads. The Main Fork of Box Canyon also had a more extensive flood plain which was dominated by sand. Thus, it is likely that a significant portion of the discharge in the canyon travels interstitially. While sand also dominates the stream bed in the East Fork of Box Canyon, bedrock and rubble are more prominent features. The presence of plunge pools allowed development of small stretches with somewhat sorted coarse substrates. The sorting/embedding of sediments in the East Fork of Box Canyon are a function of both discharge and sediment transport. Thus, in years with low discharge, one would predict an increase in embedded substrates while higher discharge years should enhance sorting. In addition, increased sediment input will tend to increase the embeddedness of the substrate. As the substrate becomes more embedded, water infiltration decreases and a tendency for interstitial anoxia develops, thus, influencing community structure. Since the East Fork of Box Canyon has a gradient that would favor a greater variation in sediment conditions, it would be expected to show greater fluctuations.

The analyses were completed on two levels. First, the entire data set was examined with canonical correspondence analysis giving a general picture of the changes in the system over time. However, this ordination included taxa that only occurred rarely in the samples. Several being only collected once during the four-year sampling period. The potential bias induced by rare taxa was removed in a second analysis by eliminating all taxa that occurred in a cumulative density of less than 50 over the four-year sampling period. This second analysis retained 36 of the 60 taxonomic designations accumulated over the sampling period.

The total taxa based station-date ordination showed two important trends. First, the Main Fork of Box Canyon (open circles, Figure 2) had the least year-to-year variation, and second, while the East Fork stations had a much greater amplitude in their shifts from year to year, their general trajectory followed the pattern in the Main Fork station. The dynamics seen in these stations correspond to changes in benthic invertebrate taxa composition and abundances. An examination of the taxa that corresponded to the placement of the stations in the ordination showed that a number of rare taxa were placed at the extremes in the ordination plot. For instance, in the Diptera (Figure 3) *Rhabdomastix* and *Ptychoptera* were in the far right of the upper right quadrant, and *Atherix* and Culicidae were in the upper left quadrant. These taxa were rare in the samples occurring only once or twice over the four year sampling period. Similar situations existed with other taxonomic groups.

Figure 2. Full taxa data set plot of stations from the Main Fork of Box Canyon (Main = ○) and the four stations on the East Fork of Box Canyon from 2003 through 2006. (Station 1= ■; Station 2 = ▲; Station 3 =▼; Station 4 = ◆)

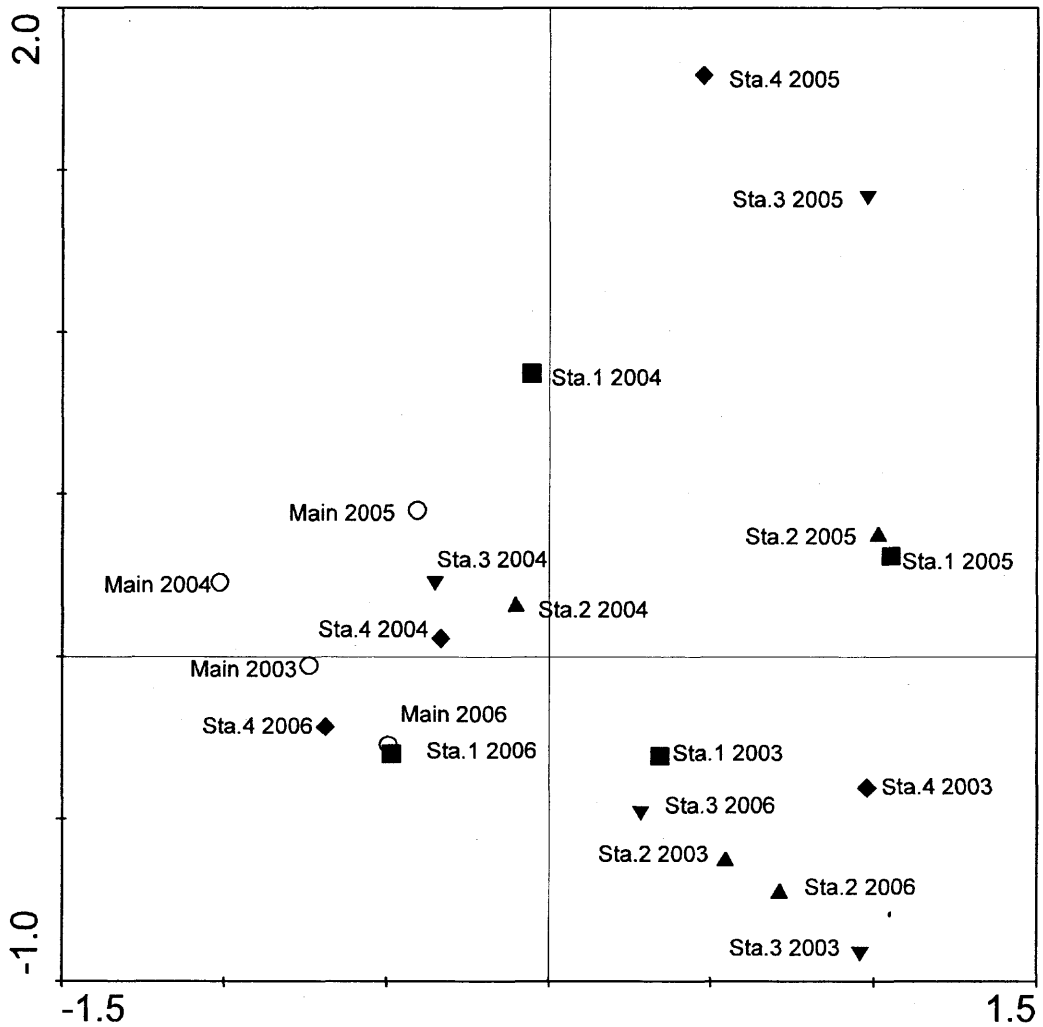
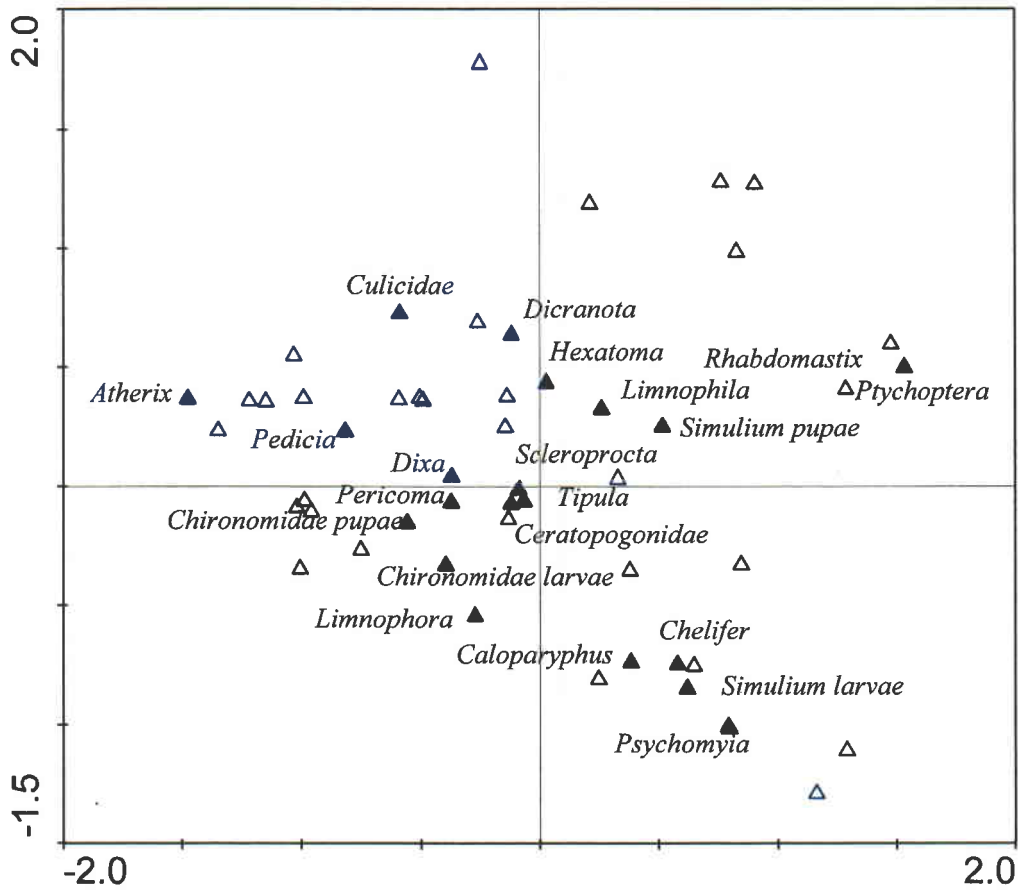


Figure 3. Ordination plot of all taxa utilized in the generation of the full taxa data set plot of stations. Diptera are labeled and denoted with a solid triangle.



This raised concern that their inclusion could be generating incorrect patterns in the ordination or at least could be distorting the general trends observed among and between sampling stations (Figure 2). Because of this, the data set was culled, all rare taxa were removed from the data set, and the analysis was re-run. The reduced data set generated the same ordination patterns among stations (Figures 4, 5, 6, 7, and 8) as seen in the full data set ordination (Figure 2). Thus, the two general observations noted above still hold: the Main Fork of Box Canyon had the least year-to-year variation, and the East Fork stations followed the year-to-year pattern in the Main Fork station but with much greater amplitude.

The four collections on the Main Fork of Box Canyon (Figure 4) stay in the left half of the ordination plot throughout the sampling period with their trajectory over time (note arrows on Figure 4) mirroring that station's trajectory generated by the full data set (Figure 2). This trajectory, forming

a triangle with the shift from the station's 2003 position up and to the left in 2004, then up and to the right in 2005, and finally down and to the left in 2006, was a general theme repeated in several of the East Fork stations as well (Figures 6 and 7). Station 1 (Figure 5) differed in the shift from 2004 to 2005 where the station shifted down and to the right, and Station 4 differed in that in 2006 the station returned close to the 2004 position (Figure 8) rather than toward the 2003 position. The reduced variation in the Main Fork of Box Canyon relative to the East Fork stations could be related to differential responses due to subsidence under the East Fork of Box Canyon or to the greater environmental variability in the East Fork stations which could be expected given the East Fork's steeper gradient and absent flood plain. These two factors are confounded since only a single year of pre-subsidence data was collected (2003). However, the fact that the four East Fork of Box Canyon sites followed similar trajectories suggests that the steeper slope in the East Fork of Box Canyon may be the dominant driving force in the greater variability in that area.

The synchrony between the Main Fork and East Fork stations can be summarized as follows. The 2003 Main Fork station (Figure 5) falls just below the medium line separating the upper and the lower left quadrants of the plot and is approximately at the top center of the lower left quadrant. The 2004 Main Fork station shifted up and to the left in the upper left quadrant, and in 2005, it shifted further up and to the right, but still stayed within the upper left quadrant. The 2006 Main Fork station shifted to the lower left quadrant below and to the right of the 2003 sample. This can be viewed as making a small clockwise loop or triangle in ordination space over the four years of observation. The East Fork of Box Canyon samples make a similar loop or triangle but with a greater amplitude. These stations begin in the lower right quadrant, shift up and to the left into the upper left quadrant in 2004, and then in 2005, the four stations are in the upper right quadrant. The 2006 East Fork of Box Canyon samples are in the lower half of the plot. These four stations are also making a clockwise loop in ordination space. Thus, the consecutive shifts in the Main Fork of Box Canyon from 2003 to 2004 to 2005 to 2006 mirror the directional shifts in the four East Fork of Box Canyon stations over that same time period. The major difference is the initial positioning (in 2003) of the Main Fork of Box Canyon site to the left of the East Fork of Box Canyon stations and the magnitude of the shifts of the East Fork of Box Canyon stations. These shifts appear to be related to year-to-year differences in physical conditions, because the Main Fork is also responding to the signal, but these factors are much more amplified in the East Fork of Box Canyon.

The Main Fork of Box Canyon underwent relatively small shifts in community structure throughout the four-year sampling period. The yearly changes in the East Fork of Box Canyon generally mirrored those of the Main Fork of Box Canyon (Figure 4) but tended to be shifted to the right and to have a greater amplitude. The differences among the stations were most apparent in Station 1 in 2004 (Figure 5) where that station was higher on the vertical ordination axis of the upper left quadrant than any of the other sites for that date, and Station 4 in 2005 (Figure 8) which was much higher in the upper right quadrant, and the 2006 Station 4 site. Interestingly, in 2006, both Stations 1 and 4 converged to the 2006 Main Fork of Box Canyon station state while Stations 2 and 3 (Figures 6 and 7) of the East Fork of Box Canyon both returned closer to their 2003 states in the lower right quadrant of the ordination.

Figure 4. Ordination plot based on the reduced data set (36 taxa) showing the trends of the Main Fork of Box Canyon Station through time.

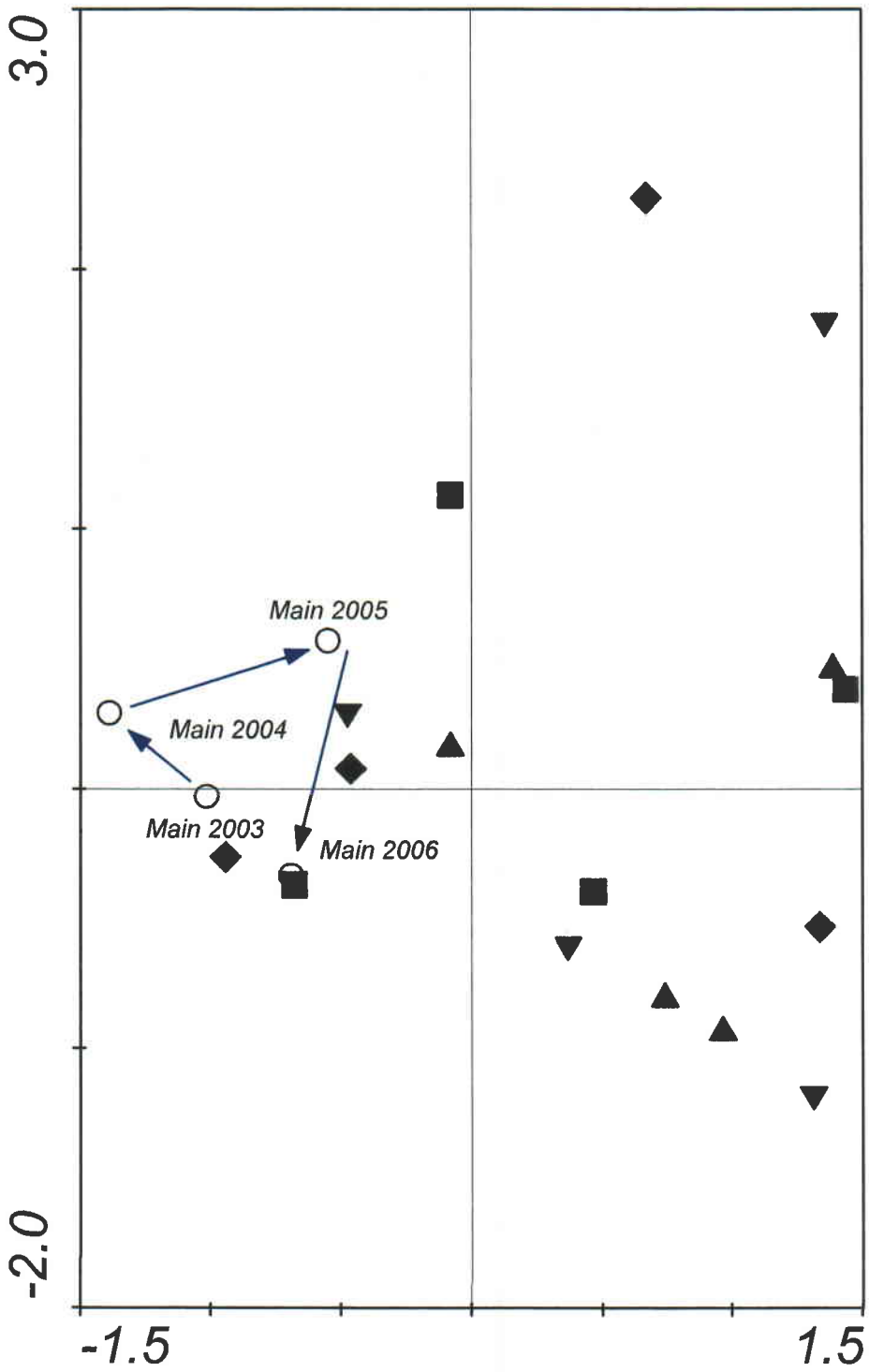


Figure 5. Ordination plot based on the reduced data set (36 taxa) showing the trends of the East Fork of Box Canyon Station 1 through time.

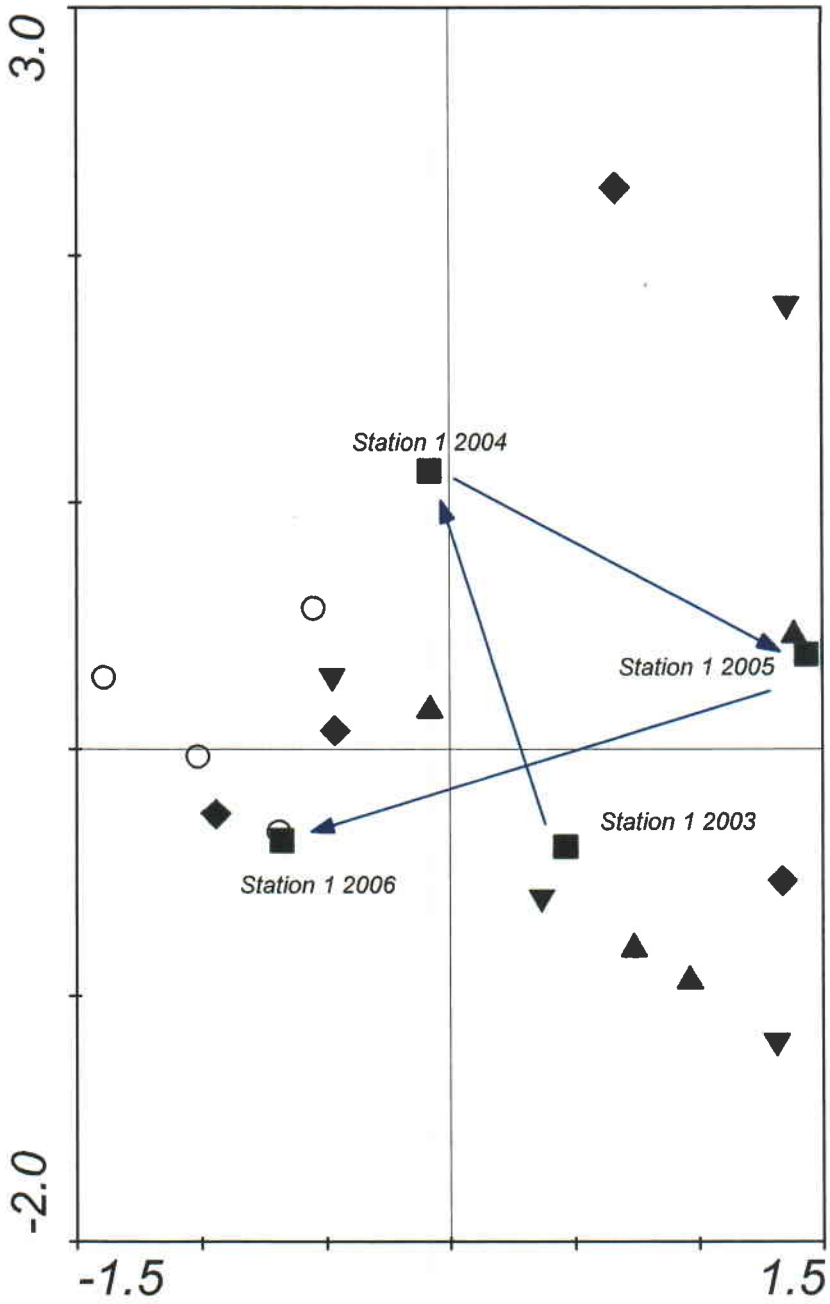


Figure 6. Ordination plot based on the reduced data set (36 taxa) showing the trends of the East Fork of Box Canyon Station 2 through time.

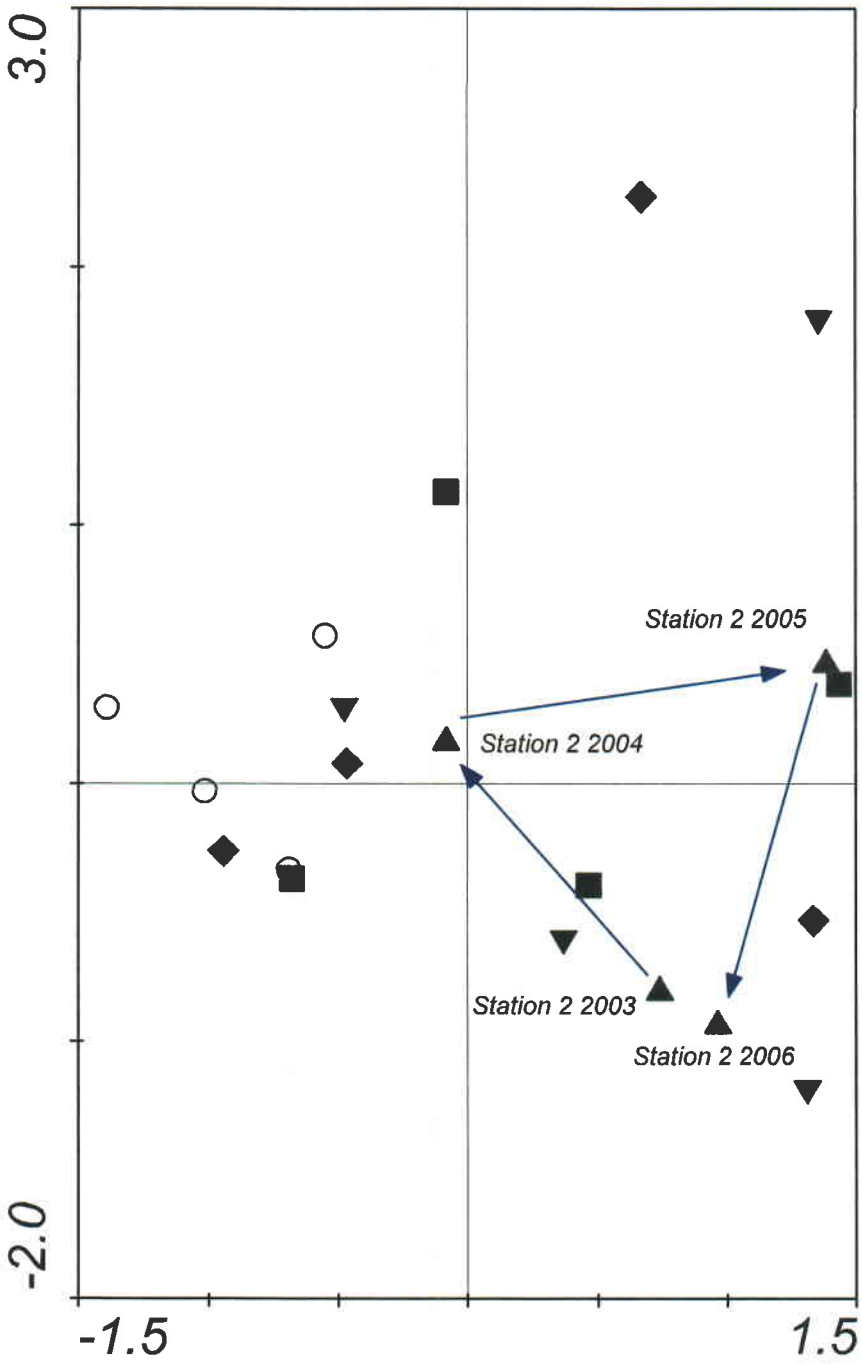


Figure 7. Ordination plot based on the reduced data set (36 taxa) showing the trends of the East Fork of Box Canyon Station 3 through time.

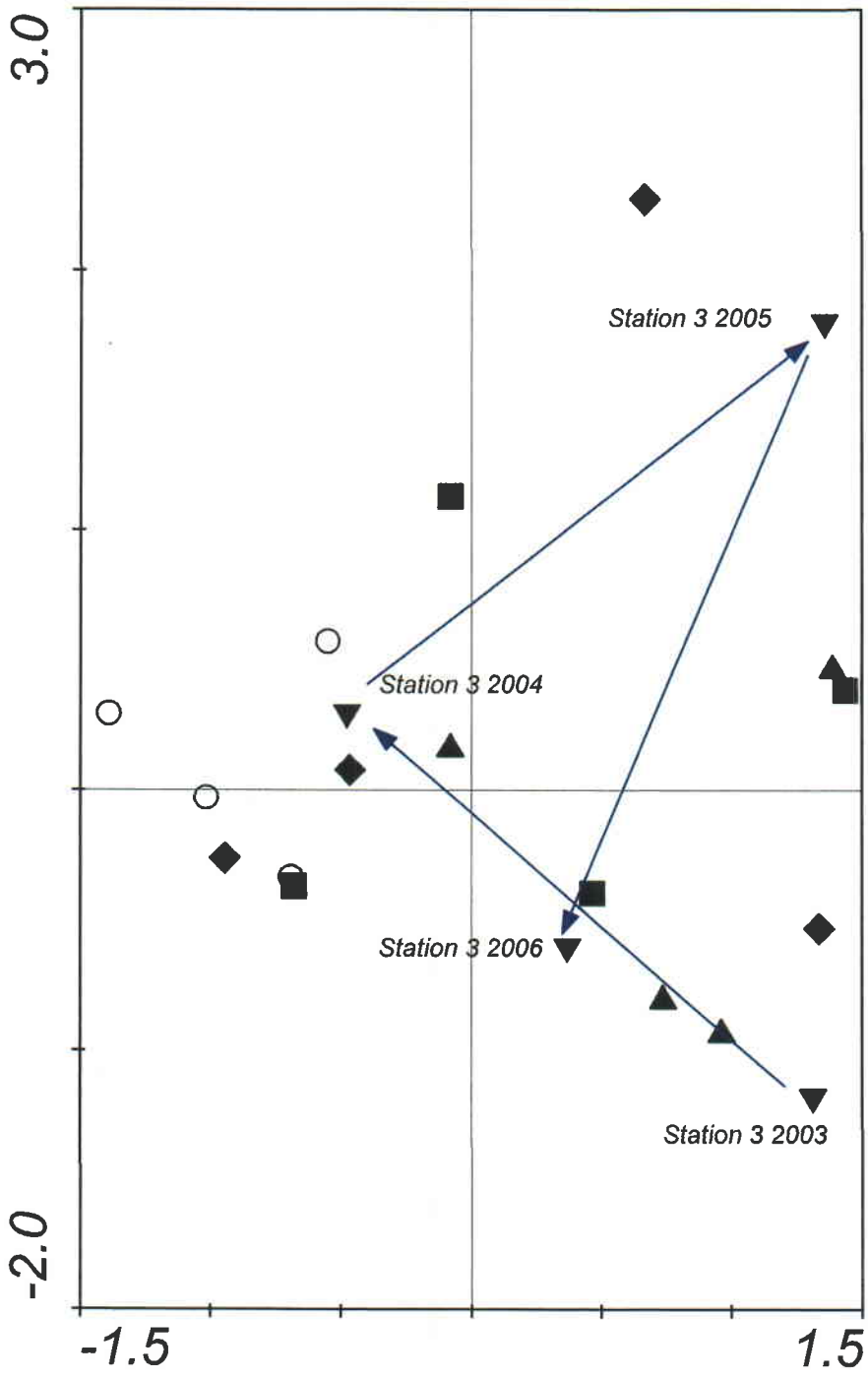
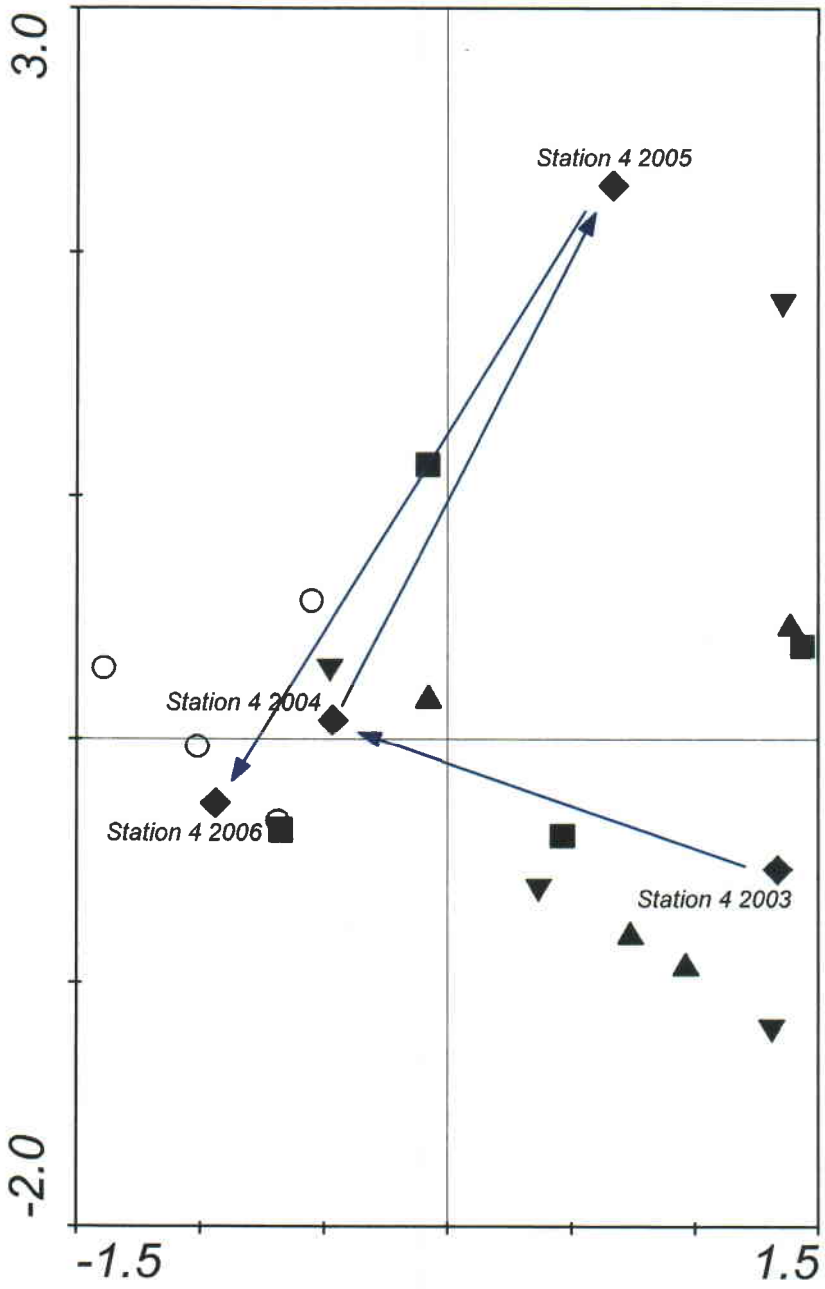


Figure 8. Ordination plot based on the reduced data set (36 taxa) showing the trends of the East Fork of Box Canyon Station 4 through time.



These shifts in community structure were also reflected in the cluster analysis (Figure 1). Station 1 in 2004 (1-04) is the most dissimilar member of the 2004 East Fork of Box Canyon cluster, and Station 4 in 2005 (4-05) is the most dissimilar member of the 2005 East Fork of Box Canyon cluster. Stations 1-06 and 4-06 have low dissimilarity in the cluster analysis and are found within the Main Fork of Box Canyon cluster (denoted by M) reflecting their positions in the ordination near the Main Fork sites. The other two 2006 East Fork of Box Canyon stations fell more closely to the 2003 sites with Station 2 being very close to its original state in 2003. Interestingly, neither of these two latter sites fell close to the other 2003 sites in the cluster analysis (Figure 1). Instead, they joined the Main Fork stations as very dissimilar members of that cluster. This suggests that the two analyses, while generally giving the same associations, were not completely agreeing on relationships in the case of these two sites in 2006.

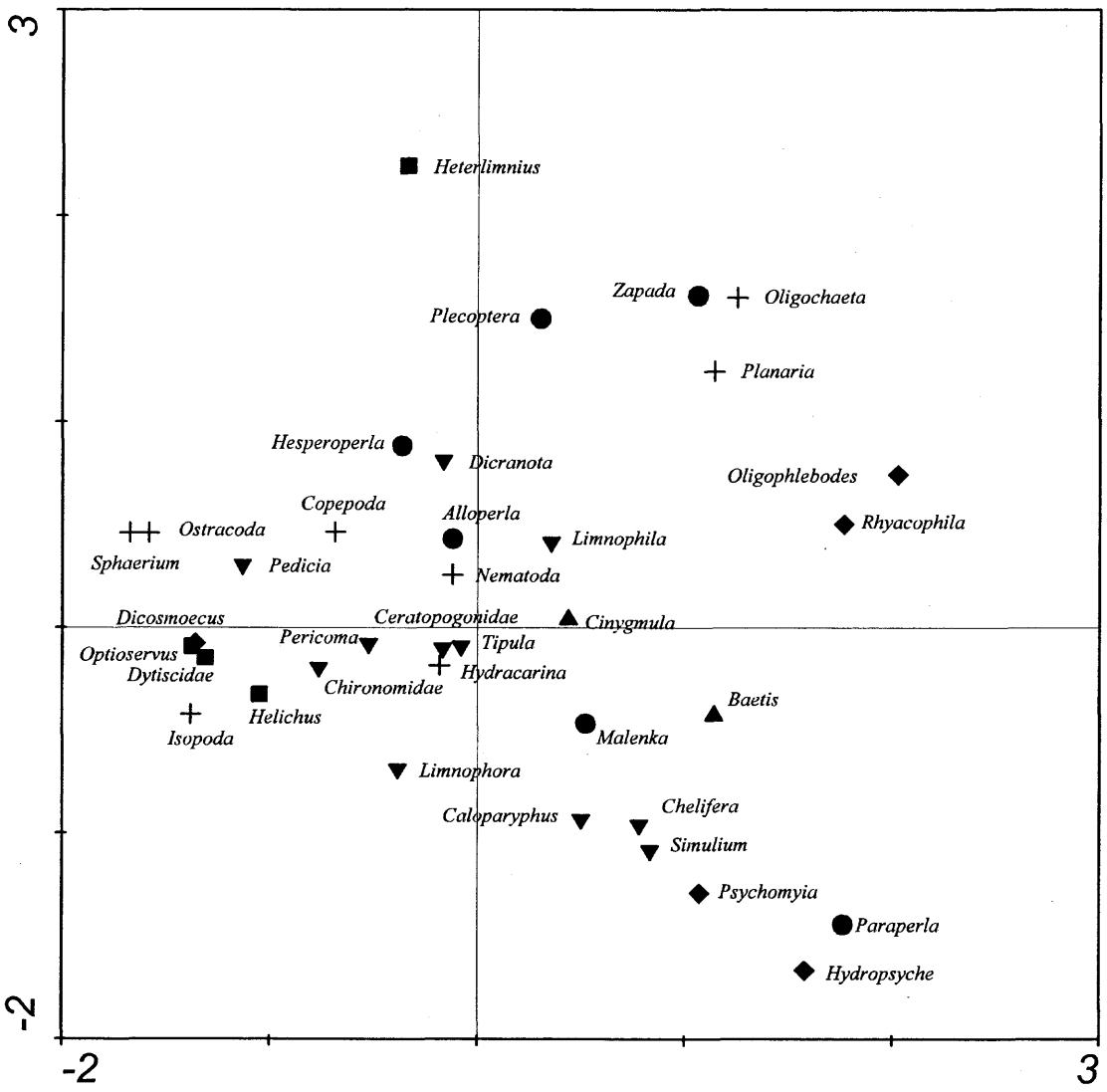
The taxa that were most important in separating the stations in the ordination can be inferred from the placement of the stations in Figures 2, 4, 5, 6, 7, and 8. Stations in the left half of the plots are more like the Main Fork of Box Canyon, which above was described as having more quiet waters and was observed to have anoxic sediments during the sampling periods. Stations in the right half of the plot were more likely to have sorted or partially sorted, oxygenated substrates.

The correspondence analysis allows us to associate taxa with the positioning of the stations (Figures 4-8). The taxa that are more abundant are likely more robust in giving information about the habitat conditions in the various stations at different sampling dates. For this reason, select taxa from the reduced data set will be discussed. The taxa (Figure 9) corresponding to stations falling in the left half of the station ordination plots (Figure 2) include a number of crustaceans (copepods, isopods, and ostracods); the fingernail clam, *Sphaerium*; the trichopteran, *Dicosmoecus*; a number of Coleoptera (dytiscids, *Helichus*, *Optioservus*); and some dipterans (*Pedicia*, *Pericoma*, *Limnophora*, Chironomidae).

Fingernail clams are often found in standing water especially ponds and wetlands where fine anoxic sediments are found. They are filter and sediment feeders and can withstand drying by estivating. They will burrow into the sediment (Thorp and Covitch, 1991). Ostracods and copepods are found in both open water if current is low to negligible and at the sediment water interface when current increases (Shiozawa, 1986). The isopod, *Asellus*, is common in Utah waters especially tail waters below reservoirs. They can live both interstitially and on the surface of the substrate and do well in both well oxygenated and oxygen stressed conditions.

Helichus and dytiscid beetles are both found in flowing waters but are also found in slow moving systems as well as ponds and sloughs. Both adult and larval dytiscids are able to obtain their oxygen directly from the air rather than water and, thus, are not limited to well oxygenated systems. The larvae of *Helichus*, a dryopid beetle, are terrestrial or possibly semiaquatic while the adults are aquatic. *Optioservus*, an elmid beetle, was a surprise in its position in the ordination. This group has larvae that do well under low oxygen condition while the adults require high oxygen availability (Merritt and Cummins, 1996). The fact that samples were taken in riffle areas may have mitigated the oxygen constraints on the adults since they would be able to find sustainable microhabitats where the water moves around rubble in the stream.

Figure 9. Ordination of reduced data set focusing on taxa with moderate or greater abundance. Symbols: ▲ = Ephemeroptera; ● = Plecoptera; ■ = Coleoptera; ◆ = Trichoptera; ▼ = Diptera; ✚ = other.



The dipterans, *Pericoma* (a psychodid) and *Limnophora* (a muscid), are both burrowers in depositional habitats and are predators. *Pedicia* (a tipulid) is a lotic depositional burrower that is found in stream margins in fine sediments and detritus. This group is also predatory. Chironomids are such a large diverse family with so many habitat specializations that any attempt to classify them would be erroneous unless they were taken to at least genus if not to the species level. Nevertheless, their placement in the left half of the ordination suggests that taxa favoring quiet waters were predominant in the samples. The only trichopteran occurring in the left half of the ordination is *Dicosmoecus,* a case building limnephillid caddisfly, which is typically found in lotic erosional habitats where it is a scraper-shredder feeding on detritus. Generally, case building caddisflies can irrigate their cases with water to enhance oxygen uptake.

A number of taxa were in the center of the ordination plot. Those provided little resolution to the placement of the stations. Dipterans, such as *Tipula* and Ceratopogonidae, water mites (*Hydracarina*), nematodes, and the stonefly, *Alloperla*, while present in enough abundance to be included, provided little information in this analysis and, therefore, will not be discussed.

The right half of the ordination separates vertically into an upper right quadrant and a lower right quadrant. Immature plecopterans and *Zapada* are both in the upper right quadrant as are the trichopterans, *Oligophlebodes* and *Rhyacophila*. Oligochaetes and planarians are also in this quadrant. The nemourid stonefly, *Zapada*, is a detritivore and tends to live interstitially in the substrate. They require either accumulations of detritus or sediments in which they can burrow. *Oligophlebodes* favor lotic erosional habitat and is a scraper-gatherer clinging on rocks. The free living caddisfly, *Rhyacophila*, is a predator and generally requires well oxygenated waters. Oligochaetes require habitats in which they can burrow and prefer conditions where water is flowing as opposed to heavily depositional habitats (Jordan, et al.,1999) while planaria are predators that can survive under a broad range of oxygen levels.

The lower right half of the ordination contains the plecopterans, *Malenka* and *Paraperla*; the mayfly, *Baetis*; the caddisflies, *Hydropsyche* and *Psychomyia*; and the dipterans, *Caloparyphus*, *Chelifera*, and *Simulium*. *Malenka,* a nemourid stonefly, and *Paraperla*, a chloroperlid, both tend to live interstitially in the substrate or in detrital packs. *Malenka* is a detritivore while the functional status of *Paraperla* may be a collector-gatherer or predator. Both would require sorted substrates if they are to live interstitially. *Baetis* is a known vagrant genus which is able to quickly invade after perturbations. The hydropsychid caddisfly, *Hydropsyche,* is considered to be a stress tolerant taxon and often is an early taxon following perturbations. *Psychomyia* is found in erosional habitats where it constructs silk tubes and feeds as a collector-gatherer and scraper. The empid, *Chelifera,* is a burrower which prefers lotic depositional habitats, while *Caloparyphus*, a stratiomyid, lives in erosional habitats and feeds as a collector-gatherer. *Simulium* is a filter feeder and is a very quick invader into recently disturbed areas of streams.

From these general associations, a prediction of the habitat conditions for three regions of the station ordination is possible. The samples in the lower right quadrant, which are the 2003 samples (Figures 2, 4, 5, 6, and 8) for the East Fork of Box Canyon stations, and Stations 2 and 3 in 2006 represent

what appears to be recently colonized and sorted habitat. This implies that a moderate flood may have impacted the East Fork during the summer of 2003 generating the community structure dominated by vagrant species and taxa that were able to utilize the interstitial spaces resulting from sorting of the sediments. A severe flood was known to have occurred in 2006 just prior to sampling. The samples in the middle left quadrant represent low flow and/or depositional conditions . These include all of the Main Fork of Box Canyon samples as well as the 2004 East Fork of Box Canyon samples. The 2006 samples from Stations 1 and 4 were also located in this quadrant. These represent conditions where either low flow dominates the station (Main Fork stations, all years), low flow was characteristic of the particular season (2004 East Fork of Box Canyon stations), or unique geomorphological characteristics of a station allowed accumulation of detritus sufficient to favor the slow water taxa (Stations 1 and 4 in 2006)

The samples in the upper right quadrant represent conditions with sustained higher flow and sorting in the sediments allowing the development of invertebrate communities reflecting the continuity of those conditions. These conditions occurred in 2005 and were most enhanced in Stations 3 and 4 of the East Fork of Box Canyon. Stations 1 and 2, while in the upper right quadrant, were much closer to the center axis of the ordination indicating a potential perturbation impacting those stations.

Conclusions

The Main Fork of Box Canyon differs from the East Fork of Box Canyon in water chemistry. That difference was clear in the 2003 sampling period and has continued throughout the study. In 2006, conductivity in both forks decreased, and while alkalinity stayed constant in the Main Fork of Box Canyon and in the East Fork of Box Canyon, alkalinity declined to the lowest levels recorded. This appeared to be related to the flood that hit the area a week prior to the 2006 benthic sampling. Hardness remained approximately the same throughout the study period, but pH increased. This change could have been the result of increased leaching or an effect of the loss of organic material from the stream channel with the flood event.

The total number of taxa in the Main Fork of Box Canyon was moderate compared to the samples from previous years, but Stations 1 and 2 of the East Fork tied for the highest number of taxa recorded. Stations 3 and 4 of the East Fork had moderate numbers of taxa relative to previous years. It appears that no clear trend can be seen with the number of taxa. Biomass in the Main Fork of Box Canyon in 2006 was low although not as low as in 2004. Station 1 of the East Fork of Box Canyon had its highest biomass in 2006, but the other stations had intermediate or low (Station 4) biomass estimates. This may reflect an increase in smaller organisms which would be expected after a flood.

The densities of invertebrates in the Main Fork of Box Canyon were the lowest recorded in the four-year sampling period. However, in the East Fork of Box Canyon, the highest densities recorded occurred in 2006. This seems to be inconsistent with the strong flooding that took place a short time before sampling. The increase in Station 1 was driven by high numbers of chironomids while the increase in Station 2 was driven mainly by high numbers of *Baetis* and simuliids with moderate

numbers of chironomids. Station 3 had high numbers of *Baetis* and chironomids, and Station 4 was driven mostly by high densities of chironomids. All of these abundant taxa are known vagrants capable of rapidly recolonizing streams, although in the case of a major flood, such as the one that struck the East Fork, it is unknown where these taxa would have found refuge during peak flood discharge. It is unlikely that all of these represent newly hatched individuals, but vagrant taxa are also likely capable of quickly responding to spates by drifting to stream margins and then readily following the receding water levels.

The overall diversity in 2006 was the lowest recorded in the four years of the study. While the Main Fork station was low, it was not as low as it was in 2003, but Stations 1, 3, and 4 of the East Fork of Box Canyon all recorded their lowest diversity values. This again reflects the flood event of 2006. The CTQa and BCI for the Main Fork station indicated the greatest 'stress' recorded over the four-year study period, but in the Main Fork, the same indices gave mixed results. Station 1 indicated an improvement in condition while Stations 2, 3, and 4 all showed a reduction in condition. These latter values suggest the flooding in the East Fork of Box Canyon resulted in an increase in stress tolerant taxa.

The cluster analysis using all four years of sampling also indicated a change in station behavior. While all East Fork stations for 2003, 2004, and 2005 clustered together by year and the Main Fork sample periods formed a separate cluster, the 2006 samples joined with the Main Fork cluster. East Fork Stations 1 and 4 fell within the Main Fork cluster while East Fork Stations 2 and 3 were more distantly associated with the Main Fork cluster. Given the strong dissimilarity between the Main Fork cluster and the 2003, 2004, and 2005 East Fork clusters, this represents a major shift in community composition for the East Fork stations. As noted with other measures above, this is most likely related to the 2006 flood.

The correspondence analysis gives a comprehensive picture of the changes in the stations over the four-year period. From 2003 through 2005, all stations showed the same trends, but the Main Fork station followed a much dampened path indicating that this station had much less annual variation. The fact that all stations, both the Main Fork and the East Fork, were in synchronous trajectories over that same time period suggests that annual changes in weather may have been setting the directions that the communities in both streams followed. The main difference between the Main Fork of Box Canyon and the East Fork of Box Canyon appears to be amplitude of change in the communities rather than differences in the direction of movement. This strongly argues for physical differences between the streams being a major force in community structure, and the overriding physical difference is stream gradient.

The four East Fork of Box Canyon stations moved synchronously from 2003 to 2004 to 2005. In 2006, their trajectories split with Stations 2 and 3 moving toward their 2003 conditions, and Stations 1 and 4 converging to the Main Fork of Box Canyon condition. This split appears to be driven by the flood and the patchy differences of erosion/deposition and detrital retention at the four stations. No clear impact can be attributed to subsidence with these data. Instead, the role of annual variation in precipitation as well as chance intense storm events appear to dominate in determining community structure.

Literature Cited

Boyd, C. E. 1990. Water quality in ponds for aquaculture. Alabama Agriculture Experiment Station. Auburn, Alabama. 482 pp.

Braak, C. J. F. and P. Smilauer. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (Version 4.5). Microcomputer Power. Ithaca, NY. 500 pp.

Jordan, S., D. K. Shiozawa, and J. M. Schmid-Araya. 1999. Benthic invertebrates of a large, sandy river system: The Green and Colorado Rivers of Canyonlands National Park, Utah. Archiv für Hydrobiologie 147:91-127.

Krebs, C. J. 1989. Ecological Methodology. Harper and Row Pub. Inc. New York, NY. 654 pp.

Merritt, R. W. and K. W. Cummins. (eds.) 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Co. Dubuque, Iowa. 862 pp.

Pielou, E. C. 1977. Mathematical Ecology. John Wiley and Sons. NY, NY. 385 pp.

Poole, R. W. 1974. An Introduction to Quantitative Ecology. McGraw-Hill, Inc. 532 pp.

Rolf, F. J. 2000. NTSYSpc: Numerical taxonomy and multivariate analysis system. Version 2.1. Exeter Software. Setauket, NY.

Shiozawa, D. K. 1986. The seasonal community structure and drift of microcrustaceans in Valley Creek, Minnesota. Canadian Journal of Zoology 64:1655-1664.

Shiozawa, D. K. 2004. An Assessment of the Macroinvertebrates of Box Canyon, Sevier County, Utah in October, 2003. A report to Canyon Fuels Corporation. 10 pp.

Shiozawa, D. K. and M. K. Kauwe. 2006. An Assessment of the Macroinvertebrates of Box Canyon, Sevier County, Utah in October, 2005. A report to Canyon Fuels Corporation. 20 pp.

Thorp, J. H. and A. P. Covich. 1991. Ecology and classification of North American Freshwater Invertebrates. Academic Press. San Diego, CA. 911 pp.

Winget, R. N. and F. A. Mangum. 1979. Biotic condition index: integrated biological, physical, and chemical stream parameters for management. U. S. Forest Service Intermountain Region. Ogden, UT.