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INVESTIGATION OF TRACE METALS IN AQUATIC INSECTS AND BED SEDIMENTS OF THE LOWER CLARK FORK RIVER, 1996-1997

by

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for the

U.S. Environmental Protection Agency
and
Montana Department of Environmental Quality

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Table of Contents

Executive Summary

Fine-grained bed sediments and benthic macroinvertebrates were collected from three sites on the Clark Fork River (East Missoula, Missoula, Alberton) on six occasions (July , September and November 1996; March and August 1997). Sediment and insect samples were analyzed for trace elements believed to be contaminants at this site. Insect species for which analyses were conducted included *Hydropsyche cockerelli, H. occidentalis, Pteronarcys californica, Claassenia sabulosa,* and *Arctopsyche grandis.*

The mean concentrations of copper and zinc in fine-grained sediments were highest at the Missoula site. The concentrations of both metals at Missoula were not significantly different from concentrations at East Missoula, while both sites were significantly different (and greater) than concentrations at Alberton. The East Missoula site showed no temporal trends for either metal, while at both the Missoula and Alberton sites, concentrations of both copper and zinc were significantly different (and lower) in July 1996 than those measured in August 1997.

The East Missoula site had significantly greater mean copper and zinc concentrations than the Missoula and Alberton sites for all insect species, with the exception of *Claassenia*, which was similar at all sites. In no case was the mean copper or zinc concentration at Missoula significantly different than Alberton. Copper concentrations in *Hydropsyche cockerelli* were higher in similarly-aged animals in August 1997 than in July 1996 at East Missoula and Alberton, but slightly lower at Missoula. Copper concentrations in *Arctopsyche* were higher in similarly-aged animals in August 1997 than in July 1996 for both East Missoula and Missoula; this was opposite the effect seen at Alberton. For *Pteronarcys*, copper concentrations in first- and second-year animals increased from March to August 1997, a time period spanning the spring runoff flows.

The seasonal pattern of benthic invertebrate abundance was determined for the Missoula site and results showed this pattern to be similar to that expected in temperate-region streams. Total number of organisms averaged 257.0 per sample in July 1996, rose to 423.3 in September and reached a peak of 809.7 in November. Numbers dropped substantially in January (176.7) before rising to 399.7 in August. The precipitous drop between November and January may have been due to the severe ice conditions and scour occurring at the site during this time. The seasonal pattern of abundance of individual insect taxa was also similar to what would be expected.

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Purpose and Scope

Large quantities of ice formed on the upper Clark Fork and Blackfoot Rivers in the winter of 1995-1996. A thaw occurred in early February 1996 and ice began to break up and move down the Clark Fork River. Montana Power Company personnel at the Milltown Dam quickly removed the flashboards on the spillway in order to prevent damage to the superstructure of the dam. This lowered the water level, causing significant quantities of sediment to be washed from the reservoir. In addition, ice scour along the bed and banks of the Clark Fork River immediately above the reservoir contributed to the sediment load. Trace metals in the river water below the dam were measured after this event and found to be quite high, particularly in the total recoverable fraction. On February 9, the U.S. Geological Survey (USGS) measured copper in the water at concentrations of 400 ug/L (total recoverable) and 11 ug/L (dissolved)(USEPA 1998). Montana Fish Wildlife and Parks (MFWP) was concerned about the effects of these metals on the aquatic ecosystem of the river below Milltown, and initiated a one year study. The first sampling session in July 1996 was intended to determine if the metals mobilized by this ice event had a lingering effect on the insects and sediment of the river. Subsequent sampling between July 1996 and August 1997 was intended to establish reference levels of contamination from which the effects of future hydrological events could be evaluated.

Methods and Materials

Sample Design and Collection. The sampling design was based upon the objective of quantifying temporal and spatial trends in trace metal concentrations in biota and sediments of the Clark Fork River below Milltown Dam. Three sites were chosen for this purpose: 1) the East Missoula site near the Sha-Ron Fishing Access Site in East Missoula (T13N, R19W, sec13). Exact location of sample collections varied, but all were within the area from the boat ramp upstream about 600 feet to the pipeline crossing. This site is the same location as the "Clark Fork above Missoula" site of the USGS (Hornberger et al. 1997) and "Station 15.5" of the Montana Department of Environmental Quality (McGuire 1997); 2) the Missoula site was near the Kelly Island Fishing Access site in Missoula (T13N, R20W,sec20). Exact location of samples varied--invertebrates were taken anywhere from the mouth of the Bitterroot River to about 1000 feet above the access site. Sediments were sampled at the access site in July 1996, but thereafter were collected upstream between the Reserve Street Bridge and the Missoula Wastewater Treatment plant; 3) the Alberton site was located downstream of the town of Alberton (T15N, R23W, sec32). This site is the same as the "Clark Fork River below Missoula" station of the USGS (Hornberger et al 1997). The bulk of invertebrates were collected from the same riffle area used by the USGS, but occasionally a stretch of river a mile above and below this station was used. Sediments were sampled from this station in July and September 1996, but thereafter were sampled about two miles upstream at the Natural Pier Fishing Access Site.

Bed sediments and benthic macroinvertebrates were collected for metals analysis using the methods and procedures of Dodge et al. (1997). Three bed sediment samples were collected from

each site. Sediments were collected from the surface of depositional areas along the river margin, usually in the slow areas behind rocks. Acid-washed polypropylene scoops were used to collect the sediment. Sediments that appeared to be in a reduced state (darker color) were not sampled. Sediments were passed through a 63 um filter, using river water as a carrier, and stored in 500 mL plastic bottles.

Benthic macroinvertebrates were usually collected on the same day as the sediments. Five benthic insect species were targeted for metals analysis: three caddisflies (*Hydropsyche cockerelli, Hydropsyche occidentalis, Arctopsyche grandis)* and two stoneflies (*Pteronarcys californica, and Claassenia sabulosa).* These taxa were selectively removed from kick-net samples and placed in acid-rinsed plastic containers filled with river water. The taxa were held together in the containers; separate containers were not provided for individual species. The containers were placed on ice for 6-10 hours to allow the insects to depurate the contents of their digestive tracts. After this time, the water was drained and the insects immediately frozen. To determine community composition, benthic macroinvertebrates were collected with a modified Hess sampler (0.1 square meter diameter, 1 mm mesh), using methods described by McGuire (1997). Three replicate samples were collected from each site, selecting the most heterogenous habitat in riffles. Samples were placed in 1-quart Mason jars and preserved with ethanol. Samples were collected at all sites on five occasions between July 1996 and August 1997. The only exception to this was January 1997, when ice conditions precluded sampling at all sites but Missoula.

Sample Analysis and Treatment of Data. For metals analysis, insects samples were thawed and individuals were identified and sorted by species and size groups. There were usually 50-100 individuals per size group for the caddisfly species, while 10-20 individuals was more typical for the stoneflies. For the largest size groups of stoneflies, there were occasions where as few as five individuals were used. For the largest *Claassenia* (greater than 25 mm in length) there was probably no uncertainty with regard to correct identification, but with smaller animals there was probably occasional misidentification of a few individuals which may have been any one of the following genera: *Isogenoides, Skwala, Calineuria.* Ten individuals from each size group were measured for total length. Each insect sample was rinsed with distilled water, transferred to acid-washed plastic centrifuge vials and placed in an oven at 60°C until dry. These samples were then ground with a mortar and pestle and prepared for metals analysis by microwave-digestion for approximately 6 minutes in a solution of 4 mL nitric acid and 1 mL hydrochloric acid. The digestate was then brought to a 50 mL volume with distilled water. Samples were then analyzed by graphite furnace AAS (Atomic Absorption Spectroscopy) or ICP (Inductively Coupled Plasma) analysis. The procedure for metals analysis of sediments was similar to insects, except that sediments were dried in the same plastic vials in which they had been collected.

Statistical calculations and tests were performed by using SPSS software (SPSS, 1993). Determinations of statistical significance were based on $P<0.05$ levels.

Quality Assurance Testing

Procedural blanks for bed sediment and insect samples contained the same reagents (nitric and hydrochloric acid, distilled water) that were used for sample preparation. Zinc was the only element for which contamination was detected (Table 1). One of these contaminated samples had a concentration of 0.006 ug/mL, which is very near to the detection limit (0.005 ug/mL), while the other sample was much higher (0.032 ug/mL). This highly contaminated blank actually contained 0.32 ug zinc (0.032 ug/mL X 10 mL), which is about 4% of the amount of zinc in the insect samples in this study (80 ug/g zinc X 0.10 g dry weight = 8 ug zinc) or 1% of the amount of zinc in the sediment samples (120 ug/g zinc X 0.25 g dry weight = 30 ug zinc). These errors are considered minor and no adjustment was made to any of the insect or bed-sediment values.

Standard reference materials used in this study were bovine liver (as a surrogate for insect tissue) and sediment. Mean recovery efficiency for bovine liver was within 90% of the certified concentration for copper and cadmium, but was low for zinc (68%) and high for lead (198%) and arsenic (206%)(Table 2). Recovery for sediments was much better; mean recovery efficiency ranged from 97% for arsenic to 105% for zinc. The 95% confidence intervals for recovery efficiency were always greater than the error considered acceptable. The certified acceptance limits were about 90 and 110% of the mean value for arsenic, cadmium, lead and zinc, and 60 and 140% for copper. In comparison, the confidence levels that were achieved were about 80 and 120% of the mean value for arsenic, cadmium, lead and zinc, and 55 and 145% for copper.

Results and Discussion

Metals in fine-grained sediments. An understanding of the trends in sediment metals must include an examination of the hydrologic events that transported sediments to the sites, and the extent to which the sampled sediments were reflective of those events. The discharges occurring at our three sites are fairly well portrayed by measurements taken at the USGS gage stations above Missoula (near East Missoula) and below Missoula (below the confluence of the Bitterroot River). The discharges measured near East Missoula should be very similar to those occurring at our East Missoula and Missoula sites, while the discharges from the station below Missoula are somewhat less than those occurring at our Alberton site. At both stations, the peak flows from the February 1996 ice-out occurred on the 10th, when flows averaged 12,900 cfs above Missoula and 20,300 cfs below Missoula. Over 31,000 tons of sediment were discharged from Milltown Dam during the four peak days of the February event (USEPA 1998). These sediments were probably transported farther downstream as a result of the higher flows during spring runoff in 1996. These flows peaked at 18,300 cfs on June 10 above Missoula and at 37,400 cfs on May 19 below Missoula. After the spring runoff in 1996, the hydrograph followed a typical pattern of flows dropping through the fall and winter. High flows were not seen on the river again until spring 1997. The 1997 flows were much higher than in 1996 and peaked on May 18 at both stations when discharge got to 26,400 cfs above Missoula and 54,100 cfs below Missoula.

Table 1. Metal analyses of procedural blanks for insect and sediment samples. Changes in detection limits for a specific element reflect a change in instrument used (ICP vs. AAS).

Sample Period	Dilution Ratio	Metal concentration (ug/mL)				
		Arsenic	Cadmium	Copper	Lead	Zinc
July 1996	1:9	<0.001	<0.001	<0.005	<0.001	<0.005
July 1996	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
July 1996	1:9	<0.001	<0.001	<0.005	<0.001	<0.005
September 1996	1:9	<0.001	<0.001	<0.005	<0.001	<0.005
September 1996	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
September 1996	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
November 1996	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
November 1996	1:9	<0.001	<0.001	<0.005	<0.05	0.032
March 1997	1:9	<0.001	<0.002	<0.005	<0.001	0.006
March 1997	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
August 1997	1:9	<0.001	<0.001	<0.005	<0.05	<0.005
August 1997	1:9	<0.001	<0.001	<0.005	<0.05	<0.005

Table 2. Recovery efficiency for metal analysis of standard reference materials (SRM) for insects and sediment.					
Metal	Number of measurements	Certified concentration (ug/g)	SRM recovery (ug/g) Mean	95% CI	Acceptance limits for SRM (ug/g)
Insect (NBS #1577, Bovine Liver)					
Arsenic	5	0.050*	0.103	0.025-0.181	--**
Cadmium	5	0.50	0.47	0.43-0.51	--
Copper	5	160	144	132.8-149.6	--
Lead	4	0.13	0.257	0.217-0.297	--
Zinc	4	127	86.7	74.7-98.7	--
Sediment (USGS #5)					
Arsenic	6	216	210	166-256	196-236
Cadmium	6	158	162	128-196	142-174
Copper	4	58.9	66.6	34.1-97.1	31.3-82.5
Lead	7	309	324	258-390	291-327
Zinc	7	598	588	500-676	551-645

*Uncertified concentration

**Ranges not provided with material

All sediments for this study were sampled at discharges between 1,500 and 7,500 cfs, which correspond to water surface elevations 5-10 feet lower than those during spring runoff and 3-8 feet lower than during the 1996 ice-out (Table 3). Therefore, all of the sediment samples were clearly collected from within the portion of the channel that had been influenced by all of these events. The fact that spring runoff flows in 1996 and 1997 were much higher than during the ice-out event strongly suggests that the ice-out sediments were being transported through and downstream from our sites during the course of our study. However, we have no way to know when or where we may have sampled the ice-out sediments.

Spatial Patterns. The mean concentrations of most metals in the sediments (arsenic, copper, iron, manganese, nickel, lead and zinc) were highest at the Missoula site. Mean concentrations of silver and cadmium were highest at East Missoula, while concentrations of chromium were highest at Alberton (Tables 4 and 5). Concentrations of copper and zinc at Missoula averaged 270.5 and 556.4 ug/g, respectively, only slightly higher than the corresponding concentrations at East Missoula (247.8 and 531.9 ug/g), but much higher than at Alberton (129.7 and 274.8 ug/g). The data for these two metals were subjected to statistical analysis, and results showed that East Missoula and Missoula were not significantly different in terms of mean copper or zinc concentrations (Table 6), while both of these sites were significantly different (and greater) than concentrations at Alberton.

Temporal Patterns. There were distinct differences between the sites in terms of temporal changes in metals in the sediments. One-way ANOVA was used to test the null hypothesis that the metal concentrations on all sampling dates had equal means. At East Missoula, no significant differences were seen for any of the metals tested (Figures 1-4, Table 7). In contrast, the null hypothesis was rejected for arsenic, cadmium, copper, lead, and zinc at both the Missoula and Alberton sites. Measurements of copper and zinc at these two sites were subjected to further statistical analysis. Bonferroni t-test comparisons were done for the mean concentration of copper and zinc on each sampling date. Where significant differences were found, almost all showed an increase in concentration over time. At Missoula, all of the differences (10 of 10 tests) showed an increase over time, while at Alberton, 11 of 14 significant tests showed an increase over time (Tables 8 and 9). At both sites, copper and zinc levels measured in July and September 1996 were significantly different (and lower) than those measured in August 1997. These findings are qualified by the fact that the sampling location for sediments was changed for both sites during the study (after July 1996 at Missoula and after September 1996 at Alberton), and it is possible that there were differences in metal concentrations between the two locations. Nonetheless, the September 1996 levels of copper and zinc were still significantly lower at Missoula than the August 1997 samples; similarly the November 1996 copper and zinc levels at Alberton were significantly lower than in August 1997.

One possible explanation for the increase in copper and zinc levels over time at Missoula and Alberton, but not East Missoula, is that it was a reflection of the movement of the sediments that had washed out of Milltown Dam in February 1996. This explanation assumes the sediment from the reservoir had moved past the East Missoula site by the time this study began in July 1996 but was

Table 3. Water surface elevations (ft) at two Clark Fork River Stations during 1996 and 1997. Elevations are relative to datum at each site, and represent mean daily elevations unless noted otherwise. (USGS data).

Date	Clark Fork above Missoula	Clark Fork below Missoula
2-10-96	9.04 (max. elev.)	7.54 (max. elev.)
5-19-96	--	9.20 (max. elev.)
5-19-96	9.94 (max. elev.)	--
7-29-96	3.40	--
7-31-96	--	2.48
9-3-96	2.80	--
9-4-96	--	1.78
11-6-96	2.92	--
11-6-96	--	1.78
3-25-96	4.60	--
3-26-96	--	4.00
5-18-97	12.59 (max. elev.)	12.18 (max. elev.)
8-12-97	3.45	2.63

Table 4. Concentrations of metals (ug/g dry weight) in fine-grained sediments (<63 um diameter) from three sites on the Clark Fork River. Negative values indicate that the sample was below the detection limit.

Location	Date	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
E Missoula	7/29/96	0.5	13.7	1.2	5.8	162	9940	590	6	43.4	327
E Missoula	7/29/96	1.5	35.9	2.8	6.1	335	11300	569	7.8	82.4	810
E Missoula	7/29/96	0.6	19.8	1.5	5	153	9110	400	5.4	40	321
Missoula	7/30/96	0.9	25.4	2.1	6.5	222	11200	600	7	62.4	434
Missoula	7/30/96	0.7	21.4	1.3	5.7	155	10500	640	6.1	49.1	309
Missoula	7/30/96	0.7	24.2	1.6	6.4	192	11800	770	7.5	57.2	370
Alberton	7/31/96	0.4	9.2	0.8	6.9	117	10000	365	6.4	40.3	246
Alberton	7/31/96	0.4	9.4	0.8	6.6	115	10500	618	6.3	38.7	249
Alberton	7/31/96	0.4	9.1	0.7	5.6	93.7	9900	514	5.8	35.3	200
E Missoula	9/5/96	0.8	19.8	1.6	3.7	153	10200	436	6.3	40.5	312
E Missoula	9/5/96	1	21.3	1.8	4.4	216	10200	654	7	60.8	439
E Missoula	9/5/96	1.4	37.8	2.3	4.9	350	11800	517	8.5	74.7	607
Missoula	9/3/96	1.3	24.5	1.8	4.7	216	11300	260	7.7	60.8	450
Missoula	9/3/96	1.2	23.6	2.4	5	237	10900	517	8.3	67.4	498
Missoula	9/3/96	1.3	20.8	2.2	5.1	265	11100	628	7.9	78.4	531
Alberton	9/4/96	0.5	6.7	0.7	3.2	67.7	7300	563	5.4	26	159
Alberton	9/4/96	0.4	8.1	1	3.9	86.9	8530	629	5.7	31.1	196
Alberton	9/4/96	0.2	6.8	0.3	2.8	43.8	6200	505	4.4	10.3	120
E Missoula	11/6/96	1.3	30.8	2	5.3	279	8260	401	6.1	32.6	642
E Missoula	11/6/96	1.3	14.2	2.1	6.3	290	9113	458	7.1	38.2	647
E Missoula	11/6/96	1.8	29.6	2.5	6.8	359	9720	550	8.2	50.6	757
Missoula	11/5/96	2.3	27.2	2.9	7.3	351	10800	701	8.7	55.5	742
Missoula	11/5/96	1.8	26.3	2.9	7.6	327	11000	856	9.1	53.2	713
Alberton	11/6/96	0.8	8.5	1.2	8.7	117	7900	323	5.3	19.4	295
Alberton	11/6/96	0.8	6.2	1.2	5.3	120	8400	548	6.5	27	291
Alberton	11/6/96	0.8	10	1.2	5.7	120	7900	700	4.9	23.6	295
Missoula	1/23/97	-1	23.8	-2	-2	265	8420	669	10.1	48.3	522
Missoula	1/23/97	-1	27.8	-2	2.6	242	8350	578	10.2	34.6	536
Missoula	1/23/97	-1	20.8	-2	-2	250	10500	557	9.9	34.8	602
Alberton	3/27/97		20.6	1.2		194		588		34.8	340
Missoula	3/26/97		31.6	2		266		601		48.7	574
Missoula	3/26/97		29.5	2.3		310		694		55.4	620
Missoula	3/26/97		36.5	2		294		695		55.6	565

Table 4. Concentrations of metals (ug/g dry weight) in fine-grained sediments (<63 um diameter) from three sites on the Clark Fork River. Negative values indicate that the sample was below the detection limit.

Location	Date	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
E Missoula	3/25/97		25.8	1.8		231		453		44.9	497
E Missoula	3/25/97		22.3	1.6		202		428		47.9	443
E Missoula	3/25/97		28.5	2.2		264		444		38.4	603
Alberton	3/26/97		20.6	1.2		198		592		29.9	344
Alberton	3/26/97		22.8	1.4		204		619		44.1	352
E Missoula	8/12/97		16.3	1.5		194		402		35.3	446
E Missoula	8/12/97		25	2.4		272		527		44.3	563
E Missoula	8/12/97		22.2	2.4		257		571		36.1	564
Missoula	8/12/97		32.6	3.9		341		240		55.7	702
Missoula	8/12/97		24.7	2.4		282		471		42.4	572
Missoula	8/12/97		33.3	3.8		383		924		58.7	718
Alberton	8/12/97		15	1.5		159		571		23.3	351
Alberton	8/12/97		13.8	1.4		155		672		29.5	338
Alberton	8/12/97		13.8	1.4		154		622		17.5	346

Table 5. Concentration of metals (ug/g dry weight) in fine-grained sediments from three sites on the Clark Fork River.

SITE	Statistics	Variables									
		AG	AS	CD	CR	CU	FE	MN	NI	PB	ZN
East Missoula	N	9	15	15	9	15	9	15	9	15	15
	Mean	1.1333	24.2000	1.9800	5.3667	247.8000	9960.3333	493.3333	6.9333	47.3400	531.8667
	Median	1.3000	22.3000	2.0000	5.3000	257.0000	9940.0000	458.0000	7.0000	43.4000	563.0000
	Minimum	.50	13.70	1.20	3.70	153.00	8260.00	400.00	5.40	32.60	312.00
	Maximum	1.80	37.80	2.80	6.80	359.00	11800.00	654.00	8.50	82.40	810.00
	Std. Deviation	.4359	7.2882	.4539	.9823	68.5161	1100.2447	80.2956	1.0700	14.5241	152.6017
Missoula	N	11	17	17	11	17	11	17	11	17	17
	Mean	.6545	26.7059	1.6235	4.2636	270.4706	10533.6364	729.4706	8.4091	54.0118	556.3529
	Median	.9000	25.4000	2.1000	5.1000	265.0000	10900.0000	669.0000	8.3000	55.5000	565.0000
	Minimum	-1.00	20.80	-2.00	-2.00	155.00	8350.00	471.00	6.10	34.60	309.00
	Maximum	2.30	36.50	3.90	7.60	383.00	11800.00	1260.00	10.20	78.40	742.00
	Std. Deviation	1.1588	4.6124	1.8576	3.3859	59.5841	1123.2299	226.4838	1.3330	10.8929	122.7156
Alberton	N	9	15	15	9	15	9	15	9	15	15
	Mean	.5222	12.0400	1.0667	5.4111	129.6733	8514.4444	561.9333	5.6333	28.7200	274.8000
	Median	.4000	9.4000	1.2000	5.6000	120.0000	8400.0000	588.0000	5.7000	29.5000	295.0000
	Minimum	.20	6.20	.30	2.80	43.80	6200.00	323.00	4.40	10.30	120.00
	Maximum	.80	22.80	1.50	8.70	204.00	10500.00	700.00	6.50	44.10	352.00
	Std. Deviation	.2224	5.4984	.3395	1.8897	47.4239	1399.5098	103.1486	.7106	9.1658	76.3546
Total	N	29	47	47	29	47	29	47	29	47	47
	Mean	.7621	21.2255	1.5596	4.9621	218.3000	9729.0690	600.6383	7.0897	43.8106	458.6809
	Median	.8000	22.2000	1.6000	5.3000	216.0000	10000.0000	578.0000	7.0000	42.4000	446.0000
	Minimum	-1.00	6.20	-2.00	-2.00	43.80	6200.00	323.00	4.40	10.30	120.00
	Maximum	2.30	37.80	3.90	8.70	383.00	11800.00	1260.00	10.20	82.40	810.00
	Std. Deviation	.7844	8.6177	1.1985	2.3874	84.8473	1449.7483	182.8093	1.5747	15.7423	174.3491

Table 6. Comparisons of mean copper and zinc concentrations in fine-grained sediments at the three sites. Levels of significance (P) are based on Bonferroni t-test comparisons.

Dependent variable	Site A	Site B	Mean Difference (A-B)	Sig.
Copper	East Missoula	Missoula	-22.7	.856
	East Missoula	Alberton	118.1*	.000
	Missoula	Alberton	140.8*	.000
Zinc	East Missoula	Missoula	-24.5	1.000
	East Missoula	Alberton	257.1*	.000
	Missoula	Alberton	281.6*	.000

*The mean difference is significant at the P=0.05 level.

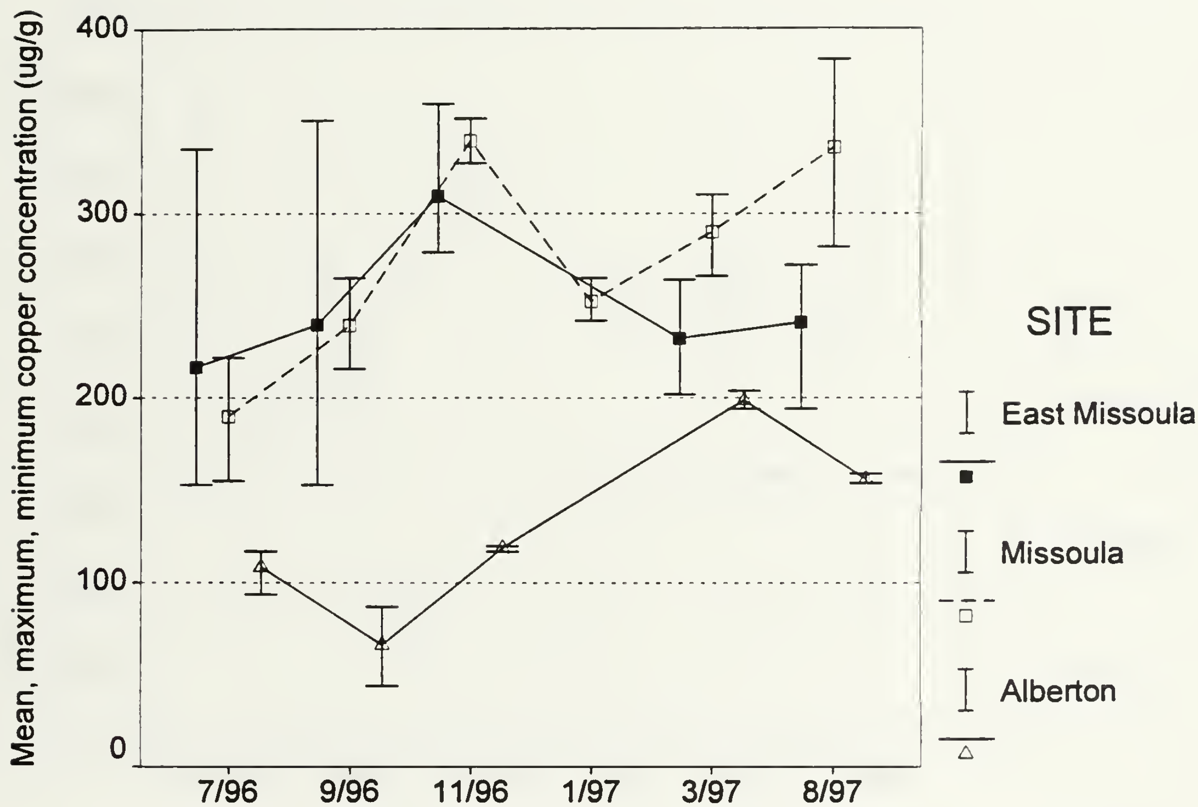

Figure 1. Copper concentrations (ug/g dry weight) in fine-grained bed sediments of the Clark Fork River at three sites.

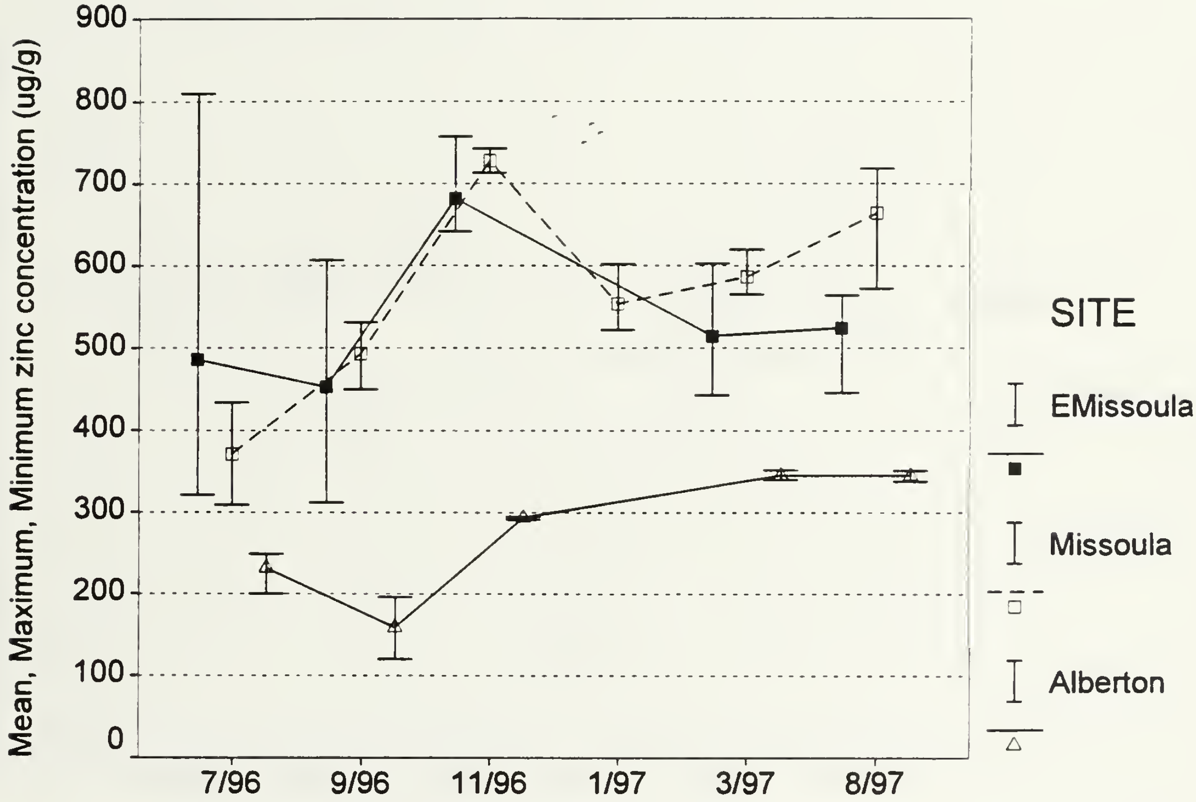

Figure 2. Zinc concentrations (ug/g dry weight) in fine-grained bed sediments of the Clark Fork River at three sites.

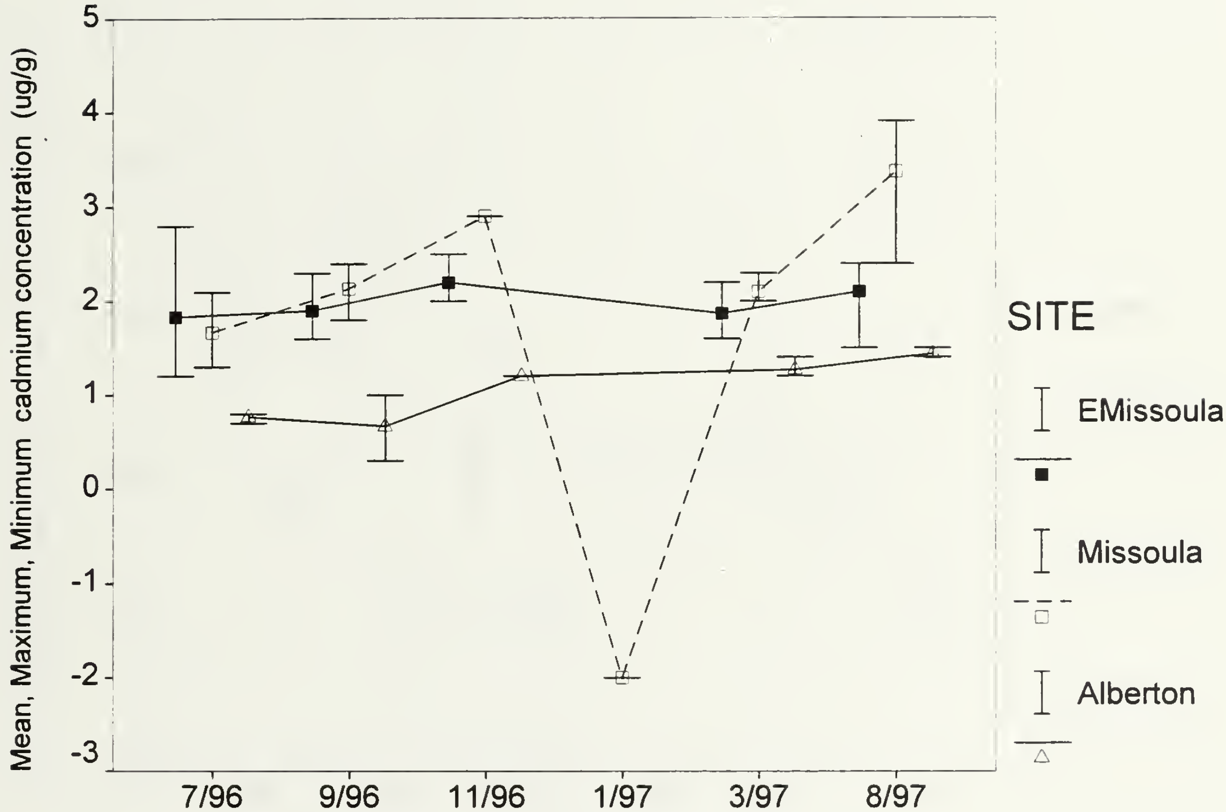

Figure 3. Cadmium (ug/g dry wt) in fine-grained bed sediments. Negative value indicates that concentration was below detection limit.

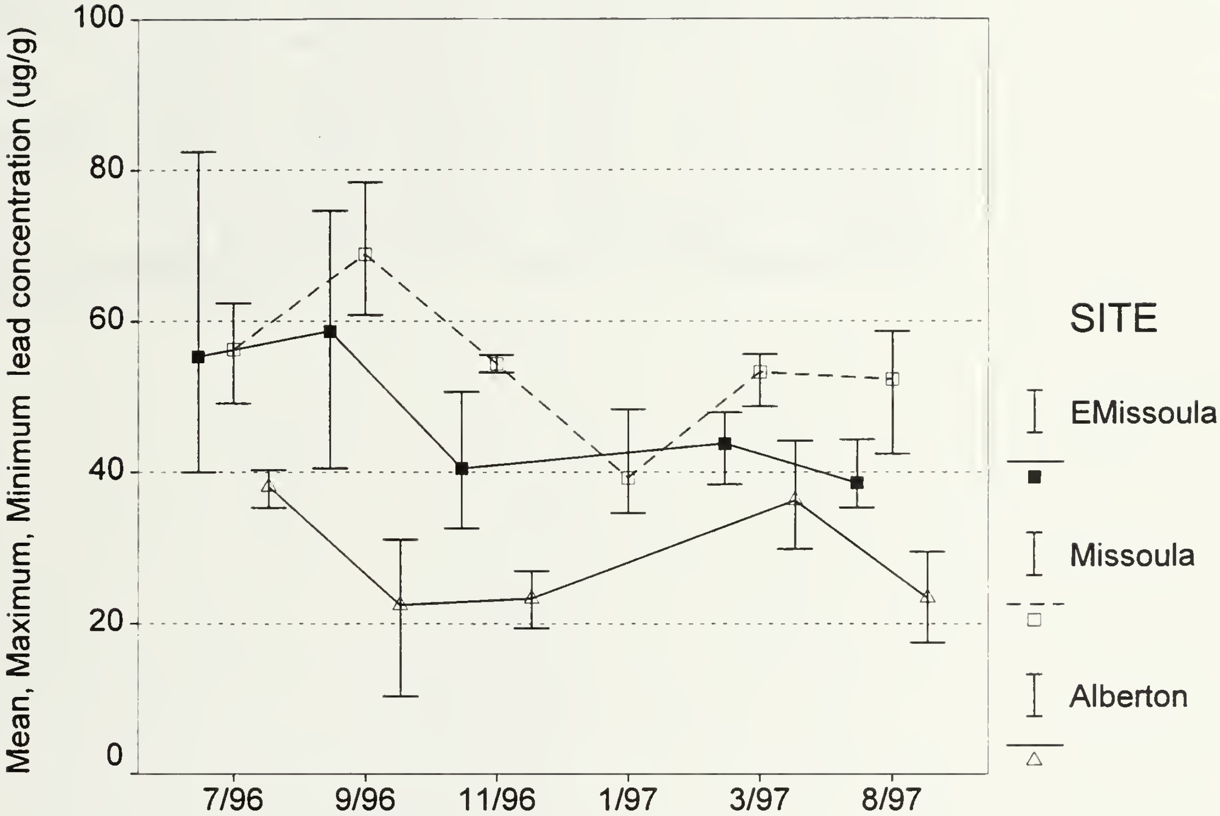

Figure 4. Lead concentrations (ug/g dry wt) in fine-grained bed sediments of the Clark Fork River at three sites.

Table 7. Results of one-way ANOVA tests of the differences between mean metal concentrations in fine-grained sediments at each site over time. In the case where homogeneity of variance test failed, significance level is based on the Kruskal Wallis (K-W) nonparametric test.

	East Missoula		Missoula		Alberton	
	F	Sig.	F	Sig.	F	Sig.
Arsenic	0.18	0.942	4.46	0.018*	80.3	0.000*
Cadmium	0.30	0.870	59.1	0.000*	K-W	0.014*
Copper	0.76	0.574	10.1	0.001*	56.4	0.000*
Manganese	0.59	0.676	K-W	0.834	0.67	0.631
Lead	1.25	0.351	5.32	0.010*	3.99	0.035*
Zinc	K-W	0.271	15.6	0.000*	42.2	0.000*

*Significant at $P<0.05$ level

Table 8. Comparisons of mean copper concentrations at different sampling times at Missoula and Alberton. Differences based on Bonferroni t-tests. Tests for which differences increased significantly over time are indicated with a "+"; tests decreasing significantly over time are indicated with a "-".

	Missoula							Alberton				
	A	B	C	D	E	F		A	B	C	D	E
A. July 1996			+		+	+	A. July 1996		-		+	+
B. Sept 1996						+	B. Sept 1996			+	+	+
C. Nov 1996							C. Nov 1996				+	+
D. Jan 1997							D. Mar 1997					+
E. Mar 1997							E. Aug 1997					
F. Aug 1997												

Table 9. Comparisons of mean zinc concentrations at different sampling times at Missoula and Alberton. Differences based on Bonferroni t-tests. Tests for which differences increased significantly over time are indicated with a "+"; tests decreasing significantly over time are indicated with a "-".

	Missoula							Alberton				
	A	B	C	D	E	F		A	B	C	E	F
A. July 1996			+	+	+	+	A. July 1996		-		+	+
B. Sept 1996			+			+	B. Sept 1996			+		+
C. Nov 1996							C. Nov 1996					
D. Jan 1997							D. Mar 1997					
E. Mar 1997							E. Aug 1997					
F. Aug 1997												

still moving into and through the other sites. However, it is also possible that these trends were due to or influenced by unique or different conditions at each site which might affect the metal concentrations. Boggs (1994) suggested that such conditions might include differences in streamflow, sediment deposition, sediment size fractions, organic matter content, metal-oxide content, and proportions of oxidized to reduced sediments. A further concern is that we may have committed Type I or Type II errors in our statistical analysis; the error being due to the inherent variability of sediment metal concentrations or perhaps an inappropriate temporal scale within which we sampled (2-4 month intervals).

The high flows during spring runoff in 1997 apparently resulted in a much larger loading of metals to the Clark Fork River than had been recorded during the previous 12 years (Lambing 1998). However, based on samples taken for this study, there was no clear effect on concentrations of copper and zinc in sediments. As discussed above, there were no significant changes over time at East Missoula. Even at Missoula and Alberton, where the ANOVA test revealed significant changes, there was no difference in mean zinc concentrations at either site when comparing pre-runoff conditions (March 1997 samples) to post-runoff conditions (August 1997). For copper, no difference was seen at the Missoula site for the two time periods, while at Alberton, copper actually decreased from March to August 1997.

Metals in benthic insects. Although spatial and temporal trends were seen with all metals, the only metals subjected to statistical analysis were copper and zinc.

Spatial Patterns. The *Hydropsyche* species *(H. cockerelli and H. occidentalis)* displayed the most consistent drop in copper concentrations from East Missoula to Missoula and then to Alberton. For all dates combined, the mean copper concentration was 55.0 and 52.9 ug/g at East Missoula, decreasing to 40.5 and 35.6 ug/g at Missoula, and 29.7 and 28.3 ug/g at Alberton for *H. cockerelli* and *H. occidentalis,* respectively (Tables 10, 11 and 12). For *Pteronarcys*, mean copper concentrations were highest at East Missoula (71.0 ug/g) but similar at Missoula (52.4 ug/g) and Alberton (53.0 ug/g)(Table 13). *Claassenia* showed the least variation in copper between sites, ranging from a high of 48.4 ug/g at East Missoula to a low of 44.3 ug/g at Alberton (Table 14). *Arctopsyche* had the lowest copper concentrations of all species, decreasing from a high of 40.0 ug/g at East Missoula to a low of 18.0 ug/g at Alberton (Table 15).

The spatial patterns of zinc were generally similar to those of copper. *Claassenia* had the highest concentrations of all species, which were also low in variability between sites (ranging from a high of 179.3 ug/g at East Missoula to a low of 171.7 ug/g at Missoula). *Pteronarcys* also had high zinc levels at East Missoula (178.1 ug/g), but concentrations decreased to their lowest at Missoula (153.9 ug/g). The *Hydropsyche* species were quite similar: both had highest zinc levels at East Missoula (172.8 and 173.3 ug/g for *H. occidentalis* and *H. cockerelli,* respectively) and lowest levels at Alberton (136.0 and 121.2 ug/g). *Arctopsyche* had the lowest zinc concentrations, but still showed a decrease in a downstream direction (148.0 ug/g at East Missoula, 121.3 ug/g at Missoula and 119.9 ug/g at Alberton).

Table 10. Metal concentrations in benthic insects from the Clark Fork River, July 1996-August 1997. ARC= *Arctopsyche grandis;* CHE= *Cheumatopsyche spp.;* CLA=*Claassenia sabulosa;* COC= *Hydropsyche cockerelli;* OCC= *Hydropsyche occidentalis;* PTR= *Pteronarcys californica.* Size of sample (N) indicated in Comments column if it contained fewer than 10 individuals. Negative values indicate that concentration was below detection limit.

Location	Date	Species	Length (mm)		Concentration, ug/g (dry weight)										Comments
			Mean	Range	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
East Missoula	7/29/96	CLA	17.5	13.50-22.0	0.5	0.7	1	0.3	31.4	63.6	70.9	-4.1		153	
East Missoula	7/29/96	CLA	26	24.5-27.5	-0.2	0.5	1	0.2	60	44.6	48.2	-4	0.4	177	
East Missoula	7/29/96	CLA	31.6	27.5-35.0	-0.2	0.6	1.4	0.2	62.3	58.9	71.6	-4	0.4	140	
East Missoula	7/29/96	COC	9.3	7.0-11.5	-1	3	1.3	1.3	39.7	1050	616	20.3	5.1	210	N=7
East Missoula	7/29/96	OCC	11.2	9.0-14.0	-0.2	1.3	0.7	0.6	31.3	551	486	-3.7	3.4	121	
East Missoula	7/29/96	OCC*	11.2	9.0-14.0	-0.2	1.7	0.8	0.8	32.8	679	508	-4	4	116	
East Missoula	7/29/96	PTR	17	13.5-23.5	-0.3	3.2	0.4	0.9	59.5	705	437	-5.7	3.1	170	
East Missoula	7/29/96	PTR	33.6	29.0-37.5	-0.2	3.3	0.5	1.2	64.4	928	610	-3.7	4.5	156	N=7
East Missoula	7/29/96	ARC	13.8	10.0-16.0	-0.2	1.3	1.2	0.6	19.8	454	426	-3.8	2.4	118	
Missoula	7/30/96	CLA	16.1	12.5-21.0	-0.2	0.8	1.1	0.2	31.6	71.6	48.2	-3.8	0.5	162	Also collected on 8/9/96
Missoula	7/30/96	CLA	21.2	18.0-24.5	-0.2	1	1.1	0.3	43.3	90.4	42	-3.8	0.3	166	Also sampled on 8/9/96
Missoula	7/30/96	CLA	32.4	29.5-33.5	-0.2	0.6	1.3	0.2	51.6	79.8	52.2	-3.9	0.2	140	Also sampled on 8/9/96, N=6
Missoula	7/30/96	COC	10.3	7.5-15.0	-0.2	2.7	0.6	1	48.6	720	581	-8.6	6.8	180	Also sampled on 8/9/96
Missoula	7/30/96	OCC	13	9.5-15.0	-0.2	1.4	0.4	0.4	19.6	286	322	-3.7	2.3	84.3	Also sampled on 8/9/96
Missoula	7/30/96	OCC*	13	9.5-15.0	-0.2	1.2	0.3	0.4	20.3	260	313	-3.9	2	88.9	Also sampled on 8/9/96
Missoula	7/30/96	PTR	21.7	16.5-26.0	-0.2	6	0.3	0.7	35.1	566	348	-3.9	3	146	Also sampled on 8/9/96, N=7
Missoula	7/30/96	PTR	28.6	26.5-33.0	-0.2	4.9	0.2	0.8	41.1	456	320	-4.1	2.8	138	Also sampled on 8/9/96, N=7
Missoula	7/30/96	PTR	38.1	34.5-43.0	-0.2	6.4	0.4	0.9	51.4	712	428	-3.6	2.8	144	Also sampled on 8/9/96, N=6
Missoula	7/30/96	ARC	11.2	9.0-14.0	-0.2	1.4	0.6	0.3	12.6	206	278	-4	1.8	110	Also sampled on 8/9/96
Missoula	7/30/96	ARC	16.5	15.5-18.5	-0.2	1.3	0.6	0.2	8.9	144	184	-3.2	2.3	79.9	Also sampled on 8/9/96
Alberton	7/31/96	CLA	18.5	14.0-22.0	-0.2	0.6	1.1	0.2	38.9	78.9	70.1	-4	0.4	185	
Alberton	7/31/96	CLA	24.1	21.0-27.0	-0.2	0.6	1	0.4	43.1	45.9	56.5	-4	0.2	160	
Alberton	7/31/96	CLA	27	24.0-34.5	-0.2	0.4	1	0.2	47.2	63.7	81.2	-4	0.4	172	N=9
Alberton	7/31/96	CLA*	27	24.0-34.5	-0.2	0.5	0.9	0.2	49.7	54.5	68.9	-4	0.4	160	
Alberton	7/31/96	COC	8.3	6.5-14.0	-0.2	2.3	0.6	1	28.5	826	640	-4.9	9.5	119	N=9
Alberton	7/31/96	OCC	13.1	10.5-15.0	-0.2	1.7	0.4	0.5	22.6	368	520	-4	9.7	98.8	
Alberton	7/31/96	PTR	23	15.5-33.0	-0.2	4.2	0.4	1.8	60.6	1720	558	-4	5.1	175	N=5
Alberton	7/31/96	ARC	9.9	6.0-14.0	-0.2	2.3	0.6	0.8	20.1	713	733	13.4	2.7	149	
East Missoula	9/5/96	CLA	14.9	11.0-17.0	-0.2	1	0.9	0.4	47.8	316	137	-4	1.5	223	
East Missoula	9/5/96	CLA	21.6	18.5-24.5	-0.2	0.8	0.8	0.2	38.7	100	87.6	-4	0.5	185	
East Missoula	9/5/96	CLA	26.5	25.0-32.5	-0.2	0.6	0.7	0.2	53.5	113	92.4	-4	0.4	163	N=9
East Missoula	9/5/96	COC	9.1	7.5-10.5	-0.2	2.8	0.7	1.2	52.7	908	803	-4	6	166	
East Missoula	9/5/96	OCC	12.2	10.5-14.0	-0.2	2.8	0.7	1.2	48.8	921	1490	-4	6.3	178	

*Duplicate sample

Table 10. Metal concentrations in benthic insects from the Clark Fork River, July 1996-August 1997. ARC= *Arctopsyche grandis;* CHE= *Cheumatopsyche spp.;* CLA=*Claassenia sabulosa;* COC= *Hydropsyche cockerelli;* OCC= *Hydropsyche occidentalis;* PTR= *Pteronarcys californica.* Size of sample (N) indicated in Comments column if it contained fewer than 10 individuals. Negative values indicate that concentration was below detection limit.

Location	Date	Species	Length (mm)		Concentration, ug/g (dry weight)										Comments
			Mean	Range	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
East Missoula	9/5/96	PTR	14.5	9.5-21.0	-0.2	3.1	0.4	1.1	58.1	1150	822	-4	4.7	184	
East Missoula	9/5/96	PTR	27.5	24.5-30.0	-0.2	2.6	0.4	1	61.8	893	863	-4	4.7	189	
East Missoula	9/5/96	PTR	33.8	32.0-37.0	-0.2	1.9	0.2	0.7	52.3	417	626	-4	2.3	180	
East Missoula	9/5/96	ARC	14.7	12.0-16.0	-0.3	2.8	0.8	0.9	39.2	726	862	-5.4	4.6	160	
East Missoula	9/5/96	ARC	19.4	16.5-22.0	-0.3	2.4	0.9	0.8	34.1	720	580	-5.8	4.2	152	
East Missoula	9/5/96	CHE	8	6.5-9.0	-1.1	6.6	1.4	2.6	95.2	2410	1290	22.7	14.3	268	
Missoula	9/3/96	CLA	11	7.0-13.5	-0.2	0.7	0.5	0.2	30.7	96.8	114	-4	0.8	168	
Missoula	9/3/96	CLA	17.8	15.0-19.0	-0.2	0.5	0.5	0.2	32.5	89.9	81.9	-4	0.4	144	
Missoula	9/3/96	CLA	25.3	22.5-31.0	-0.2	0.4	0.5	0.2	63.8	77.9	130	-4.3	0.4	185	N=8
Missoula	9/3/96	COC	9.8	8.0-11.0	-0.2	2.3	0.5	0.6	28.8	513	411	-4	2.9	128	
Missoula	9/3/96	COC	14.2	13.0-15.5	-0.2	2.2	0.4	0.5	24.3	380	364	-4	2.7	104	
Missoula	9/3/96	OCC	11.3	8.0-14.0	-0.2	2	0.4	0.6	26.3	444	533	-4	3	131	
Missoula	9/3/96	PTR	11.6	10.0-12.5	-0.7	4.5	-0.7	1.1	48.6	859	455	13.3	3.9	206	
Missoula	9/3/96	PTR	26.3	23.0-31.0	-0.2	3.7	0.4	0.9	45.8	719	428	-4	2.8	152	N=6
Missoula	9/3/96	PTR	38.8	37.0-41.0	-0.2	5.5	0.2	0.5	37.8	453	429	-4	1.8	140	N=5
Missoula	9/3/96	ARC	16	13.0-19.0	-0.2	1.7	0.3	0.3	13.3	227	241	-4	1.4	108	
Missoula	9/3/96	ARC	20	16.5-23.0	-0.2	1.5	0.3	0.2	11.4	137	236	-4	1.8	98.8	
Missoula	9/3/96	ARC	25.3	23.0-28.0	-0.2	1.5	0.2	0.2	10.7	133	183	-4	1.2	93.9	
Alberton	9/4/96	CLA	16.5	11.5-20.0	-0.2	0.6	0.4	0.2	33.9	114	88.6	-4	0.2	171	
Alberton	9/4/96	CLA	24.1	22.0-26.0	-0.2	0.5	0.4	0.2	48.9	64.7	64.3	-4	-0.2	158	
Alberton	9/4/96	CLA	31.8	30.0-33.0	-0.2	0.4	0.4	0.2	47	46.8	90	-4	-0.2	209	
Alberton	9/4/96	COC	10.8	9.0-12.5	-0.2	1.8	0.3	0.8	23.5	648	524	-4	2.6	108	
Alberton	9/4/96	COC	13.8	13.0-15.0	-0.2	1.8	0.3	0.8	23.2	597	550	-4	2	101	
Alberton	9/4/96	OCC	11	8.5-13.0	-0.2	1.8	0.3	0.8	24.3	620	593	-4	2.4	119	
Alberton	9/4/96	PTR	23.6	19.0-34.0	-0.2	3	0.3	0.8	51.5	721	387	-4	1.6	156	N=5
Alberton	9/4/96	ARC	14.6	12.5-18.0	-0.2	1.9	-0.2	0.4	14.5	340	480	-4.4	1.4	101	
Alberton	9/4/96	ARC	23	21.0-26.0	-0.2	2.2	0.3	0.7	16.3	368	454	-5.2	1	98.5	
Alberton	9/4/96	CHE	10.3	8.5-12.0	-0.3	3.6	0.4	2.7	45.2	2560	1040	-6.3	5.6	166	
East Missoula	11/7/96	CLA	11.7	10.0-13.0	-0.2	3.2	0.6	0.6	49.9	356	162	-4.2	2.8	195	
East Missoula	11/7/96	CLA	17.7	16.0-19.5	-0.2	3.3	0.5	0.3	44	284	132	-4.3	1.4	188	
East Missoula	11/7/96	CLA	24.6	22.0-28.5	-0.2	0.8	0.4	0.3	48.6	86.8	191	-4.3	1	161	
East Missoula	11/7/96	COC	11.6	9.0-13.0	-0.2	4.3	0.5	0.9	49.2	907	2600	-3.6	10.7	179	
East Missoula	11/7/96	COC	15.3	14.0-16.5	-0.2	4.1	0.4	0.8	46.2	757	2250	-3.8	6.7	149	

*Duplicate sample

Table 10. Metal concentrations in benthic insects from the Clark Fork River, July 1996-August 1997. ARC= *Arctopsyche grandis;* CHE= *Cheumatopsyche spp.;* CLA=*Claassenia sabulosa;* COC= *Hydropsyche cockerelli;* OCC= *Hydropsyche occidentalis;* PTR= *Pteronarcys californica.* Size of sample (N) indicated in Comments column if it contained fewer than 10 individuals. Negative values indicate that concentration was below detection limit.

Location	Date	Species	Length (mm)		Concentration, ug/g (dry weight)										Comments
			Mean	Range	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
East Missoula	11/7/96	OCC	10.5	7.5-14.0	-0.2	4.2	0.5	0.9	49.6	910	2700	-4.2	11.5	188	
East Missoula	11/7/96	PTR	14.1	7.5-20.5	0.2	4.4	0.6	0.5	81.1	1040	792	-4.5	8.1	205	
East Missoula	11/7/96	PTR	28.9	25.0-35.0	0.2	4.9	0.6	1.2	81	1000	864	-4.2	7.4	177	
East Missoula	11/7/96	PTR	41.6	39.5-45.0	-0.2	9.6	0.4	0.8	63.2	543	745	-3.7	4.3	167	N=8
East Missoula	11/7/96	ARC	16.5	15.0-18.0	-0.2	5.9	0.6	0.9	52.9	868	1001	-7.3	7.6	177	
East Missoula	11/7/96	ARC	19.7	19.0-21.0	-0.2	4	0.4	0.2	32.4	451	1000	-4	4.7	143	
East Missoula	11/7/96	ARC	24.9	24.0-26.0	-0.2	2.6	0.4	0.6	33.8	497	984	-3.8	4.9	149	
Missoula	11/5/96	CLA	14.1	13.0-16.5	-0.2	1.7	0.4	0.4	44.8	237	99.2	-4.4	1.7	210	
Missoula	11/5/96	CLA	19.8	17.5-21.5	-0.2	1.5	0.4	0.3	39.6	182	85	-4.2	2.9	206	
Missoula	11/5/96	CLA	25	22.5-27.0	-0.2	0.2	0.3	0.2	42.2	54.4	91.3	-3.6	1.5	146	
Missoula	11/5/96	COC	14.1	13,0-15.5	-0.2	2.6	0.3	0.6	37	447	948	-3.7	11.4	135	
Missoula	11/5/96	COC*	14.1	13.0-15.5	-0.2	2.7	0.4	0.6	35.8	444	897	-4.1	11.3	133	
Missoula	11/5/96	OCC	8.8	6.5-10.5	-0.2	2.8	0.4	0.8	36.4	525	919	-4.1	3.7	165	
Missoula	11/5/96	PTR	13.9	11.5-17.0	-0.2	3.7	0.4	0.8	49.1	688	467	-4.1	5.4	168	
Missoula	11/5/96	PTR	22.1	18.5-29.0	-0.2	7.9	0.4	1.2	55.6	899	482	-4.1	3.4	173	
Missoula	11/5/96	PTR	39.8	36.0-44.0	-0.2	0.2	0.4	0.4	41.3	54.6	87	-3.5	1.4	138	N=6
Missoula	11/5/96	ARC	17.7	16.5-20.0	-0.2	2.2	0.3	0.4	19.9	254	466	-3.9	3.4	134	
Missoula	11/5/96	ARC	25.3	23.0-27.0	-0.2	2.1	0.3	0.5	21.9	259	495	-3.8	2.1	132	
Alberton	11/6/96	cla	14.7	10.0-17.0	-0.2	2.2	0.3	0.3	37.8	250	119	-4.2	1.2	200	
Alberton	11/6/96	CLA	19.3	18.0-20.5	-0.2	3.5	0.3	0.5	43.6	354	140	-3.7	1.9	208	
Alberton	11/6/96	CLA	23.9	21.0-27.5	-0.2	-0.2	0.2	0.2	43.7	65.1	78.3	-3.6	0.4	149	
Alberton	11/6/96	COC	14.5	13.0-16.5	-0.2	2.6	-0.2	0.7	30.4	518	770	-3.7	5.5	115	
Alberton	11/6/96	OCC	7.9	7.0-9.0	-0.2	2.7	0.3	1.1	32.8	619	1070	-5	6.4	159	
Alberton	11/6/96	OCC	12.1	11.0-13.0	-0.2	2.6	0.2	0.8	27	486	953	-3.9	4.1	129	
Alberton	11/6/96	OCC*	12.1	11.0-13.0	-0.2	2.3	0.2	0.7	32.1	592	1140	4.3	5.8	154	
Alberton	11/6/96	PTR	27.8	27.0-29.0	-0.2	7	-0.2	0.7	43.1	411	461	-4.2	7	148	N=3
Alberton	11/6/96	ARC	18.5	16.0-20.0	0.2	3.2	0.2	0.8	21.1	404	684	-4.3	4.8	134	
Alberton	11/6/96	ARC	22.1	21.0-23.5	-0.2	3.2	0.2	0.2	19.5	346	675	-3.8	3.6	119	N=8
Missoula	1/22/97	COC	16.1	14.5-18		2.5	0.7		45.6	490	877		7	148	
Missoula	1/22/97	COC	13.1	10.5-14		2.7	0.8		44.9	523	1020		7.6	168	
Missoula	1/22/97	OCC	11.3	7.5-15		3	0.9		44	650	1160		8.1	180	
Missoula	1/22/97	CLA	25.2	22.5-27		0.8	0.6		47.2	133	69		1.2	145	
Missoula	1/22/97	CLA	20.3	18.5-22		1.5	0.6		60.3	315	81.6		1.9	184	

*Duplicate sample

Table 10. Metal concentrations in benthic insects from the Clark Fork River, July 1996-August 1997. ARC= *Arctopsyche grandis;* CHE= *Cheumatopsyche spp.;* CLA=*Claassenia sabulosa;* COC= *Hydropsyche cockerelli;* OCC= *Hydropsyche occidentalis;* PTR= *Pteronarcys californica.* Size of sample (N) indicated in Comments column if it contained fewer than 10 individuals. Negative values indicate that concentration was below detection limit.

Location	Date	Species	Length (mm)		Concentration, ug/g (dry weight)										Comments
			Mean	Range	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
Missoula	1/22/97	CLA	15.5	13-17		1	0.7		55.3	262	68.2		1.8	191	
Missoula	1/22/97	ARC	25.6	23-29		2.2	0.8		37.4	327	560		4.1	153	
Missoula	1/22/97	ARC	19.5	18-22		2.4	0.9		41.2	405	653		5.2	173	
Missoula	1/22/97	PTR	38.3	35-43		4	0.4		43.4	333	256		2.7	137	
Missoula	1/22/97	PTR	25.7	22.5-28		2.8	0.4		43.5	479	275		3.7	140	
Missoula	1/22/97	PTR	14.7	11.5-19		1.8	0.4		31.9	357	274		3.1	128	
Missoula	3/27/97	COC	13.9	13.0-15.0		1.8	0.8		42.9				9.6	154	Also sampled on 4/14/97
Missoula	3/27/97	COC	17.7	16.5-19.5		2.6	0.8		46.1				9.5	134	Also sampled on 4/14/97
Missoula	3/27/97	CLA	15.7	14.0-17.5		0.9	0.6		77.8				1.8	240	Also sampled on 4/14/97
Missoula	3/27/97	CLA	26.1	25.0-27.0		0.7	0.5		55.5				1.3	136	Also sampled on 4/14/97
Missoula	3/27/97	CLA	19	18.5-22.5		0.7	0.5		62.5				1.6	160	Also sampled on 4/14/97
Missoula	3/27/97	PTR	14.5	11.0-18.0		1.5	0.4		37				4.2	134	Also sampled on 4/14/97
Missoula	3/27/97	PTR	21	19.0-26.0		2.2	0.4		41.1				7.4	140	Also sampled on 4/14/97
Missoula	3/27/97	PTR	33.3	29.0-42.0		3.5	0.4		58.5				5.6	154	Also sampled on 4/14/97,
Missoula	3/27/97	ARC	19.7	19.0-22.0		1.6	0.9		32.2				5.7	140	Also sampled on 4/14/97
Missoula	3/27/97	ARC	24.7	23.0-27.0		1.7	0.8		29.5				4.2	118	Also sampled on 4/14/97,
Missoula	3/27/97	OCC	10.7	9.0-12.0		3.4	0.6		46				17.8	185	Also sampled on 4/14/97
Alberton	3/26/97	CLA	18.3	17.0-20.5		0.8	0.5		48.3				1.4	227	
Alberton	3/26/97	CLA	16.2	15.0-17.5		0.5	0.7		52.1				2.5	238	
Alberton	3/26/97	CLA	23.3	21.5-24.5		0.5	0.4		47.5				2.4	170	
Alberton	3/26/97	OCC	10.6	8.0-12.5		2.7	0.6		32.1				6.4	180	
Alberton	3/26/97	COC	14.3	10.5-16.5		3.1	0.5		35.4				6.1	153	
East Missoula	3/25/97	COC	13.8	13.0-14.5		4.4	0.9		67.1				16.5	193	
East Missoula	3/25/97	COC	16.7	15.5-18.5		3.7	0.8		62				14.1	178	
East Missoula	3/25/97	PTR	36.4	32.5-41.0		7.6	0.7		92.7				11.4	188	N=5
East Missoula	3/25/97	PTR	25.6	21.0-29.0		6.2	0.6		72.7				7.8	163	N=4
East Missoula	3/25/97	PTR	11.3	9.0-13.0		1.9	0.8		65				9.5	198	N=7
East Missoula	3/25/97	ARC	25.4	23.5-27.5		1.5	0.6		30.6				4.3	119	
East Missoula	3/25/97	ARC	18.7	16.5-21.0		2.2	0.9		40.1				5.4	166	
East Missoula	3/25/97	OCC	11.9	10.0-13.5		4.6	1.3		70.3				17.6	221	
East Missoula	3/25/97	CLA	26.3	25.0-27.0		1.6	1		57.1				2.3	172	
East Missoula	3/25/97	CLA	20	17.5-23.0		1.3	0.6		50.9				1.9	154	
East Missoula	3/25/97	CLA	14.8	12.5-17.0		0.9	0.6		51				2.1	179	

*Duplicate sample

Table 10. Metal concentrations in benthic insects from the Clark Fork River, July 1996-August 1997. ARC= *Arctopsyche grandis;* CHE= *Cheumatopsyche spp.;* CLA=*Claassenia sabulosa;* COC= *Hydropsyche cockerelli;* OCC= *Hydropsyche occidentalis;* PTR= *Pteronarcys californica.* Size of sample (N) indicated in Comments column if it contained fewer than 10 individuals. Negative values indicate that concentration was below detection limit.

Location	Date	Species	Length (mm)		Concentration, ug/g (dry weight)										Comments
			Mean	Range	Ag	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
Alberton	8/14/97	COC	12.5	11.0-14.0		1.9	0.7		37.4				4.3	131	
Alberton	8/14/97	CLA	30.1	28.0-34.0		0.6	0.9		46.1				0.5	168	N=7
Alberton	8/14/97	CLA	22.4	19.0-26.5		0.6	1.1		42.2				0.4	172	N=7
Alberton	8/14/97	ARC	14.7	12.5-17.0		1.3	0.6		16.4				1.7	118	
Alberton	8/14/97	OCC	12.1	11.0-13.0		1.8	0.7		30.7				3.8	130	
Alberton	8/14/97	PTR	23.5			3.2	-1.1		56.8				2.1	161	N=1
East Missoula	8/13/97	COC	11.7	9.0-14.0		4.1	0.9		67.8				9.9	138	
East Missoula	8/13/97	OCC	11.1	9.5-12.0		3.5	0.9		64.3				8.5	156	
East Missoula	8/13/97	CLA	28.7	24.5-33.0		0.5	1.1		48.5				0.5	156	
East Missoula	8/13/97	CLA	19.5	17.5-22.0		1	1.2		44.8				0.8	235	
East Missoula	8/13/97	CLA	13.7	9.5-16.0		1	1.1		38				0.9	209	
East Missoula	8/13/97	PTR	15.5	12.0-17.0		5.9	0.6		85.8				7.3	186	
East Missoula	8/13/97	PTR	23.6	21.0-26.0		5.3	0.6		66.7				5.3	164	
East Missoula	8/13/97	PTR	34.1	32.5-37.0		4.4	0.6		90.3				5.2	166	N=4
East Missoula	8/13/97	ARC	9.8	8.0-11.0		3.8	1.3		64.5				7	171	
East Missoula	8/13/97	ARC	13.9	12.0-15.5		3	1.1		47.7				5.8	144	
East Missoula	8/13/97	ARC	19.5	16.5-24.0		2.7	1		45.2				5.1	129	
Missoula	8/12/97	CLA	14.1	12.0-16.0		0.6	1		29				0.4	181	
Missoula	8/12/97	CLA	18.2	16.5-20.5		0.9	1.1		39.1				0.5	161	
Missoula	8/12/97	CLA	27	24.0-31.0		0.8	1.1		58				0.4	166	
Missoula	8/12/97	ARC	17.2	15.0-20.0		2.6	0.8		25.4				2.9	113	
Missoula	8/12/97	ARC	13.3	12.0-14.5		2.7	0.9		24				3.1	123	
Missoula	8/12/97	OCC	10.7	8.5-13.0		2.9	0.9		41.5				5.6	133	
Missoula	8/12/97	COC	11.3	10.0-13.0		3.6	0.9		46.3				5.9	136	
Missoula	8/12/97	PTR	24.2	22.0-26.0		5.2	0.7		128				7.7	185	
Missoula	8/12/97	PTR	32.5	30.0-36.0		7.9	0.8		102				10.1	193	

*Duplicate sample

Table 11. Metal concentrations (ug/g dry weight) in Hydropsyche cockerelli, July 1996-August 1997.

SITE		AG	AS	CD[a]	CR	CU	FE	MN	NI	PB	ZN
East Missoula	Mean	-.3600	3.4625	.7750	.9600	52.1400	855.5714	1194.4286	-7.0800	9.0500	166.6000
	Median	-.2000	3.9000	.7500	.9000	52.7000	908.0000	803.0000	-3.8000	8.3000	166.0000
	Minimum	-1.00	1.30	.40	.60	31.30	551.00	486.00	-20.30	3.40	121.00
	Maximum	-.20	4.40	1.30	1.30	67.80	1050.00	2600.00	-3.60	16.50	210.00
	N	5	8	8	5	10	7	7	5	8	10
Missoula	Mean	-.2000	2.5556	.6444	.6750	40.5000	512.1667	700.1667	-5.0750	7.0444	143.0000
	Median	.	2.6000	.7000	.6000	44.9000	501.5000	729.0000	-4.0000	7.0000	136.0000
	Minimum	-.20	1.80	.30	.50	24.30	380.00	364.00	-8.60	2.70	104.00
	Maximum	-.20	3.60	.90	1.00	48.60	720.00	1020.00	-3.70	11.40	180.00
	N	4	9	9	4	9	6	6	4	9	9
Alberton	Mean	-.2000	2.2500	.4167	.8250	29.7333	647.2500	621.0000	-4.1500	5.0000	121.1667
	Median	.	2.1000	.4000	.8000	29.4500	622.5000	595.0000	-4.0000	4.9000	117.0000
	Minimum	-.20	1.80	.10	.70	23.20	518.00	524.00	-4.90	2.00	101.00
	Maximum	-.20	3.10	.70	1.00	37.40	826.00	770.00	-3.70	9.50	153.00
	N	4	6	6	4	6	4	4	4	6	6
Total	Mean	-.2615	2.7913	.6304	.8308	42.5720	685.3529	885.0588	-5.5615	7.2087	147.2000
	Median	-.2000	2.6000	.7000	.8000	44.9000	648.0000	770.0000	-4.0000	6.7000	148.0000
	Minimum	-1.00	1.30	.10	.50	23.20	380.00	364.00	-20.30	2.00	101.00
	Maximum	-.20	4.40	1.30	1.30	67.80	1050.00	2600.00	-3.60	16.50	210.00
	N	13	23	23	13	25	17	17	13	23	25

a. Only one cadmium value was below detection. This value was arbitrarily given a value half that of the detection limit.

Table 12. Metal concentrations (ug/g dry weight) in Hydropsyche occidentalis, July 1996-August 1997.

SITE		AG	AS	CD	CR	CU	FE	MN	NI	PB	ZN
East Missoula	Mean	-.2000	3.7750	.8500	1.0500	58.2500	915.5000	2095.0000	-4.1000	10.9750	185.7500
	Median	.	3.8500	.8000	1.0500	56.9500	915.5000	2095.0000	-4.1000	10.0000	183.0000
	Minimum	-.20	2.80	.50	.90	48.80	910.00	1490.00	-4.20	6.30	156.00
	Maximum	-.20	4.60	1.30	1.20	70.30	921.00	2700.00	-4.00	17.60	221.00
	N	2	4	4	2	4	2	2	2	4	4
Missoula	Mean	-.2000	2.5833	.6000	.6000	35.6333	476.2500	733.5000	-3.9333	6.7500	146.3833
	Median	.	2.8500	.5000	.6000	38.9500	484.5000	726.0000	-4.0000	4.6500	149.0000
	Minimum	-.20	1.40	.40	.40	19.60	286.00	322.00	-4.10	2.30	84.30
	Maximum	-.20	3.40	.90	.80	46.00	650.00	1160.00	-3.70	17.80	185.00
	N	3	6	6	3	6	4	4	3	6	6
Alberton	Mean	-.2000	2.2167	.4167	.8000	28.2500	523.2500	784.0000	-4.2250	5.4667	135.9667
	Median	.	2.2000	.3500	.8000	28.8500	552.5000	773.0000	-4.0000	5.2500	129.5000
	Minimum	-.20	1.70	.20	.50	22.60	368.00	520.00	-5.00	2.40	98.80
	Maximum	-.20	2.70	.70	1.10	32.80	620.00	1070.00	-3.90	9.70	180.00
	N	4	6	6	4	6	4	4	4	6	6
Total	Mean	-.2000	2.7437	.5937	.7889	38.5188	582.9000	1026.0000	-4.1000	7.3250	152.3188
	Median	.	2.7500	.5500	.8000	34.6000	572.0000	936.0000	-4.0000	6.3500	157.5000
	Minimum	-.20	1.40	.20	.40	19.60	286.00	322.00	-5.00	2.30	84.30
	Maximum	-.20	4.60	1.30	1.20	70.30	921.00	2700.00	-3.70	17.80	221.00
	N	9	16	16	9	16	10	10	9	16	16

Table 13. Metal concentrations (ug/g dry weight) in Pteronarcys californica, July 1996-August 1997.

SITE		AG	AS	CD[a]	CR	CU	FE	MN	NI	PB	ZN
East Missoula	Mean	-.1125	4.5929	.5286	.9250	71.0429	834.5000	719.8750	-4.2250	6.1143	178.0714
	Median	-.2000	4.4000	.6000	.9500	65.8500	910.5000	768.5000	-4.0000	5.2500	178.5000
	Minimum	-.30	1.90	.20	.50	52.30	417.00	437.00	-5.70	2.30	156.00
	Maximum	.20	9.60	.80	1.20	92.70	1150.00	864.00	-3.70	11.40	205.00
	N	8	14	14	8	14	8	8	8	14	14
Missoula	Mean	-.2556	4.2176	.4088	.8111	52.4235	547.9667	354.0833	-4.9556	4.2235	153.8824
	Median	-.2000	4.0000	.4000	.8000	43.5000	522.5000	388.0000	-4.0000	3.4000	144.0000
	Minimum	-.70	.20	.20	.40	31.90	54.60	87.00	-13.30	1.40	128.00
	Maximum	-.20	7.90	.80	1.20	128.00	899.00	482.00	-3.50	10.10	206.00
	N	9	17	17	9	17	12	12	9	17	17
Alberton	Mean	-.2000	4.3500	.3375	1.1000	53.0000	950.6667	468.6667	-4.0667	3.9500	160.0000
	Median	.	3.7000	.3500	.8000	54.1500	721.0000	461.0000	-4.0000	3.6000	158.5000
	Minimum	-.20	3.00	.10	.70	43.10	411.00	387.00	-4.20	1.60	148.00
	Maximum	-.20	7.00	.55	1.80	60.60	1720.00	558.00	-4.00	7.00	175.00
	N	3	4	4	3	4	3	3	3	4	4
Total	Mean	-.1900	4.3829	.4486	.9000	59.9371	700.1565	496.2609	-4.5300	4.9486	164.2571
	Median	-.2000	4.2000	.4000	.8500	56.8000	705.0000	455.0000	-4.0000	4.5000	164.0000
	Minimum	-.70	.20	.10	.40	31.90	54.60	87.00	-13.30	1.40	128.00
	Maximum	.20	9.60	.80	1.80	128.00	1720.00	864.00	-3.50	11.40	206.00
	N	20	35	35	20	35	23	23	20	35	35

a. Only 3 of 35 cadmium values were below detection. These values were arbitrarily assigned values half that of the detection level.

Table 14. Metal concentrations (ug/g dry weight) in Claassenia sabulosa, July 1996-August 1997.

		Variables									
SITE	Statistics	AG	AS[a]	CD	CR[b]	CU	FE	MN	NI	PB	ZN
East Missoula	Mean	-.1222	1.1867	.8600	.2556	48.4333	158.1000	110.3000	-4.1000	1.2071	179.3333
	Median	-.2000	.9000	.9000	.3000	48.6000	100.0000	92.4000	-4.0000	.9500	177.0000
	Minimum	-.20	.50	.40	.10	31.40	44.60	48.20	-4.30	.40	140.00
	Maximum	.50	3.30	1.40	.60	62.30	356.00	191.00	-4.00	2.80	235.00
	N	9	15	15	9	15	9	9	9	14	15
Missoula	Mean	-.2000	.8500	.7111	.2222	48.0444	140.8167	80.2167	-4.0000	1.0889	171.7222
	Median	.	.8000	.6000	.2000	46.0000	93.6000	81.7500	-4.0000	1.0000	166.0000
	Minimum	-.20	.20	.30	.10	29.00	54.40	42.00	-4.40	.20	136.00
	Maximum	-.20	1.70	1.30	.40	77.80	315.00	130.00	-3.60	2.90	240.00
	N	9	18	18	9	18	12	12	9	18	18
Alberton	Mean	-.2000	.7462	.6462	.2125	44.8077	104.1375	83.6250	-3.9125	.7923	183.6154
	Median	.	.6000	.5000	.1500	46.1000	64.9000	79.7500	-4.0000	.4000	172.0000
	Minimum	-.20	.10	.20	.10	33.90	45.90	56.50	-4.00	-.20	149.00
	Maximum	-.20	3.50	1.10	.50	52.10	354.00	140.00	-3.60	2.50	238.00
	N	8	13	13	8	13	8	8	8	13	13
Total	Mean	-.1731	.9304	.7413	.2308	47.2565	136.0621	90.4931	-4.0077	1.0400	177.5652
	Median	-.2000	.7000	.6500	.2000	47.2000	89.9000	81.9000	-4.0000	.8000	171.5000
	Minimum	-.20	.10	.20	.10	29.00	44.60	42.00	-4.40	-.20	136.00
	Maximum	.50	3.50	1.40	.60	77.80	356.00	191.00	-3.60	2.90	240.00
	N	26	46	46	26	46	29	29	26	45	46

a. Only one arsenic value was below detection. This value was arbitrarily assigned a value half that of the detection limit.

b. 10 of 26 chromium values were below detection. These values were arbitrarily given a value half that of the detection limit.

Table 15. Metal concentration (ug/g dry weight) in Arctopsyche grandis, July 1996-August 1997.

		Variables									
SITE	Statistics	AG	AS	CD[a]	CR[b]	CU	FE	MN	NI	PB	ZN
East Missoula	Mean	-.2333	2.9273	.8364	.6667	40.0273	619.3333	808.8333	-5.0167	5.0909	148.0000
	Median	-.2000	2.7000	.9000	.7000	39.2000	608.5000	923.0000	-4.7000	4.9000	149.0000
	Minimum	-.30	1.30	.40	.20	19.80	451.00	426.00	-7.30	2.40	118.00
	Maximum	-.20	5.90	1.30	.90	64.50	868.00	1001.00	-3.80	7.60	177.00
	N	6	11	11	6	11	6	6	6	11	11
Missoula	Mean	-.2000	1.9154	.5923	.2857	22.1846	232.4444	366.2222	-3.8429	3.0154	121.2769
	Median	.	1.7000	.6000	.3000	21.9000	227.0000	278.0000	-4.0000	2.9000	118.0000
	Minimum	-.20	1.30	.20	.10	8.90	133.00	183.00	-4.00	1.20	79.90
	Maximum	-.20	2.70	.90	.50	41.20	405.00	653.00	-3.20	5.70	173.00
	N	7	13	13	7	13	9	9	7	13	13
Alberton	Mean	-.1200	2.3500	.3333	.5800	17.9833	434.2000	605.2000	-6.2200	2.5333	119.9167
	Median	-.2000	2.2500	.2500	.7000	17.9500	368.0000	675.0000	-4.4000	2.2000	118.5000
	Minimum	-.20	1.30	.10	.20	14.50	340.00	454.00	-13.40	1.00	98.50
	Maximum	.20	3.20	.60	.80	21.10	713.00	733.00	-3.80	4.80	149.00
	N	5	6	6	5	6	5	5	5	6	6
Total	Mean	-.1889	2.3733	.6300	.4944	27.8867	398.9500	558.7500	-4.8944	3.6800	130.8033
	Median	-.2000	2.2000	.6000	.4500	24.7000	357.0000	527.5000	-4.0000	3.8500	130.5000
	Minimum	-.30	1.30	.10	.10	8.90	133.00	183.00	-13.40	1.00	79.90
	Maximum	.20	5.90	1.30	.90	64.50	868.00	1001.00	-3.20	7.60	177.00
	N	18	30	30	18	30	20	20	18	30	30

a. Only one cadmium value was below detection. This value was arbitrarily assigned a value half that of the detection limit.

b. Only one chromium value was below detection. This value was arbitrarily assigned a value half that of the detection limit.

Statistical analysis of these data with one-way ANOVA showed that for all species but *Claassenia* we can reject the null hypothesis (at the P=0.05 level) that the mean copper concentrations are the same at the three sites (Table 16). For zinc, the null hypothesis was rejected in *Pteronarcys, H.Cockerelli,* and *Arctopsyche*, but not *H. occidentalis* and *Claassenia*. In all cases where the null hypothesis was rejected, it was because of differences between the high mean values at the East Missoula site and lower values at one of the other sites. Pairwise comparisons showed that the East Missoula site had a significantly greater mean copper value than Missoula for *Pteronarcys,* both *Hydropsyche* species, and *Arctopsyche* (Table 17). *Pteronarcys, H. cockerelli* and *Arctopsyche* also had significantly higher mean concentrations of zinc at East Missoula than at Missoula. Copper concentrations were also significantly higher at East Missoula than Alberton for both *Hydropsyche* species and *Arctopsyche*; for zinc, only *H. cockerelli* was significantly higher at East Missoula than Alberton. In no case was the mean copper or zinc concentrations at Missoula significantly different than Alberton.

Temporal Patterns. Insects were sampled five times at East Missoula and Alberton, and six times at Missoula during the thirteen months of the study. This was done in order to identify changes in metal concentrations in insects that could result from significant hydrologic events in the drainage or changes in Milltown Dam operation. This type of evaluation must consider the periods of emergence of the insects being sampled and account for the different cohorts for species living longer than one year (e.g. three years for *Pteronarcys*). Consequently, we have restricted our analysis of temporal trends to those situations where the age of the insects is clearly understood. We have used length-frequency analysis as the technique for estimating the age of animals. For example, *H. cockerelli* larva at the Missoula site were close to emerging on March 27, 1997 when lengths ranged from 13.0-19.5 mm. When this species was sampled five months later on August 12, 1997, the lengths ranged from 10.0-13.0 mm, which we assumed to be from a new generation of animals. Also, we have not included *Claassenia* in this analysis because it may have some ability to regulate copper (Cain et al. 1992) and therefore seems to be a poor barometer of changes in the copper levels in the physical media (water, sediment).

Pteronarcys was the only species for which we were able to sample individuals that had lived through the February 1996 ice-out event. These individuals were first sampled in July 1996 as 2nd- and 3rd-year animals. A comparison of the metal concentrations in these animals with younger animals born during or after high water in 1996 can serve to isolate some of the effects of the February event. Results show that the 1st-year animals, sampled in September or November 1996, had similar or higher levels of both copper or zinc (Table 18). This suggests that the older *Pteronarcys* animals did not have unexpectedly high levels of copper and zinc, and if there were any lingering effects from the February event, they were not manifested as high body burdens of metals.

Pteronarcys was also the only species we sampled that could be used to evaluate whether there were changes in copper and zinc concentrations in animals that lived through the 1997 runoff. This comparison was possible for a combination of first- and second-year animals at Missoula and East Missoula (Table 19). At East Missoula, the mean concentrations of the metals changed little from March to August: copper increased slightly from 68.8 ug/g to 80.9 ug/g, while zinc decreased from

Table 16. Results of one-way ANOVA tests of the differences between mean copper and zinc concentrations at the three sites.										
	Pteronarcys californica		*Hydropsyche cockerelli*		*Hydropsyche occidentalis*		*Arctopsyche grandis*		*Claassenia sabulosa*	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Copper	3.7	0.035	13.5	0.000	7.6	0.006	12.3	0.000	0.8	0.473
Zinc	6.4	0.005	9.0	0.002	1.6	0.239	5.1	0.013	0.9	0.404

Table 17. Comparisons of mean copper and zinc concentrations in insect tissues at the three sites. Levels of significance (P) are based on Bonferroni t-test comparisons.

			Pteronarcys californica		*Hydropsyche cockerelli*		*Hydropsyche occidentalis*		*Arctopsyche grandis*		*Claassenia sabulosa*	
Dependent variable	Site A	Site B	Mean Difference (A-B)	Sig.	Mean Difference (A-B)	Sig.	Mean Difference (A-B)	Sig.	Mean Difference (A-B)	Sig.	Mean Difference (A-B)	Sig.
Copper	East Missoula	Missoula	18.6*	.039	14.5*	.013	17.2	.054	17.8*	.001	0.4	1.000
	East Missoula	Alberton	18.0	.344	25.2*	.000	24.6*	.005	22.0*	.001	4.1	0.512
	Missoula	Alberton	-0.6	1.000	10.8	.096	7.4	.743	4.2	1.000	3.7	0.550
Zinc	East Missoula	Missoula	24.2*	.004	30.3*	.044	26.4	.694	26.7*	.021	7.6	1.000
	East Missoula	Alberton	18.1	.305	52.1*	.001	36.8	.309	28.1	.060	-5.4	1.000
	Missoula	Alberton	-6.1	1.000	21.8	.238	10.4	1.000	1.4	1.000	-13.1	0.560

*The mean difference is significant at the 0.05 level.

Table 18. Concentration of copper and zinc (ug/g dry weight) in different *Pteronarcys* size groups in the Clark Fork River, 1996.

July 1996 (2nd yr or older animals)			September 1996 (1st yr animals)			November 1996 (1st yr animals)		
Size range (mm)	Cu	Zn	Size range (mm)	Cu	Zn	Size range (mm)	Cu	Zn
East Missoula								
13.5-23.5	59.5	170	9.5-21.0	58.1	184	7.5-20.5	81.1	205
29.0-37.5	64.4	156						
Mean =	**62.0**	**163**						
Missoula								
16.5-26.0	35.1	146	10.0-12.5	48.6	206	11.5-17.0	49.1	168
26.5-33.0	41.1	138						
34.5-43.0	51.4	144						
Mean =	**42.5**	**143**						

Table 19. Comparison of copper and zinc concentrations (ug/g dry wt) in different size groups of *Pteronarcys* before and after exposure to runoff in spring 1997.

	March 1997			August 1997		
Site	Size range (mm)	Cu	Zn	Size range (mm)	Cu	Zn
East Missoula	9.0-13.0	65	198	12.0-17.0	85.8	186
East Missoula	21.0-29.0	72.7	163	21.0-26.0	66.7	164
East Missoula				32.5-37.0	90.3	166
	Mean =	**68.8**	**180.5**	**Mean =**	**80.9**	**172**
Missoula	11.0-18.0	37	134	22.0-26.0	128	185
Missoula	19.0-26.0	41.1	140	30.0-36.0	102	193
	Mean =	**39.0**	**137**	**Mean =**	**115**	**188**

180.5 ug/g to 172 ug/g. This was in contrast to the trend at Missoula where copper concentrations increased markedly from 39 to 115 ug/g and the zinc increased from 137 to 188 ug/g.

Another useful comparison that can be made is of the metal concentrations in animals born slightly before or during the runoff periods of 1996 and 1997. Any differences in metal concentrations can probably be attributed, at least in part, to differing amounts of exposure to metals in water and sediment during the runoff itself. This comparison was possible for *Hydropsyche cockerelli* and *Arctopsyche* at all sites. Four of the six comparisons for copper showed an increase from 1996, with an average increase of 32% for *H. cockerelli* and 99% for *Arctopsyche* for all three sites combined (Table 20). For zinc there was no obvious trend, as only three of six comparisons showed an increase over time. Furthermore, the average change in zinc concentration over time was a - 17% for *H. cockerelli* and +12% for *Arctopsyche.* These results suggest that conditions were more conducive for the accumulation of copper, but not zinc, during the spring of 1997 than the spring of 1996.

Community composition of benthic invertebrates. Three Hess samples were collected from each site in July, September and November of 1996 and again in August of 1997. Ice conditions in January 1997 prevented us from sampling all but the Missoula site, while rising water in March 1997 precluded sampling at all sites.

The Hess samples from the Missoula site were analyzed and summarized for this report. The total number of organisms averaged 257.0 per sample in July 1996, rose to 423.3 in September and reached a peak of 809.7 in November. Numbers dropped substantially in January (176.7) before rising to 399.7 in August 1997 (Figure 5, Tables 21-25). This pattern is generally consistent with that described by Hynes (1970) for stream-dwelling insects in temperate regions. This pattern is one in which most insects reach their peak numbers in late fall-early winter as a result of the growth and recruitment of young from reproduction the previous summer. Throughout the winter, numbers decline as a result of death, and by spring additional reductions result from insect emergence. Minimum numbers are then typically reached in late spring. On the Clark Fork there was a precipitous drop in just two months from November to January. Whether or not this is typical is unknown, but the severe ice conditions and scour on the river at the time may have had an effect on the densities of near-shore dwellers. Regardless of the cause for the low numbers in January, the populations subsequently increased to the point that the August 1997 numbers (399.7) were actually somewhat higher than the July 1996 numbers (257.0).

This seasonal pattern in abundance described by Hynes (1970) was followed at the Missoula site by Dipterans, caddisflies and stoneflies, but not by mayflies. Mayflies had a density of 174.3 per Hess sample in July 1996, but then dropped to 69.7 in September and back up again to 174.7 in November. No obvious explanation can be provided for this pattern. Caddisflies were unusual in that their highest densities were reached in August 1997, at which time they were more than nine times more plentiful (259) than they were in July 1996 (27.7). Most of the difference between these two samples was due to the increase in numbers of one species *(H.cockerelli)* in August 1997. On that date, *H. cockerelli* made up 67.2% of the total caddisflies at the site, whereas in July 1996 the

Table 20. Comparison of copper and zinc concentrations (ug/g dry wt) in insects born before or during spring runoff.

		July 1996			August 1997		
Site	Species	Size range (mm)	Cu	Zn	Size range (mm)	Cu	Zn
E. Missoula	*H. cockerelli*	7.0-11.5	39.7	210	9.0-14.0	67.8	136
Missoula	*H. cockerelli*	7.0-15.0	48.6	180	10.0-13.0	46.3	136
Alberton	*H. cockerelli*	6.5-14.0	28.5	119	11.0-14.0	37.4	131
					Average change 1996 to 1997 =	**+32%**	**-17%**
E. Missoula	*Arctopsyche*	10.0-16.0	19.8	118	8.0-11.0	64.5	171
Missoula	*Arctopsyche*	9.0-14.0	12.6	110	12.0-14.5	24	123
Alberton	*Arctopsyche*	6.0-14.0	20.1	149	12.0-17.0	16.4	118
					Average change 1996 to 1997 =	**+99%**	**+12%**

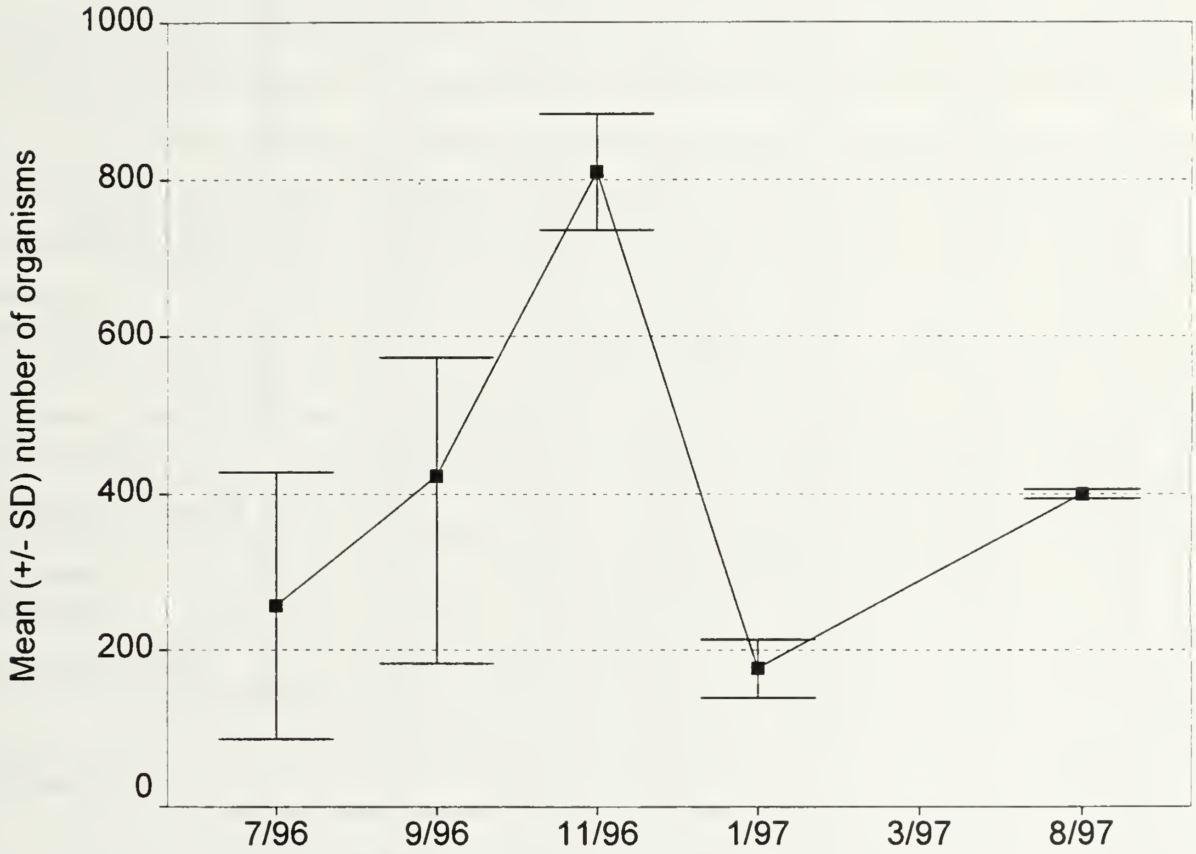

Figure 5. Number of benthic organisms per Hess sample from the Missoula site. N=4 for 7 & 9/96; N=3 for other dates.

Table 21. Enumeration of macroinvertebrate taxa from Hess samples at the Missoula site, July 24, 1996.							
Taxon	Sample 1	Sample 2	Sample 3	Sample 4	SUM	Mean	SD
COLEOPTERA	0	4	5	0	9	2.2	2.6
DIPTERA	11	26	150	0	187	46.7	69.7
EPHEMEROPTERA	95	109	301	192	697	174.3	94.7
PLECOPTERA	2	1	7	11	21	5.2	4.6
Claassenia sabulosa	1	0	[illegible]	3	9	2.3	2.2
Pteronarcys californica	1	0	2	8	11	2.7	3.6
TRICHOPTERA	24	12	40	35	111	27.7	12.4
Hydropsyche cockerelli	2	1	6	2	11	2.7	2.2
Hydropsyche occidentalis	4	2	10	12	28	7.0	4.8
Arctopsyche grandis	3	1	1	4	9	2.2	1.5
AMPHIPODA	0	0	1	0	1	0.3	0.5
GASTROPODA	0	0	0	1	1	0.3	0.5
ANNELIDA	0	0	0	1	1	0.3	0.5
TOTAL ORGANISMS	132	152	504	240	1028	257.0	171.2

Table 22. Enumeration of macroinvertebrate taxa from Hess samples at the Missoula site, September 3, 1996.

Taxon	Sample 1	Sample 2	Sample 4	Sample 4	SUM	Mean	SD
COLEOPTERA	5	7	10	11	33	8.3	2.8
DIPTERA	90	158	251	119	623	155.7	68.6
EPHEMEROPTERA	79	66	44	45	279	69.7	19.0
PLECOPTERA	17	10	15	24	73	18.3	3.9
Claassenia sabulosa	11	10	10	10	42	10.5	0.6
Pteronarcys californica	6	7	5	10	28	7.5	2.2
TRICHOPTERA	90	173	268	152	683	170.7	73.8
Hydropsyche cockerelli	34	62	44	47	187	46.7	11.6
Hydropsyche occidentalis	34	90	178	79	355	69.7	62.4
Arctopsyche grandis	4	4	13	9	30	7.5	3.9
ANNELIDA	2	0	0	0	2	0.5	1.0
TOTAL ORGANISMS	288	421	633	351	1693	423.3	150.0

Table 23. Enumeration of macroinvertebrate taxa from Hess samples at the Missoula site, November 5, 1996						
Taxon	Sample 1	Sample 2	Sample 3	SUM	Mean	SD
COLEOPTERA	6	3	20	29	9.7	9.1
DIPTERA	232	415	317	964	321.3	91.6
EPHEMEROPTERA	128	210	186	524	174.7	42.1
PLECOPTERA	75	70	116	261	87.0	25.2
Claassenia sabulosa	22	12	26	60	20.0	7.2
Pteronarcys californica	8	1	8	17	5.7	4.0
TRICHOPTERA	291	128	239	650	216.7	87.7
Hydropsyche cockerelli	70	22	73	165	55.0	28.6
Hydropsyche occidentalis	171	64	111	349	115.3	53.6
Arctopsyche grandis	7	4	15	26	8.7	5.7
GASTROPODA	0	0	1	1	0.3	0.6
TOTAL ORGANISMS	732	818	879	2429	809.7	73.9

Table 24. Enumeration of macroinvertebrate taxa from Hess samples at the Missoula Site, January 23, 1997						
Taxon	Sample 1	Sample 2	Sample 3	SUM	Mean	SD
COLEOPTERA	0	0	3	3	1.0	1.7
DIPTERA	40	87	110	237	79.0	35.7
EPHEMEROPTERA	35	36	1[illegible]	90	30.0	9.5
PLECOPTERA	47	55	30	132	44.0	12.8
Claassenia sabulosa	10	[illegible]	[illegible]	21	7.0	2.6
Pteronarcys californica	0	[illegible]	0	4	1.3	2.3
TRICHOPTERA	1[illegible]	32	22	68	22.7	9.0
Hydropsyche cockerelli	[illegible]	12	4	18	6.0	5.3
Hydropsyche occidentalis	[illegible]	[illegible]	10	34	11.3	4.2
Arctopsyche grandis	[illegible]	0	[illegible]	2	0.7	[illegible]
TOTAL ORGANISMS	136	210	184	530	176.7	37.5

Table 25. Enumeration of macroinvertebrate taxa from Hess samples at the Missoula site, August 12, 1997

Taxon	Sample 1	Sample 2	Sample 3	SUM	Mean	SD
COLEOPTERA	6	0	3	9	3.0	3.0
DIPTERA	14	7	44	65	21.7	19.7
EPHEMEROPTERA	10	157	98	294	98.0	9.0
PLECOPTERA	22	16	16	54	18.0	3.5
Claassenia sabulosa	6	10	7	26	8.0	1.5
Pteronarcys californica	10	6	7	24	8.0	2.6
TRICHOPTERA	268	276	233	777	259	22.9
Hydropsyche cockerelli	201	157	164	522	174	23.6
Hydropsyche occidentalis	25	25	10	65	20	8.7
Arctopsyche grandis	7	31	21	59	19.7	12.1
TOTAL ORGANISMS	399	406	394	1199	399.7	6.0

percentage was only 9.7%. The 1997 year-class of *H. cockerelli* may have been particularly strong relative to other caddisflies, but the differences in density may have also been due to a differences in the emergence times of the two previous year classes. The fact that the *H. cockerelli* were larger in August 1997 (mean of 11.3 mm total length, minimum of 10.0 mm) than in July 1996 (mean 10.3 mm, minimum 7.5 mm) suggests that the 1996 year-class had emerged and reproduced earlier than the 1995 year-class and the new-generation larva were large enough to be sampled or were utilizing locations that we sampled.

In summary, the trends in seasonal insect abundance seemed to follow the natural pattern expected for temperate-region streams. The one exception to this was the sharp drop in total insect numbers from November 1996 to January 1997, although we suspect that local ice scour (not from above Milltown Dam) was responsible.

Comparison with USGS Data

There were three instances in 1996 and 1997 where the USGS sampled insects and sediments from the same site and at nearly the same time as samples collected for this study. In August 1996, the USGS sampled at the Alberton site about two weeks after sampling was done for this study, while in 1997, the USGS sampled both the Alberton and East Missoula sites about one week earlier than we did. The USGS analyzed 2-5 replicate samples for each insect species or sediment, while we had 2-3 replicate samples on all occasions for sediments and *Claassenia* and once for *Arctopsyche*. However, we only analyzed single samples for *Hydropsyche cockerelli* and in 2 of 3 instances for *Arctopsyche,* and these single samples preclude reliable comparisons between the studies.

The one instance where we analyzed three samples of *Arctopsyche grandis* was East Missoula in 1997, and the mean copper concentration in this study was 52.5 ug/g, within 0.5% of the mean value of 54.6 ug/g calculated by the USGS (Table 26). Mean values for *Claassenia* were always somewhat higher for the USGS, ranging from 1% higher at East Missoula in 1997 to 30% higher at Alberton in 1996. The copper concentrations calculated by the USGS for sediments were always higher than those in this study. The mean USGS value was 25% higher at Alberton in 1996 (136 vs 108.6 ug/g), 23% higher at Alberton in 1997 (192 vs 156 ug/g), and 214% higher at East Missoula in 1997 (516 vs 241 ug/g).

With the exception of the sediment samples at East Missoula in 1997, the copper concentrations calculated for this study are in good agreement with those generated by the USGS. Even differences up to 30% are probably not significant, given the standard deviation values associated with each mean. In addition, some of the differences may be due to variability in laboratory preparation and analysis. In this study, blind duplicates submitted to the laboratory varied by as much as 19%. Finally, differences in the exact locations of sampling may also have contributed to the observed variations in copper levels. The sediments we sampled at Alberton in 1997 were from a spot several miles upstream from where the USGS sampled. Also, some of the insects that we sampled at

Alberton in 1997 were from the same riffle sampled by the USGS, but some were from riffles up to a mile away.

Even with the differences between the studies, the USGS data are consistent with the finding in this study that copper concentrations in sediments increased with time at Alberton. Between August 1996 and August 1997, the USGS showed copper in sediment to increase 41%, from 136 ug/g to 192 ug/g; likewise, in this study the sediment copper increased 44% over roughly the same time period. The USGS samples at Turah showed that this phenomenon was not restricted to the river below Milltown Dam. Between August 1996 and 1997, the sediment copper at Turah increased 78%, from 356 ug/g to 635 ug/g.

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We wish to thank Russ Forba (USEPA) and Jim Scott (MDEQ) for acknowledging the need for this study and providing the funds to see it implemented. Dan McGuire of McGuire Consulting provided valuable assistance in helping us correctly identify the aquatic insects. Sam Luoma, Michelle Hornberger and Ellen Axtmann, all of the USGS, provided valuable suggestions to enable us to sample in accordance with their methods and techniques. Michelle Hornberger also provided useful comments on a draft of this report.

Table 26. Comparison of mean (± SD) copper concentrations (ug/g dry weight) in aquatic insects and fine-grained sediments in August 1996 and 1997 as measured by the USGS (Dodge et al. 1997, Dodge et al 1998, Hornberger, pers. comm.) and in July 1996 and August 1997 from this study. Sample size is in parenthesis.

Site/ Collector	*Hydropsyche cockerelli*	*Arctopsyche grandis*	*Claassenia sabulosa*	Sediment
1996				
Turah (USGS)	50.8±11.2 (3)	40.2±6.6 (5)	45.3±7.6 (3)	356±18 (3)
E. Missoula (This study)	39.7 (1)	19.8 (1)	51.2±17.2 (3)	216.7±103 (3)
Missoula (This study)	48.6 (1)	10.7±2.6 (2)	42.2±10.0 (3)	189.7±34 (3)
Alberton (This study)	28.5 (1)	20.1 (1)	43.1±4.2 (3)	108.6±13 (3)
Alberton (USGS)	24.5±2.8 (3)	13.1±2.7 (3)	56.1±8.3 (3)	136±6 (3)
1997				
Turah (USGS)	109±7 (3)	92.9±25 (5)	64.2±18.6 (3)	635±31 (3)
E. Missoula (This study)	67.8 (1)	52.5±10.5 (3)	43.8±5.3 (3)	241.0±42 (3)
E. Missoula (USGS)	89.2±6.4 (3)	54.6±20 (3)	44.4±9.3 (2)	516±62 (3)
Missoula (This study)	46.3 (1)	24.7±1.0 (2)	42.0+14.8 (3)	335.3±51 (3)
Alberton (This study)	37.4 (1)	16.4 (1)	44.1±2.8 (2)	156.0±3 (3)
Alberton (USGS)	42.1±4.7 (3)	28.6±6.9 (4)	49.7±7.7 (2)	192±17 (3)

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