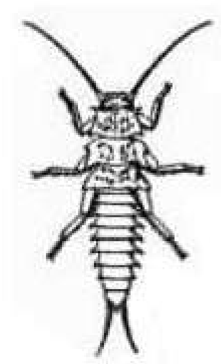

2001 Kootenai River Macroinvertebrate Contaminant Study

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Abstract

Benthic organisms can be exposed to a host of contaminants associated with sediments and water. The sedentary nature of benthic macroinvertebrates makes them a good indicator of direct exposure at the site where they are collected. The purpose of this project was to determine levels of metals, organochlorine pesticides and Aroclor PCBs in macroinvertebrates collected from 6 sites in the Lower Kootenai River, throughout a 1-year period. Rock basket, substrate mat and multiplate samplers were used to collect macroinvertebrates. Samplers were picked clean on a monthly basis and monthly samples were composited by site. The Shorties Island and Crossport sample sites produced the smallest and largest sample sizes, respectively. A total of 25 metals, 11 organochlorine pesticide and 3 Aroclor PCB compounds were detected in macroinvertebrate tissues. Concentrations of metals and Organochlorines indicated a relatively even distribution of compounds throughout the Lower Kootenai River. The Shorties Island sample contained the highest number of metal compounds and the Porthill sample contained lead levels that were 4-5 times higher than samples from the other sites. When compared with tissue levels of metals and organochlorine compounds in Kootenai River white sturgeon, macroinvertebrate tissues generally contained higher concentrations. The lipid:organochlorine content of macroinvertebrates was 1:21. Samples from Shorties Island, Crossport and Troy contained higher lipid content than samples from Copeland, Porthill or Kootenay Lake.

Acknowledgements

Thank you to Genny Hoyle for assistance with sample collection. Thanks also to the staff at the Kootenai Tribal hatchery for assistance with equipment. Funding was provided by Bonneville Power Administration through Project #198806400 – Kootenai River White Sturgeon Studies.

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Introduction

Limitations to secondary productivity (i.e. macroinvertebrates) and resulting effects on fish populations in the Kootenai River ecosystem are an important issue (KRSS 2000). Sources of potential limitations include in-stream and riparian habitat degradation, declining primary productivity, overgrazing by predatory species and contaminants. While various projects are addressing the other limiting factors, this project focuses on the contaminant issue.

Benthic organisms are exposed to a host of sediment-bound and temporarily stabilized contaminants (specifically metals and organochlorine compounds) and are known to bioaccumulate them (Krantzberg 1989). Because benthic macrinvertebrates are not migratory, it is likely that concentration levels indicate direct exposure at each sampling site. However, many benthic macroinvertebrates make diurnal migrations to and from the sediment/water interface, increasing their availability to predators and creating a vehicle for mobilization of sediment-bound and stabilized contaminant compounds (Evans and Lasenby 1983). If organisms take up compounds from the sediment and are consumed by other organisms, the contaminants can be re-mobilized and re-entered into the food chain. The contamination of benthic food organisms can be a significant health hazard for higher food chain organisms (Woodward et. al 1995).

The biomonitoring of contaminants in aquatic ecosystems is best achieved through the collection of biota representative of several trophic levels (Zaranko et. al 1997). Therefore, this project compliments concurrent studies assessing contaminant effects on Kootenai River white sturgeon, *Acipenser transmontanus* (Kootenai Tribe of Idaho; Kruse and Scarnecchia 2002) and non-game fish species as well as contaminant bioaccumulation in primary producers, water and sediment (US Fish and Wildlife Service In Press).

The purpose of this project was to determine levels of metals, organochlorine pesticides and Aroclor PCBs in macroinvertebrates collected throughout a 1-year period from the Kootenai River between Troy, MT and Kootenay Lake, B.C., Canada. The results could indicate potential exposure for higher food chain organisms. The compounds chosen for analysis were selected because they have the highest likelihood of being present from input by dominant industrial activities (i.e. agriculture, mining and hydropower operations).

Methods

Macroinvertebrate samplers (rock baskets, substrate mats, and multiplate samplers) were deployed in January, 2001 at Troy MT, Crossport, Shorties Island, Copeland, Porthill and Kootenay Lake (Figure 1). In order to account for seasonal variability in tissue concentrations, samplers were checked monthly, for 12 months, through December, 2001. During each check, all macroinvertebrates were hand-picked from each sampler at each site (assuming that all organisms would be eligible for predation by other organisms, species, sizes and age classes were combined). Because monthly samples were too small to analyze individually, the 12 monthly samples were composited by site. Samples were frozen and shipped to AXYS Analytical Services Ltd. in Sidney, B.C., Canada for analysis of metals, organochlorine pesticides and Aroclor PCBs (AXYS Analytical 2002, ALS Environmental 2002). Resulting tissue residue data were analyzed for means and ranges of wet weight concentrations. Only results exceeding MDLs were used. Non-detects were removed from the analysis. Results were compared between sample sites.

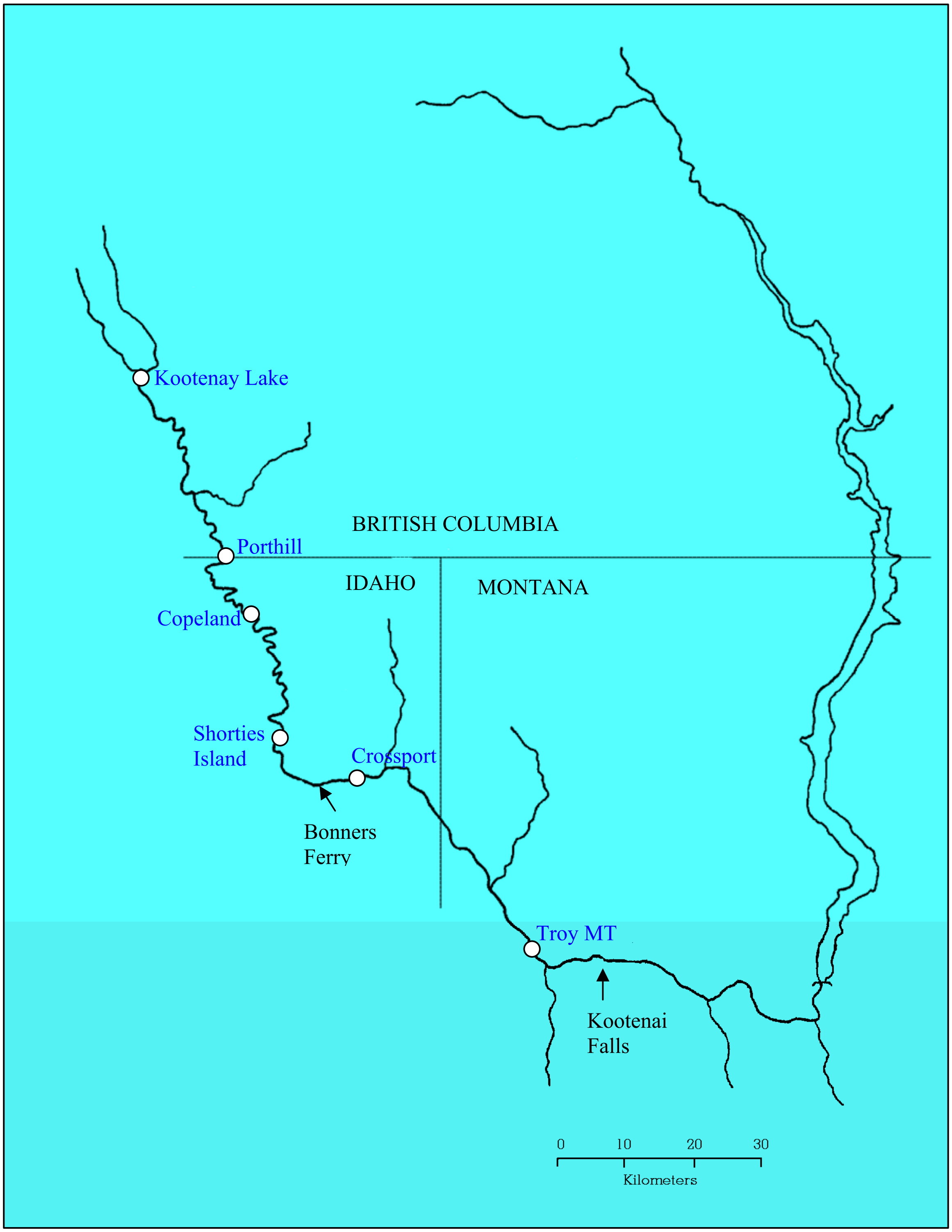

Figure 1. Map of sample sites for the Lower Kootenai River macroinvertebrate contaminant study, 2001.

Concentrations of organochlorine compounds were also converted to lipid-normalized concentrations using the following calculations:

1) Sample size in terms of lipids (lipid wt) = Sample size (g) x % lipids

2) Lipid normalized concentration = $\frac{\text{Concentration of OC compound x sample wet wt (g)}}{\text{Lipid wt (g)}}$

Lipid normalized concentrations were compared with standard detected concentrations and were also used to determine if differing concentrations (among sites and organisms) were attributable to lipid content. Macroinvertebrate tissue concentrations were also compared with bioaccumulated concentrations previously detected in Kootenai River white sturgeon ovarian and whole-body tissues. Lipid:Organochlorine compound ratios were also calculated to assess food web biomagnification in relation to lipid content.

Basic water quality parameters (pH, DO, temp, turbidity/TDS and conductivity) were collected (using either a Hach 156 multiprobe or a Hydrolab) at each sample site from January through September. Water quality data was summarized by site and month.

Results

The smallest sample sizes were collected at Shorties Island and the largest sample was collected at Crossport (Figure 2). Macroinvertebrate species collected include members of the Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Chironomidae and Oligochaeta families. Troy, Crossport and Shorties Island samples contained higher lipid content than Copeland, Porthill or Kootenay Lake samples (Figure 3). The sample collected at Crossport contained the highest concentration of lipids (Figure 3).

Macroinvertebrate tissues were analyzed for 29 metal, 32 organochlorine pesticide and 3 Aroclor PCB compounds. Of these, 25 metals, 11 organochlorine pesticides and 3 Aroclor PCBs were detected in tissues (Tables 1 & 2). Although most metal compounds were detected at greater than 50% of the sites, arsenic, cadmium, molybdenum, tin and vanadium were only detected at one to three of the six total sites (Figure 4a-4e). Levels of all metals varied between sites.

The PCB Aroclor 1260, and the organochlorine pesticides hexachlorobenzene and p'p' DDE were detected at all sites. Detection of other organochlorine compounds was not consistent among sites (Figures 4f-4h). Lipid normalized concentrations of organochlorine compounds were up to 85 times that of the standard detected concentrations (Table 3). The lipid:organochlorine compound (pesticides and Aroclor PCBs) ratio for macroinvertebrate samples was 1:2073. Water quality data are displayed in figure 5.

Table 1. Concentrations (wet weight) of metals detected in macroinvertebrates collected from the Kootenai River between Troy, Montana and Kootenay Lake, B.C., Canada, January-December, 2001.

Metal compound	Number of samples (% of total samples)	Concentration (ppm)	
		Range	Mean+SD
Aluminum	6 (100)	167.000 - 566.000	299 + 140.509
Arsenic	1 (17)	2.000	NA
Barium	6 (100)	6.300 - 24.500	10.733 + 6.983
Cadmium	6 (100)	0.200 - 0.700	0.333 + 0.197
Calcium	6 (100)	3300.000 – 9410.000	6351.667 + 2820.960
Chromium	6 (100)	1.600 - 4.500	2.667 + 1.147
Cobalt	6 (100)	0.200 - 0.800	0.400 + 0.210
Copper	6 (100)	2.900 - 9.700	7.383 + 2.625
Iron	6 (100)	368.000 – 1220.000	575.833 + 323.384
Lead	5 (83)	0.900 - 7.700	2.500 + 2.928
Lithium	6 (100)	0.100 - 0.400	0.250 + 0.105
Magnesium	6 (100)	258.000 – 754.000	517.500 + 159.191
Manganese	6 (100)	29.000 – 184.000	64.783 + 58.830
Mercury	6 (100)	0.005 - 0.022	0.011 + 0.006
Molybdenum	2 (33)	0.200 - 0.300	0.250 + 0.071
Nickel	6 (100)	1.400 - 3.000	2.017 + 0.634
Phosphorus	6 (100)	1490.000 – 1920.000	1691.660 + 138.912
Potassium	6 (100)	857.000 – 1780.000	1407.833 + 301.589
Sodium	6 (100)	696.000 – 971.000	826.167+ 97.014
Strontium	6 (100)	3.870 - 9.020	6.487+ 2.229
Thallium	6 (100)	3.000 - 6.000	5.167+ 1.169
Tin	1 (17)	0.800	--
Titanium	6 (100)	6.3000 - 96.000	24.983 + 35.120
Vanadium	3 (50)	0.600-1.200	0.833 + 0.321
Zinc	6 (100)	15.600-67.500	39.367 + 18.048

Table 2. Concentrations (wet weight) of Organochlorine pesticides and Aroclor PCBs detected in macroinvertebrates collected from the Kootenai River between Troy, Montana and Kootenay Lake, B.C., Canada, January-December, 2001.

Organochlorine compound	Number of samples (% of total samples)	Concentration (ppb)	
		Range	Mean+SD
Pesticides			
Hexachlorobenzene	6 (100)	0.081 – 0.647	0.241 + 0.206
Heptachlor	5 (83)	0.000 – 0.819	0.174 + 0.361
Aldrin	3 (50)	0.092 – 0.249	0.191 + 0.086
Oxychlordane	2 (33)	0.259 – 0.288	0.273 + 0.021
o'p'-DDE	2 (33)	0.014 – 0.040	0.027 + 0.019
p'p'-DDE	6 (100)	0.261 – 1.150	0.580 + 0.331
Trans-Nonachlor	3 (50)	0.041 – 0.045	0.044 + 0.002
p'p'-DDD	1 (17)	0.245	--
o'p'-DDT	1 (17)	0.097	--
p'p'-DDT	2 (33)	0.151 – 1.040	0.595 + 0.629
Aroclor PCBs			
Aroclor 1016/1242	1 (17)	0.106	--
Aroclor 1254	3 (50)	0.275 – 0.284	0.279 + 0.005
Aroclor 1260	6 (100)	0.286 – 9.560	3.816 + 3.242
Percent Lipids	6	1.500 – 3.600	2.567 + 0.709
Sample weight	6	1.030 – 9.040	4.977 + 2.914

Table 3. Lipid normalized wet weight concentrations of Organochlorine pesticides and Aroclor PCBs detected in macroinvertebrates collected from the Kootenai River between Troy, Montana and Kootenay Lake, B.C., Canada, January-December, 2001.

Organochlorine compound	Number of samples (% of total samples)	Lipid Normalized Concentration (ppb)	
		Range	Mean±SD
Pesticides			
Hexachlorobenzene	6 (100)	4.643 – 22.310	9.720 ± 6.969
Heptachlor	5 (83)	1.356 – 28.241	14.798 ± 19.011
Aldrin	3 (50)	3.293 – 15.400	9.840 ± 6.114
Oxychlordane	2 (33)	7.167 – 10.286	8.726 ± 2.205
o'p'-DDE	2 (33)	0.486- 1.119	0.802 ± 0.448
p'p'-DDE	6 (100)	0.261 – 1.150	0.580 ± 0.331
Trans-Nonachlor	3 (50)	1.244 – 1.974	1.562 ± 0.374
p'p'-DDD	1 (17)	10.652	--
o'p'-DDT	1 (17)	4.230	--
p'p'-DDT	2 (33)	6.565 – 45.217	25.891 ± 27.331
Endosulphan sulfate	1 (17)	56.200	--
Aroclor PCBs			
Aroclor 1016/1242	1 (17)	2.944 – 16.533	10.058 ± 6.817
Aroclor 1254	3 (50)	7.639 – 12.348	9.972 ± 2.355
Aroclor 1260	6 (100)	10.214 – 329.655	145.552 ± 109.233
Percent Lipids	6	1.5 – 3.6 %	2.57 ± 0.71 %
Sample lipid weight	6	0.050 – 0.212 g	0.137 ± 0.112 g

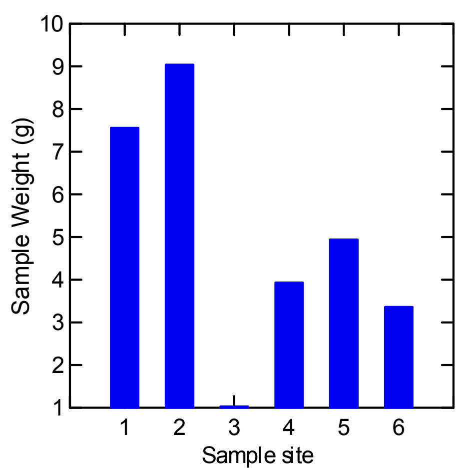

Figure 2. Size (g) of Kootenai River macroinvertebrate samples collected in 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

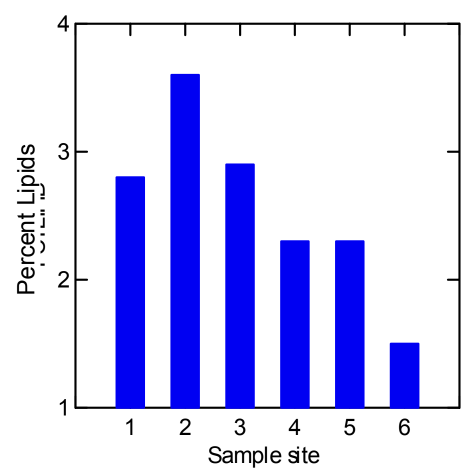

Figure 3. Percent lipid content of Kootenai River macroinvertebrate samples collected in 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

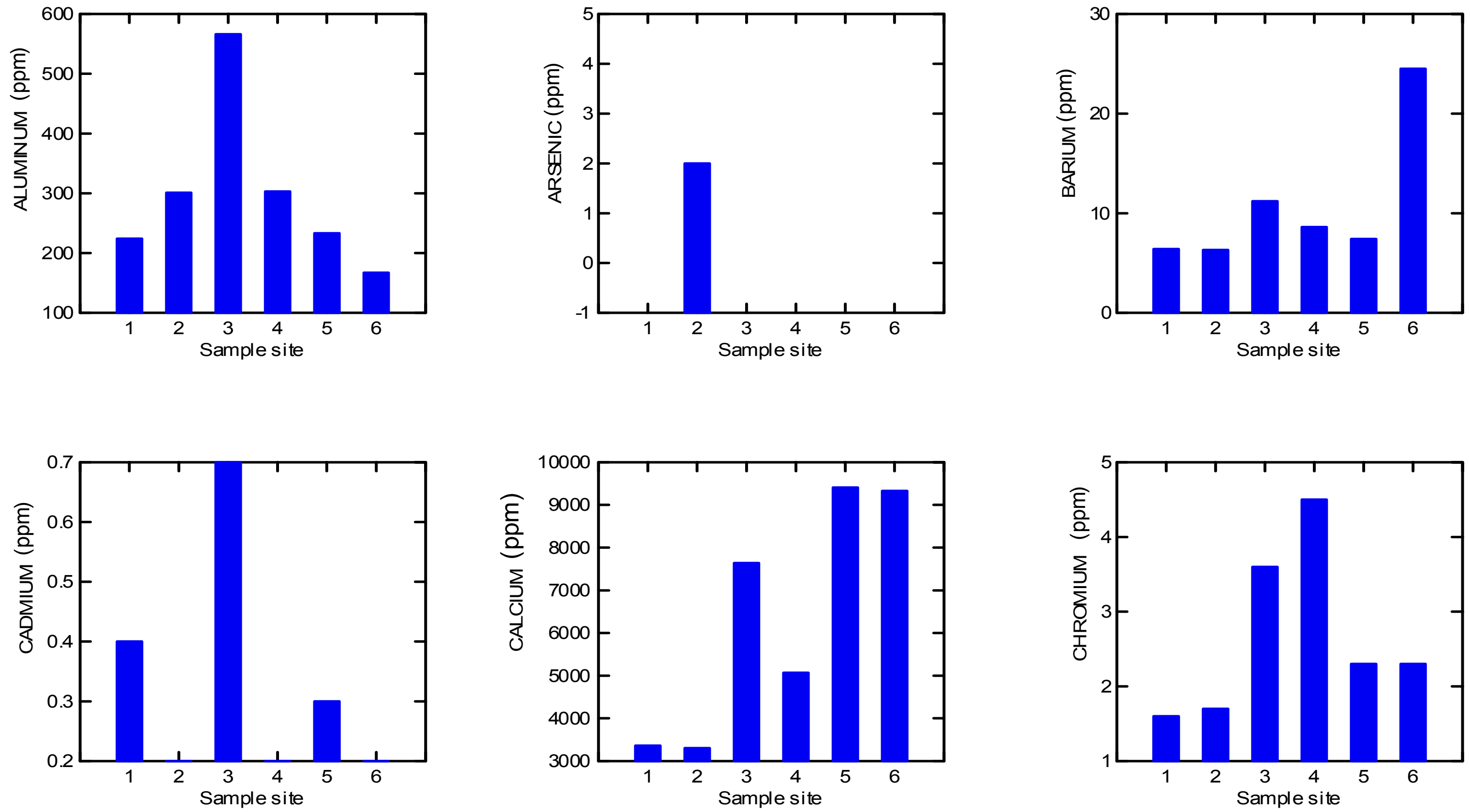

Figure 4a. Concentrations (wet weight; ppm) of aluminum, arsenic, barium, cadmium, calcium and chromium detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

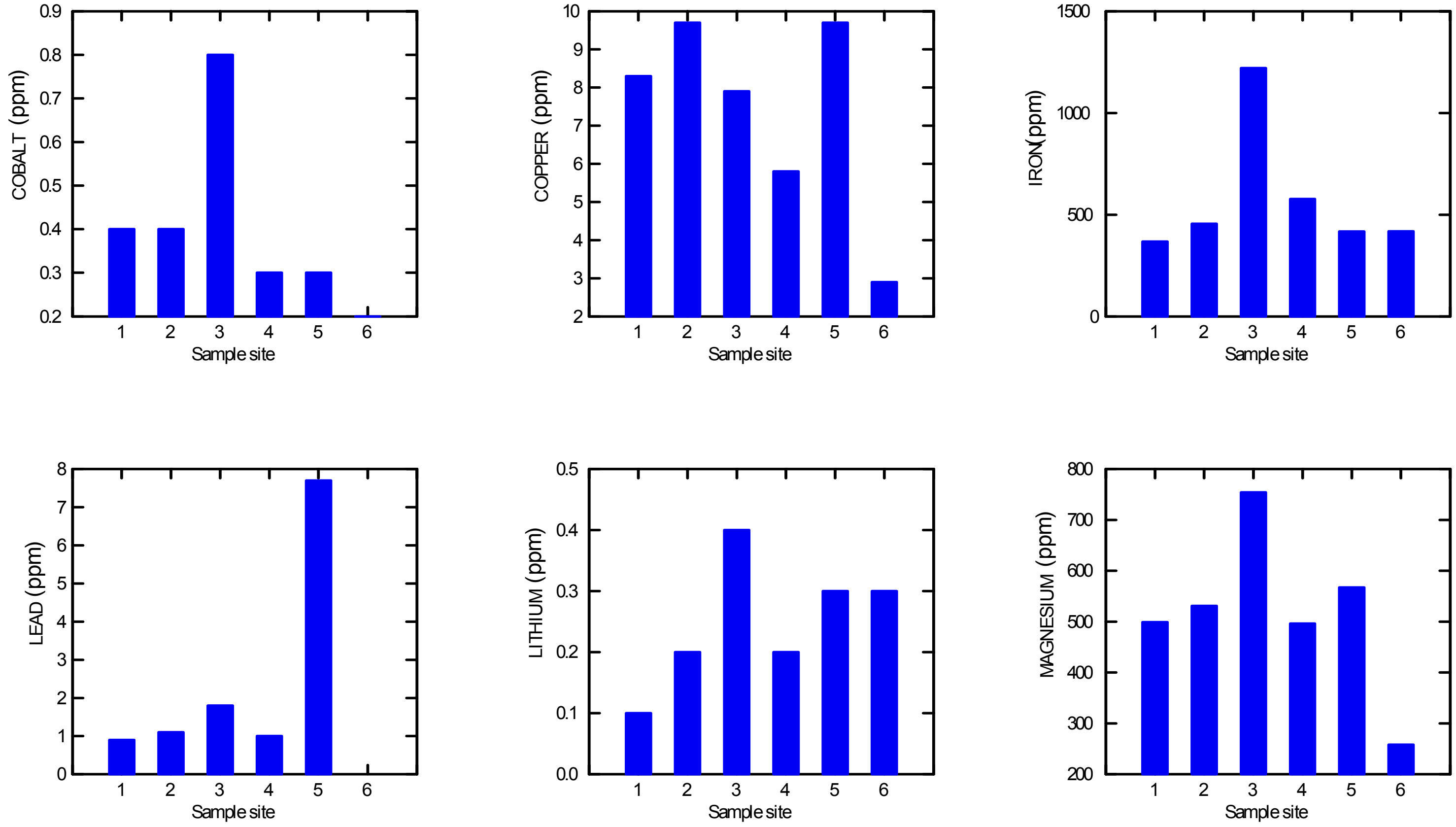

Figure 4b. Concentrations (wet weight; ppm) of cobalt, copper, iron, lead, lithium and magnesium detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

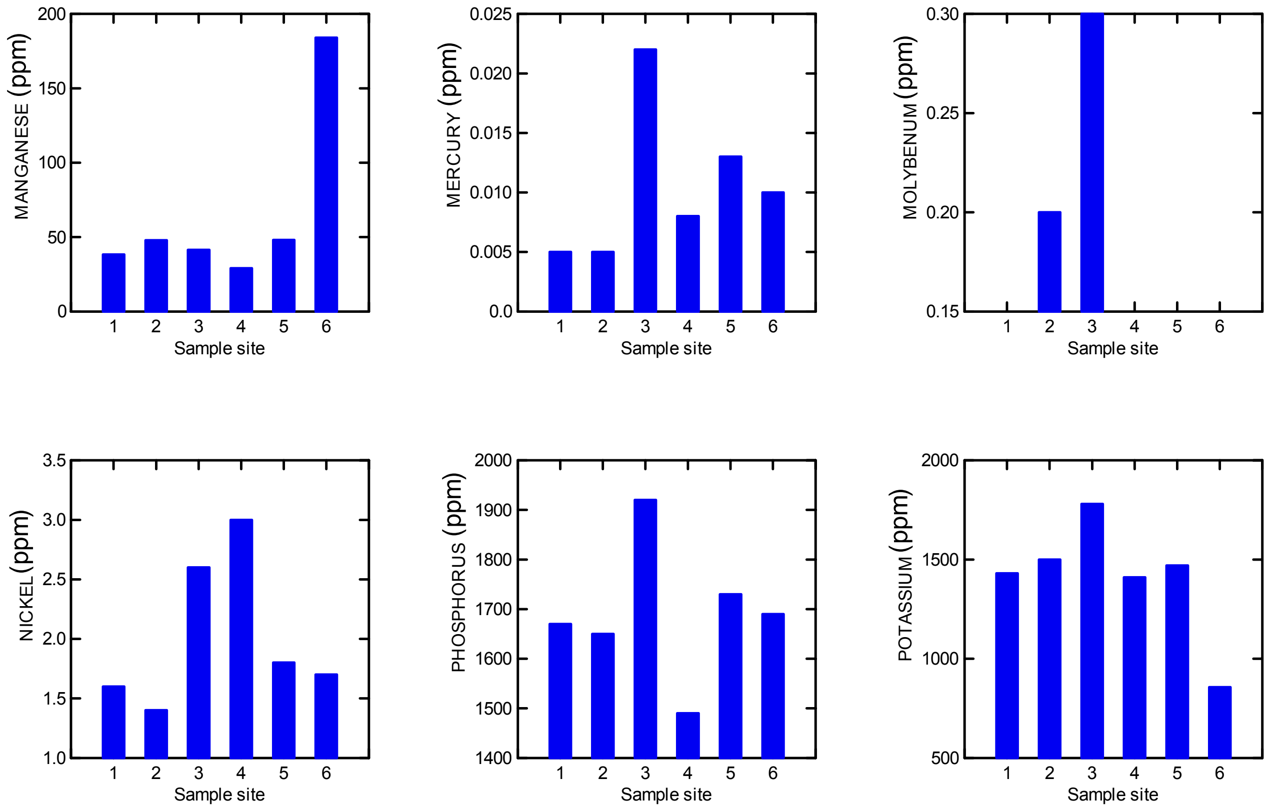

Figure 4c. Concentrations (wet weight; ppm) of manganese, mercury, molybdenum, nickel, phosphorus, and potassium (ppm) detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

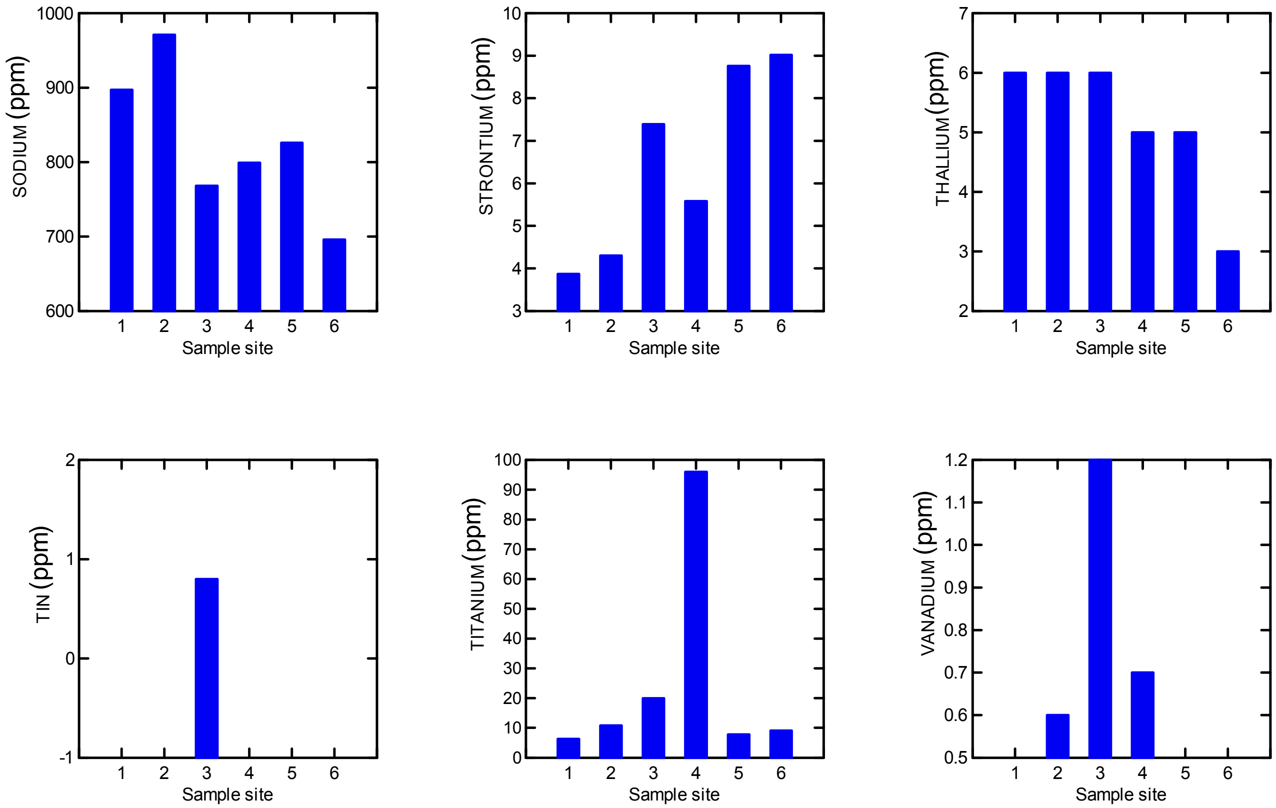

Figure 4d. Concentrations (wet weight; ppm) of sodium, strontium, thallium, tin, titanium and vanadium detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

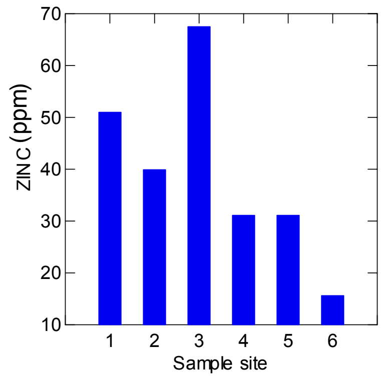

Figure 4e. Concentrations (wet weight; ppm) of zinc detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

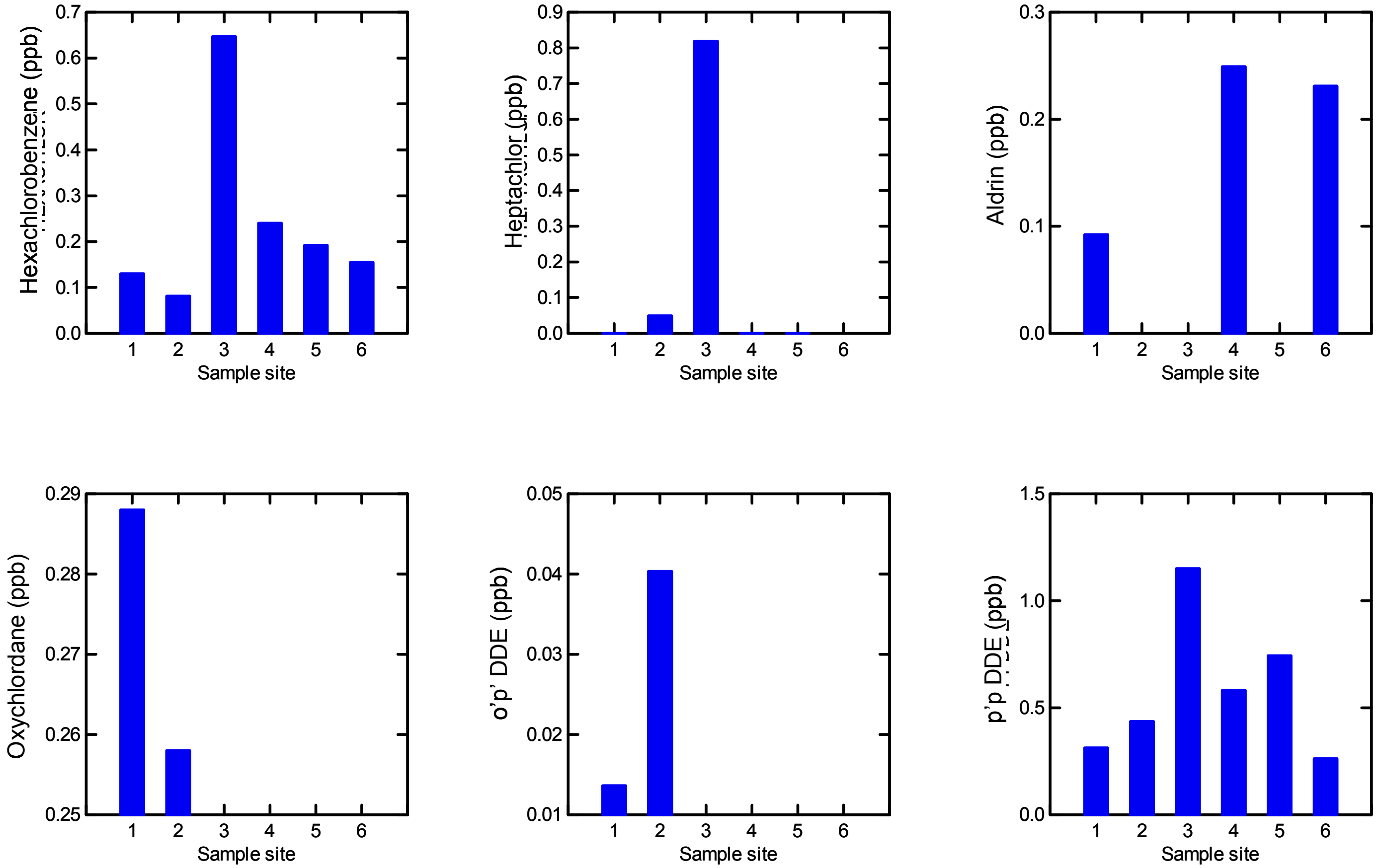

Figure 4f. Concentrations (wet weight; ppb or ng/g) of hexachlorobenzene, heptachlor, aldrin, oxychlordane, and DDE (organochlorine pesticides) detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

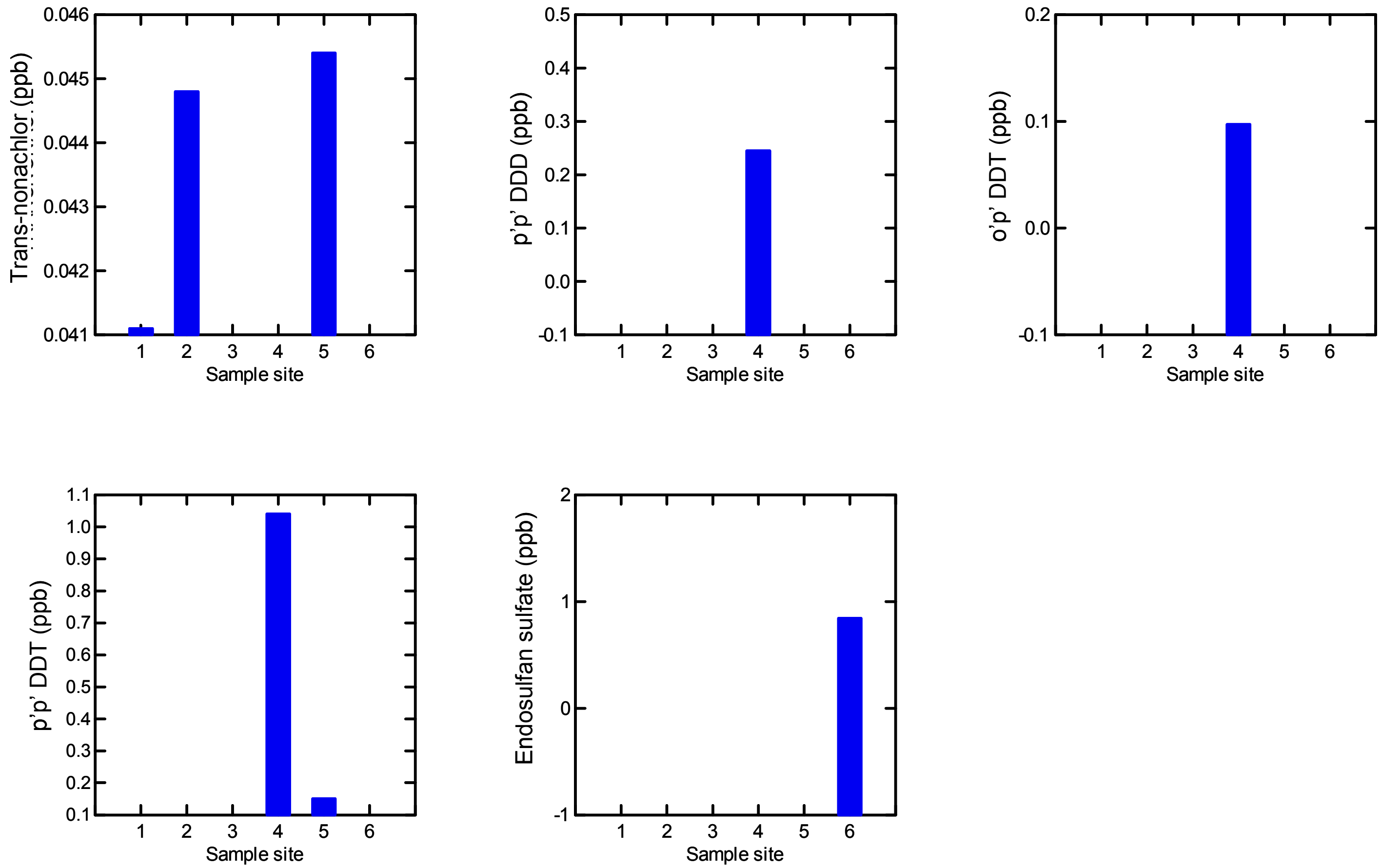

Figure 4g. Concentrations (wet weight; ppb or ng/g) of trans-nonachlor, p'p DDD, DDT, and endosulfan sulfate (organochlorine pesticides) detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

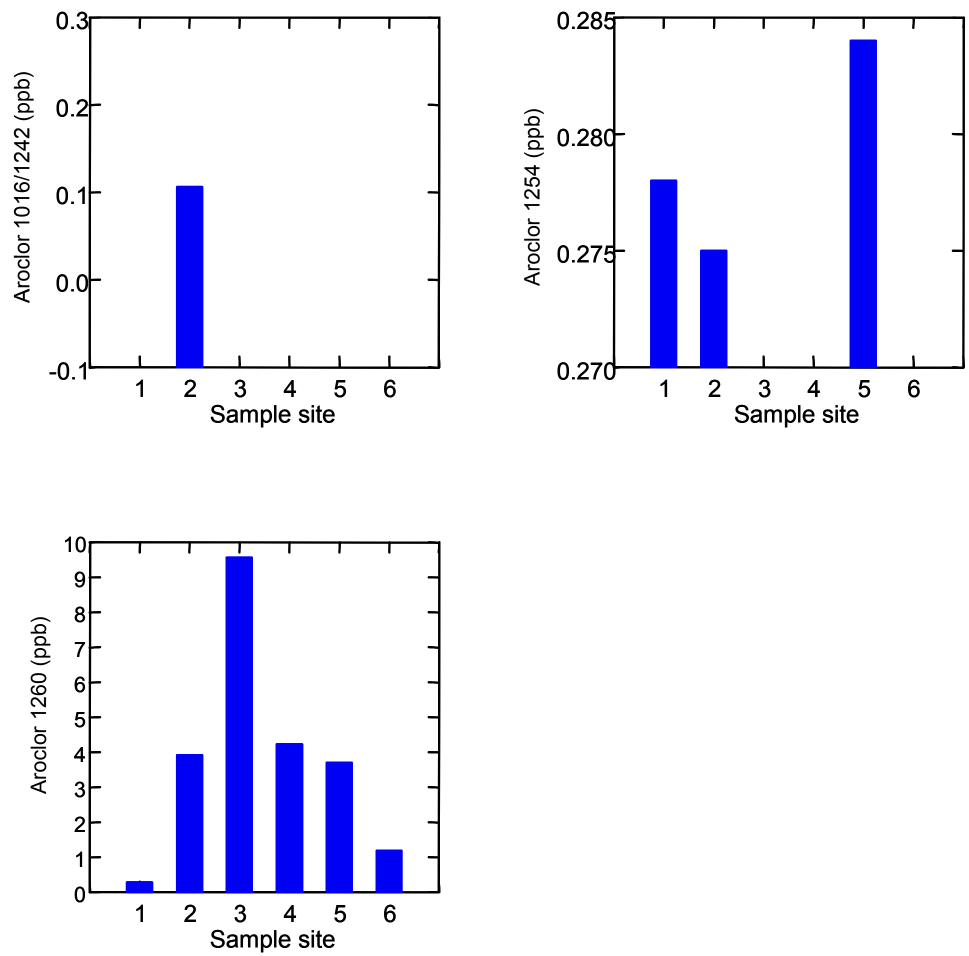

Figure 4h. Concentrations (wet weight; ppb or ng/g) of Aroclor 1016/1242, Aroclor 1254 and Aroclor 1260 (PCBs) detected in Kootenai River macroinvertebrates, 2001. 1=Troy, 2=Crossport, 3=Shorties Island, 4=Copeland, 5=Porthill, 6=Kootenay Lake

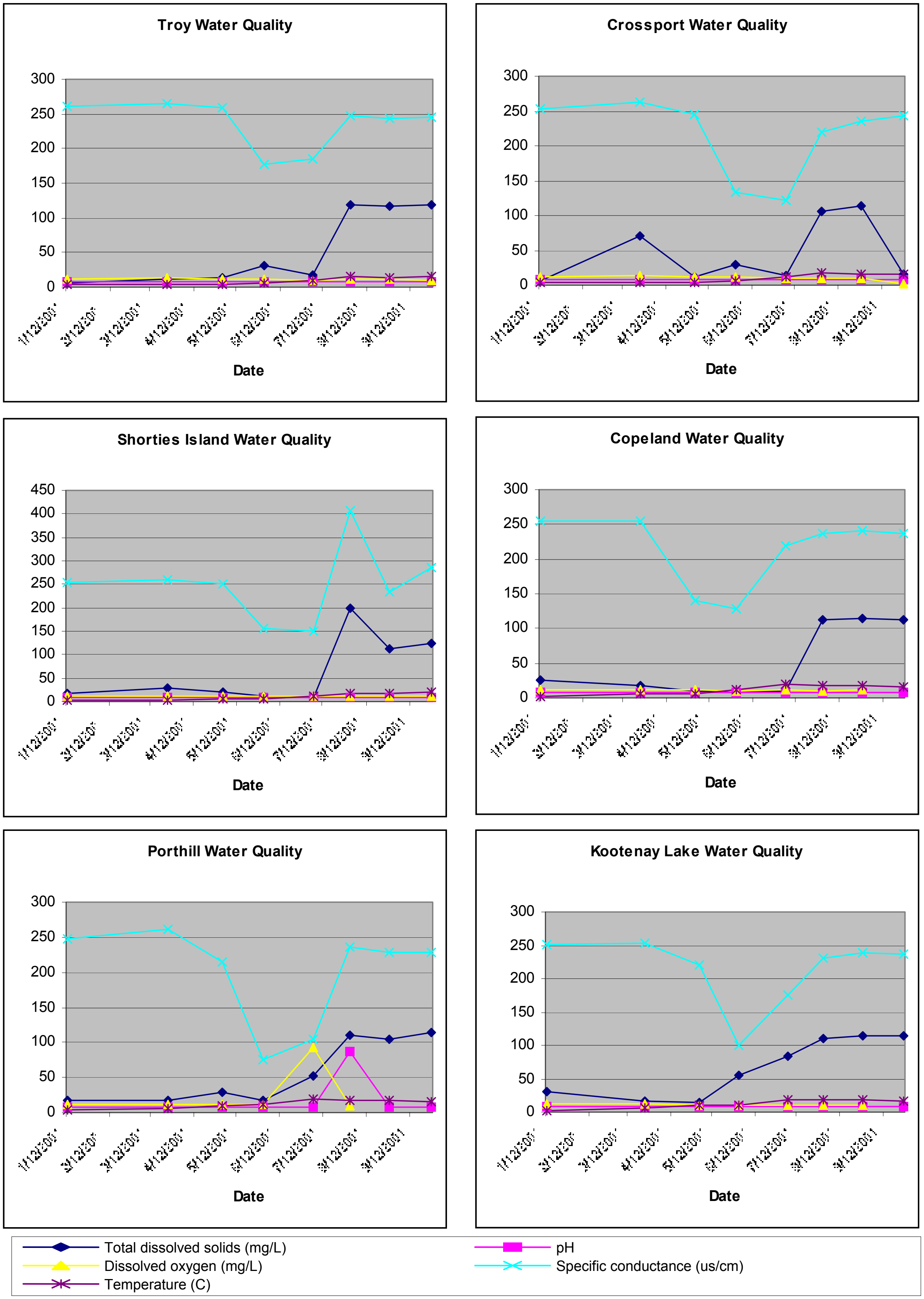

Figure 5. Water quality data for Lower Kootenai river macroinvertebrate sample sites, January-September, 2001.

Discussion

Patterns of bioaccumulation are variable for different xenobiotic compounds and can be influenced by seasonal influences on metabolic activity, life stage or by organism speciation (Heath 1995). Collection of samples over a 12 month period and compositing samples from all 12 months (for each site) should theoretically mask any variation due to these factors and provides an overall estimate of body burden (and bioaccumulation potential for predatory species) throughout the year.

Concentrations of metals detected in macroinvertebrates indicated a relatively even distribution of compounds throughout the lower Kootenai River. Two exceptions were the Shorties Island and Porthill sites. The Shorties Island sample contained the highest concentrations for 10 of 20 metals of significance. Potential sources of metals contaminantion are unclear for the Shorties Island reach. Levels of lead were 4-5 times higher at the Porthill site, below the mouth of Boundary Creek. The high lead levels are potentially due to lead in runoff from the Continental Mine on Blue Joe Creek, a tributary to the headwaters of Boundary Creek (Maxim Technologies 2003). When compared to the other sampling sites, levels of copper, barium and strontium were also relatively high at the Porthill site.

Macroinvertebrates can tolerate and control bioaccumulation of zinc (Krantzberg and Stokes 1989); however, they are less able to tolerate lead and cadmium loading. The food-chain effect of metals has been described as a relationship in which biomagnification is not observed and bioconcentration factors are small, but the amount of metal transferred by food can be high enough to attain biologically harmful concentrations in fish (Dallinger et al. 1987). Younger fish and benthic fish are more susceptible than older or pelagic fish because their diets consists primarily of benthic organisms (Woodward et al. 1995). Except for the fact that mercury, arsenic and selenium levels were higher in juvenile and adult sturgeon tissue (Kruse 2000), all other metal concentrations were higher in macroinvertebrate tissues.

Aquatic organisms are capable of bioaccumulating organochlorine comounds (i.e. PCBs and organochlorine pesticides; lipophillic or fat-loving compounds) above concentrations found in their prey (Zaranko et al. 1997). Since organic matter readily sorbs organochlorine compounds and most second-order aquatic organisms (i.e. macroinvertebrates) feed selectivly on organic matter, there is a great potential for PCB uptake through feeding. In addition, these compounds have been shown to be eliminated very slowly or not at all from benthic organisms (Meier and Rediske 1984).

Organochlorine compounds are lipophilic or fat soluble and are generally associated with fat concentrations in the organism. Therefore, it was necessary to calculate tissue concentrations based on lipid content of the samples in order to achieve a more representative value. Lipid normalized concentrations were up to 85 times the standard detected levels and in some cases exceeded levels shown to have adverse effects on macroinvertebrates (Jarvinen and Ankley 1999). Lipid and bioaccumulated organochlorine compound concentrations are assumed to be related (Berglund et. al 2000, Zaranko et. al 1997). Macroinvertebrate samples collected for this study possessed a higher lipid:organochlorine compound (pesticides and Aroclor PCBs) ratio (1:2073) than Kootenai River white sturgeon ovarian tissue (1:67) and juvenile sturgeon tissue (1:48; Kruse 2000). These results indicate that although lipid levels were 2-3 times lower in macroinvertebrate than in sturgeon tissue, biomagnification in sturgeon tissue was not apparent and macroinvertebrates actully bioaccumulated higher concentrations of organochlorine compounds than the sturgeon. Other studies have also failed to find evidence of biomagnification in relation to lipid content and food web placement (Berglund et. al 2000).

At this point the source of organochlorine compounds is unclear. However, it is suspected that historic input of contaminants from agricultural operations (pesticides), Libby Dam (i.e. PCBs from transformers) and other industrial operations throughout the basin are potential sources. Of the 14 organochlorine compounds detected, only hexachlorobenzene, DDE and the PCB Aroclor 1260 were present in macroinvertebrates collected from all sites. However, some of the compound levels detected in samples from only one or two sites were at concentrations that could potentially reduce survival of macroinvertebrates (Jarvinen and Ankley 1999).

It is recommended that this study be conducted again in the near future and that sampling efforts for all levels of food chain organisms and be aligned with sampling of water and sediment characteristics. In order to adequately assess bioaccumulation throughout the food chain all elements and biota (algae, macroinvertebrates, fish, water and sediments) should be collected during the same time frame (i.e. every 5-10 years for 12 months).

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