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Temporal and Spatial Variability of Metal Concentrations in Fine-Grained Bed Sediments and Benthic Insect Larvae of the Clark Fork River, Montana

by

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Temporal and Spatial Variability of Metal Concentrations in Fine-Grained Bed Sediments and Benthic Insect Larvae of the Clark Fork River, Montana.

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The scale and magnitude of variability in metal contamination of fine-grained bed sediments and two taxa of benthic insect larvae (*Hydropsyche occidentalis* and *Isogenoides sp.*.) was determined for one hydrocycle along 200 km of an acid-mine waste contaminated river (Clark Fork River, Montana, U.S.A.). B-type and transition metals behaved congruently, thus Cu and Fe are presented as representative. Spatial variability, distribution away from source, was significant in both sediments and insects. Temporal variability in sediments and insects was also significant. The magnitude of spatial and temporal variation in both sediments and insects decreased with decreasing sampling scale. Spatial distribution of sediment metal concentrations seems to result from dilution away from the source. Temporal variability in sediment metal concentrations could not be strongly correlated with either discharge or TSS. Insect metal concentration distribution corresponds to relative sediment metal concentrations, but temporal variability seems under other, possibly physiologic controls. Coatings of predominantly Mn-oxides, as those on *H. occidentalis*, are a possible mechanism of insect metal concentration variation.

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Introduction

Bioavailability controls the impact of trace metal contamination on biota. The most bioavailable forms of metals are those which can be absorbed and incorporated by biologic systems, making ions the most bioavailable species in solution. Although metal ions in solution are much more bioavailable than metal species found in association with sediments, Luoma (1989) states that the source of metals in at least some aquatic biota is from bed sediments. Metal concentrations in aquatic bed sediments tend to exceed concentrations in the water column by several orders of magnitude, compensating for lower bioavailability of sediment bound metals (Luoma 1989). Distribution coefficients for Cu in the Clark Fork River, Montana, U.S.A., as an example, can range as high as 2.7×10^5 (sediment data from this study, water data from U.S.G.S., Helena, MT., pers. comm.). Acidity and redox changes in the environment or body (e.g. gut or gill surfaces) of an animal can increase the bioavailability of sediment- or particulate-associated trace metals. Bioaccumulation is one result of elevated levels of bioavailable metals in the environment. Animals without effective metal regulation can accumulate higher concentrations over time. This can continue until the metal levels in the animal actually exceed environmental concentrations (bioconcentration). Biomagnification results as animals at higher trophic levels accumulate metals at greater concentrations than their prey (Timmermans 1993)

These sediment-biota relationships are especially significant in river systems contaminated with metal-rich wastes from large-scale mining and smelting. The Upper Clark Fork River Basin of western Montana has sustained extensive environmental damage consequential to the mining of sulfide ore deposits containing Ag, Cu, Pb, and Zn (Nimick and Moore 1991). Mineral exploitation in the Butte and Anaconda areas began in the 1860's before the practice of constructing mine or mill waste containment facilities. Waste rock and mill tailings were disposed of in the channel and along the flood plain of the Clark Fork River and some of its headwater tributaries. These primitive mining practices, coupled with flooding near the turn of the century, have resulted in downstream flood plain deposits of mine tailings in excess of two million cubic meters (Moore and Luoma 1990). Much of the 10 M tons of mine waste introduced to the river is fine-grained (Nimick and Moore 1991). This aspect alone, regardless of metal contamination, has altered the character of the Clark Fork River which is predominantly cobbled bed. As well, metal-contaminated overbank deposits killed existing riparian vegetation, leaving a legacy of naked slickens along Silver Bow Creek and the Upper Clark Fork River. These deposits continue to be a source of elevated levels of Ag, As, Cd, Cu, Fe, Mn, Ni, Pb, and Zn to the aquatic ecosystem (Nimick and Moore 1991). To assess bioavailability and the biological impact of this contamination, measurements of the sediments and biota are necessary (Lynch et al. 1988; Luoma 1989).

Different sediment types and aquatic larval insect species along the Clark Fork River have been sampled for trace metal analysis for a number of years (Brooks and Moore 1989; Axtmann et al. 1990; Nimick and Moore 1991). Fine-grained bed sediments have been sampled in the Clark Fork River because: 1) much of the fine-grained sediment originated as tailings; 2) the < 63 mm grain size fraction possesses the most interactive factors in trace metal adsorption - increased surface area, clay minerals, organic matter and Mn-Fe oxides; and

3) the fine-grained bed sediments at the water-substrate interface are usually considered responsible for active downstream transport and exchange of trace metals and hence influence bioavailability (Horowitz 1982; Salomans and Forstner 1984; Elder 1988). Aquatic invertebrates are useful in monitoring contaminated systems because they can provide a record of long-term biotic response to contamination and to periodic events that might escape a program of intermittent monitoring of the sediments only (Lynch et al. 1988). Benthic insect larvae, in particular, serve this purpose as they live in close contact with contaminated sediments, and are relatively easily sampled in adequate numbers for analysis. Benthic living caddisflies are omnivorous filter feeders and provide an indication of bioconcentration and rates of bioaccumulation. They are metal tolerant and have a history as subjects of contamination research (Resh and Unzicker 1975; Darlington and Gower 1989; Axtmann et al. 1990; Gower and Darlington 1990; Moore et al. 1991). Stoneflies prey on other benthic species and allow us to monitor biomagnification of metals in the food chain; taxa from the Perlodidae have been sampled in the Clark Fork River and its tributaries in previous studies (Axtmann et al. 1990; Moore et al. 1991).

For one hydrocycle we sampled fine-grained bed sediments and two species of caddisflies of the genus *Hydropsyche* (family Hydropsychidae, order Trichoptera), *H. occidentalis* and *H. cockerelli*; and two genera of stoneflies of the family Perlodidae (order Plecoptera), *Isogenoides sp.* and *Skwalla sp.*. Data revealed continuous change in the levels of contamination in both sediments and biota. Such variability is an intrinsic characteristic of natural systems. To interpret measurements accurately, the magnitude and scale of spatial and temporal variability in the measured parameters should be understood.

Unknown temporal variability in contaminant concentrations in sediments and biota can result in faulty interpretations (Thomson-Becker and Luoma 1985; Morrisey et al. 1992). However, detailed examination of temporal variations in trace metal concentrations within bed sediments or animal populations is rare, even though determination of temporal/spatial variability is necessary in implementing an effective monitoring system. In an attempt to address contamination variability, this study quantifies the temporal and spatial variability of trace metal concentrations in the fine-grained bed sediments and two taxa of aquatic benthos of the Clark Fork River, Montana.

Methods

Study Area

A main tributary of the Columbia River, the Clark Fork River drains all of western Montana. Water and sediments from the most contaminated reaches find their way into populated stretches of the river and multiple use reservoirs. To study the spatial and temporal distribution/variability of this extensive contamination, we located four sampling stations on a 200 km reach of the Upper Clark Fork River downstream from Warm Springs Creek (Fig. 1). Three stations (Deer Lodge, Gold Creek, and Turah Bridge) were located near U.S.G.S. gauging stations to have available water chemistry and stream flow data (Lambing, J., U.S.G.S., Helena, MT, pers. comm.). An additional sediment sampling station was established at Bearmouth, intermediate between Gold Creek and Turah Bridge, the two stations farthest apart. Benthic insects were sampled from riffle areas at Deer Lodge, Gold Creek, and Turah Bridge stations. By sampling sediments and insects from the same stations on the same dates, we hoped to identify any correspondences between sediment metal levels and variability and accumulation and variability in the insect larvae sampled.

Interpretation of data is affected by variance within spatial or temporal sampling intervals. Different sampling scales utilize measurements at different intervals as replicates. Whether means are calculated from replicates which are monthly, seasonal, or annual measurements, for example, can change the amount of variation expected between means. We analyzed spatial variability in sediment and insect metal concentrations on scales of entire study reach, upper and lower sections, and within stations. To test temporal variability, we segregated the data on annual (15 or 13 month), seasonal (sediment only) and monthly scales.

The year of the study, Oct. 1991 - Dec. 1992, was a low water year with an early spring runoff (Fig. 2) (see Appendix I for additional hydrographs).

Sediment

We sampled for 15 months (to encompass one hydrocycle), bimonthly from October 1991 to April 1992, and monthly from June 1992 to December 1992. Three or four fine-grained bed sediment sample replicates were collected as composites of an ~50 m stretch of channel at each sampling station. A 250 ml batch of slurry was collected by sieving sediments and ambient river water through 63 mm nylon sieve. On 21 September 1992 samples of the oxidized top layer of sediments and the underlying reduced sediments were collected separately from two ~ 1 m^2 plots at Deer Lodge, Gold Creek and Bearmouth. Turah Bridge was not included because of insufficient sediment. All samples were packed on ice for transport to the laboratory. After centrifuging for 15 minutes at ~2000 rpm, the water was discarded and the samples were oven dried at 70° C to constant dry weight (~ 24 hours). Dried sediment cakes were ground and a portion collected on paper to a nominal weight of 0.5 gm. Each sample was digested with a concentrated aqua-regia microwave digestion in teflon digestion vessels (after Essig and Moore, 1993). Digestion batches included duplicates, spikes, blanks and standards (U.S.G.S. SED2). The digests were decanted into polypropylene centrifuge tubes, rinsing repeatedly with Milli-Q water to ensure removal of digest. After diluting with Milli-Q water to a nominal weight of 50 gm, digests were centrifuged at ~ 2500 rpm for 5 minutes to clarify and then decanted into 2 oz. Nalgene storage bottles for later analysis.

Concentrations of trace metals were determined using inductively coupled argon plasma emission spectrometry (ICAPES). Tables 1 and 2 list limits of detection, percent recovery of standard, duplicate, and spike analysis, and percent standard deviation of Cd, Ni, Co, Cu, Zn, Mn, Fe and Ca concentrations in sample replicates.

Insects

Sampling was conducted bimonthly, except when severe weather interfered, for a 13-month period from October 1991 until October 1992. This schedule was intended to encompass all life stages of the larvae and one complete hydrocycle. Benthic insect larvae were collected using nylon mesh kick nets in the riffle areas at the Deer Lodge, Gold Creek, and Turah Bridge sediment sampling stations. Two types of insects were collected: caddisflies of the order Trichoptera, family Hydropsychidae and stoneflies of the order Plecoptera, family Perlodidae. On site, insects were sorted by family using plastic acid-washed forceps and placed in acid washed, quart size, plastic storage containers with ambient river water.

Ideally, a sample was considered complete when enough individuals had been collected to comprise a minimum of four replicates from each family. It was desirable to have samples of at least 80 stoneflies and 400 caddisflies per station. During depuration (clearing sediments from the gut) and transport to the lab, the storage containers were kept on ice. At the lab the insects were rinsed with deionized water and packed with a minimum of liquid in plastic Ziploc bags and frozen. Thawed insects were sorted to genus and species. Three species of Hydropsychidae were determined: *Hydropsyche cockerelli, H. occidentalis,* and *Cheumatopsyche spp.* Within the Perlodidae, larvae were distinguished between two genera: *Isogenoides spp.* and *Skwala spp.* (Merritt and Cummins 1984; Schefter and Wiggins 1981; Cain, D., U.S.G.S.-W.R.D., 345 Middlefield Rd., Menlo Park, CA 94025, pers. comm.). Reference samples were kept. When there was a difference in sizes, insects were separated accordingly and measured from the anterior of the head segment to the posterior of the last abdominal segment. Sorted insects were rinsed clean of particulates in ultra-clean Milli-Q deionized water. Beginning in April 1992, caddisflies that were apparently accumulating a coating, were preserved separately in ethanol for SEM-EDX analysis to determine the composition of the coating.

Each species or genera was divided into as many replicates as possible and each replicate placed in a tared glass vial. The desired minimum dry weight of each replicate was 50 mg. The insect samples were oven dried at 70° C to constant dry weight. Dried insect samples were digested by hot 16N HNO_3 reflux (after Cain et al. 1992).

Analysis of trace metal concentrations in the insect samples was by ICAPES. Six initial instrument standardizing solutions and a method blank at the beginning and end and after every 10-15 samples were run during analysis. Six bovine liver biological standards (NBS 1577a) and 2 blanks were digested and analyzed separately (Table 1). Insect sample metal concentrations obtained were comparable to results from Axtmann et al. (1990) at the same sampling sites and during the same month.

Coatings were analyzed by scanning electron microscope-energy dispersive X-ray (SEM-EDX) at the U.S.G.S., Menlo Park, CA. Samples were thawed immediately before being mounted on glass slides and freeze dried. Samples were coated with gold-palladium for analysis. (see Appendix I for detailed methods).

Results: Variability

Variability in Sediment Metal Concentrations

Many of the metals studied varied spatially and temporally within the study reach. Trends tended to group metals into two suites: Cu-Cd-Zn (B-type metal cations) and Fe-Ni-Co (transition-metal cations) (Stumm and Morgan 1981) (Table 3). Copper and Zn can also be grouped with transition-metals in aquatic environments depending on oxidation state and acidity (Stumm and Morgan 1981). Because of the congruent behavior of the metals in the two suites, discussion of variability can be simplified by using Cu and Fe as representative metals (see Appendix II for complete sediment data).

Spatial variability, downstream distribution, of metal concentrations between stations along the entire reach of river sampled was found to be significant for both Cu ($p<0.001$) and Fe ($p<0.001$) (Fig. 3.A). There was a marked change in concentrations between the upper (Deer Lodge to Gold Creek) and lower (Bearmouth to Turah Bridge) sections. Comparison between the two sections showed both Cu ($p<0.001$) and Fe ($p<0.001$) variability to be significant. However, variability between stations within the upper section was significant for Cu ($p<0.001$) but not for Fe ($p=0.06$). Similarly, within the lower section Cu variability was significant ($p<0.001$) and Fe variability was not ($p=0.15$). Percent standard deviation over the entire reach sampled generally exceeded the percent standard deviation in upper and lower sections and of replicate samples at each site (Table 4.A, replicates in B).

Because of periodic spikes, spatial distribution trends could appear to be quite different than those we found, if sampling was limited to a date when one of the downstream stations exceeded an upstream station in sediment metal concentration. At Bearmouth especially, there were erratic, high measurements of some metals. Copper showed a more consistent downstream distribution trend than Fe.

Temporal variability (Fig. 3.B) in sediment metal concentrations was greatest at a sampling scale of 15 months. The obvious seasonal division in the data comes after April, 1992. This date corresponds to the end of spring runoff; the decrease and lessening of month to month variability; and the change from bimonthly to a monthly sampling schedule. When the data are analyzed to compare concentrations of metals on dates of high or low stream flow (flow above or below the 15 month mean comprise the replicate samples of two populations) no significant variation is found, however (Table 4.B). Comparison of the data from October 1991 to April 1992 (season A) and June 1992 to December 1992 (season B) by ANOVA shows significant variability in Cu and Fe concentrations at Deer Lodge and Gold Creek but not at Turah Bridge. Variability within seasons A and B is significant, excepting Fe concentrations in season A at Deer Lodge. Monthly variability (using means of sample replicates for each date) over the 15 month study interval is significant at all stations for both Cu and Fe (Table 4.B). The variability of the 15 monthly means, as represented by percent standard deviation, generally exceeds the percent standard deviation of seasonal and monthly sample replicates of Cu and Fe concentrations (Table 4.B).

Discussion: ANOVA (95% CI) results allow us to show that metal concentrations vary significantly over the entire reach, between upper and lower sections and between stations. Temporal variability was significant between months for the entire sampling period and generally between seasons. The variability, as percent standard deviation (% STD), generally decreased with decreasing spatial and temporal scale. Therefore, the expected error of data from sampling one location once a year would exceed the error of data from several sampling stations collected on several dates.

Past studies of the Clark Fork River have established a sequential decrease in fine-grained bed sediment metal concentrations downstream from the source of contamination at Butte and Anaconda (Brooks and Moore 1989; Axtmann et al. 1990). This study generally supports the previous findings regarding spatial distribution in sediment metal concentrations. Temporal variability for most metals results in the downstream distribution trend moving up and down the concentration axis over time along the entire study reach. However, downstream stations can periodically exceed upstream stations in concentrations of some metals.

The data show clear temporal variability in all metal concentrations at all the sampling sites. Studies of temporal variations in sediment trace metal concentrations from any aquatic environment in increments of less than a year are rare in the literature (Morrisey et al. 1992, Thomson-Becker and Luoma 1985). In a study of marine sediments, Morrisey et al. (1992) examined temporal variation of Cu, Pb, Zn on a diminishing time scale of months, weeks, days. They wished to determine the effect of temporal variability on accuracy and to delineate a minimum time scale of variability. Not only did they find daily variability of the same magnitude as seasonal variability but also spatial heterogeneities within areas < 4 m diameter. Thomson-Becker and Luoma (1985) found annual, seasonal, and daily variability in several parameters of San Francisco Bay sediments. In the Clark Fork River, we found that sediment trace metal concentrations varied significantly on three time scales: 15 months, seasonal, and monthly. Variation in the data, spatial and temporal, decreased with decreasing scale. Therefore, measurements once a year at only one location on the Upper Clark Fork River can be expected to have greater error than measurements taken at several stations at on several dates.

Variability in Insect Metal Concentrations

Insect data, after ANOVA (95% CI), indicated less significant spatial variability (downstream distribution) in both species of insects than was found in the sediments. Downstream concentrations of Fe occasionally exceeded upstream concentrations. When time was considered, greater significance of spatial distributions of Fe concentrations was revealed. Temporal variability was significant at all scales. The percent standard deviation of the data generally decreased with decreasing sampling scale.

Three species of filter feeding Hydropsychids (caddisflies) were routinely collected: *H. occidentalis*, *H. cockerelli* and a *Cheumatopsyche sp.* . Of these, only data for *H. occidentalis* are reported (other results in Appendix III). *H. cockerelli* occasionally occurred in large numbers, but *H. occidentalis* was always present at all sites. The two species were not combined because of species variability in metal concentrations. Populations of *Cheumatopsyche* during this study were too small to be considered. Of the two stoneflies sampled, *Isogenoides sp.* . were collected more regularly and in greater numbers than members of the genus *Skwala*. Only results for *Isogenoides sp.* . are reported here. The 15 April 1992 sampling coincided with stonefly emergence at all sites along the river. Because stoneflies in the Clark Fork are in the larval stage for ~ two years, members of the next cohort were just large enough to be trapped at Gold Creek and Turah Bridge. No stoneflies were collected at one or more stations on 15 April 1992, 18 June 1992, and 20 August 1992.

Insects were analyzed for Cd, Ni, Co, Cu, Zn, Mn, Fe, and Ca to correspond with data from the sediment samples (see Appendix III for detailed insect data). Measured concentrations of Cd, Cu, Zn and Ca in stoneflies exceeded those in caddisflies. Mn and Fe and its associated metals Ni and Co have higher concentrations in caddisflies. Results of analysis of Cu and Fe concentrations are presented as representative. ANOVA of Cu and Fe concentrations between caddisflies and stoneflies yields p values of <0.05 and <0.001, respectively. The species of benthic insect larvae collected in this study are capable not only of accumulating metals in their tissues over time, but of concentrating some trace metals in ratios that exceed those found in the sediments (e.g. Mn:Fe in caddisflies, Cd:Cu and Zn:Cu in both caddisflies and stoneflies). Evidence of biomagnification exists, in that stoneflies tend to have higher concentrations and ratios of trace metals than hydropsychids.

Plots of the data indicate trends of decreasing metal concentrations in insects away from the source of contamination (Fig. 4). Over the entire reach, ANOVA indicates significant spatial variability in both caddisflies and stoneflies for Cu ($p<0.001$ and $p<0.05$, respectively) but not for Fe concentrations ($p>0.05$) (Table 5.A). When spatial variability along the entire study reach was analyzed by date the results for Fe are significant. The variability within upper and lower reaches — Deer Lodge to Gold Creek and Gold Creek to Turah Bridge, respectively, was not significant except for Cu in caddisflies of the upper reach ($p<0.05$). Copper concentrations maintained a sequential downstream distribution on all sampling dates in both caddisfly and stonefly samples, but Fe concentrations did not. Periodic changes in metal distribution was more prevalent in stoneflies than caddisflies.

Temporal variability (Fig. 5) in the insect data was assessed over the 13 month sampling period or on each bimonthly sampling date. The percent standard deviation over the 13 month sampling period greatly exceeds the percent standard deviation of each bimonthly sample's replicates (Table 5.B). Variability over thirteen months is significant at all sites for both species with the exception of some stonefly values at Turah Bridge. The expected error for insect data collected once a year from a single location would, like data for sediments, exceed the error for data collected from several locations on several dates.

Discussion: Inter-species variability is an accepted feature of biological systems (Shutes et al. 1993; Hare et al. 1991; Resh and Unzicker 1975). Stoneflies had overall higher measured concentrations of Cu, Zn, Cd and Ca than caddisflies which could result from biomagnification or higher rates of accumulation. Caddisfly samples were higher in Mn and Fe and its associated metals Ni and Co, possibly due to either coatings or gut content. ANOVA of Cu and Fe concentrations showed significant difference between caddisflies and stoneflies. In studies of the Clark Fork River and its tributaries both Axtmann et al. (1990) and Moore et al. (1991) found species variability in trace metal concentrations, but no biomagnification in Perlid stoneflies. Detritus feeders, such as caddisflies, which ingest sediment can possibly accumulate more contaminants than species higher on the food chain (Jenne and Luoma, 1977;Axtmann et al. 1990). Hare and Campbell (1992) who studied Cd, Cu, and Zn in six taxa from a temperate fresh water lake found no evidence of biomagnification in the predatory alderfly (*Sialis sp.*).

A downstream distribution trend in whole body concentrations of metals supports results of other studies in this system and elsewhere (Lynch et al. 1988; Darlington and Gower 1990; Axtmann et al. 1990; Moore et al. 1991; Dukerschein et al. 1992). Axtmann et al. (1990) found the same spatial distribution in whole body Cu, Cd, and Pb concentrations in caddisflies and stoneflies in the Upper Clark Fork. However, increased sampling frequency shows the distributional trends moving up and down the concentration axis. Bimonthly sampling revealed temporal variation in the spatial sequence of Fe distributions. For this reason ANOVA of spatial distributions of Fe, by date, gave a higher degree of significance. Differences in larval development could cause samples from a downstream site to temporarily have higher metal concentrations than an upstream site. The degree of spatial and temporal variability we encountered indicates that data collected from several stations on several dates will have a lower expected error than a single sampling effort.

Results: Mechanisms

Possible Mechanisms of Sediment Metal Concentration Variability

To identify which factors might be influencing metal concentrations in fine-grained bed sediments, sediment metal concentrations were analyzed versus average monthly stream flow and average monthly total suspended sediment (TSS) concentrations (data for TSS were not available for Gold Creek). No strong correlations exist except between sediment Cu concentrations and TSS at Turah Bridge (Table 6). However, weak trends towards increased sediment metal concentrations with increasing discharge are evident. There is a possible direct relationship between TSS and sediment metal concentrations when the entire study reach is considered, as both TSS and metals decrease downstream.

Data from samples of corresponding oxidized and reduced sediments, collected on 21 September 1992, indicate that reduced fine-grained sediments have predominantly higher concentrations of metals than oxidized fine-grained sediments (Fig. 6). There are several instances where the difference between oxidized and reduced samples exceeds the error of the composite sample for the metal collected on the same date.

Discussion: Decreasing trends in spatial distribution of sediment contaminant concentrations is usually attributed to mixing and dilution with uncontaminated sediments (Chapman et al. 1983). Increases in metal concentrations in Clark Fork River sediments during the spring could be attributed to sediment deposition from areas of greater contamination upstream, maintaining the same distributional trends, although concentrations at each station increase. However, there is also variability in Fe and Ni, baseline elements in this system, which should not be as affected by deposition from upstream as the enriched metals (Essig and Moore 1993). Statistical analysis of the data failed to show strong correlations between sediment metal concentrations and either stream discharge or TSS concentrations. However, even without good statistical correlations between sediment metal concentrations and stream discharge or TSS, trends are indicated that might become clearer with more study.

The oxidized-reduced sample measurements indicate the possibility of differing concentrations caused by changes in the ratio of oxidized to reduced sediments. The redox environment could be affected by stream flow and sediment input, baseflow, organic matter content and biotic activity (Salomans and Forstner 1984). High dissolved organic matter can correspond with low stream flow and increased metals in the soluble phase (Elder 1988). Perhaps this is one factor involved in the removal of sediment associated metals in the Clark

Fork after runoff. Thomson-Becker and Luoma (1985) studied temporal variation in parameters that can influence trace metal concentrations through adsorption: grain size, organic materials and iron concentrations. They found temporal changes in estuarine fine-grained particle concentrations in response to wind velocities and runoff. Extractable organic matter and extractable-iron varied directly with fine-grained concentration variation. The character of a sampling station can possibly have substantial influence on metal concentrations measured due to factors of stream flow, sediment deposition, sediment size fractions, organic matter content, metal oxide content, and proportions of oxidized to reduced sediments. Krantzberg and Stokes (1985) studied the effects of bioturbation on Cu and Zn partitioning and found a positive correlation. Salomans and Forstner (1984) found high percent standard deviation of trace metal concentrations in fine-grained river sediments and argued for core sampling to determine temporal variation.

Possible Mechanisms of Insect Metal Concentration Variability

There is significant inter-species, spatial and temporal variation in concentrations of metals in whole body samples of larval caddisflies and stoneflies. Benthic insect samples exhibit a downstream distribution in metal concentration. Downstream distributions of Cu have r^2 values of 0.79 and 0.53 for sediments and insects, respectively. However, there are no correlations between temporal variations in insect metal concentrations and sediment metal concentrations (Table 7.A). Sediment and insect metal concentrations plotted as ratios are useful in visualizing relationships (Fig. 7). Relative degrees of concentration and enrichment between the parameters become clear. The baseline metals Fe and Ni have nearly the same ratio in insects as in sediments (Table 8). When ratios of other metals are compared to iron it is evident that the insects are preferentially concentrating some metals with respect sediment ratios. Most notable is the increased ratio of Mn:Fe in caddisflies by an order of magnitude. Variation in the ratios by station reflect downstream concentration trends; a consistent decrease in Cu and negligible decrease in Fe, for example. The plot of Cu:Fe also shows increased concentrations of Cu in stoneflies as compared to caddisflies, although caddisflies have a higher ratio of Fe. Evidence of bioconcentration and biomagnification can be seen in the ratios of table 8.

Correlations between insect metal concentrations and stream discharge and TSS varied by site, metal and species (Table 7.B,C). Generally, correlations between these factors were weak or nonexistent.

Life cycle stage and body size are possible controlling factors in insect trace metal variability (Darlington et al. 1986; Jop 1991). Increasing weight of individuals not only reflects body size but maturity. Average dry weight per individual was compared to changes in metal concentrations. Correlations between insect metal concentrations and average dry weight/individual varied between stations, species, and metals (Table 7.D). Although erratic at other stations, at Deer Lodge there was a consistent negative relationship between weight and metal concentrations in caddisflies and a positive one in stoneflies.

When compared to earlier samples many *H. occidentalis* and *H. cockerelli* sampled in April 1992, appeared coated on the abdominal segments. Some of these preserved individuals in addition to fresh specimens were analyzed by SEM-EDX. Figure 8 includes SEM images and corresponding scans of the coatings. It is evident from the scans that the coatings are predominantly Mn with some Fe. Because the detection limit of the instrument is ~ 500 µg/g (Oscarson, R., U.S.G.S., 345 Middlefield Rd., Menlo Park, CA 94025, pers. comm.), the Zn peak indicates that there are higher levels of Zn in the coatings than in the whole body analysis — Deer Lodge caddisfly Zn concentration for 15 April 1992 = 211 µg/g. Influence of the coatings on caddisfly Mn concentrations can be noted in the order of magnitude increase in Mn:Fe ratios between insects and sediments (Table 8).

Discussion: Measurement of bioaccumulation and bioconcentration is the most effective method currently to assess the bioavailability of metals to the food web (Luoma 1989). Metal ratios show that the insects in the Clark Fork are concentrating some trace metals with respect to others. It is not apparent that the insects are responding temporally to bioavailable metals associated with either stream flow or TSS. However, stream flow and TSS would transport the most bioavailable species of trace metals, either ions in solution or metals that could be ingested adsorbed to particulates (Jenne and Luoma 1977; Luoma 1989).

This study supports past findings that indicate monitoring enrichment of metals in biota requires a knowledge of their life cycle and physiological processes (Jenne and Luoma 1977; Luoma 1989; Bryan and Langston 1992).Temporal variations in caddisfly metal concentrations seemed to be controlled by factors other than temporal variations in sediment metal concentrations, perhaps by the life stage and physiology of the animals. Data on temporal variations in insect metal concentrations are rare but it seems to support physiological controls on temporal variations and environmental controls on degree of contamination and relative spatial variation (Lynch et al. 1988; Jop 1991; Hare and Campbell 1992). Low metal concentrations in caddisflies on 19 June 1992 probably correspond to the imago or pre-emergent stage of the larvae, a stage in the lifecycle when trace metal concentrations can drop (Jop 1991). Other studies find that trace metal concentrations are inversely proportional to larval weight, implicating adsorption as a major control of concentration (Darlington et al. 1986). Data from this work mostly contradict a consistent inverse relationship between individual dry weight and metal concentration. Inverse trends did occur in caddisflies where environmental metal concentrations are highest. Gut sediment content at Deer Lodge where environmental metal concentrations are high could account for this. Also, the tendency of these insects to become coated with metal oxides between molting could be enhancing the expected relationship between individual weight and whole body metal concentration at Deer Lodge. Even though Mn-Fe oxide accretion would be limited by surface to volume ratio of the animal, the Mn-Fe oxides themselves have large surface areas — up to 350 m2/g compared to 7.2 to 24.3 m2/g for fine-grained sediment as measured in the Rhine (Horowitz 1982; Robinson 1983; Salomans and Forstner 1984). Thus, the chemical and physical properties of Mn-Fe oxides could possibly be causing enough adsorption and incorporation of trace metals over time as coatings continue to accrete to overcome the insect volume to surface area restrictions downstream at Gold Creek (no weight to concentration trend) where coatings, as evidenced by Mn concentrations, are not significantly different from Deer Lodge. Metals adsorbed to Mn-oxides on caddisflies could enhance the amount of metals available to the food web. Luoma (1989) reports the transfer factor of Ag bound to Mn-oxides to be 100-fold higher than that for Fe-oxides.

Weight to metal concentration relationships are less easily distinguished in the stone fly data (where no coatings occur)(Table 7.D). Cu and Fe are at their lowest concentrations in the young cohort sampled on or after the April emergence.

The disappearance of stoneflies from the areas sampled is a phenomenon worth further investigation if they are to be used as biomonitors. Kick net sampling only disturbs the surface of the substrate, usually large cobbles with some underlying coarse sand. It seems plausible stone flies are using the hyporheic zone as a retreat. They were essentially absent on dates when none were collected, but before and after, were present in normal populations. Stanford and Gaufin (1974) found stoneflies habitually residing in the hyporheic zone of the Tobacco River, MT for much of their early life cycle. Stress factors, such as low water levels and increased temperature, could cause this response. Resh (1979) warns of difficulties sampling benthic invertebrates residing in the hyporheic zone.

Conclusion

We found significant spatial and temporal variability in metal concentrations in fine-grained bed sediments and benthic insect larvae of the Clark Fork River. Spatial distribution trends were relatively constant (excluding periodic increases of some downstream concentrations for some metals above concentrations at an upstream station). However, this consistent downstream distribution moved up and down the concentration axis on a temporal basis. The variability of the data, as represented by percent standard deviation, decreased with decreasing sampling scale. It is clear that expected error of data collected once a hydrocycle from a single station on an extensive stretch of river will be much larger than that from frequent sampling over several less widely spaced intervals.

Continuous monitoring over a longer period perhaps could elucidate the mechanisms responsible for variability in metal concentrations. It is clear that the insects attain a degree of contamination relative to the spatial distribution of the environmental contamination. Temporal variations in insect metal concentrations seem under control of other processes, perhaps physiology, and do not correlate well with sediment, discharge, or TSS. Stoneflies' higher Cd, Cu, and Zn concentrations are due possibly to higher tissue burdens expected with biomagnification. However, caddisfly metal concentrations seem influenced by surface adsorption and possibly gut content.

Sediment metal concentrations also failed to correlate well with either discharge or TSS. Relationships to hydrology may be more complex than demonstrable by simple correlations. Investigation of water chemistry, along with the physical elements of sediment transport could better define the mechanisms of sediment metal concentration variability.

TABLE. 1. Limits of detection (LOD) (derived from sediment and insect blanks), and percent recovery of duplicates, spikes, and standards.

Metal	LOD (ppm)	Duplicates (mean, n=8)	Spikes * (mean,n=10)	USGS SED2 (n=10)	NBS 1577a (n=6)
Ca	0.6	100%		92%	103%
Cd	0.002	100%	118%	93%	107%
Co	0.005	101%			112%
Cu	0.06	100%	125%	102%	125%
Fe	0.35	100%		99%	116%
Mn	0.03	100%	120%	95%	119%
Ni	0.008	101%	(n=4) 117%	98%	
Zn	0.07	100%	115%	98%	111%

* Spike recovery values indicate possible evaporation of spike solution.

Table 2. Average percent standard deviation (%STD) of sediment and insect sample replicates.

	Sediment %STD				Insect %STD					
	Deer Lodge	Gold Creek	Bearmouth	Turah Bridge	Deer Lodge		Gold Creek		Turah Bridge	
Metal					*H.occidentalis*	*Isogenoides*	*H.occidentalis*	*Isogenoides*	*H.occidentalis*	*Isogenoides*
Ca	8%	7%	10%	11%	8%	15%	15%	13%	7%	28%
Cd	6%	7%	19%	8%	19%	10%	5%	13%	9%	30%
Co	5%	5%	13%	5%	14%	15%	11%	17%	5%	7%
Cu	7%	6%	15%	7%	9%	6%	5%	7%	6%	7%
Fe	8%	6%	9%	7%	9%	10%	5%	13%	4%	9%
Mn	17%	19%	19%	18%	13%	9%	10%	12%	5%	9%
Ni	5%	6%	10%	6%	15%	17%	9%	18%	8%	7%
Zn	5%	6%	27%	7%	9%	7%	3%	10%	5%	12%

Table 3. Coefficient of determination for regressions of sediment Cu and Fe concentrations versus other metals at four sampling stations, n=10, p>0.05, (a) p<0.001, (b) p<0.05.

	Deer Lodge		Gold Creek		Bearmouth		Turah Bridge	
Metal	Cu vs.	Fe vs.	Cu vs.	Fe vs.	Cu vs.	Fe vs.	Cu vs.	Fe vs.
Ca	0.39	0.88(a)	0.43	0.45	0.05	0.01	0.03	0.47
Cd	0.58 (a)	0	0.5(a)	0.64(b)	0.68(a)	0.43	0.71(a)	0.5(b)
Co	0.52(a)	0.75(a)	0.5(a)	0.71(a)	0.05	0.82(a)	0.58(a)	0.84(a)
Cu		0.24		0.77(a)		0.71(a)		0.44
Fe	0.24		0.77(a)		0.71(a)		0.66(a)	
Mn	0	0.01	0.39	0.39	0.35	0.05	0.002	0.09
Ni	0.17	0.94(a)	0.79(a)	0.95(a)	0.68(a)	0.97(a)	0.62(a)	0.94(a)
Zn	0.87(a)	0.16	0.84(a)	0.75(a)	0.6(a)	0.29	0.82(a)	0.51(b)

Table 4. P-values from ANOVA and percent standard deviations (%STD) of spatial and temporal variation in insect metal concentrations at four locations for Oct. 1991 to Dec. 1992.

A. P-values and Percent Standard Deviations for Spatial Distribution of Sediment Metal Concentrations

	Entire Reach	Upper Section	Lower Section	Between Sections
Metal	p-value / %STD	p-value / %STD	p-value / %STD	p-value
Cu	5E-12 / 43%	5E-6 / 23%	4E-5 / 25%	1.40E-09
Fe	0.0003 / 19%	0.06 / 20%	0.15 / 17%	0.0003

B. P-values and Percent Standard Deviations for ANOVA of Temporal Distribution of Sediment Metal Concentrations

	Entire Period	A 10/91-4/92	B 6/92-12/92	Delineated by Discharge	Before and After 6/92	Monthly Replicates
Metal	p-value / %STD	p-value / %STD	p-value / %STD	p-value	p-value	%STD (ave)
Deer Lodge						
Cu	1E-05 / 13%	0.004 / 15%	0.2 / 6%	0.11	0.03	7%
Fe	3E-09 / 20%	0.06 / 9%	0.05 / 7%	0.06	0.0002	8%
Gold Creek						
Cu	1E-08 / 13%	0.02 / 7%	0.001 / 8%	0.15	0.002	6%
Fe	3E-10 / 17%	0.005 / 10%	0.0003 / 10%	0.56	0.003	6%
Bearmouth *sampling begun 6/92						
Cu			0.23 / 12%			7%
Fe			0.02 / 11%			7%
Turah Bridge						
Cu	2E-10 / 20%	6E-06 / 24%	1E-05 / 18%	0.72	0.18	15%
Fe	1E-09 / 20%	2E-05 / 18%	2E-05 / 17%	0.87	0.09	9%

Table 5. P-values from ANOVA and percent standard deviations (%STD) of spatial and temporal variation in insect metal concentrations at three locations for Oct. 1991 to Oct. 1992.

A. P-values for ANOVA and Percent Standard Deviations of Spatial Distribution of Metal Concentrations in Insects: 10/91 to 10/92

		Entire Reach		Within Upper and Lower Sections (all dates)				Between Upper and Lower Sections (all dates)	
				Deer Lodge to Gold Creek		Gold Creek to Turah Bridge			
		H. occidentalis	***Isogenoides sp.***	*H. occidentalis*	*Isogenoides sp.*	*H. occidentalis*	*Isogenoides sp.*	*H. occidentalis*	*Isogenoides sp.*
	Metal	p-value/%STD	p-value/%STD	p-value/%STD	p-value/%STD	p-value/%STD	p-value/%STD	p-value	p-value
All Dates	Cu	4E-05 / 50%	0.03 / 31%	0.002/44%	0.13/28%	0.13/25%	0.14/25%	0.006	0.06
	Fe	0.43 / 28%	0.64 / 57%	0.4/31%	0.63/61%	0.82/25%	0.68/59%	0.39	0.52
By Date									
Oct. 1991	Cu	0.0006 / 53%	0.001 / 36%						
	Fe	0.08 / 22%	0.02 / 30%						
Feb. 1992	Cu	0.003 / 48%	5E-07 / 32%						
	Fe	0.005 / 17%	7E-05 / 35%						
April 1992	Cu	3E-11 / 49%	*						
	Fe	5E-07 / 18%							
June 1992	Cu	3E-13 / 47%	0.18 / 4%						
	Fe	0.14 / 4%	0.05 / 7%						
Aug. 1992	Cu	5E-06 / 73%	*						
	Fe	0.0005 / 26%							
Oct. 1992	Cu	2E-05 / 31%	0.006 / 31%						
	Fe	0.53 / 2%	0.04 / 42%						

* not enough replicates for analysis

B. P-values for ANOVA and Percent Standard Deviations of Temporal Distributions in Metal Concentrations in Insects: 10/91 to 10/92

		Entire Period		Bimonthly Replicates	
		H. occidantalis	*Isogenoides sp.*	*H. occidantalis*	*Isogenoides sp.*
	Metal	p-value/%STD	p-value/%STD	Ave. % STD	Ave. % STD
Deer Lodge	Cu	7E-09 / 26%	1E-05 / 25%	9%	6%
	Fe	4E-10 / 31%	4E-07 / 56%	9%	10%
Gold Creek	Cu	3E-07 / 26%	1E-08 / 25%	5%	5%
	Fe	2E-07 / 32%	7E-12 / 74%	5%	11%
Turah Bridge	Cu	2E-11 / 16%	0.9 / 12%	6%	8%
	Fe	5E-14 / 15%	0.09 / 26%	3%	8%

Table 6. Coefficient of determination for regressions of sediment Cu and Fe concentrations versus average monthly discharge (n=10) and TSS (n=7) at three sampling stations, p>0.05, (a) p<0.05.

	Deer Lodge		Gold Creek		Turah Bridge	
Metal	Discharge vs.	TSS vs.	Discharge vs.	TSS vs.	Discharge vs.	TSS vs.
Cu	0.26	0.43	0.44	*	0.43	0.78(a)
Fe	0.23	0.19	0.11		0.44	0.35

*no TSS data available for Gold Creek

Table 7. Slope and coefficient of determination for regressions of insect metal concentrations (IMC) versus sediment metal concentrations, discharge, TSS, and dryweight per individual, at three sampling stations, caddisflies n=6, stoneflies n=5, m=slope.

	A. IMC vs. Sediment Metal Concentrations				B. IMC vs. Average Monthly Discharge			
	H. occidentalis		*Isogenoides sp*		*H. occidentalis*		*Isogenoides sp.*	
Metal	r2	m	r2	m	r2	m	r2	m
Deer Lodge								
Cu	0.08	0.04	0.4	0.13	0.1	0.13	0.97	0.5
Fe	0.08	0.02	0.68	0.04	0.07	1.3	0.6	3.6
Gold Creek								
Cu	0.57	0.07	0.002	0.008	0.51	0.1	0	0
Fe	0.12	0.03	0.45	0.07	0.2	1.2	0	-0.01
Turah Bridge								
Cu	0.58	0.02	0.62	-0.02	0.29	0.02	0.98	-0.06
Fe	0.02	0.007	0.09	0.008	0.002	0.03	0.06	-0.15

	C. IMC vs. TSS Concentrations				D. IMC vs. Mean Dry Wgt./Individual			
	H. occidentalis		*Isogenoides sp*		*H. occidentalis*		*Isogenoides sp.*	
Metal	r2	m	r2	m	r2	m	r2	m
Deer Lodge								
Cu	0	0.02	0.001	-0.15	0.62	-13	0.56	2
Fe	0.01	-2.8	0.02	-7.1	0.5	-138	0.98	24
Gold Creek								
Cu	*no TSS data avalilable for Gold Creek				0.007	1.1	0.004	-0.08
Fe					0.03	-52	0.05	3.7
Turah Bridge								
Cu	0.69	1.4	0.98	-1.2	0.19	2.6	0.1	0.1
Fe	0.42	21	0.78	-16	0	1.5	0.82	3.1

Table 8. Ratios of metal concentrations in sediments and insects; means of all data at three sampling stations.

	Sediment			*H.occidentalis*			*Isogenoides sp.*		
	Deer Lodge	Gold Creek	Turah Bridge	Deer Lodge	Gold Creek	Turah Bridge	Deer Lodge	Gold Creek	Turah Bridge
Metal									
Cd:Cu	0.006	0.007	0.009	0.01	0.013	0.009	0.014	0.013	0.007
Zn:Cu	1.08	1.35	2.06	2.16	4.02	3.98	2.84	3.51	3.58
Co:Fe	0.0005	0.0005	0.0005	0.0002	0.0014	0.001	0.0011	0.0011	0.0013
Cu:Fe	0.06	0.05	0.03	0.1	0.06	0.05	0.29	0.19	0.22
Ni:Fe	0.0006	0.0008	0.0008	0.0012	0.0008	0.0009	0.0007	0.0012	0.0016
Mn:Fe	0.12	0.11	0.09	1.67	1.78	0.57	0.63	0.46	0.28

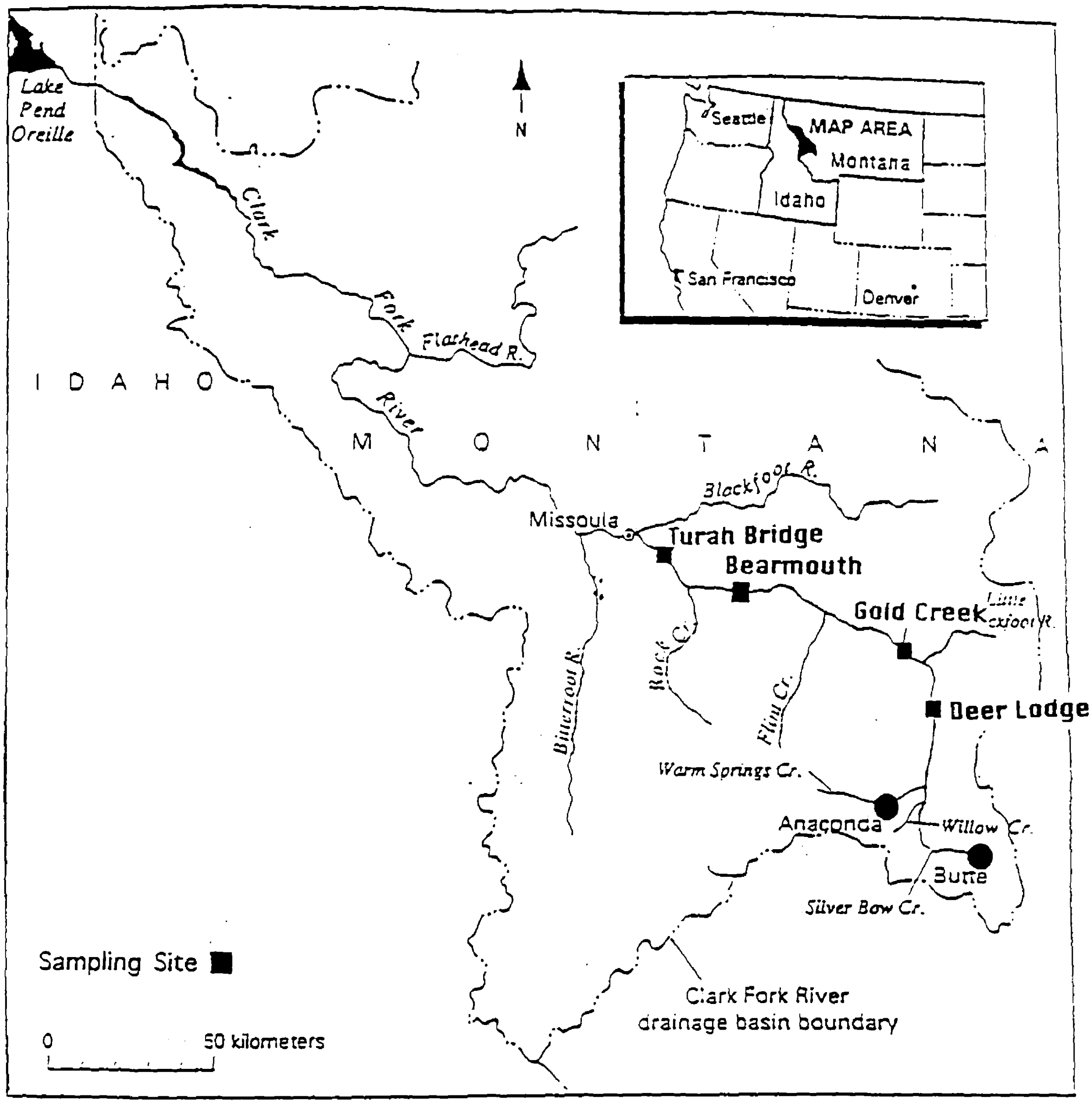
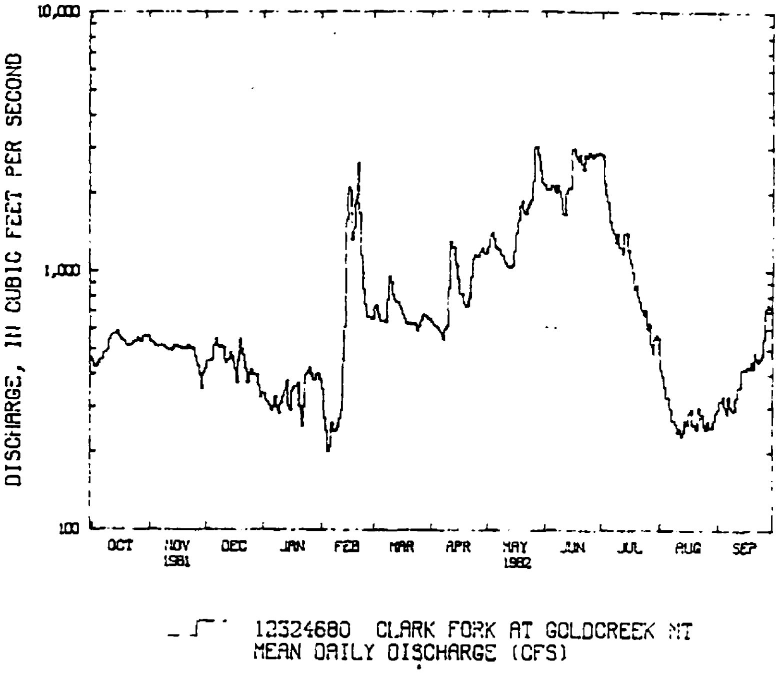


Fig. 1. Map of western Montana, U.S.A., showing the Clark Fork River drainage basin, the four sampling stations, and Butte and Anaconda.

A



B

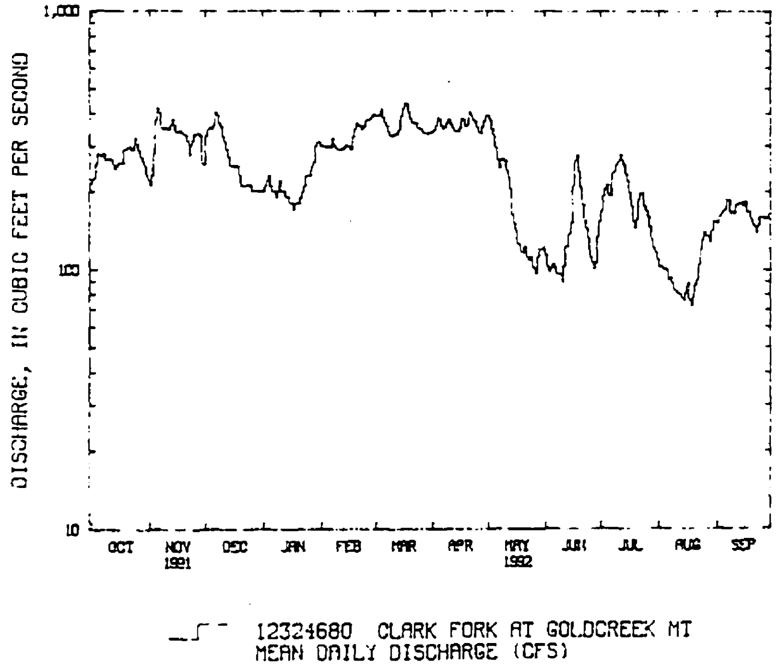


Figure 2. Hydrographs for the Clark Fork River at gold Creek, (A) 1981-1982: normal and (B) 1991-1992: low water.

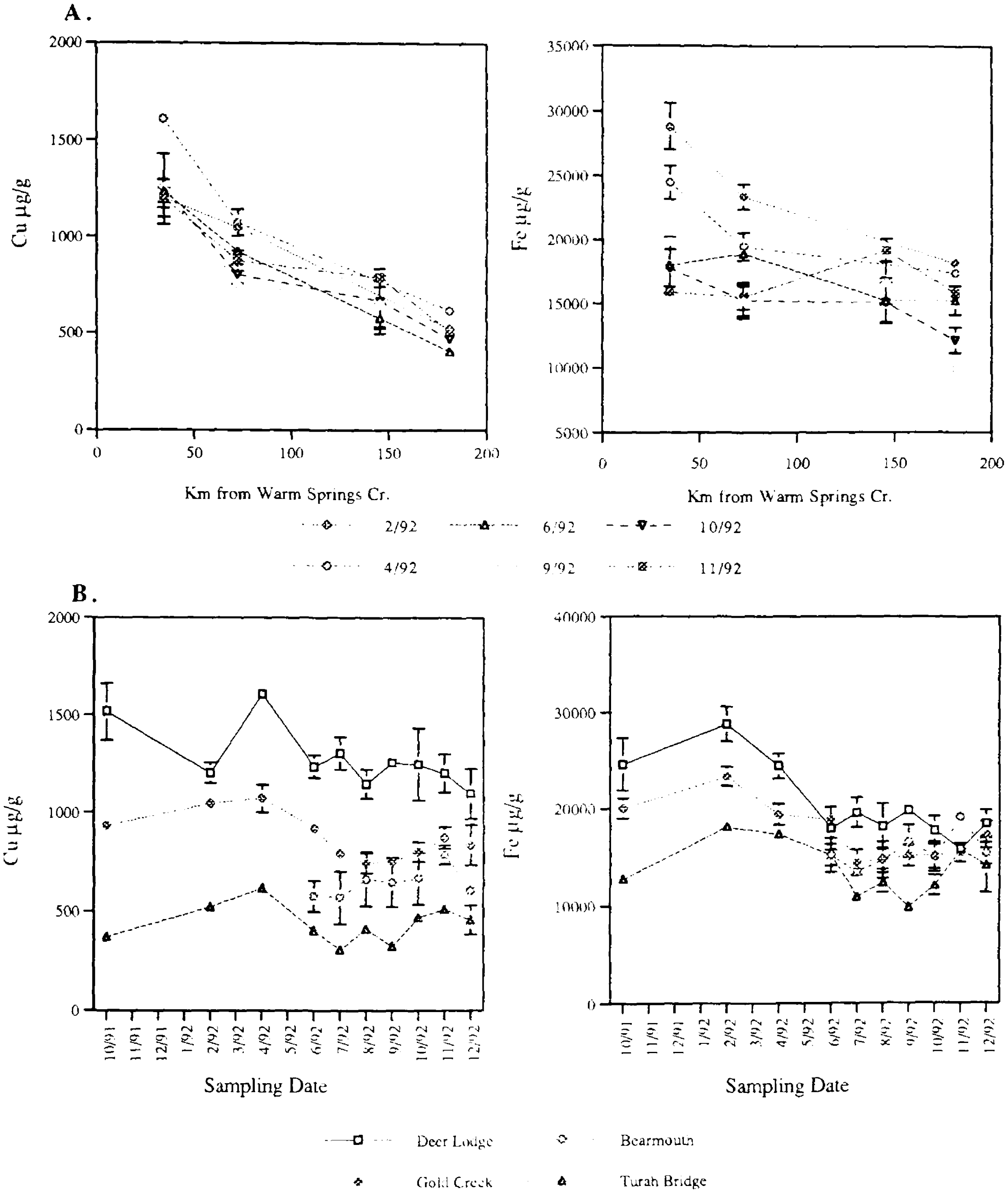


Fig. 3. Spatial (A) (six dates used as examples) and temporal (B) variability of Cu and Fe concentrations in fine-grained sediment at all stations. Where no error bars are shown, error is too small for scale.

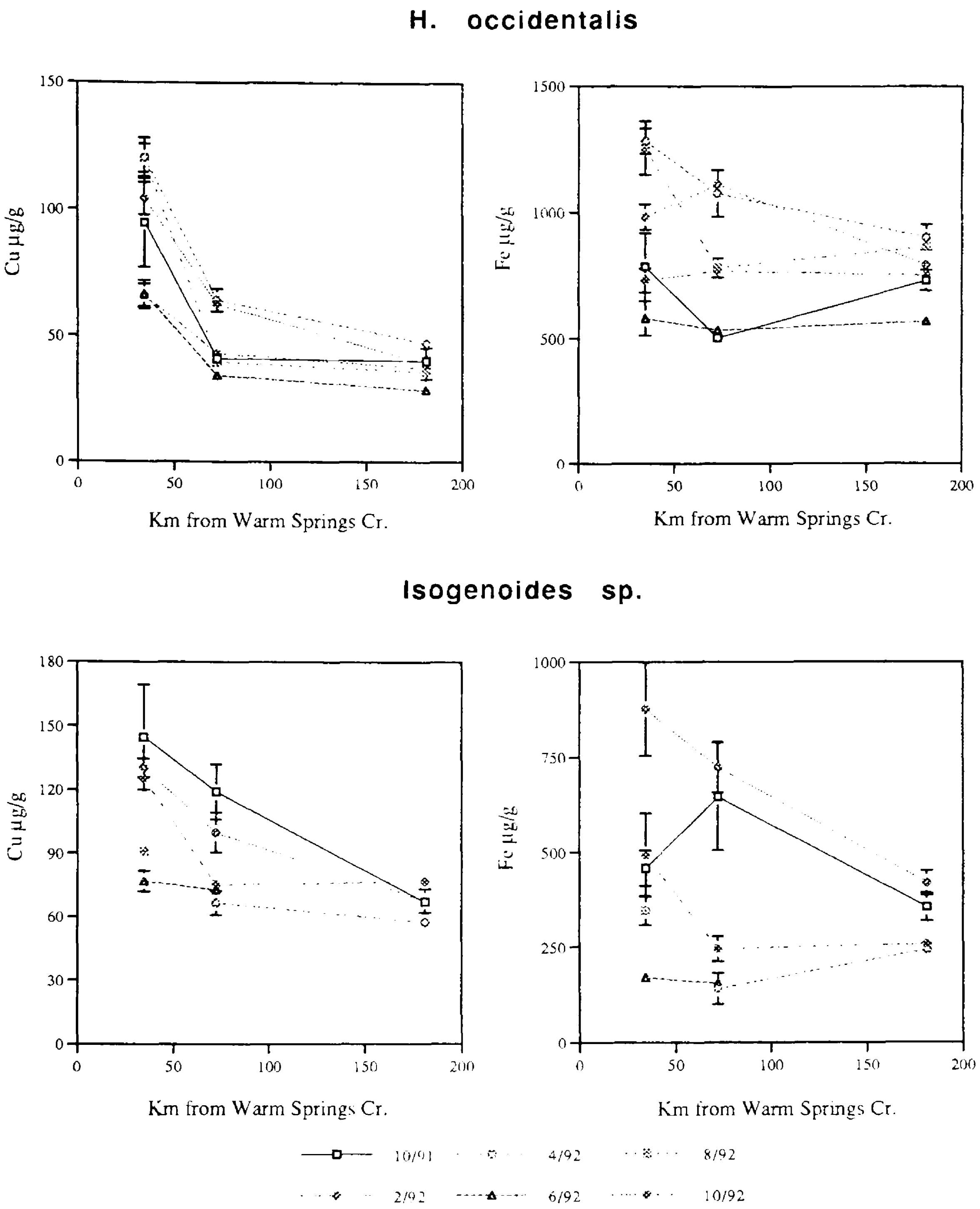


Fig. 4. Spatial variability of Cu and Fe concentrations in *H. occidentalis* and *Isogenoides sp.* Where no error bars occur, error is too small for scale or replicates are too few.

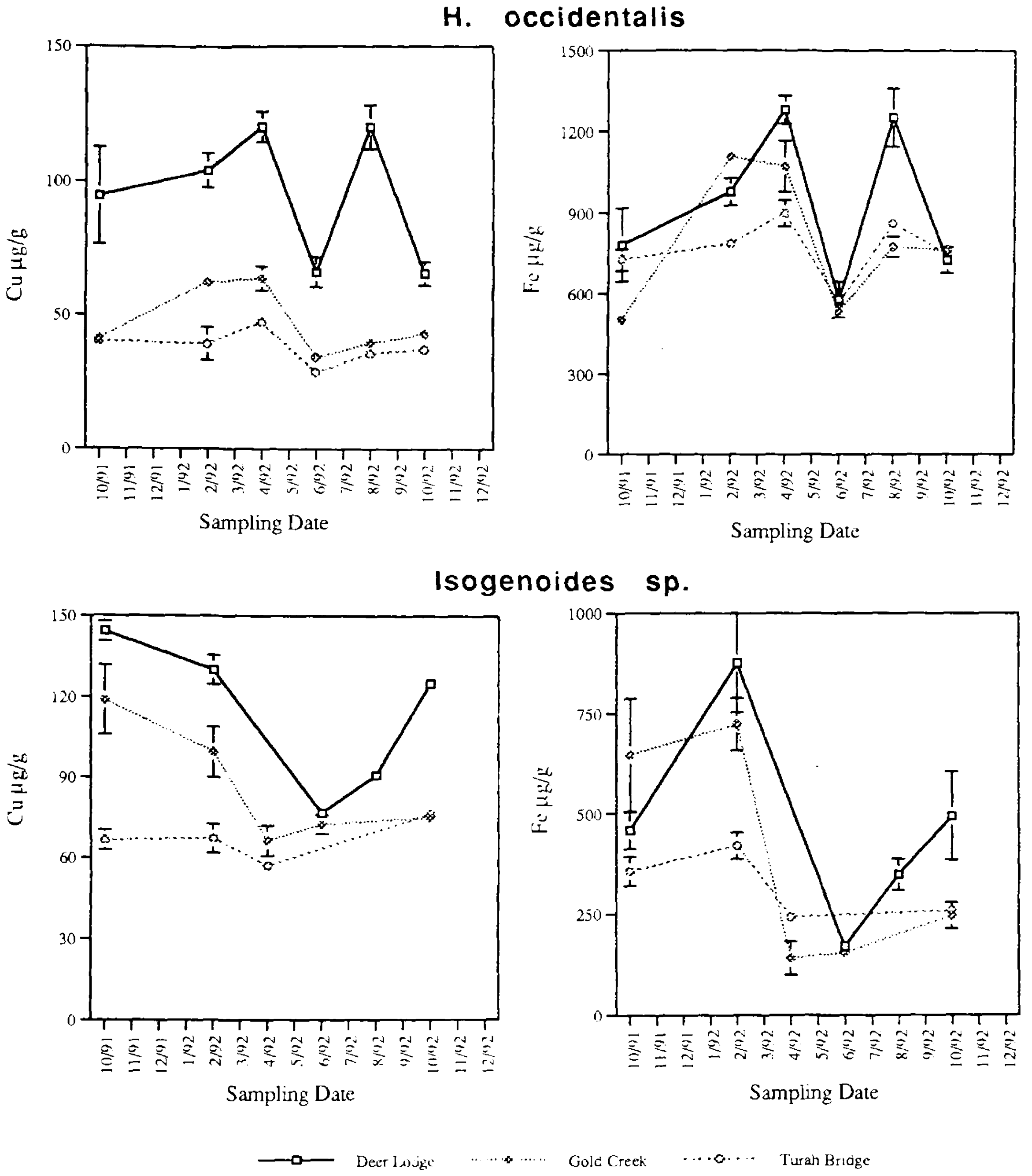


Fig. 5. Temporal variability of Cu and Fe concentrations in *H. occidentalis* and *Isogenoides sp.* Where no error bars occur error is too small for scale or replicates are too few.

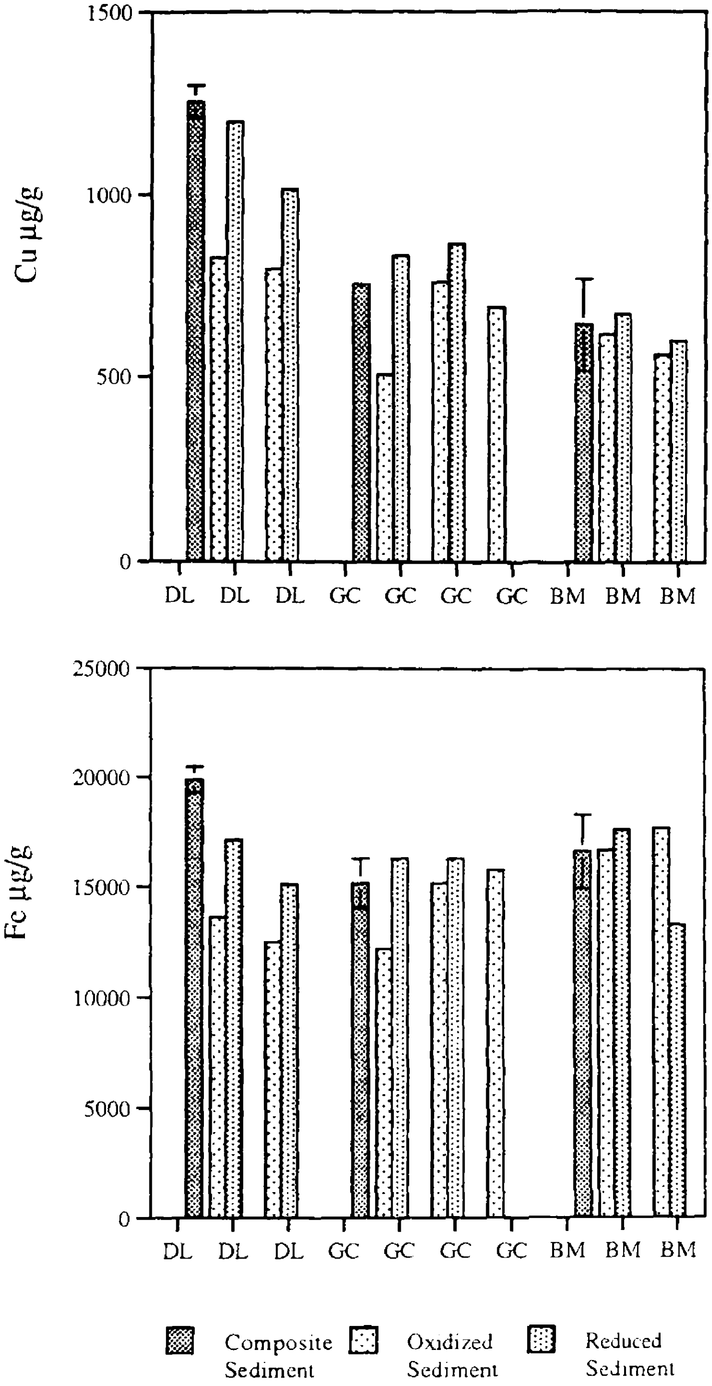


Fig. 6. Metal concentrations in oxidized, reduced and composite fine-grained sediment samples from Deer Lodge - DL, Gold Creek - GC and Bearmouth - BM. Standard deviation for composite samples only. Where composite sample columns have no error bars, error is too small for scale.

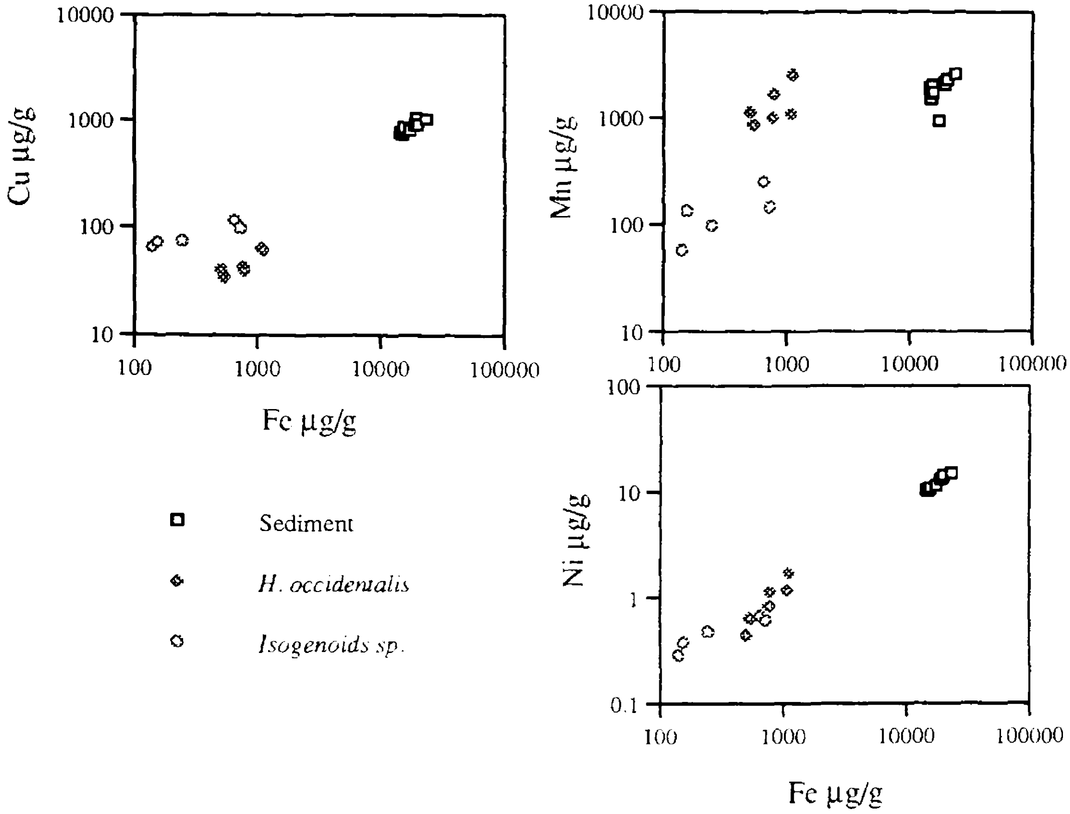


Fig. 7. Ratios of metal concentrations in sediments and insects from Gold Creek, Oct. 1991 to Dec.1992 and Oct. 1991 to Oct. 1992, respectively.

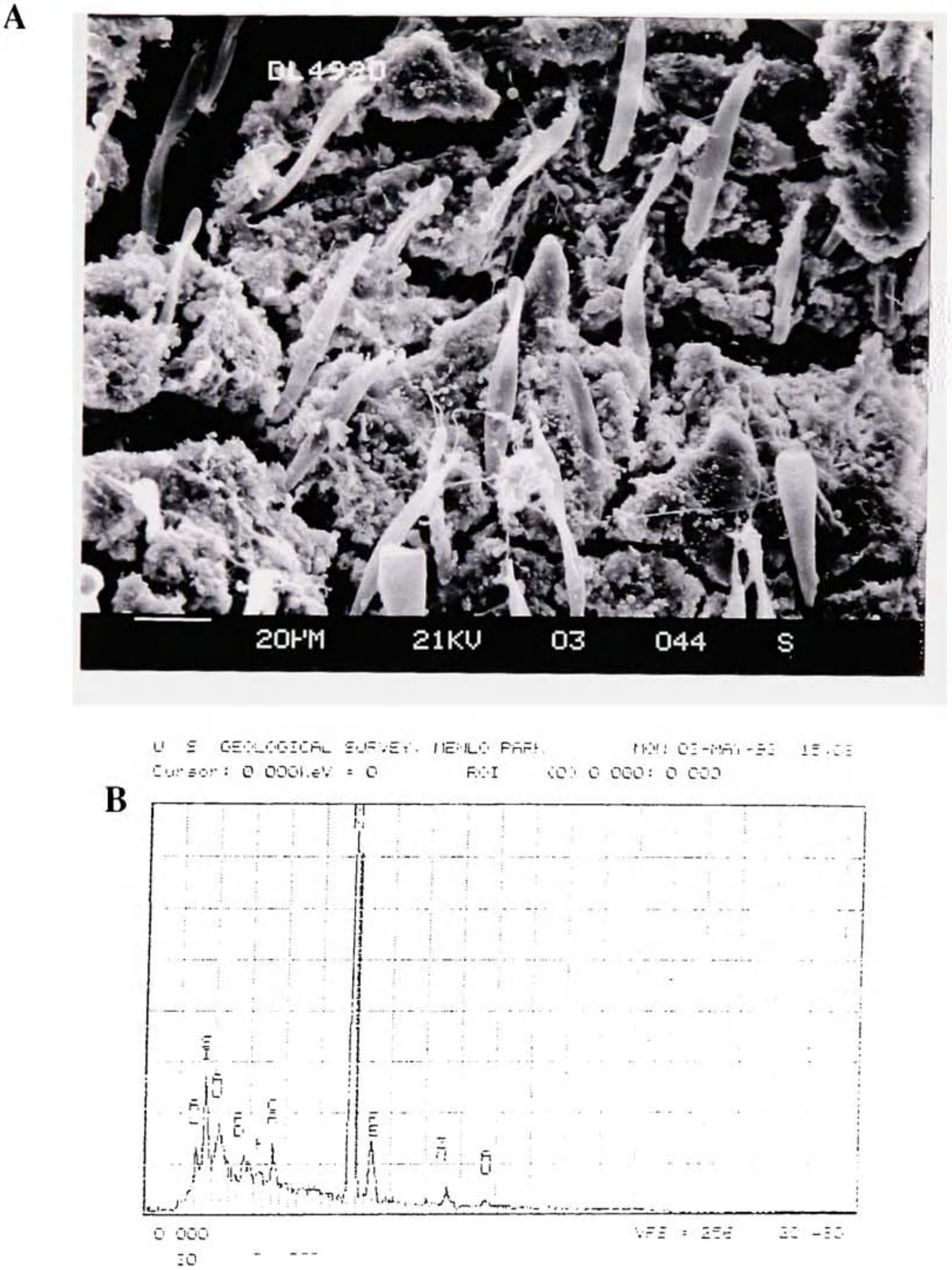


Fig. 8 SEM photomicrograph (A) and accompanying scan (B) of Mn-oxide coating on the dorsal portion of the abdominal section of an *H. occidentalis* from Deer Lodge, collected April, 1992. Setae visible protruding through coating.

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APPENDIX I

Methods

Methods

Sediment

Sampling continued for 15 months (to encompass one hydrocycle); bimonthly from 10/29/91 to 4/15/92 and monthly from 6/19/92 to 12/17/92. Three to four composite fine-grained sediment samples were collected from bed deposits along an approximately 50 m stretch of river at each sampling station. Fine-grained bed sediments were scooped with a polypropylene spoon and sieved immediately in river water through a 63 µm nylon mesh sieve into 250 ml Nalgene bottles. On 9/21/92 samples of the oxidized layer of sediments and the underlying reduced sediments were collected separately from two ~ $1m^2$ plots at Deer Lodge, Gold Creek and Bearmouth. Turah Bridge was not included because of insufficient sediment.

All samples were labeled and packed on ice for transport to the laboratory. After centrifuging for 15 minutes at ~2000 rpm and discarding the water, samples were oven dried at 70° C to constant dry weight (~ 24 hours). Dried sediment cakes were ground in their bottles to minimize the chance of contamination. Portions for digestion were collected on paper and weighed using a Denver Instruments digital scale, to a nominal weight of 0.5 gm; actual weights were recorded to 0.0001 gm. Each sample was then placed in a Savillex Corp. (#578) 120 ml teflon digestion vessel.

The sediments were digested with a concentrated aqua-regia microwave digestion. Each digestion batch of 21 vessels included a duplicate, a spike, a blank and a standard. The Standard Reference Material used was USGS SED2. To each vessel plus sediment, 0.5 ml of Milli-Q deionized water was added. Out of each digestion batch (max. 21) one replicate was repeated as a spike to which was added 0.340 ml of spike solution plus the balance of Milli-Q to equal 0.5 ml. After the capped vessels were allowed to stand for a least 1/2 hour, 1.25 ml HNO3 and 3.75 ml HCl were added to each sample and the lids replaced. After addition of the acids there was a 30 minute predigestion period. The vessels were then placed on a turntable in the microwave (General Electric Dual Wave), and heated for 7.5 minutes on the high setting (575 watts). To detect over pressurization each vessel was vented via a teflon tube into a vial of a dilute solution of NaOH with ~ 4-5 drops of phenolthalein. After digestion, the vessels were cooled for at least 15 minutes before decanting the digest into polypropylene centrifuge tubes. Rinsing the vessels into the centrifuge tubes repeatedly with Milli-Q water ensured removal of all the digest. The digests were diluted with Milli-Q water to a nominal weight of 50 gm; actual weights were recorded to 1 gm. The digests were centrifuged at ~ 2500 rpm for 5 minutes to clarify and then decanted into 2 oz. Nalgene storage bottles for later analysis.

Concentrations of trace metals were determined using inductively coupled argon plasma emission spectrometry (ICAPES). Table 1 lists limits of detection and percent recovery of standard, duplicate, and spike analysis for Ca, Cd, Co, Cu, Fe, Mn, Ni, and Zn.

Insects

Benthic insect larvae were collected in riffle areas at the Deer Lodge, Gold Creek, and Turah Bridge sediment sampling stations. Sampling was conducted bimonthly, except when severe weather interfered, for a 13 month period from 10/29/91 until 10/22/92. This schedule was intended to encompass all life stages of the larvae and one complete hydrocycle.

Insects were collected using nylon mesh kick nets. Two types of larval benthic insects were collected: caddisflies of the order Trichoptera, family Hydropsychidae and stoneflies of the order Plecoptera, family Perlodidae. On site, insects were sorted by family using plastic acid-washed forceps and placed in acid washed plastic quart size storage containers with ambient river water. Ideally, a sample was considered complete when enough individuals had been collected to comprise a minimum of four replicates from each family. In general, it was necessary to have samples of at least 80 individual stoneflies and 400 caddisflies per site. In reality, the number of individuals collected was controlled by availability. During depuration (clearing of gut of sediment) and transport to the lab, the storage containers were kept on ice in coolers. At the lab the insects were rinsed with deionized water and packed with a minimum of liquid in plastic Ziploc bags and frozen.

Using a dissecting scope, insects were sorted to genus and species. Three species of *Hydropsychidae* were determined: *Hydropsyche cockerelli, H. occidentalis,* and *Cheumatopsyche spp.* Within the Perlodidae, larvae were distinguished between two genera: *Isogenoides spp.* and *Skwala spp.* (Merritt and Cummins,1984; Schefter and Wiggins; Cain, D.,U.S.G.S.-W.R.D., pers. comm.). Reference samples of each species determined, for each sampling date and site, were preserved in ethanol for future reference. When there was a significant difference in sizes, insects were separated accordingly and measured from the anterior of the head segment to the posterior of the last abdominal segment. Sorted insects were rinsed clean of particulates in Milli-Q dionized water. All tools used in sorting were acid washed to avoid contamination. Each species or genera was divided into as many replicates as possible and each replicate placed in a tared vial. The desired minimum dry weight of each replicate was 50 mg. The insect samples were oven dried at 70° C until a constant dry weight was reached.

Some caddisflies collected in April were darker than those collected in Oct. 1991 and Feb. 1992. This phenomenon was most prevalent in samples from Deer Lodge and Gold Creek. Under higher magnification the darker individuals seemed to have a coating in appearance like that on Mn- and Fe-oxide coated sediment grains. Some of these insects were preserved separately in ethanol for SEM-EDX analysis to determine the composition of the coating.

Dried insect samples were digested by hot 16N HNO_3 reflux. After addition of 2-5 ml HNO_3, enough to cover the sample, there was a predigestion period of one day at room temperature. The samples were then placed on a hot plate and maintained just below boiling until the solution became clear and gases were no longer being released (~ 1-2 weeks). The remaining acid was evaporated and the residue was reconstituted in 5ml of 50% HCl. Allowing at least one day for dissolution of the residue, the samples were filtered into clean vials using 0.45μm Acrodisc PFTE filters.

Analysis of trace metal concentrations in the insect samples was by ICAPES. Six standardizing solutions and a method blank at the beginning and end and after every 10-15 samples. Six bovine liver biological standards (NBS 1577a) and 2 blanks were digested and analyzed separately (Table 1). Concentrations were compared to results from Axtmann et al. (1990) in Aug., at the same sampling sites and month as this study. Table 2 gives percent standard error between replicate samples of insects.

Coatings were analysed by scanning electron microscope - energy dispersive X-ray (SEM-EDX) at the U.S.G.S., Menlo Park, CA. Ethanol preserved samples were rehydrated in deionized water and frozen. Recently caught samples were rinsed and frozen. Both types of samples were thawed immediately before being mounted on glass slides and freeze dried. After freeze drying the samples were coated with gold-palladium and analysed. SEM-EDX analysis yields images and scans of proportionate elemental composition of the sample.

Percent standard deviation of all fine-grained sediment - variability of monthly sample replicates.

	Metal							
Station & Date	Ca	Cd	Co	Cu	Fe	Mn	Ni	Zn
Deer Lodge								
Oct-91	12%	9%	9%	10%	11%	10%	8%	6%
Feb-92	6%	5%	5%	4%	6%	6%	6%	3%
Apr-92	4%	4%	3%	2%	5%	3%	4%	2%
Jun-92	4%	5%	3%	5%	12%	33%	2%	4%
Jul-92	2%	7%	8%	6%	8%	13%	7%	6%
Aug-92	12%	6%	2%	7%	13%	45%	10%	6%
Sep-92	7%	5%	2%	4%	3%	16%	3%	2%
Oct-92	13%	6%	2%	15%	8%	14%	5%	8%
Nov-92	10%	5%	6%	8%	2%	14%	1%	5%
Dec-92	6%	12%	8%	12%	7%	16%	4%	11%
Average	8%	6%	5%	7%	8%	17%	5%	5%
Gold Creek								
Oct-91	9%	13%	6%	4%	5%	12%	3%	8%
Feb-92	3%	6%	4%	4%	4%	12%	6%	4%
Apr-92	3%	7%	4%	7%	6%	4%	5%	5%
Jun-92	3%	6%	4%	4%	3%	13%	4%	5%
Jul-92	4%	6%	8%	5%	9%	17%	11%	5%
Aug-92	16%	2%	7%	7%	7%	35%	9%	3%
Sep-92	5%	5%	7%	2%	7%	22%	6%	0%
Oct-92	10%	6%	1%	6%	9%	20%	8%	5%
Nov-92	10%	5%	3%	6%	6%	18%	3%	6%
Dec-92	7%	14%	9%	12%	8%	39%	9%	19%
Average	7%	7%	5%	6%	6%	19%	6%	6%
Bearmouth								
Jun-92	19%	6%	6%	14%	11%	25%	8%	11%
Jul-92	8%	17%	19%	23%	6%	24%	17%	20%
Aug-92	15%	29%	21%	21%	13%	27%	14%	57%
Sep-92	14%	35%	18%	19%	10%	9%	13%	50%
Oct-92	11%	30%	19%	20%	10%	27%	10%	41%
Nov-92	0%	7%	1%	6%	5%	9%	5%	6%
Dec-92	6%	6%	4%	5%	7%	9%	4%	4%
Average	10%	19%	13%	15%	9%	19%	10%	27%

continued:

Monthly replicate %STD continued.

	Metal							
Station & Date	Ca	Cd	Co	Cu	Fe	Mn	Ni	Zn
Turah Bridge								
Oct-91	12%	3%	7%	3%	7%	13%	9%	3%
Feb-92	3%	3%	3%	3%	2%	4%	4%	3%
Apr-92	2%	1%	1%	1%	1%	3%	3%	1%
Jun-92	14%	3%	4%	6%	7%	14%	6%	4%
Jul-92	11%	8%	2%	9%	8%	10%	4%	6%
Aug-92	11%	8%	6%	11%	8%	15%	7%	8%
Sep-92	7%	20%	4%	12%	6%	15%	8%	10%
Oct-92	10%	9%	5%	9%	8%	35%	6%	9%
Nov-92	7%	3%	4%	4%	4%	28%	2%	4%
Dec-92	28%	19%	14%	15%	20%	45%	15%	17%
Average	11%	8%	5%	7%	7%	18%	6%	7%

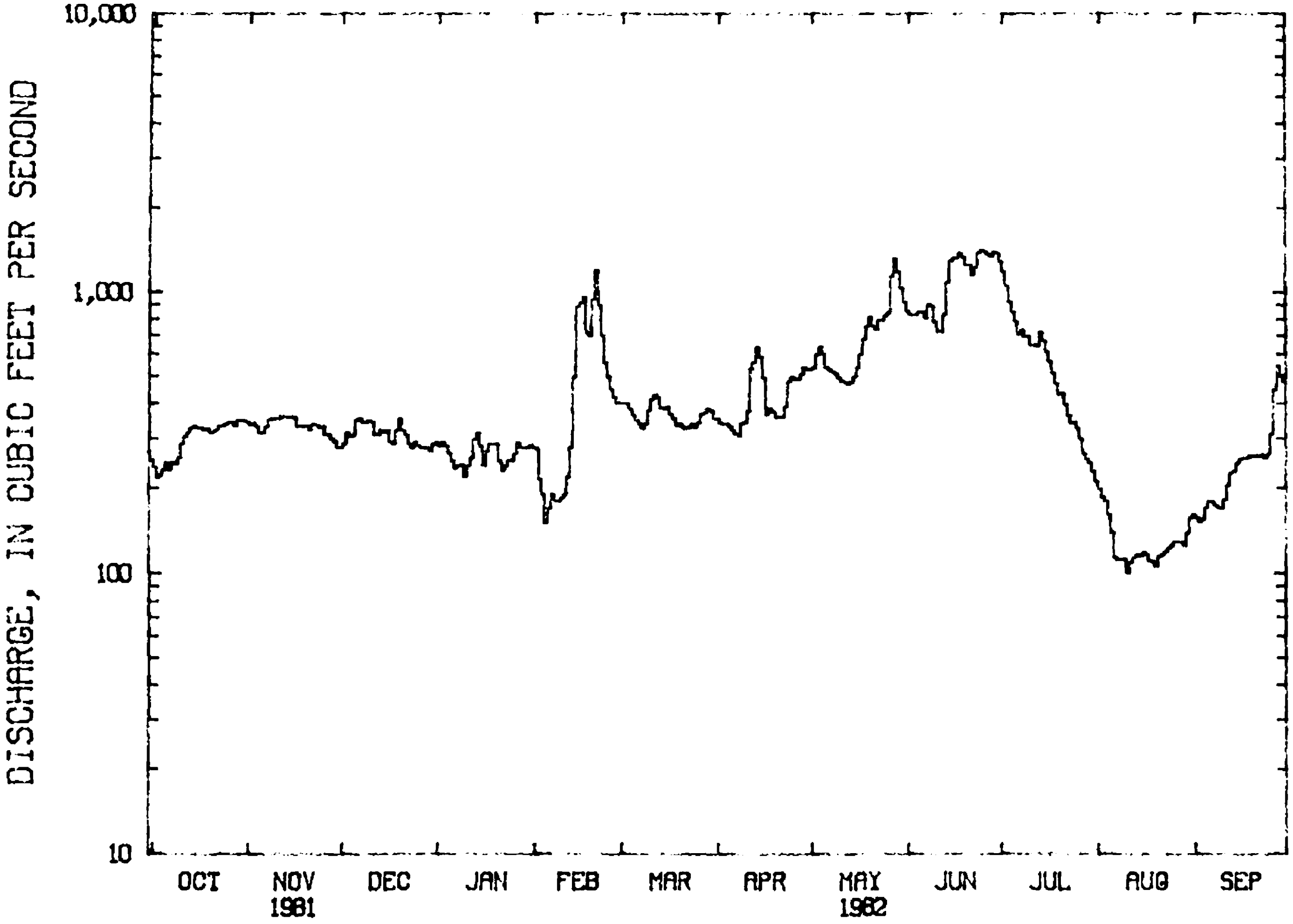
Percent standard deviation (% STD) of all insect data - variability of bimonthly sample replicates.

	Metal							
Station & Date	Ca	Cd	Co	Cu	Fe	Mn	Ni	Zn
Deer Lodge	*H. occidentalis*							
Oct-91	18%	17%	16%	19%	17%	14%	15%	16%
Feb-92	3%	7%	16%	6%	5%	13%	16%	9%
Apr-92	4%	26%	7%	5%	4%	8%	7%	3%
Jun-92	10%	29%	8%	9%	12%	9%	10%	8%
Aug-92	9%	29%	32%	7%	8%	27%	37%	13%
Oct-92	5%	6%	5%	7%	6%	7%	4%	4%
Average	8%	19%	14%	9%	9%	13%	15%	9%
	Isogenoides sp.							
Oct-91	23%	22%	26%	17%	10%	20%	11%	13%
Feb-92	27%	8%	8%	3%	14%	17%	12%	5%
Apr-92	(b)							
Jun-92	8%	8%	9%	7%	4%	4%	36%	4%
Aug-92	7%	4%	21%	2%	1%	4%	18%	7%
Oct-92	10%	9%	9%	3%	22%	2%	8%	6%
Average	15%	10%	15%	6%	10%	9%	17%	7%
Gold Creek	*H. occidentalis*							
Oct-91	(a)							
Feb-92	(a)							
Apr-92	17%	9%	0%	7%	9%	5%	18%	6%
Jun-92	4%	8%	3%	5%	4%	5%	3%	3%
Aug-92	35%	3%	32%	5%	5%	25%	13%	1%
Oct-92	5%	1%	8%	1%	1%	4%	2%	0%
Average	15%	5%	11%	5%	5%	10%	9%	3%
	Isogenoides sp.							
Oct-91	19%	20%	18%	11%	22%	19%	24%	14%
Feb-92	27%	13%	7%	10%	9%	13%	9%	16%
Apr-92	2%	15%	37%	8%	16%	12%	21%	10%
Jun-92	12%	9%	18%	5%	7%	8%	28%	6%
Aug-92	(b)							
Oct-92	7%	6%	6%	1%	13%	7%	6%	3%
Average	13%	13%	17%	7%	13%	12%	18%	10%

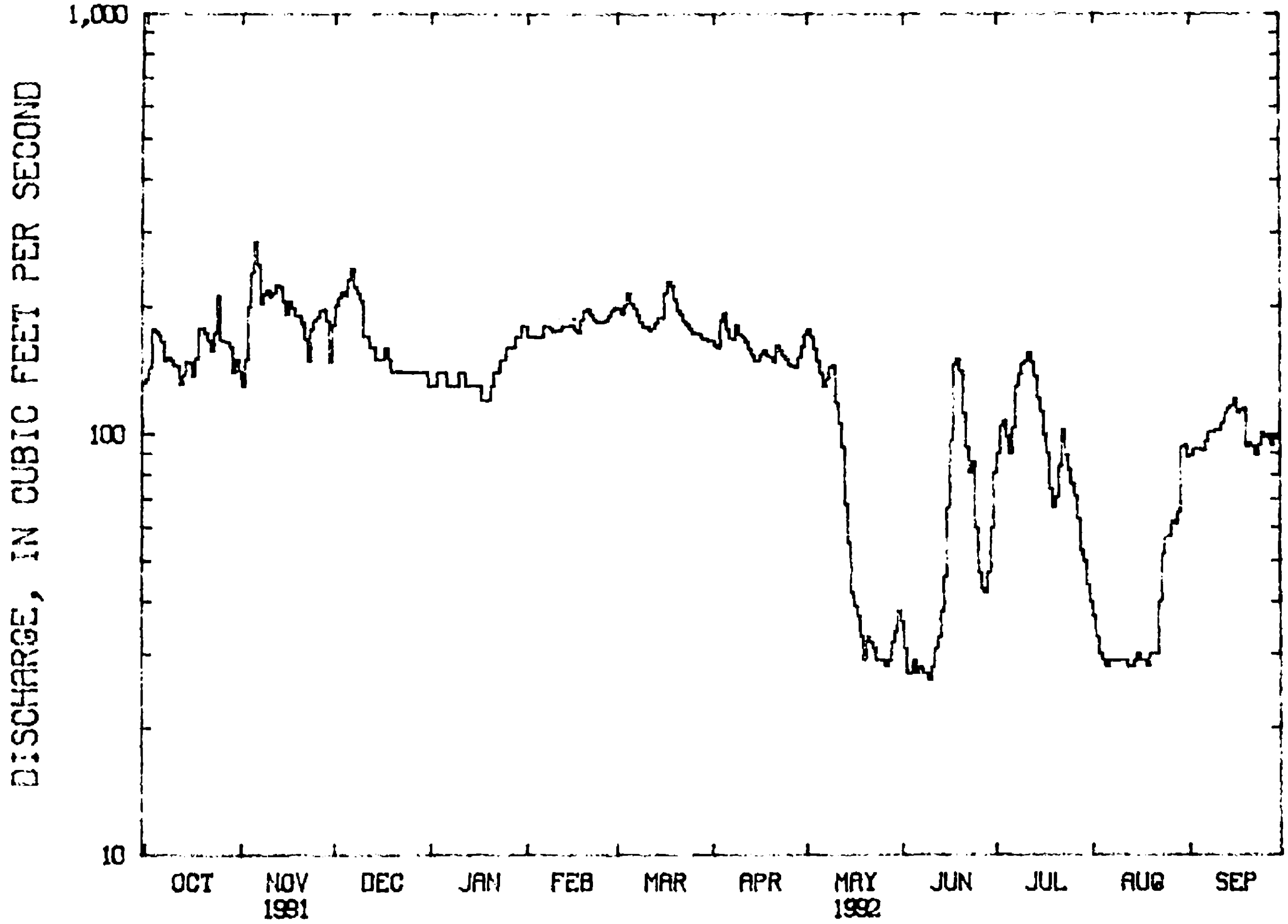
continued:

	Metal							
Station & Date	Ca	Cd	Co	Cu	Fe	Mn	Ni	Zn
Turah Bridge	*H. occidentalis*							
Oct-91	11%	9%	5%	5%	6%	7%	12%	7%
Feb-92	3%	7%	5%	16%	1%	3%	11%	2%
Apr-92	7%	6%	6%	4%	5%	6%	11%	3%
Jun-92	10%	11%	6%	4%	3%	5%	7%	2%
Aug-92	3%	4%	2%	4%	2%	2%	7%	4%
Oct-92	10%	17%	8%	2%	4%	5%	2%	9%
Average	7%	9%	5%	6%	4%	5%	8%	5%
	Isogenoides sp.							
Oct-91	22%	6%	7%	6%	10%	8%	8%	7%
Feb-92	33%	53%	7%	8%	8%	9%	6%	17%
Apr-92	(a)							
Jun-92	(b)							
Aug-92	(b)							
Oct-92	(a)							
Average	28%	30%	7%	7%	9%	9%	7%	12%

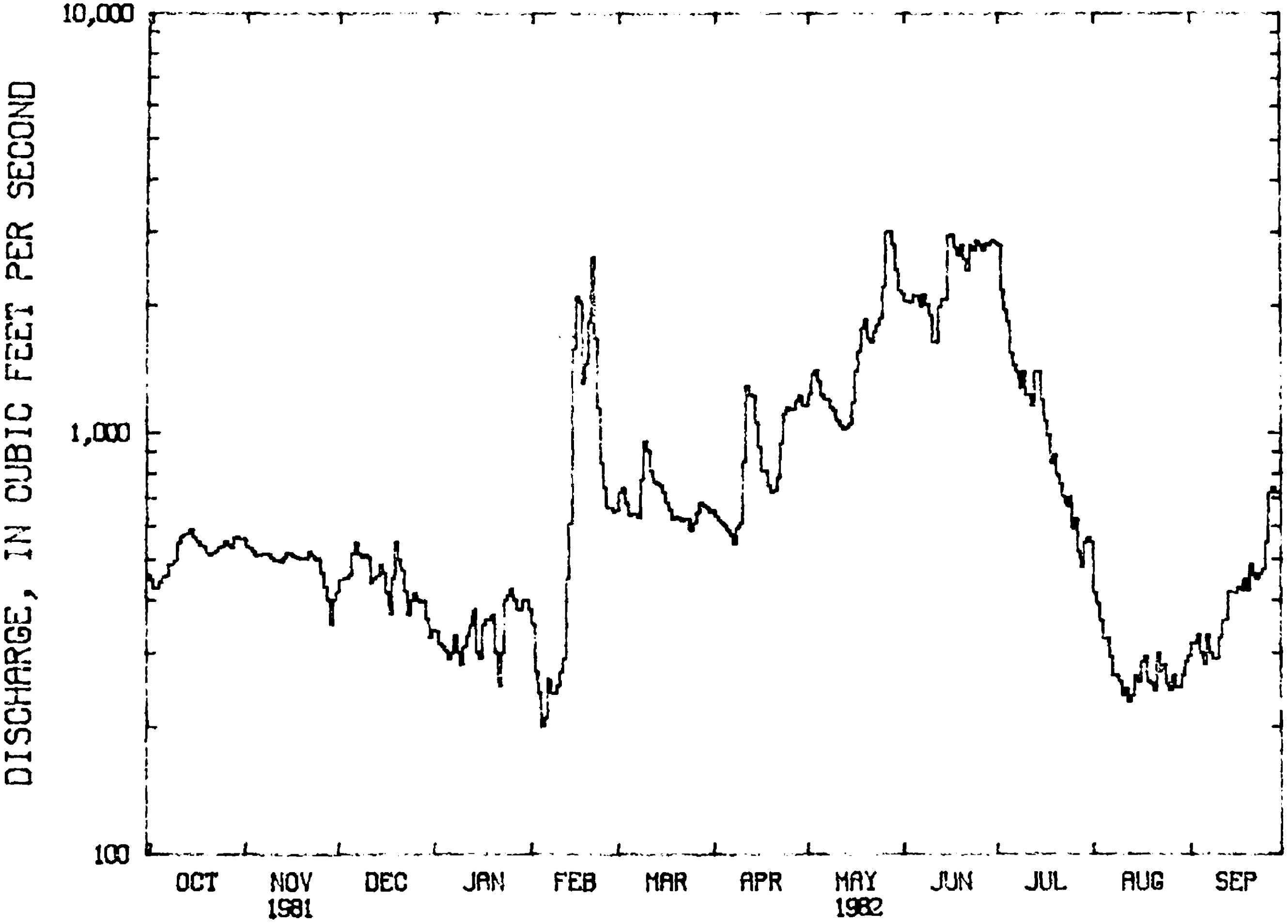
(a)-single replicate sample (b)-none collected



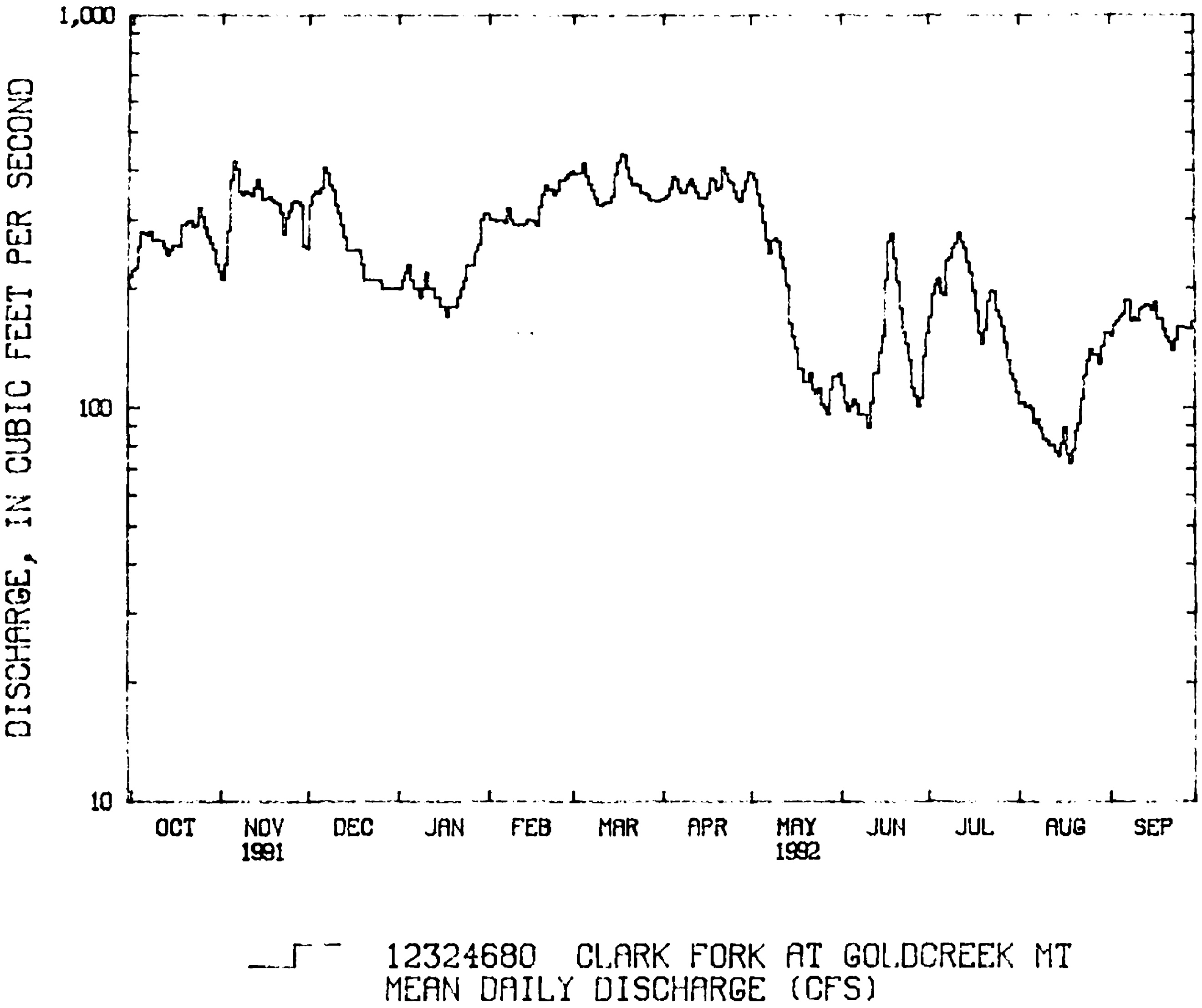
12324200 CLARK FORK AT DEER LODGE, MT.
MEAN DAILY DISCHARGE (CFS)

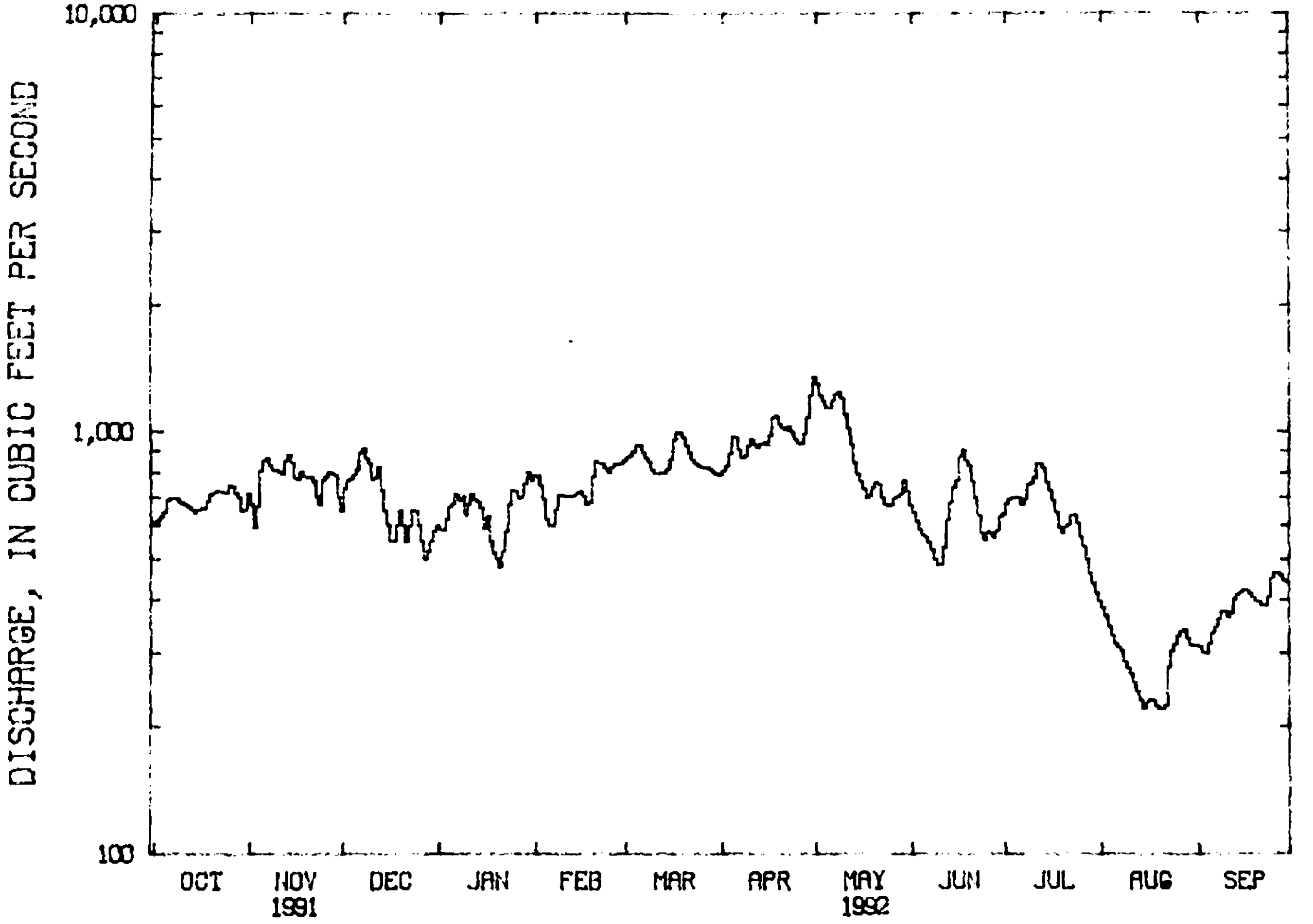


12324200 CLARK FORK AT DEER LODGE, MT.
MEAN DAILY DISCHARGE (CFS)



12324680 CLARK FORK AT GOLDCREEK MT
MEAN DAILY DISCHARGE (CFS)

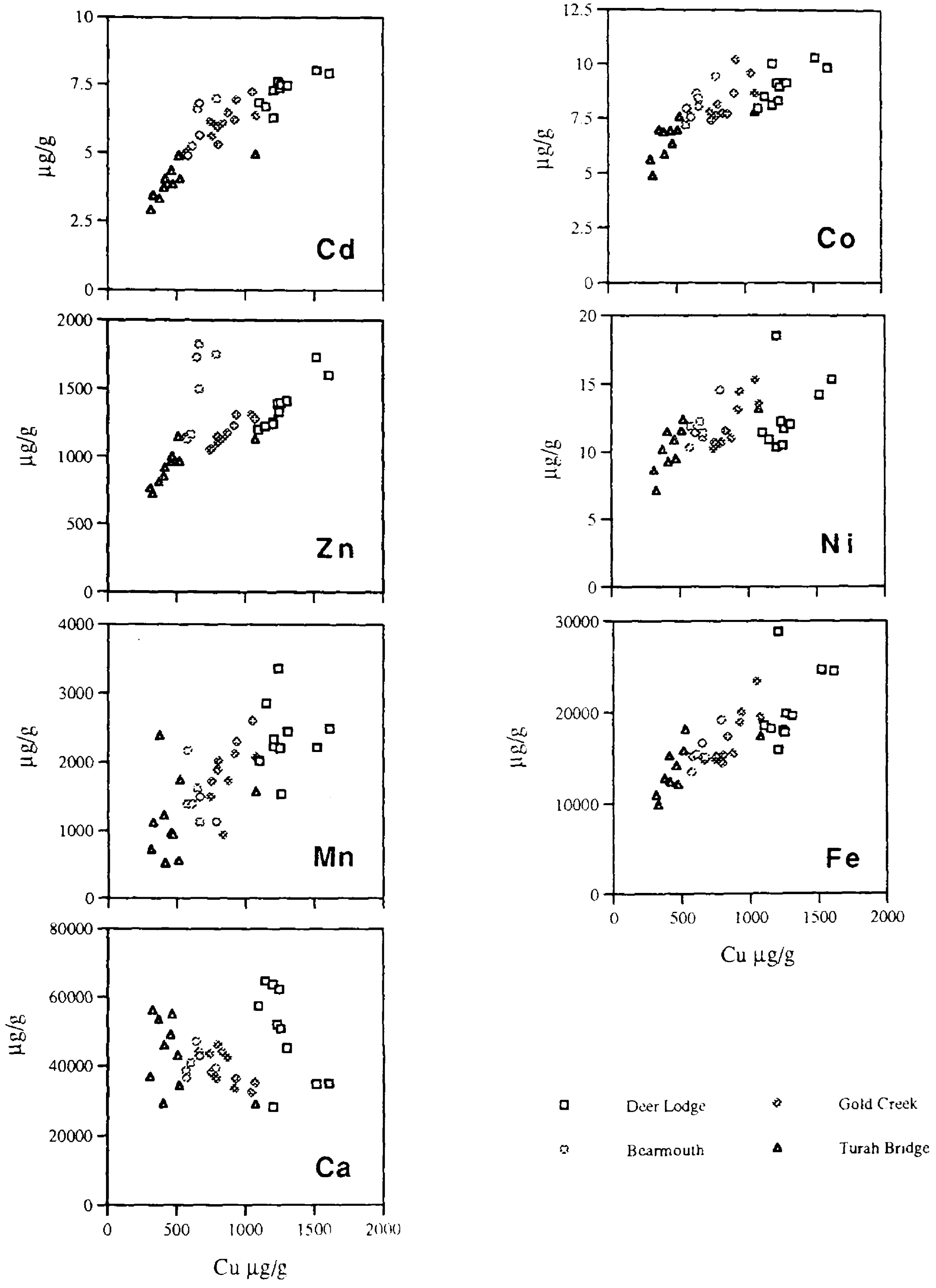

DISCHARGE, IN CUBIC FEET PER SECOND
1,000
100
10
OCT
NOV
1991
DEC
JAN
FEB
MAR
APR
MAY
1992
JUN
JUL
AUG
SEP
12324680 CLARK FORK AT GOLDCREEK MT
MEAN DAILY DISCHARGE (CFS)



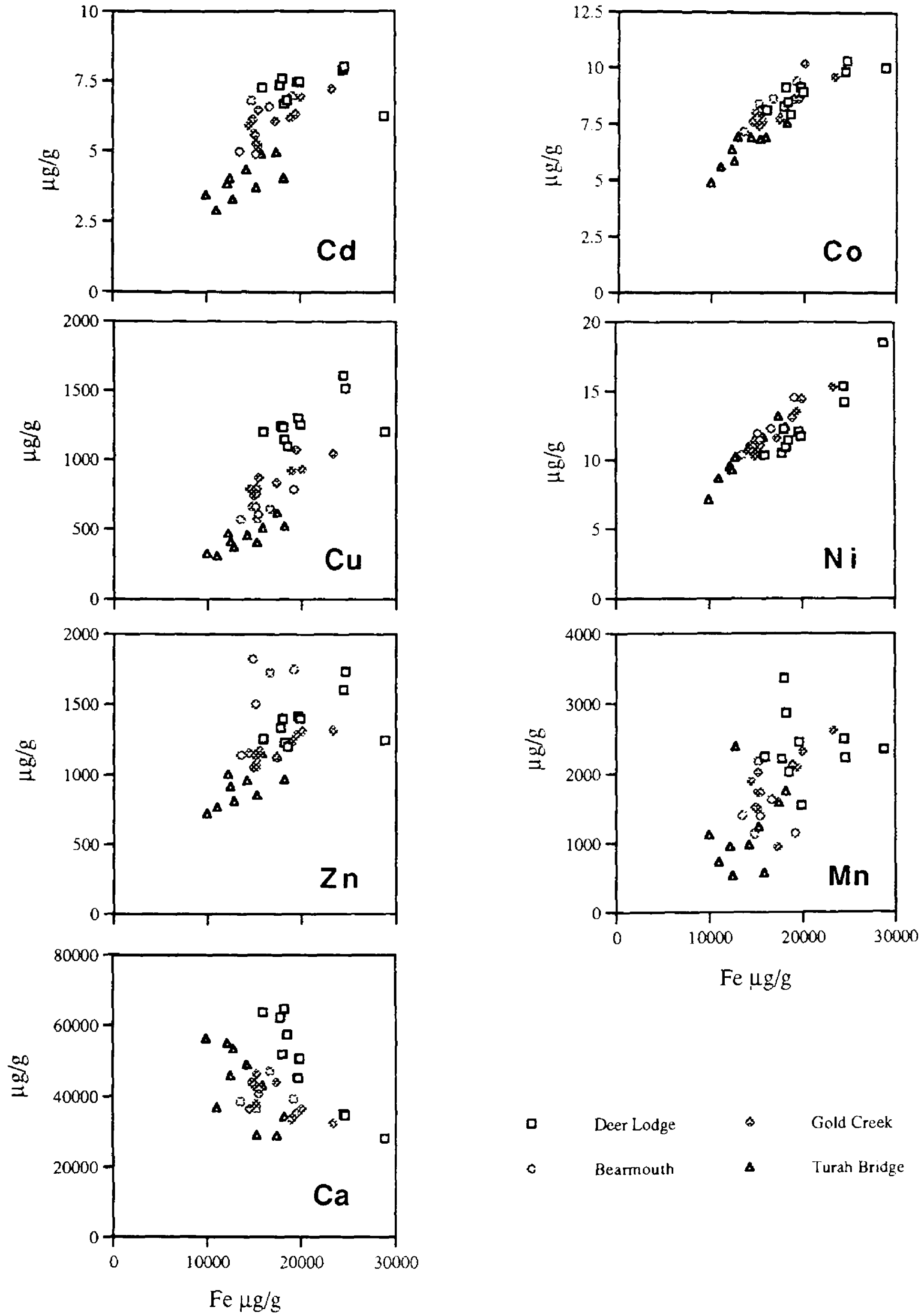
12334550 CLARK FORK AT TURAH BRIDGE NEAR BONNER MT
MEAN DAILY DISCHARGE (CFS)

APPENDIX II

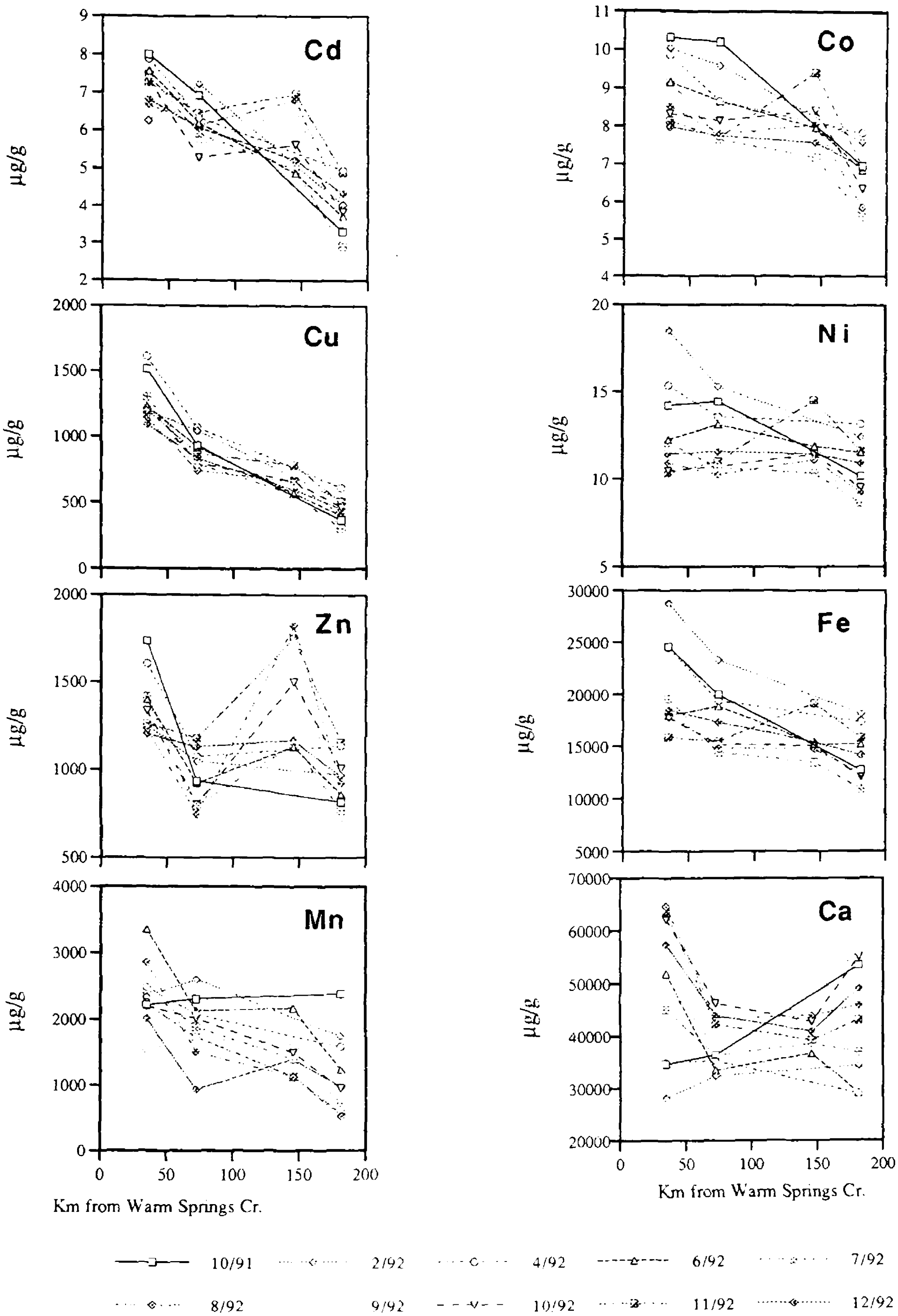
Sediments



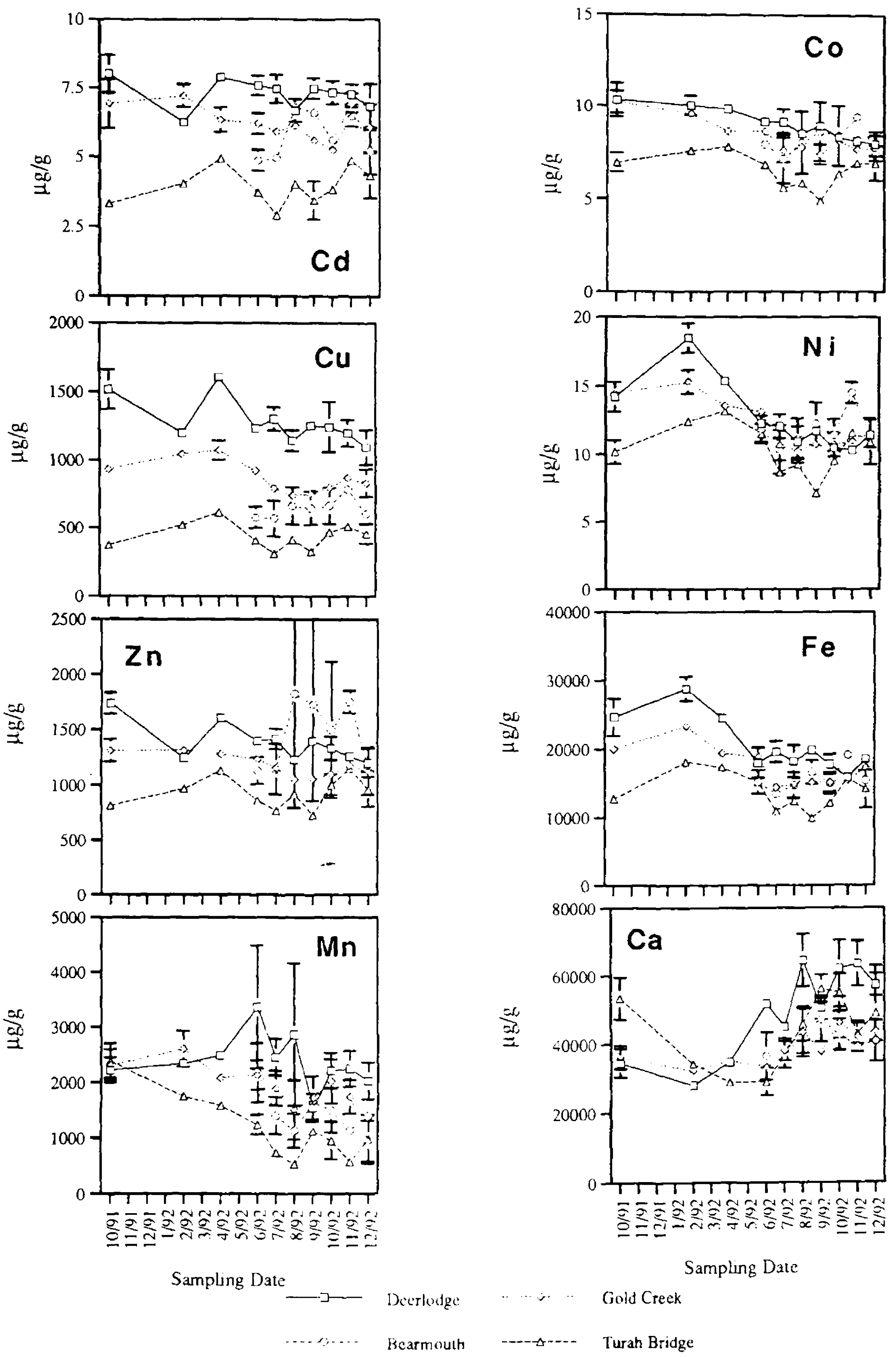
Fine-grained sediment metal concentrations vs. Cu concentrations at all stations.



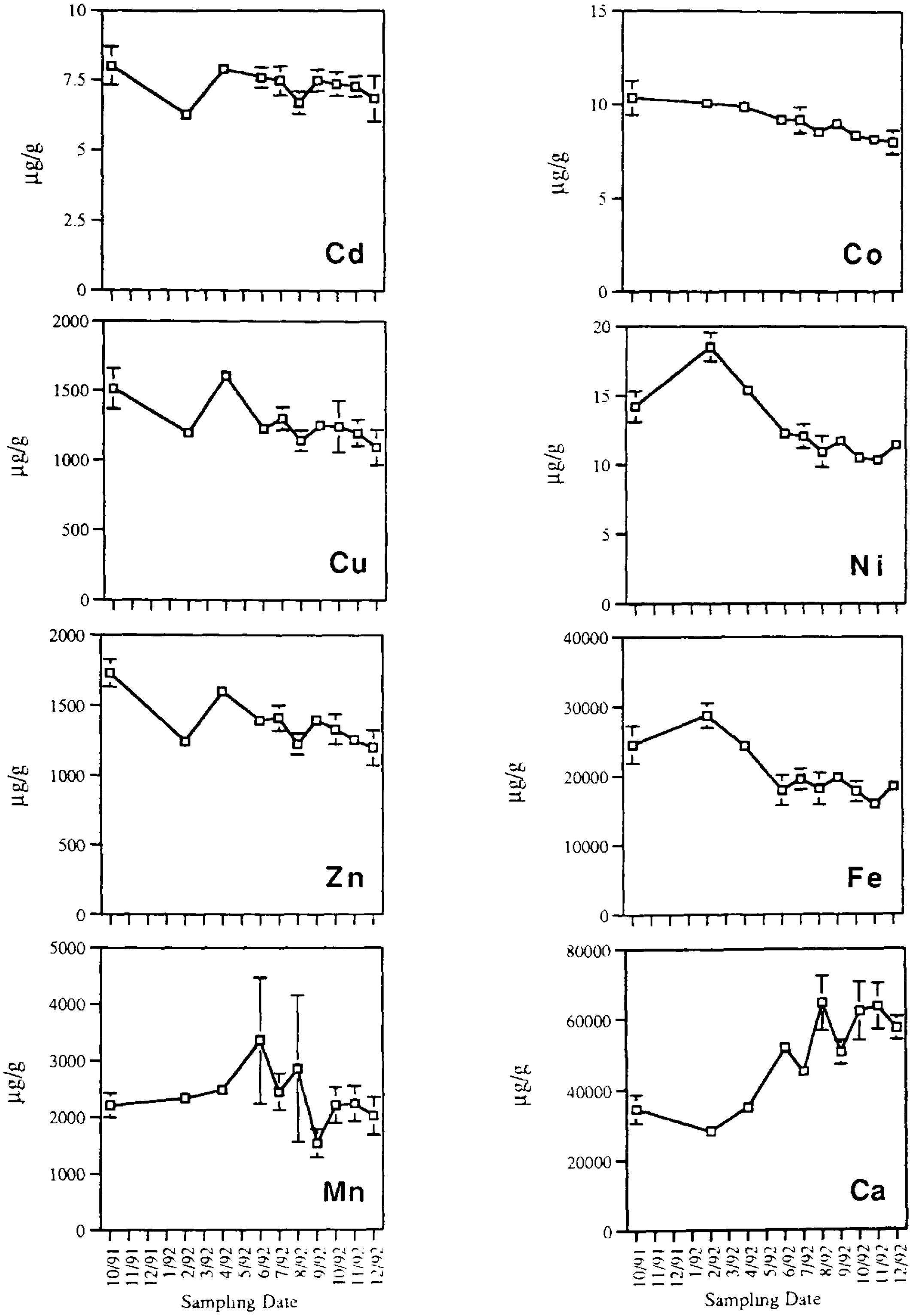
Fine-grained sediment metal concentrations vs. Fe concentrations at all sampling stations.



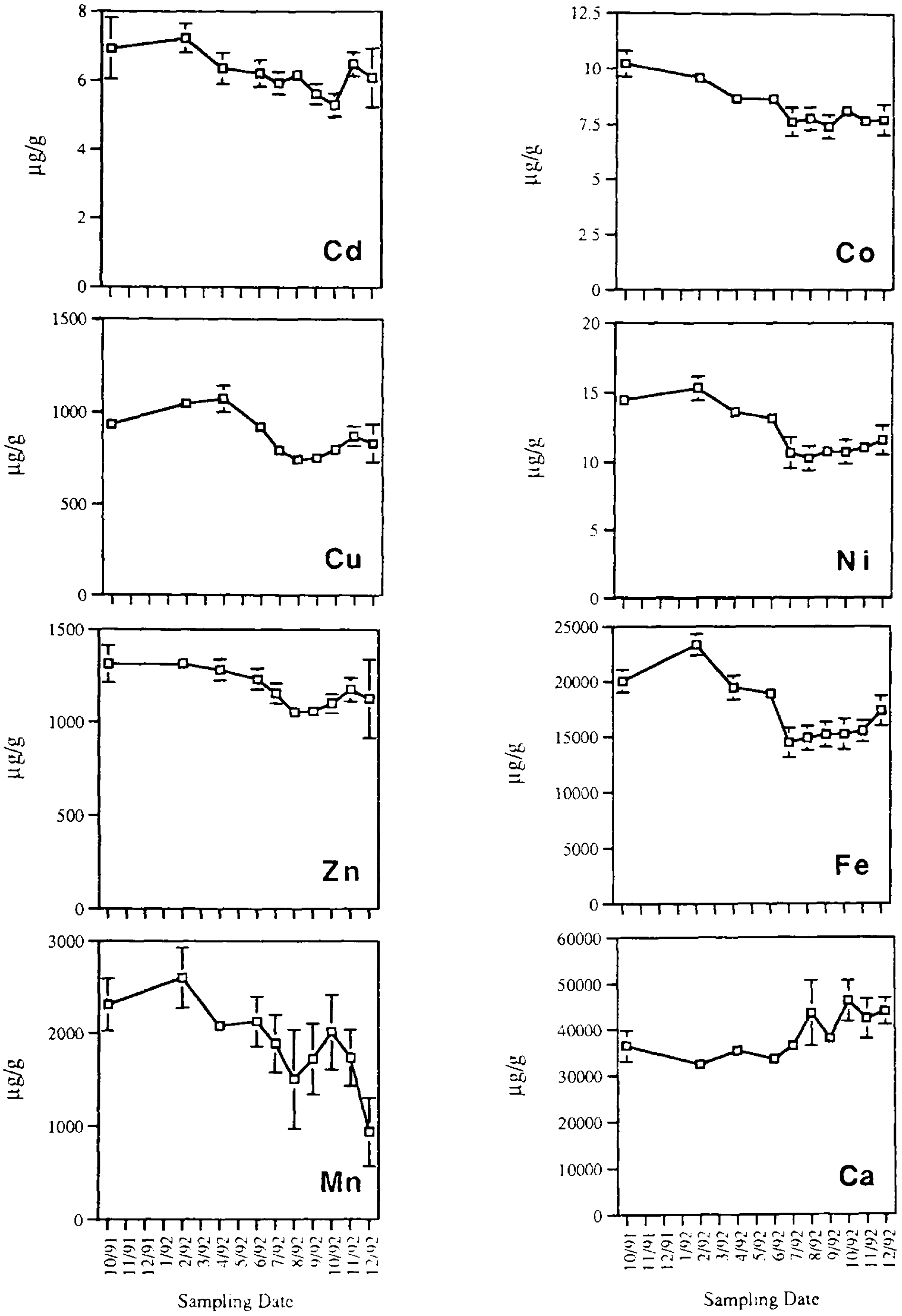
Downstream variability in fine-grained sediment metal concentrations at all stations. Error bars not included for clarity (see temporal plots).



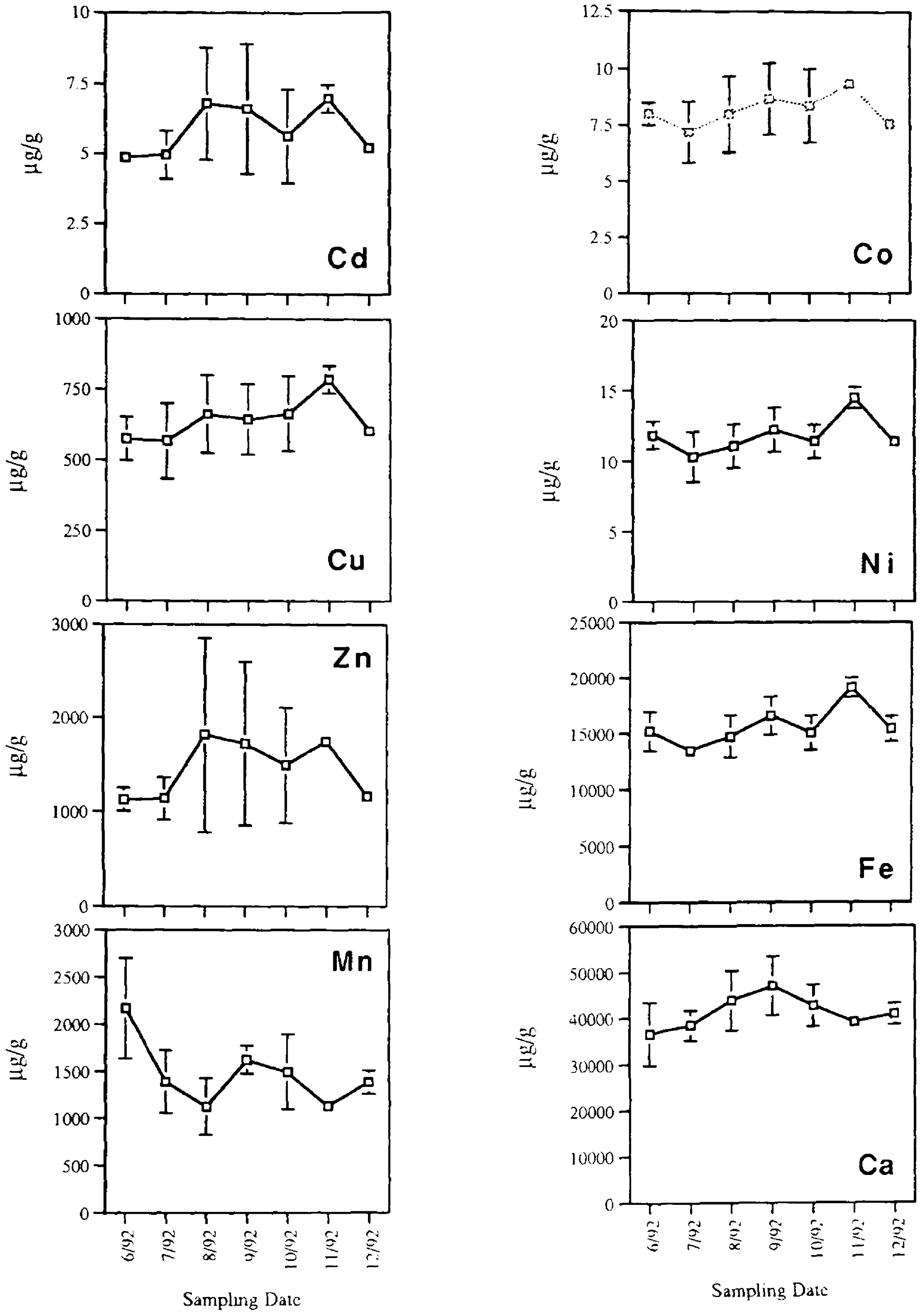
Temporal variability in fine-grained sediment metal concentrations for all sampling stations. Where no error bars are shown, error is too small for scale.



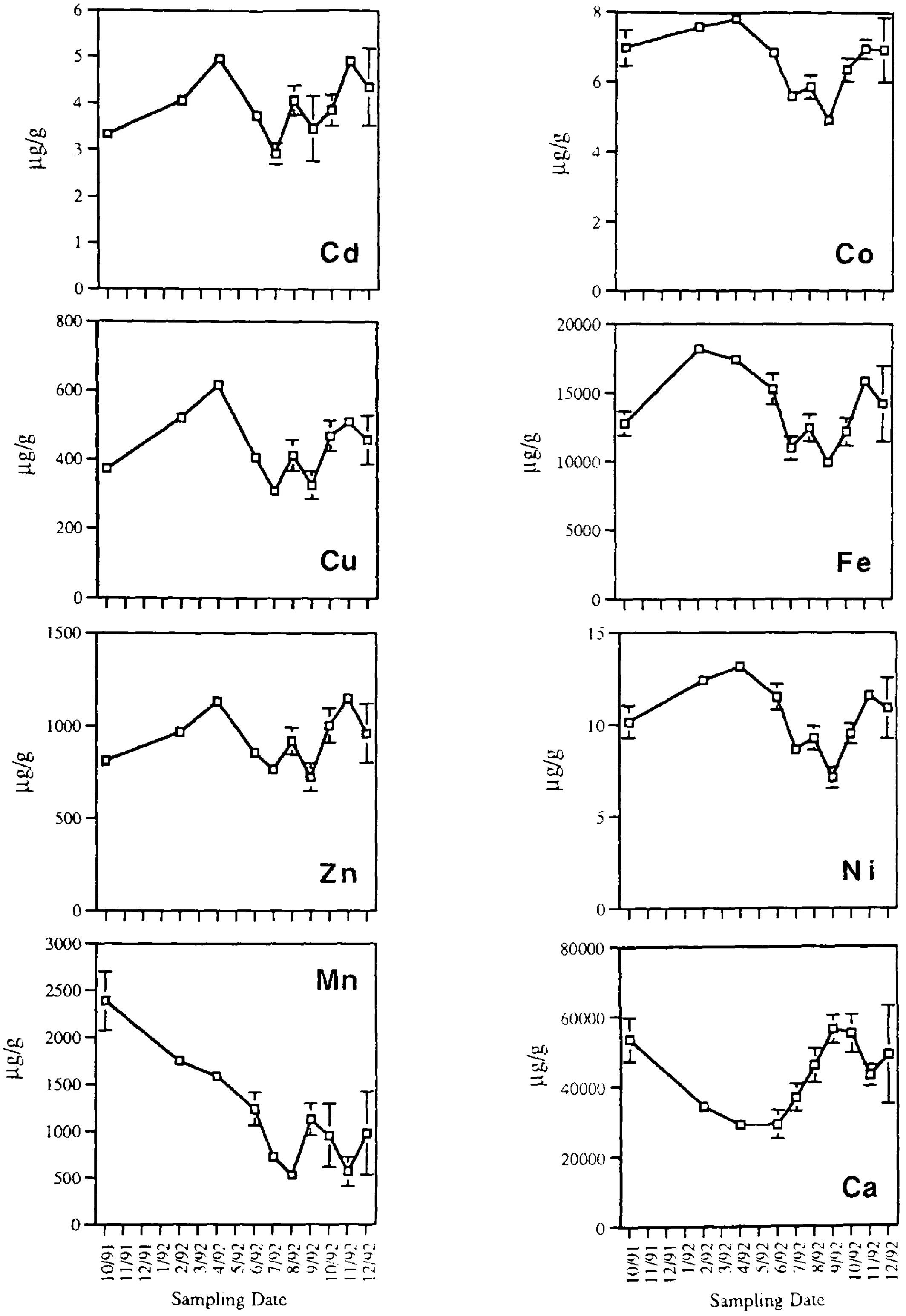
Deer Lodge fine-grained sediment metal concentration temporal variability. Where error bars not shown, error is too small for scale.



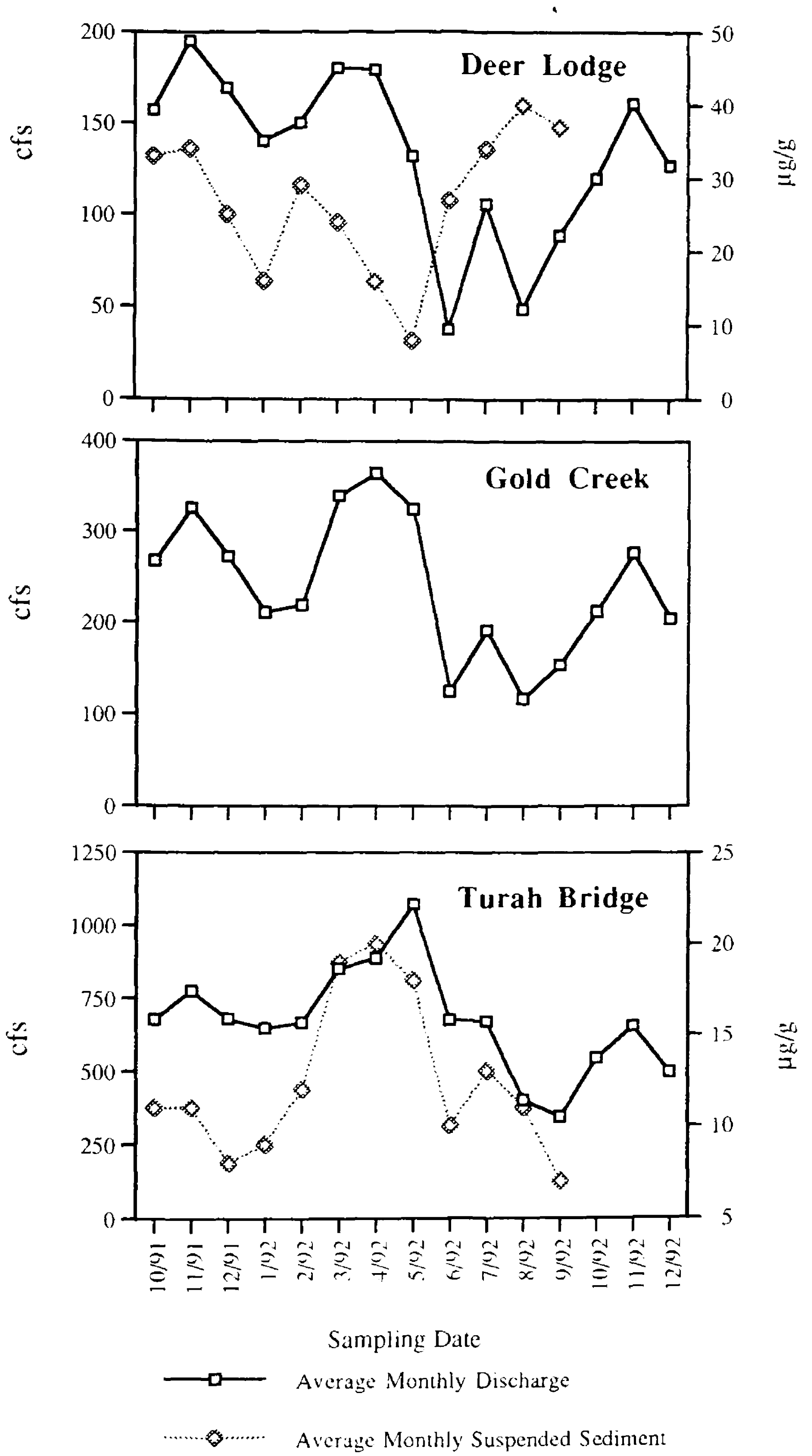
Gold Creek fine-grained sediment metal concentration temporal variability. Where no error bars are shown, error is too small for scale.



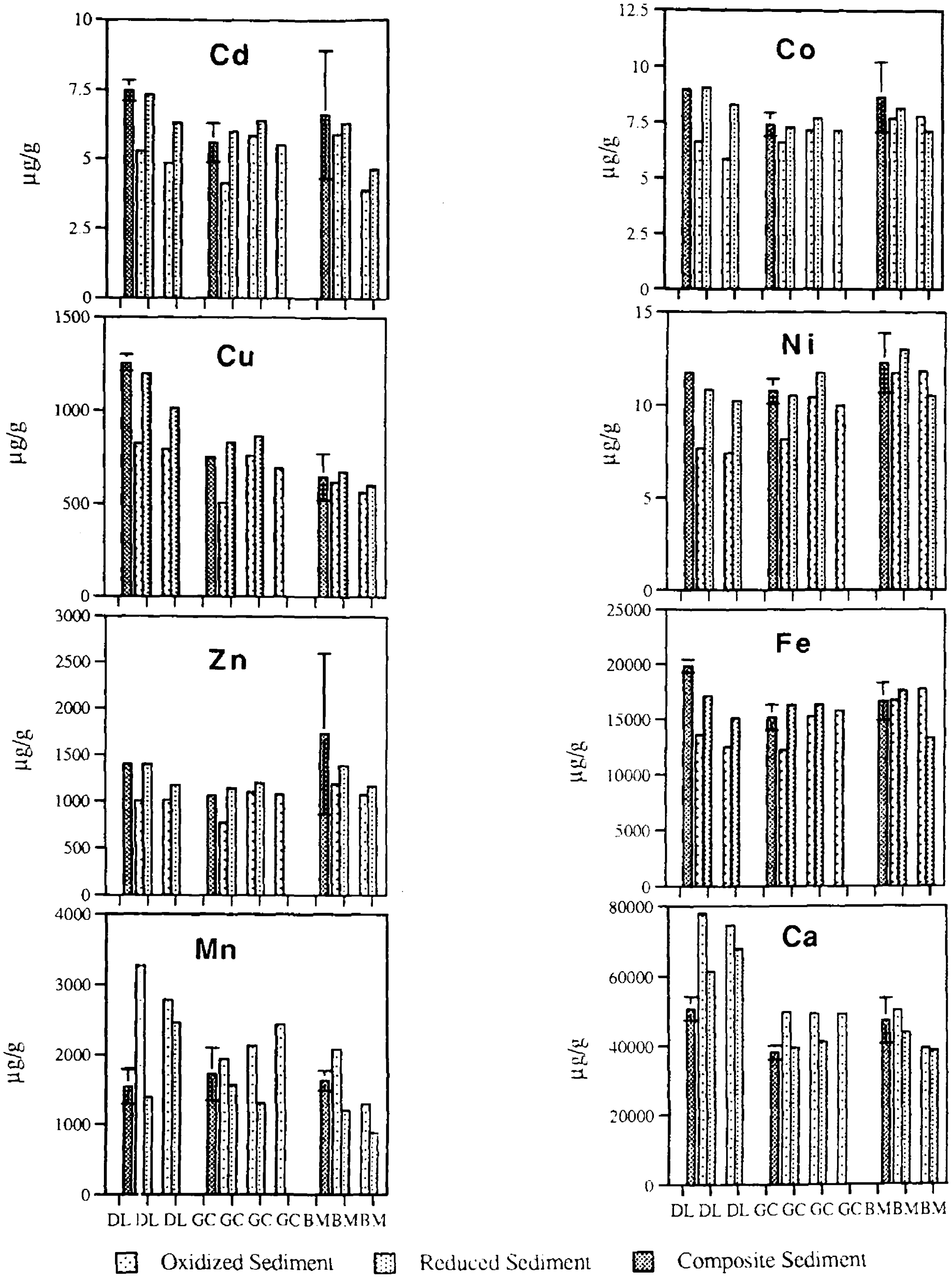
Bearmouth fine-grained sediment metal concentrations temporal variability.
Where error bars not shown, error is too smal for scale.



Turah Bridge fine-grained sediment metal concentration variability.
Where error bars not shown, error is too small for scale.



Average monthly stream flow and total suspended sediment (TSS) at Deer Lodge and Turah Bridge. Only discharge data available for Gold Creek.



Metal concentrations in oxidized, reduced and composite fine-grained sediment samples from Deer Lodge - DL, Gold Creek - GC and Bearmouth - BM. Standard deviation for composite samples only. Where composite sample columns have no error bars, error is too small for scale.

Constants and coefficients of determination for sediment metal concentrations vs. Cu and Fe concentrations.

		Cu vs.			Fe vs.	
Metal	r2	m	b	r2	m	b
Deer Lodge						
Ca	0.39	-51.1	114848	0.88	-3.06	112277
Cd	0.58	0.003	3.97	0	0	7.56
Co	0.52	0.004	4.35	0.75	0.0002	5.42
Cu				0.24	0.02	880
Fe	0.24	12.28	4847			
Mn	0	-0.02	2402	0.01	-0.012	2627
Ni	0.17	0.007	4.23	0.94	0.001	0.02
Zn	0.87	0.995	107	0.16	0.017	1027
Gold Creek						
Ca	0.43	-27.4	62805	0.45	-1.1	58190
Cd	0.5	0.004	3.41	0.64	0.0002	3.49
Co	0.5	0.006	3.37	0.71	0.0003	3.69
Cu				0.77	0.035	276
Fe	0.77	22.2	-2019			
Mn	0.39	2.49	286	0.39	0.098	184
Ni	0.79	0.014	0.15	0.95	0.001	1.5
Zn	0.84	0.79	486	0.75	0.03	663
Bearmouth						
Ca	0.05	10	34783	0.01	0.16	38767
Cd	0.68	0.01	-0.55	0.43	0.0003	0.72
Co	0.05	-0.002	2.32	0.82	0.0004	2.31
Cu				0.71	0.04	97
Fe	0.71	20	2556			
Mn	0.35	-2.82	3298	0.05	-0.05	2180
Ni	0.68	0.02	2.33	0.97	0.001	0.42
Zn	0.6	3.25	633	0.29	0.09	12
Turah Bridge						
Ca	0.03	-20	53492	0.47	-2.61	79579
Cd	0.71	0.007	1.1	0.5	0.0002	1.6
Co	0.58	0.008	2.9	0.84	0.0003	2.36
Cu				0.44	0.05	250
Fe	0.66	28	1828			
Mn	0.002	-0.33	1278	0.09	0.06	309
Ni	0.62	0.017	2.9	0.94	0.001	1.36
Zn	0.82	1.6	241	0.51	0.04	408

Constants and coefficients of determination for regressions of sediment metal concentrations vs. discharge (A) and total suspended sediment (TSS) (B).

A.

	Deer Lodge			Gold Creek			Turah Bridge		
Metal	r2	m	b	r2	m	b	r2	m	b
Ca	0.22	-131	64789	0.02	-8	40496	0.51	-46	71343
Cd	0.03	0.002	7.1	0.12	0.003	5.7	0.09	0.001	3.2
Co	0.1	0.005	8.4	0.12	0.004	7.5	0.57	0.004	4
Cu	0.26	1.7	1078	0.44	1	661	0.43	0.9	-56
Fe	0.23	41	15742	0.11	13	14631	0.44	11	7037
Mn	0.23	-4.8	2945	0.07	1.6	1563	0.19	1.6	215
Ni	0.19	0.02	9.9	0.17	0.01	10	0.58	0.009	5.1
Zn	0.11	1.2	1242	0.33	0.76	1019	0.21	0.42	682

B.

	Deer Lodge			Turah Bridge		
Metal	r2	m	b	r2	m	b
Ca	0.34	927	15703	0.4	-1773	62055
Cd	0.12	-0.03	8.2	0.44	0.11	2.5
Co	0.29	-0.04	11	0.44	0.18	4.4
Cu	0.43	-14	1763	0.78	59	218
Fe	0.19	-223	28826	0.35	468	8226
Mn	0.05	-17	2978	0.03	25	1035
Ni	0.31	-0.19	19	0.48	0.37	5.9
Zn	0.17	-9.5	1724	0.69	29	539

(no TSS data available for Gold Creek)

Sample names by date and sampling station. Kohrs Bend included although data not used in analysis.

	Sampling Stations				
Date	Turah Bridge	Bearmouth	Gold Creek	Kohrs Bend	Deer Lodge
10/31/91	TB1		GC1		DL1
2/5/92			GC2		DL2
2/6/92	TB2				
4/15/92	TB3				
4/17/92			GC3		DL3
6/18/92	TB4				
6/19/92		BM1	GC4	KB1	DL4
7/21/92	TB5				
7/22/92		BM2	GC5	KB2	DL5
8/20/92	TB6	BM3	GC6	KB3	DL6
9/17/19 (a)	TB7	BM4	GC7	KB4	DL7
10/22/92	TB8	BM5	GC8	KB5	DL8
11/25/92	TB9	BM6	GC9	KB6	DL9
12/17/92	TB10	BM7	GC10		DL10

(a) oxidized/reduced sample pairs collected on this date

Analysis summary for sediment samples.

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
TB1-W	60100.00	3.36	6.48	372.90	11800.00	2172.00	9.40	795.80
TB1-X	47300.00	3.19	7.20	361.80	13200.00	2610.00	10.60	832.00
TB1-Y	57500.00	3.44	6.60	384.80	12300.00	2076.00	9.51	793.30
TB1-Z	49300.00	3.31	7.58	371.50	13800.00	2703.00	11.20	837.40
Average	53550.00	3.32	6.96	372.75	12775.00	2390.25	10.18	814.63
STDEV	6208.33	0.10	0.52	9.43	895.82	312.24	0.87	23.31
GC1-W	37500.00	6.81	9.55	930.30	18500.00	2166.00	13.90	1278.00
GC1-X	31400.00	5.75	11.01	895.60	20800.00	1985.00	14.30	1253.00
GC1-Y	37600.00	7.37	10.14	918.50	20300.00	2551.00	14.80	1256.00
GC1-Z	39100.00	7.80	10.17	990.10	20500.00	2551.00	14.80	1462.00
Average	36400.00	6.93	10.22	933.63	20025.00	2313.25	14.45	1312.25
STDEV	3412.72	0.88	0.60	40.31	1037.22	284.30	0.44	100.45
DL1-W	39000.00	8.15	9.86	1509.00	21400.00	2547.00	12.80	1702.00
DL1-X	29400.00	7.01	10.25	1339.00	26600.00	2185.00	14.60	1635.00
DL1-Y	33500.00	8.56	11.63	1695.00	27100.00	2050.00	15.40	1869.00
DL1-Z	36800.00	8.35	9.58	1527.00	23400.00	2108.00	14.10	1733.00
Average	34675.00	8.02	10.33	1517.50	24625.00	2222.50	14.23	1734.75
STDEV	4180.41	0.69	0.91	145.52	2703.55	223.29	1.09	98.40
TB2-X	33300.00	4.11	7.76	527.00	18500.00	1751.00	12.50	999.30
TB2-Y	34600.00	4.17	7.74	534.30	18300.00	1686.00	12.90	970.50
TB2-Z	35300.00	3.90	7.29	506.30	17700.00	1818.00	11.90	938.90
Average	34400.00	4.06	7.60	522.53	18166.67	1751.67	12.43	969.57
STDEV	1014.89	0.14	0.26	14.52	416.33	66.00	0.50	30.21

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
GC2-X	33200.00	6.89	9.32	1006.00	22200.00	2590.00	14.30	1262.00
GC2-Y	31200.00	7.70	9.39	1092.00	24000.00	2295.00	15.90	1360.00
GC2-Z	32800.00	7.10	10.08	1041.00	23800.00	2945.00	15.70	1322.00
Average	32400.00	7.23	9.60	1046.33	23333.33	2610.00	15.30	1314.67
STDEV	1058.30	0.42	0.42	43.25	986.58	325.46	0.87	49.41
DL2-X	30000.00	6.37	9.98	1205.00	28300.00	2423.00	17.50	1259.00
DL2-Y	27400.00	6.50	10.59	1252.00	30800.00	2436.00	19.60	1278.00
DL2-Z	27200.00	5.94	9.56	1147.00	27300.00	2183.00	18.40	1204.00
Average	28200.00	6.27	10.04	1201.33	28800.00	2347.33	18.50	1247.00
STDEV	1562.05	0.29	0.52	52.60	1802.78	142.47	1.05	38.43
TB3-X	29700.00	4.91	7.75	614.90	17300.00	1551.00	13.40	1130.00
TB3-Y	28400.00	5.01	7.82	627.80	17600.00	1571.00	12.70	1132.00
TB3-Z	29100.00	4.97	7.93	607.10	17300.00	1637.00	13.40	1143.00
Average	29066.67	4.96	7.83	616.60	17400.00	1586.33	13.17	1135.00
STDEV	650.64	0.05	0.09	10.45	173.21	45.00	0.40	7.00
GC3-X	36400.00	5.89	8.27	997.20	18300.00	2168.00	12.80	1216.00
GC3-Y	34600.00	6.40	8.73	1136.00	20500.00	2058.00	14.10	1310.00
GC3-Z	34900.00	6.77	9.01	1084.00	19500.00	2026.00	13.80	1321.00
Average	35300.00	6.35	8.67	1072.40	19433.33	2084.00	13.57	1282.33
STDEV	964.37	0.44	0.38	70.12	1101.51	74.48	0.68	57.71
DL3-X	36400.00	8.13	9.80	1643.00	23400.00	2502.00	14.80	1639.00
DL3-Y	34000.00	8.02	10.16	1598.00	25900.00	2405.00	15.90	1608.00
DL3-Z	34300.00	7.55	9.63	1587.00	24100.00	2563.00	15.40	1568.00
Average	34900.00	7.90	9.86	1609.33	24466.67	2490.00	15.37	1605.00
STDEV	1307.67	0.31	0.27	29.67	1289.70	79.68	0.55	35.59

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
TB4-W	32200.00	3.71	6.63	374.90	13800.00	1520.00	10.60	812.40
TB4-X	23900.00	3.59	6.66	408.30	15700.00	923.90	11.50	861.10
TB4-Y	32300.00	3.82	7.13	429.80	16400.00	1136.00	12.30	877.00
TB4-Z	28300.00	3.83	7.02	411.20	15100.00	1372.00	11.70	877.50
Average	29175.00	3.74	6.86	406.05	15250.00	1237.98	11.53	857.00
STDEV	3979.43	0.11	0.25	22.85	1103.03	262.39	0.70	30.69
BM1-W	27700.00	5.23	8.52	680.80	17600.00	1676.00	12.70	1302.00
BM1-X	38700.00	4.97	7.66	561.60	15000.00	1779.00	12.00	1120.00
BM1-Y	36000.00	4.83	8.25	570.30	14900.00	2781.00	12.30	1075.00
BM1-Z	44200.00	4.52	7.46	492.40	13400.00	2465.00	10.50	1021.00
Average	36650.00	4.89	7.97	576.28	15225.00	2175.25	11.88	1129.50
STDEV	6873.38	0.29	0.50	77.91	1744.28	534.53	0.96	121.91
GC4-W	33800.00	6.70	9.06	971.10	19300.00	2408.00	13.90	1305.00
GC4-X	33200.00	5.95	8.62	881.30	18300.00	2103.00	12.50	1178.00
GC4-Y	34800.00	6.31	8.69	930.30	18600.00	2244.00	13.00	1246.00
GC4--Z	32200.00	5.88	8.31	904.50	19400.00	1772.00	13.10	1203.00
Average	33500.00	6.21	8.67	921.80	18900.00	2131.75	13.13	1233.00
STDEV	1089.34	0.38	0.31	38.48	535.41	270.28	0.58	55.61
KB1-W	34400.00	7.78	9.59	1158.00	19700.00	3803.00	12.10	1496.00
KB1-X	42000.00	6.92	9.14	971.70	17400.00	4817.00	12.30	1294.00
KB1-Y	33900.00	7.21	8.17	1212.00	14500.00	2330.00	11.20	1422.00
KB1-Z	45100.00	7.16	9.40	988.70	16000.00	4829.00	12.20	1316.00
Average	38850.00	7.27	9.08	1082.60	16900.00	3944.75	11.95	1382.00
STDEV	5576.44	0.36	0.63	120.48	2210.58	1179.01	0.51	94.33

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
DL4-W	49300.00	7.85	9.34	1247.00	17300.00	4040.00	12.10	1421.00
DL4-X	52500.00	7.95	9.34	1219.00	16700.00	4004.00	12.30	1374.00
DL4-Y	53700.00	7.34	8.74	1164.00	17700.00	3704.00	12.00	1327.00
DL4-Z	52300.00	7.21	9.24	1307.00	20300.00	1701.00	12.60	1468.00
Average	51950.00	7.59	9.17	1234.25	18000.00	3362.25	12.25	1397.50
STDEV	1871.72	0.36	0.29	59.51	1587.45	1117.70	0.26	60.68
TB5-W	34500.00	3.23	5.74	348.60	11200.00	660.60	8.92	837.90
TB5-X	34600.00	2.86	5.46	289.70	10200.00	705.70	8.47	733.30
TB5-Y	35900.00	2.88	5.59	309.30	12100.00	725.60	8.97	763.30
TB5-Z	42700.00	2.71	5.65	291.00	10400.00	833.40	8.32	738.70
Average	36925.00	2.92	5.61	309.65	10975.00	731.33	8.67	768.30
STDEV	3902.46	0.22	0.12	27.47	865.54	73.28	0.32	48.20
BM2-W	39400.00	4.45	6.29	501.50	12400.00	1076.00	9.29	1011.00
BM2-X	40000.00	4.41	6.37	472.40	11900.00	1152.00	9.32	982.60
BM2-Y	33800.00	6.23	9.18	765.30	17500.00	1751.00	13.00	1473.00
BM2-Z	41000.00	4.86	6.91	540.00	12200.00	1607.00	9.71	1108.00
Average	38550.00	4.98	7.19	569.80	13500.00	1396.50	10.34	1143.65
STDEV	3234.71	0.85	1.36	133.24	2674.57	332.91	1.79	226.04
GC5-W	36200.00	6.34	8.10	828.40	14900.00	1887.00	11.30	1212.00
GC5-X	35600.00	5.82	8.21	800.90	15700.00	1449.00	11.70	1153.00
GC5-Y	35200.00	5.56	6.81	739.20	12600.00	2109.00	9.18	1080.00
GC5-Z	38400.00	5.97	7.47	806.40	14600.00	2120.00	10.40	1173.00
Average	36350.00	5.92	7.65	793.73	14450.00	1891.25	10.65	1154.50
STDEV	1427.12	0.33	0.65	38.24	1317.83	313.76	1.12	55.38

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
KB2-W	38000.00	7.44	8.93	1100.00	16500.00	2545.00	11.50	1448.00
KB2-X	41500.00	8.33	9.33	1245.00	17500.00	2609.00	10.30	1663.00
KB2-Y	37300.00	7.17	8.20	984.80	15700.00	2544.00	10.60	1302.00
KB2-Z	43600.00	8.36	8.26	1016.00	16900.00	2940.00	10.00	1341.00
Average	40100.00	7.82	8.68	1086.45	16650.00	2659.50	10.60	1438.50
STDEV	2969.85	0.61	0.55	116.36	754.98	189.46	0.65	161.89
DL5-W	44000.00	7.85	9.55	1354.00	20500.00	2404.00	12.90	1465.00
DL5-X	46300.00	7.97	9.81	1397.00	21200.00	2434.00	12.70	1513.00
DL5-Y	44700.00	7.13	9.08	1229.00	18800.00	2887.00	11.40	1374.00
DL5-Z	45500.00	6.93	8.22	1238.00	17900.00	2087.00	11.20	1312.00
Average	45125.00	7.47	9.16	1304.50	19600.00	2453.00	12.05	1416.00
STDEV	994.57	0.52	0.70	83.92	1516.58	329.18	0.87	90.17
TB6-W	43600.00	4.25	5.85	452.40	13200.00	465.70	9.39	952.30
TB6-X	50300.00	4.25	6.31	407.70	13200.00	594.90	9.95	987.40
TB6-Y	49900.00	3.59	5.47	352.70	11100.00	608.30	8.41	818.80
TB6-Z	40200.00	4.14	5.82	442.00	12200.00	454.10	9.35	929.40
Average	46000.00	4.06	5.86	413.70	12425.00	530.75	9.28	921.98
STDEV	4936.26	0.31	0.34	44.93	1001.25	82.13	0.64	72.80
BM3-W	35500.00	9.73	10.55	866.10	17500.00	1570.00	13.40	3370.00
BM3-X	48300.00	5.93	7.24	603.50	13600.00	941.70	10.50	1322.00
BM3-Y	42100.00	6.36	7.51	623.50	13500.00	1101.00	10.40	1457.00
BM3-Z	49700.00	5.23	6.87	562.30	14400.00	912.40	10.10	1155.00
Average	43900.00	6.81	8.04	663.85	14750.00	1131.28	11.10	1826.00
STDEV	6501.28	2.00	1.69	137.22	1877.05	304.00	1.54	1036.72

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
GC6-W	48500.00	6.17	7.82	702.80	13900.00	2303.00	9.69	1018.00
GC6-X	50700.00	6.13	7.14	736.20	14000.00	1333.00	9.34	1040.00
GC6-Y	35800.00	6.03	8.38	717.90	15700.00	1186.00	11.20	1071.00
GC6-Z	39200.00	6.26	7.89	818.10	15900.00	1205.00	10.80	1086.00
Average	43550.00	6.15	7.81	743.75	14875.00	1506.75	10.26	1053.75
STDEV	7178.90	0.10	0.51	51.41	1071.99	534.83	0.88	30.58
KB3-W	35900.00	12.06	11.37	1741.00	23500.00	2304.00	13.60	2298.00
KB3-X	34100.00	13.59	10.58	1942.00	28600.00	1935.00	14.30	2926.00
KB3-Y	41400.00	9.77	9.12	1418.00	17400.00	1901.00	11.00	1733.00
KB3-Z	42200.00	8.99	9.73	1249.00	18600.00	1903.00	12.80	1680.00
Average	38400.00	11.10	10.20	1587.50	22025.00	2010.75	12.93	2159.25
STDEV	4007.49	2.11	0.98	312.27	5116.23	196.12	1.42	582.67
DL6-W	70700.00	6.35	8.38	1096.00	15100.00	3993.00	9.65	1173.00
DL6-X	69500.00	6.41	8.70	1087.00	17700.00	3960.00	10.70	1169.00
DL6-Y	64900.00	6.74	8.43	1147.00	19800.00	1925.00	10.90	1247.00
DL6-Z	53600.00	7.25	8.58	1254.00	20200.00	1575.00	12.40	1331.00
Average	64675.00	6.69	8.52	1146.00	18200.00	2863.25	10.91	1230.00
STDEV	7795.03	0.41	0.15	76.69	2339.52	1293.46	1.13	76.29
TB7-W	54900.00	2.56	4.75	297.80	9620.00	1254.00	7.00	673.50
TB7-X	61700.00	3.97	4.75	291.70	9210.00	1252.00	6.45	661.40
TB7-Y	56900.00	4.04	5.01	377.10	10700.00	895.40	7.74	821.40
TB7-Z	51900.00	3.27	5.13	339.90	10100.00	1094.00	7.40	747.60
Average	56350.00	3.46	4.91	326.63	9907.50	1123.85	7.15	725.98
STDEV	4116.23	0.70	0.19	39.89	641.42	169.75	0.55	74.16

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
BM4-W	53000.00	5.81	8.03	592.00	17100.00	1483.00	12.50	1488.00
BM4-X	51000.00	4.82	7.39	537.20	14200.00	1803.00	10.20	1053.00
BM4-Y	45700.00	5.78	8.26	632.60	17100.00	1532.00	12.30	1369.00
BM4-Z	38600.00	10.02	10.97	824.30	18100.00	1700.00	14.00	3006.00
Average	47075.00	6.61	8.66	646.53	16625.00	1629.50	12.25	1729.00
STDEV	6435.00	2.32	1.58	124.80	1683.99	148.37	1.56	870.90
GC7-W	37900.00	5.36	7.12	765.70	15500.00	1751.00	10.40	1058.00
GC7-X	40200.00	5.80	8.18	741.10	16400.00	2253.00	11.30	1052.00
GC7-Y	35400.00	5.37	7.41	766.40	15100.00	1448.00	11.30	1063.00
GC7-Z	38400.00	5.92	7.01	741.40	13700.00	1443.00	9.95	1059.00
Average	37975.00	5.61	7.43	753.65	15175.00	1723.75	10.74	1058.00
STDEV	1980.53	0.29	0.53	14.32	1123.61	381.10	0.67	4.55
KB4-W	44800.00	7.16	8.70	1041.00	18600.00	2815.00	11.20	1369.00
KB4-X	37300.00	9.15	10.89	1429.00	18800.00	1924.00	11.80	1775.00
KB4-Y	34600.00	6.19	10.34	805.40	20700.00	2160.00	16.40	1146.00
KB4-Z	36200.00	7.31	9.74	1172.00	22200.00	2192.00	13.50	1458.00
Average	38225.00	7.45	9.92	1111.85	20075.00	2272.75	13.23	1437.00
STDEV	4521.34	1.24	0.94	260.21	1703.67	380.74	2.33	260.76
DL7-W	51000.00	6.96	8.79	1226.00	20200.00	1584.00	11.70	1365.00
DL7-X	52400.00	7.61	8.94	1290.00	19100.00	1691.00	11.40	1406.00
DL7-Y	53600.00	7.86	9.27	1298.00	20400.00	1725.00	12.10	1443.00
DL7-Z	45800.00	7.48	8.85	1211.00	19700.00	1176.00	11.60	1384.00
Average	50700.00	7.48	8.96	1256.25	19850.00	1544.00	11.70	1399.50
STDEV	3435.11	0.38	0.21	44.14	580.23	252.58	0.29	33.49

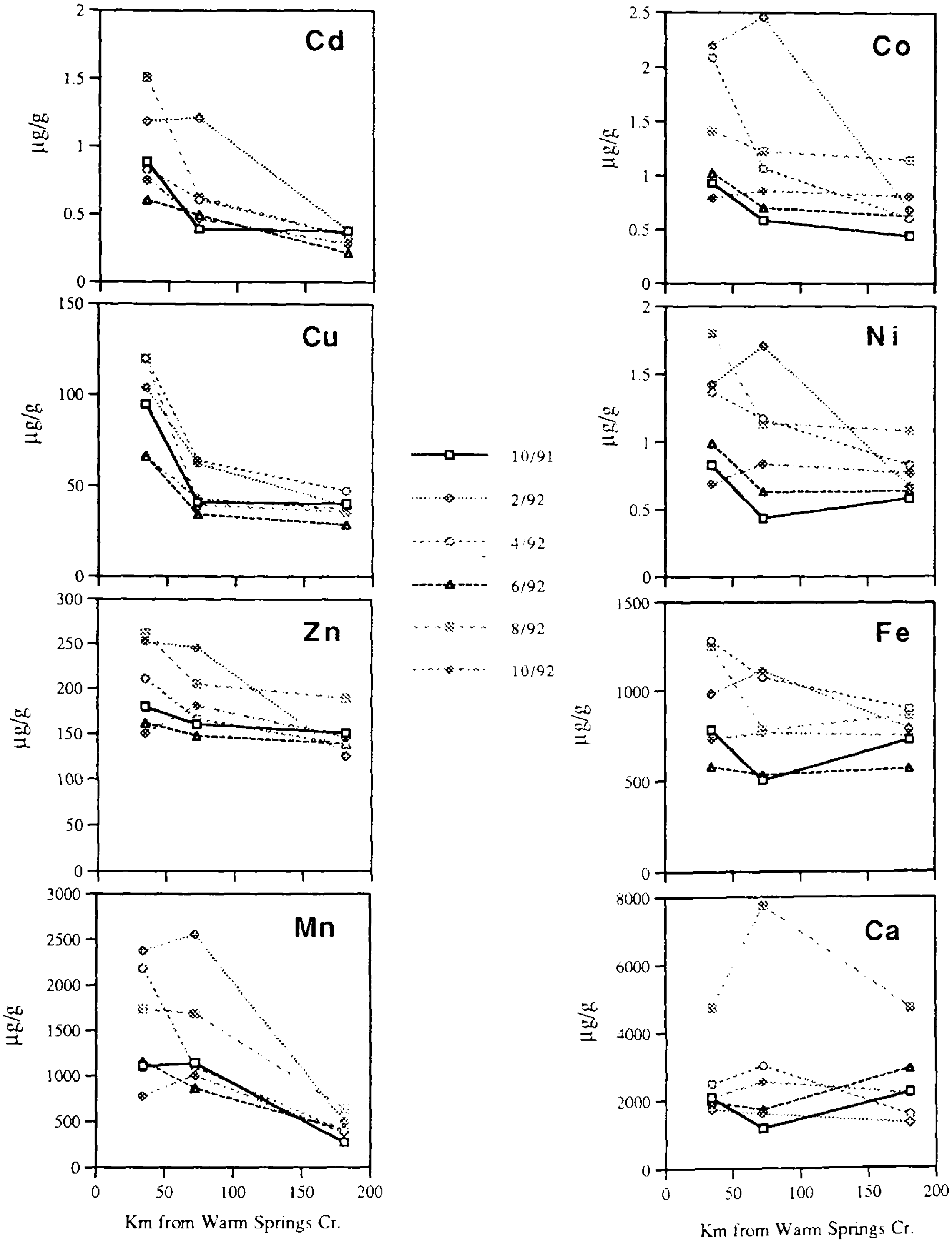
Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
TB8-W	50600.00	4.18	6.70	520.50	13500.00	971.40	10.20	1070.00
TB8-X	62800.00	3.39	6.04	412.60	11100.00	670.80	9.12	905.80
TB8-Y	51500.00	3.98	6.13	468.90	12300.00	749.30	9.71	1098.00
TB8-Z	55700.00	3.90	6.60	478.30	11700.00	1421.00	9.05	950.60
Average	55150.00	3.86	6.37	470.08	12150.00	953.13	9.52	1006.10
STDEV	5563.27	0.33	0.33	44.40	1024.70	336.89	0.54	92.50
BM5-W	46200.00	4.90	7.80	608.40	14800.00	1922.00	10.70	1149.00
BM5-X	41900.00	4.44	7.30	589.00	14300.00	1124.00	11.00	1172.00
BM5-Y	46300.00	5.06	7.78	602.90	13900.00	1196.00	10.80	1262.00
BM5-Z	36800.00	8.11	10.84	865.70	17300.00	1754.00	13.20	2419.00
Average	42800.00	5.63	8.43	666.50	15075.00	1499.00	11.43	1500.50
STDEV	4495.18	1.67	1.62	133.05	1528.34	398.49	1.19	614.27
GC8-W	51900.00	5.62	8.05	796.30	13200.00	2587.00	9.48	1093.00
GC8-X	43500.00	4.96	8.27	787.50	15500.00	2000.00	10.90	1078.00
GC8-Y	47500.00	5.05	8.23	748.80	15800.00	1842.00	11.50	1059.00
GC8-Z	42200.00	5.56	8.06	869.80	16400.00	1648.00	11.00	1178.00
Average	46275.00	5.30	8.15	800.60	15225.00	2019.25	10.72	1102.00
STDEV	4375.98	0.34	0.11	50.54	1400.89	404.95	0.87	52.54
KB5-W	59100.00	6.27	8.27	985.80	16000.00	2464.00	11.00	1296.00
KB5-X	55000.00	6.52	11.43	1086.00	22400.00	2133.00	12.50	1484.00
KB5-Y	57200.00	6.57	9.13	1070.00	17800.00	1874.00	10.10	1373.00
KB5-Z	61000.00	7.00	8.42	1019.00	18000.00	2244.00	11.10	1285.00
Average	58075.00	6.59	9.31	1040.20	18550.00	2178.75	11.18	1359.50
STDEV	2570.83	0.30	1.46	46.17	2719.68	245.35	0.99	91.77

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
DL8-W	65500.00	7.34	8.24	1146.00	16300.00	2538.00	10.20	1265.00
DL8-X	71500.00	6.92	8.25	1097.00	17500.00	2400.00	10.00	1231.00
DL8-Y	51900.00	7.21	8.28	1232.00	19800.00	1825.00	11.20	1375.00
DL8-Z	60000.00	7.92	8.53	1512.00	17500.00	2090.00	10.50	1466.00
Average	62225.00	7.35	8.33	1246.75	17775.00	2213.25	10.48	1334.25
STDEV	8332.82	0.42	0.14	185.43	1463.73	319.51	0.53	107.20
TB9-X	45500.00	4.97	6.95	517.20	16500.00	540.50	11.70	1195.00
TB9-Y	44200.00	5.03	7.24	528.30	15200.00	740.00	11.80	1165.00
TB9-Z	39800.00	4.73	6.69	487.80	15800.00	422.30	11.30	1100.00
Average	43166.67	4.91	6.96	511.10	15833.33	567.60	11.60	1153.33
STCEV	2987.19	0.16	0.28	20.93	650.64	160.57	0.26	48.56
BM6-X	39400.00	7.33	9.34	795.40	19100.00	1047.00	14.70	1817.00
BM6-Y	39100.00	7.18	9.53	832.40	20100.00	1110.00	15.20	1804.00
BM6-Z	39200.00	6.41	9.45	736.20	18300.00	1249.00	13.70	1632.00
Average	39233.33	6.97	9.44	788.00	19166.67	1135.33	14.53	1751.00
STDEV	152.75	0.50	0.09	48.53	901.85	103.36	0.76	103.26
GC9-X	37200.00	6.81	7.99	928.90	16500.00	1651.00	11.40	1246.00
GC9-Y	44700.00	6.49	7.50	823.60	15400.00	1484.00	10.70	1170.00
GC9-Z	45000.00	6.12	7.62	864.80	14600.00	2075.00	10.90	1115.00
Average	42300.00	6.47	7.70	872.43	15500.00	1736.67	11.00	1177.00
STDEV	4419.28	0.35	0.25	53.06	953.94	304.67	0.36	65.78
KB6-X	45800.00	7.00	10.18	1128.00	18800.00	1747.00	12.70	1572.00
KB6-Y	53000.00	8.92	9.52	1291.00	19000.00	1711.00	11.60	1652.00
KB6-Z	58600.00	9.23	10.05	1280.00	17300.00	2136.00	12.00	1616.00
Average	52466.67	8.38	9.92	1233.00	18366.67	1864.67	12.10	1613.33
STDEV	6416.65	1.21	0.35	91.10	929.16	235.67	0.56	40.07

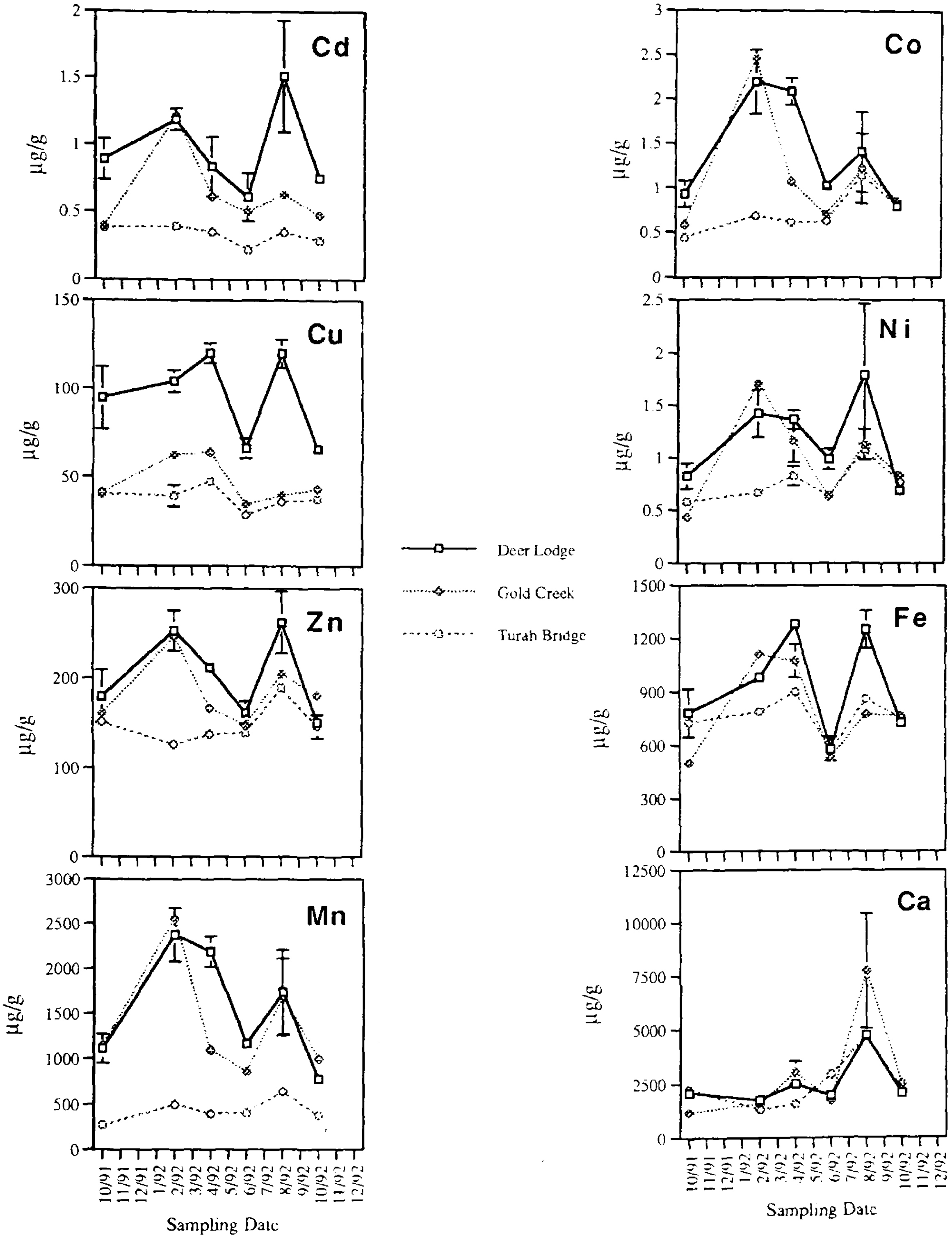
Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
DL9-X	63300.00	6.89	7.70	1112.00	16200.00	2014.00	10.40	1197.00
DL9-Y	70400.00	7.35	8.06	1185.00	15800.00	2610.00	10.30	1251.00
DL9-Z	57300.00	7.59	8.67	1305.00	15700.00	2108.00	10.30	1328.00
Average	63666.67	7.28	8.14	1200.67	15900.00	2244.00	10.33	1258.67
STDEV	6557.69	0.36	0.49	97.45	264.58	320.43	0.06	65.84
TB10-X	53800.00	4.36	6.25	421.70	12600.00	851.90	10.30	941.90
TB10-Y	60200.00	3.53	6.57	413.00	12600.00	1467.00	9.67	813.30
TB10-Z	33400.00	5.18	8.01	540.10	17400.00	605.90	12.80	1132.00
Average	49133.33	4.36	6.94	458.27	14200.00	974.93	10.92	962.40
STDEV	13996.19	0.82	0.94	71.00	2771.28	443.54	1.66	160.34
BM7-X	43400.00	4.92	7.57	570.30	15700.00	1472.00	11.50	1108.00
BM7-Y	40500.00	5.51	7.86	628.70	16400.00	1456.00	11.80	1207.00
BM7-Z	38900.00	5.28	7.30	619.60	14200.00	1251.00	11.00	1183.00
Average	40933.33	5.24	7.58	606.20	15433.33	1393.00	11.43	1166.00
STDEV	2281.08	0.30	0.28	31.42	1123.98	123.24	0.40	51.64
GC10-X	41100.00	7.06	8.49	951.60	18900.00	589.10	12.70	1361.00
GC10-Y	47000.00	5.58	7.16	788.70	16600.00	1317.00	10.60	939.00
GC10-Z	43700.00	5.61	7.59	762.60	16500.00	910.80	11.40	1083.00
Average	43933.33	6.08	7.75	834.30	17333.33	938.97	11.57	1127.67
STDEV	2956.91	0.85	0.68	102.42	1357.69	364.77	1.06	214.52
DL10-X	54900.00	6.24	7.77	992.80	17700.00	2289.00	11.40	1091.00
DL10-Y	56200.00	7.77	8.69	1238.00	20100.00	2132.00	11.90	1340.00
DL10-Z	61100.00	6.49	7.47	1058.00	17800.00	1649.00	11.00	1176.00
Average	57400.00	6.83	7.98	1096.27	18533.33	2023.33	11.43	1202.33
STDEV	3269.56	0.82	0.64	127.00	1357.69	333.55	0.45	126.57

APPENDIX III

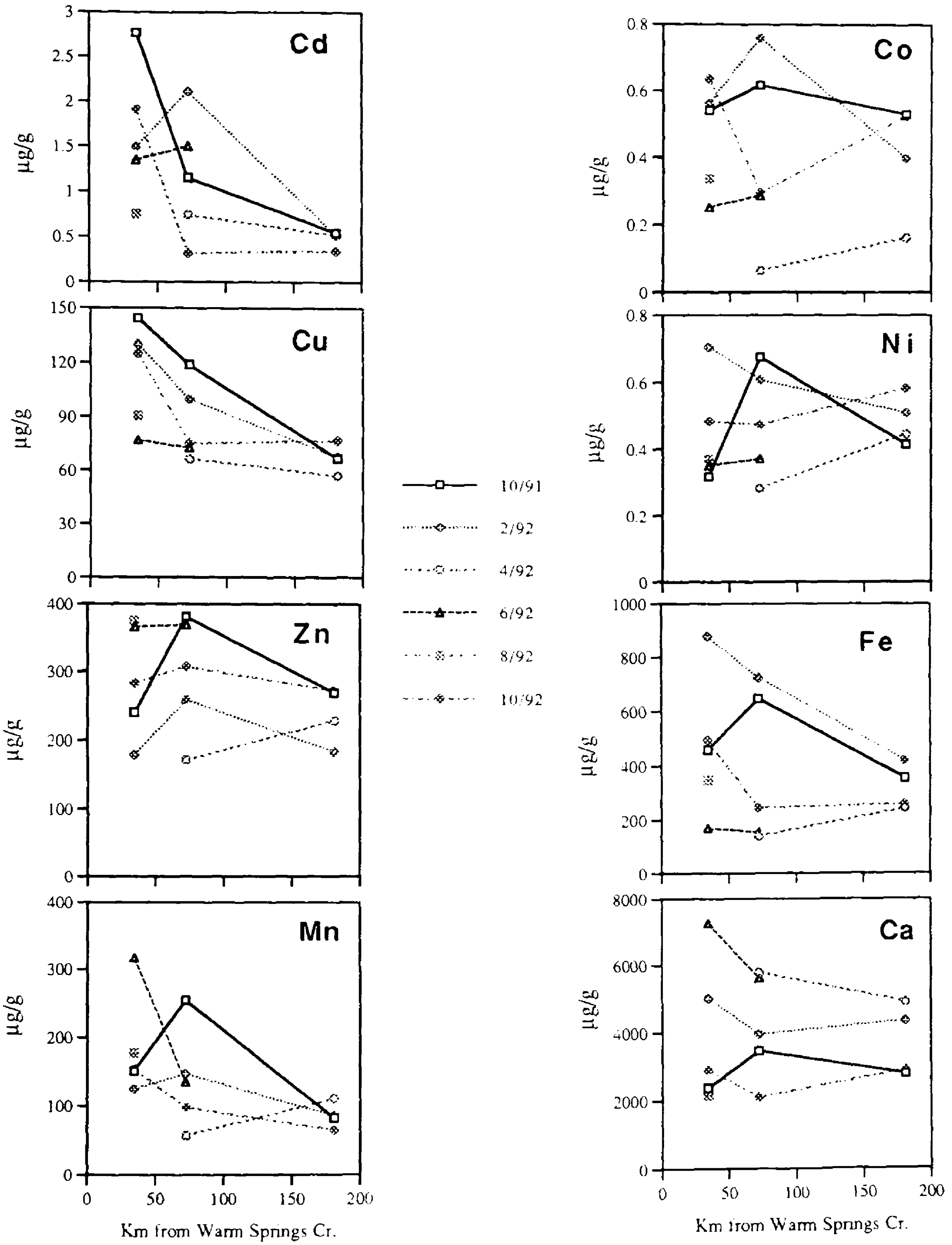
Insects



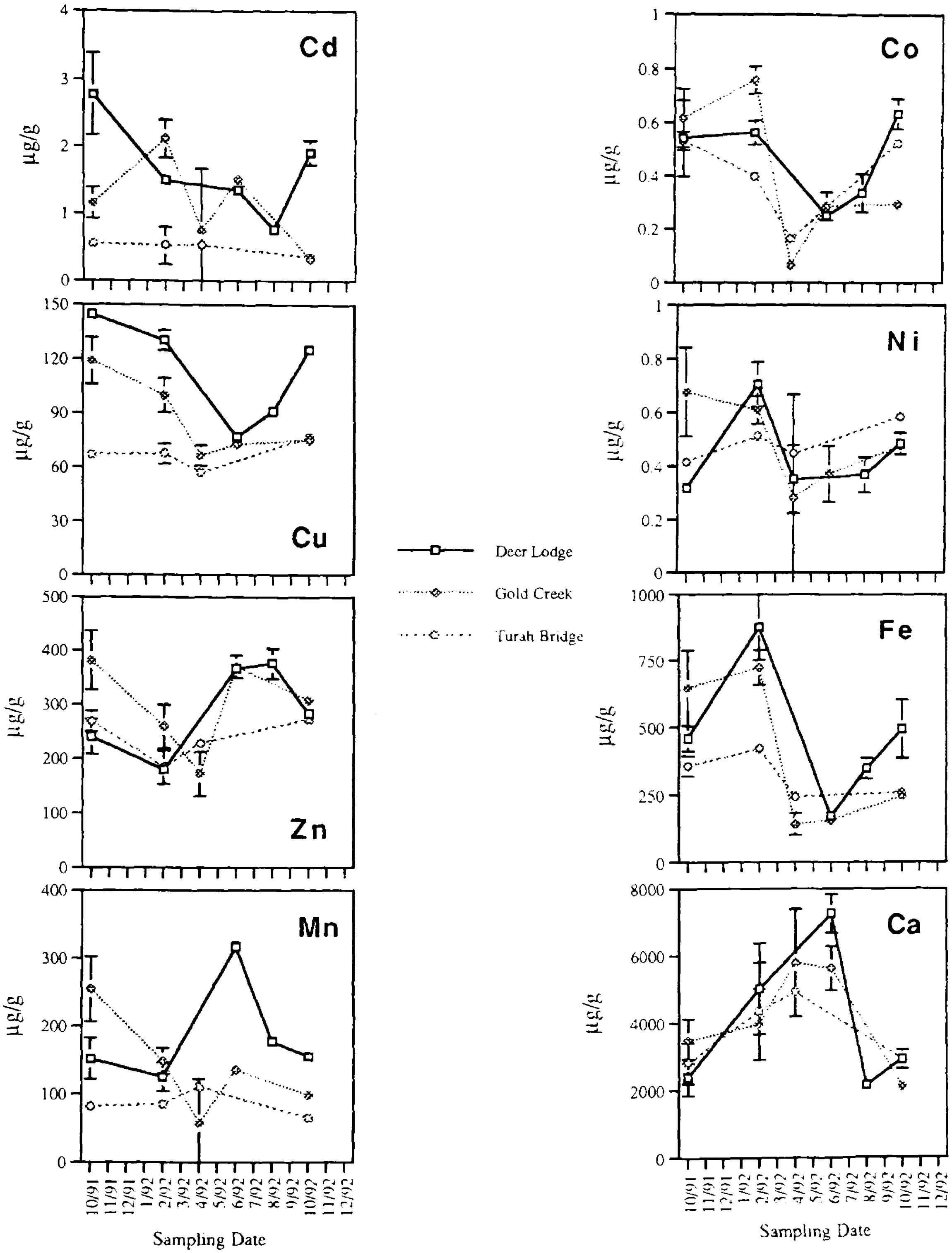
H. occidentalis : spatial variability in metal concentrations.



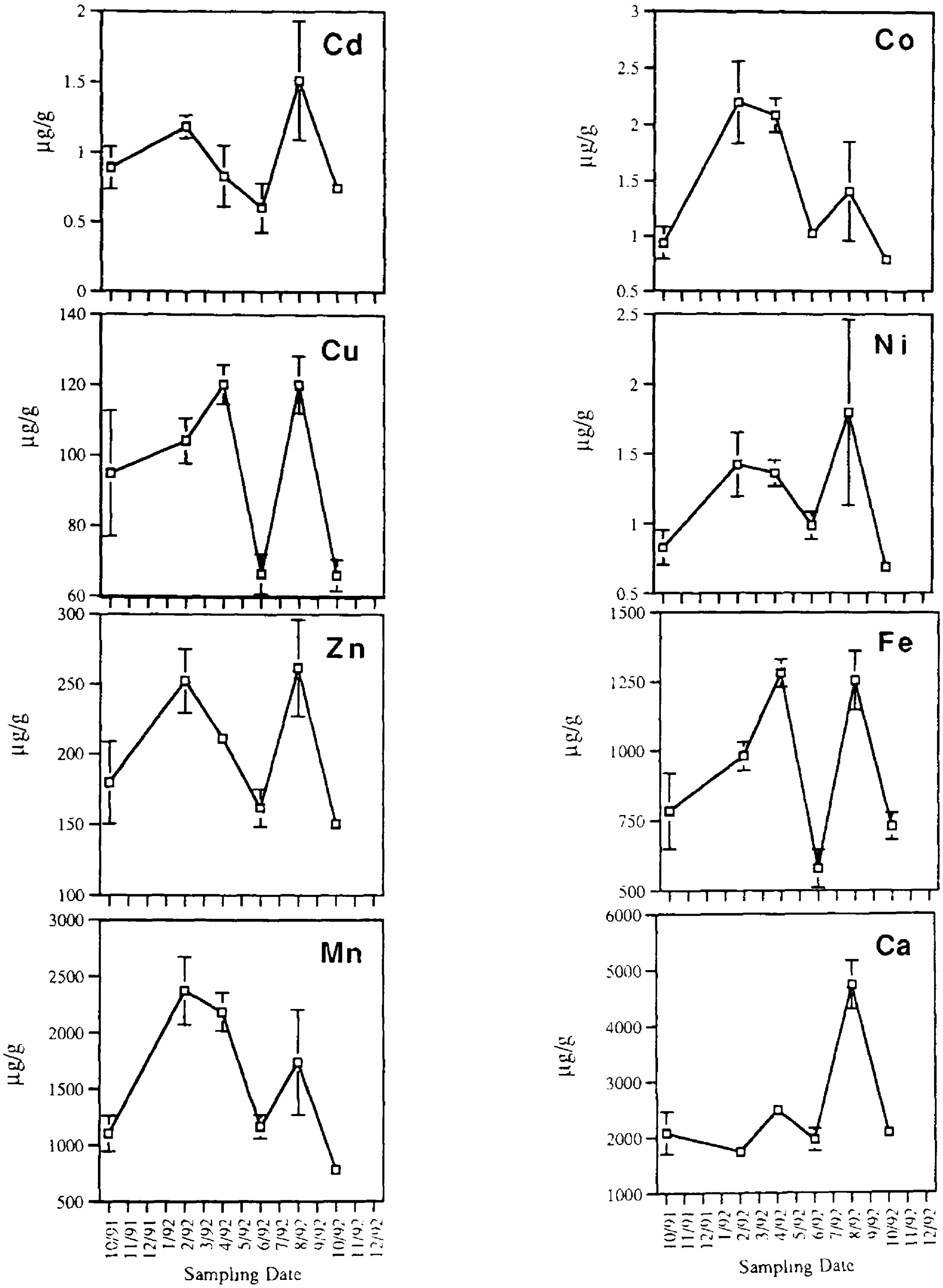
Temporal variability in *H. occidentalis* metal concentrations. Where no error bars are shown, error is too small for scale, or replicates are too few.



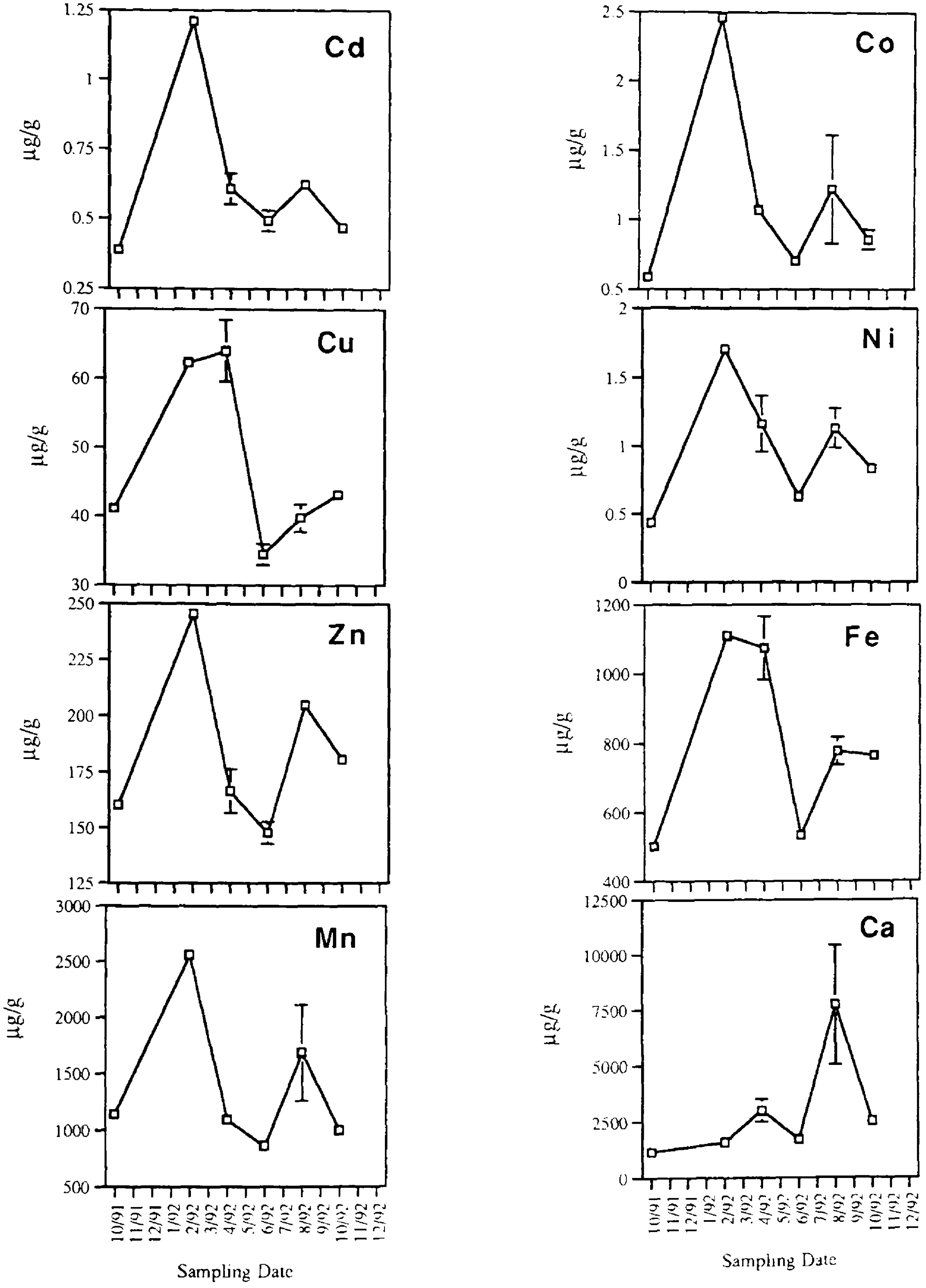
Isogenoides sp.: spatial variability in metal concentrations



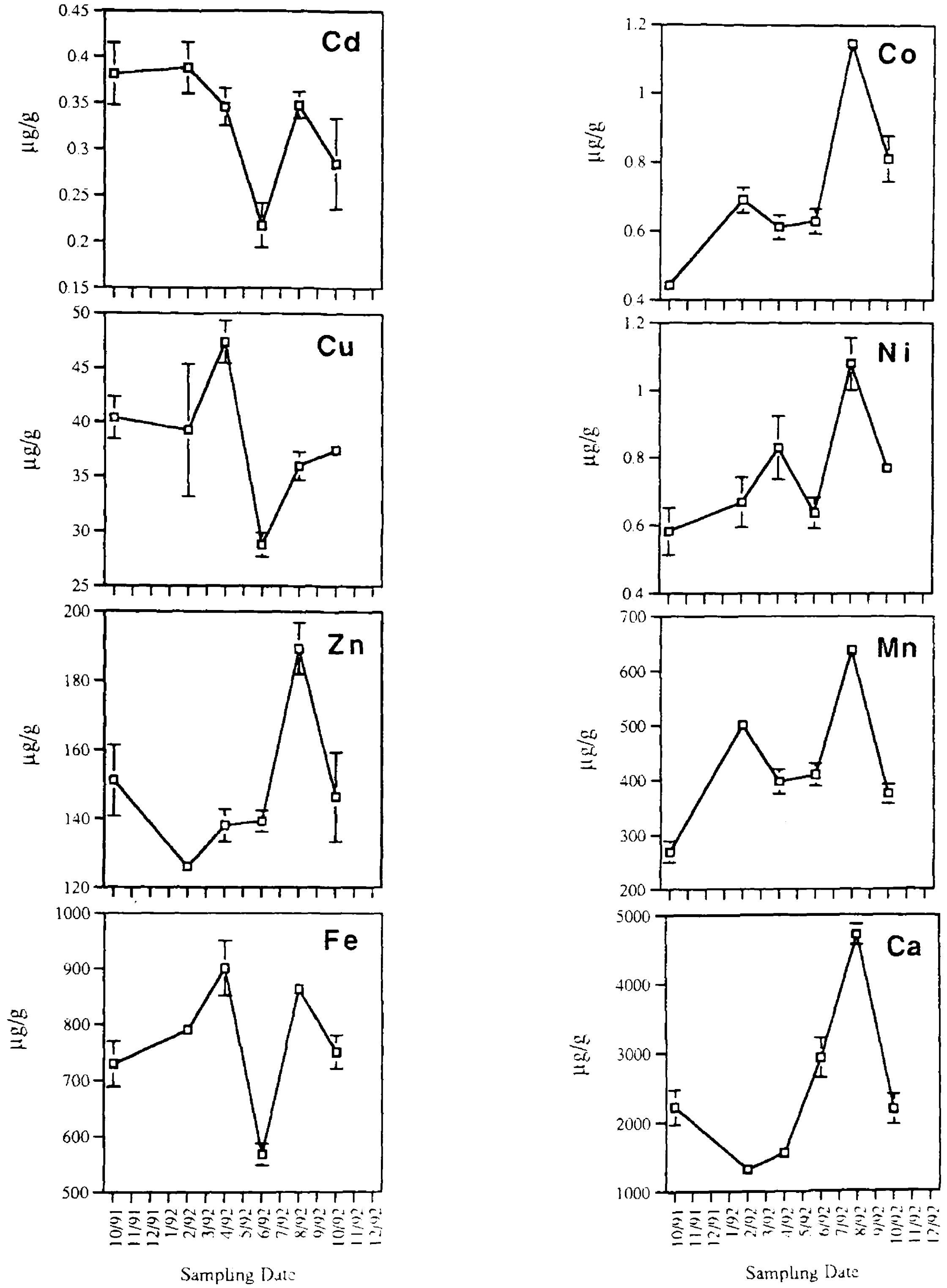
Temporal variability in *Isogenoides sp.* metal concentrations. Where no error bars are shown, error is too small for scale, or are replicates too few.



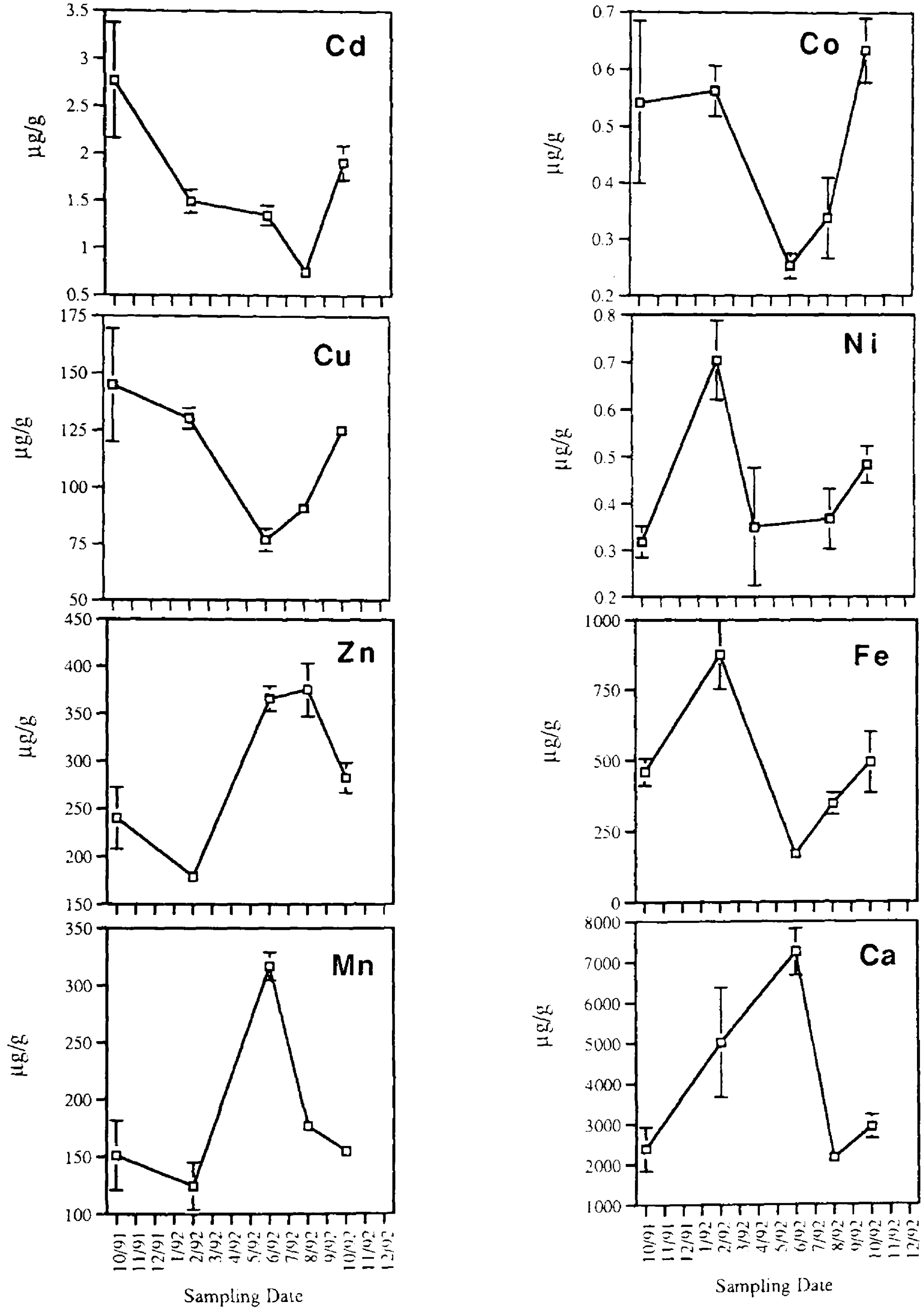
Deer Lodge *H. occidentalis* metal concentrations temporal variability. Where no error bars are shown, error is too small for scale. Feb-92 and Aug-92 values derived from only 2 replicates.



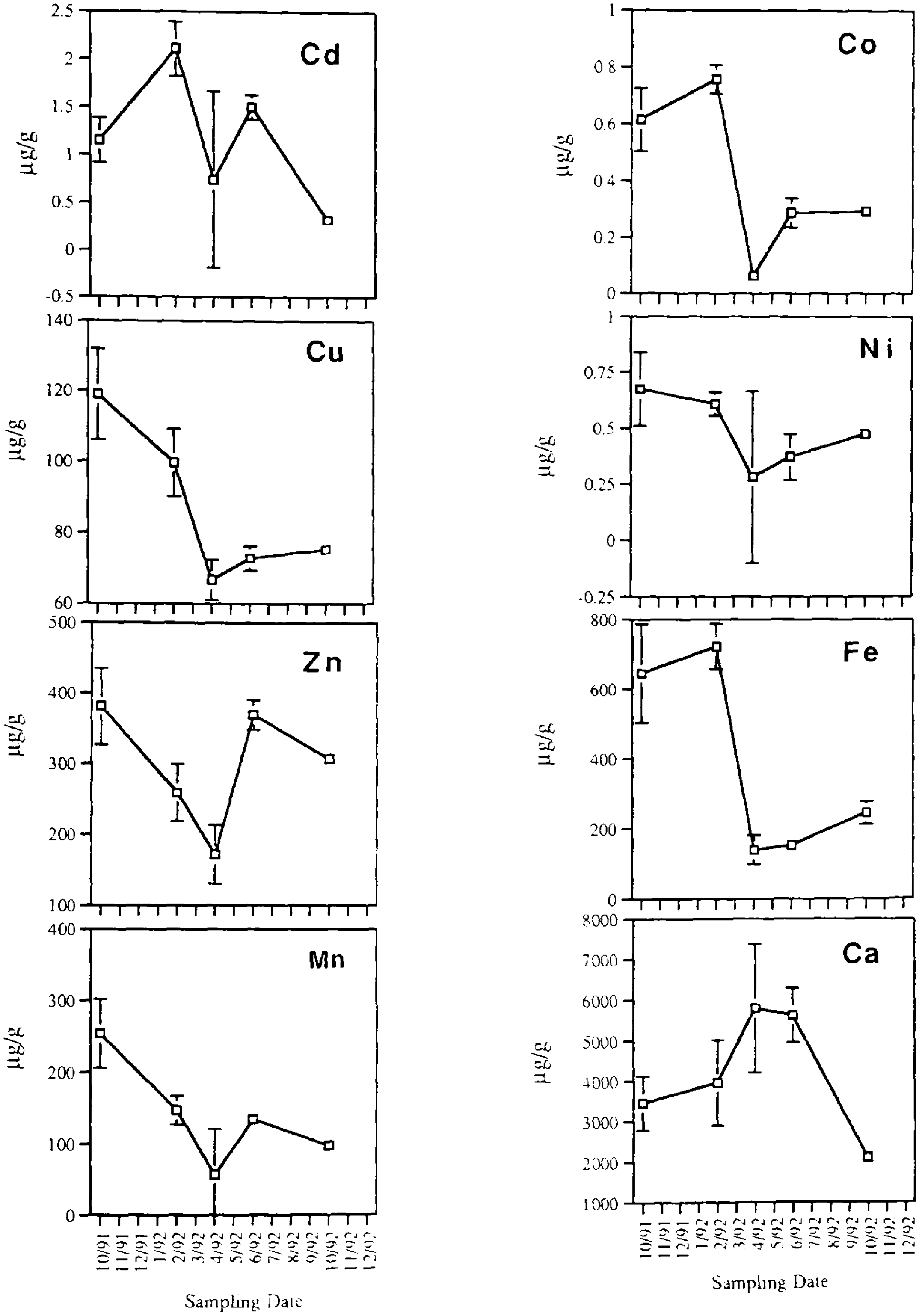
Gold Creek *H. occidentalis* metal concentrations temporal variability. Where no error bars are shown eror is too small for scale or there are too few replicates. Values from two or fewer replicates on Oct-91, Feb.-92, Oct.-92.



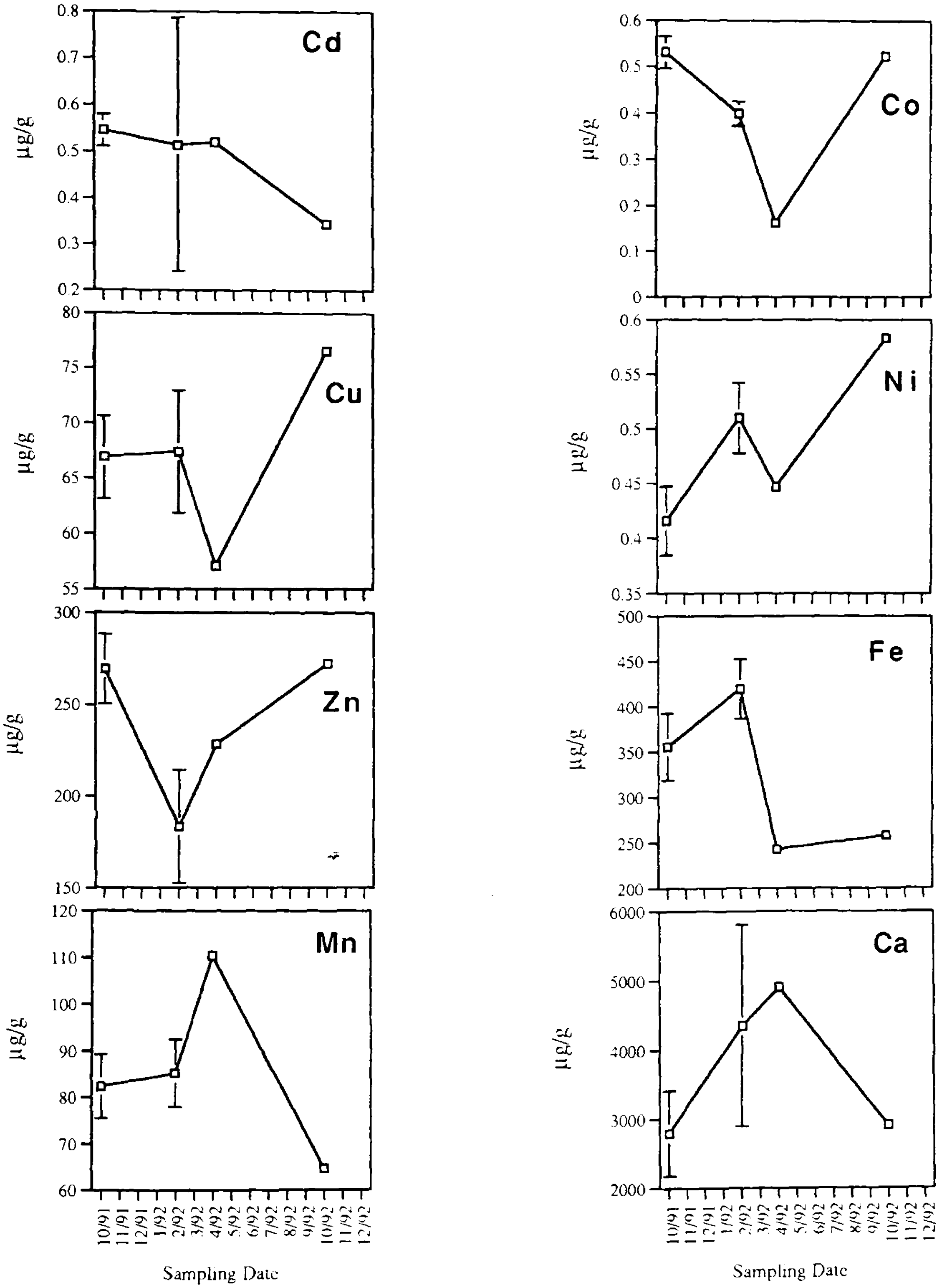
Turah Bridge *H. occidentalis* metal concentrations temporal variability. Where no error bars are shown, error is too small for scale.



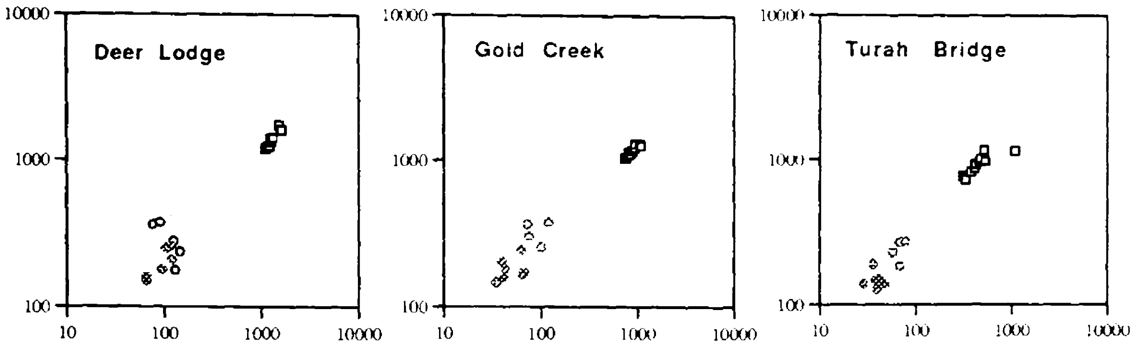
Deer Lodge *Isogenoides sp.* metal concentrations temporal variability Where no error bars are shown, error is too small for scale. Oct-92 values from only 2 replicates.



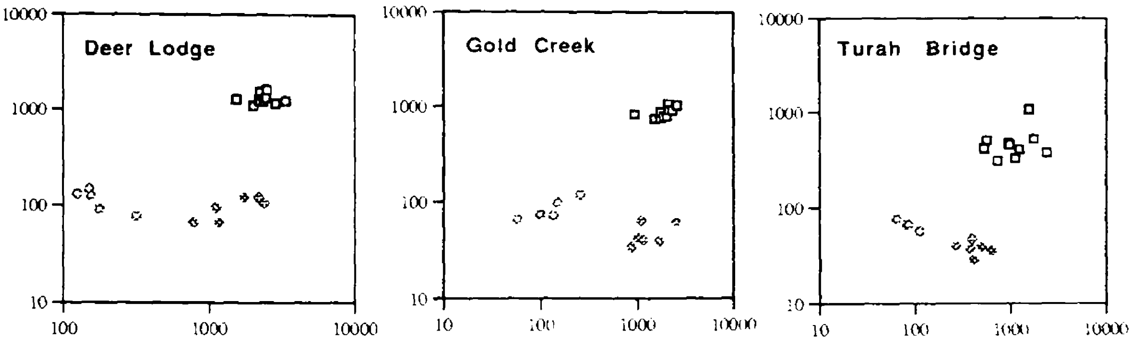
Gold Creek *Isogenoides sp.* metal concentrationstemporal variability. Where no error bars shown error too small for scale or there are too few replicates. Values from two or fewer replicates on Oct.-92.



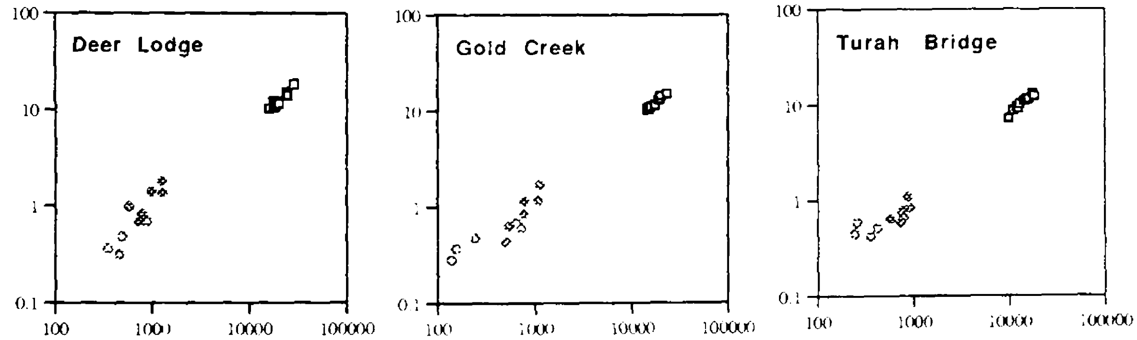
Turah Bridge *Isogenoides sp.* metal concentrations temporal variability. Where no error bars are shown, error is too small for scale or there are too few replicates. Values from two or fewer replicates on April-92 and Oct.-92.



A: X-axis Cu. Y-axis Zn. (µg/g
)



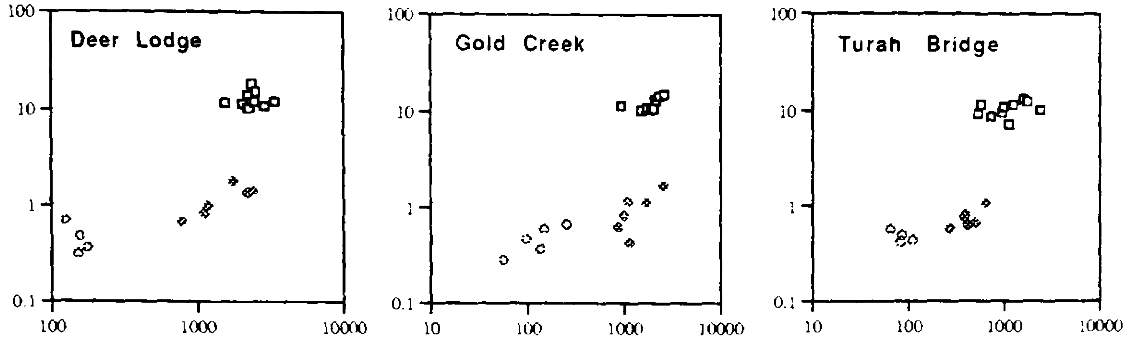
B: X-axis Mn. Y-axis Cu. (µg/g
)



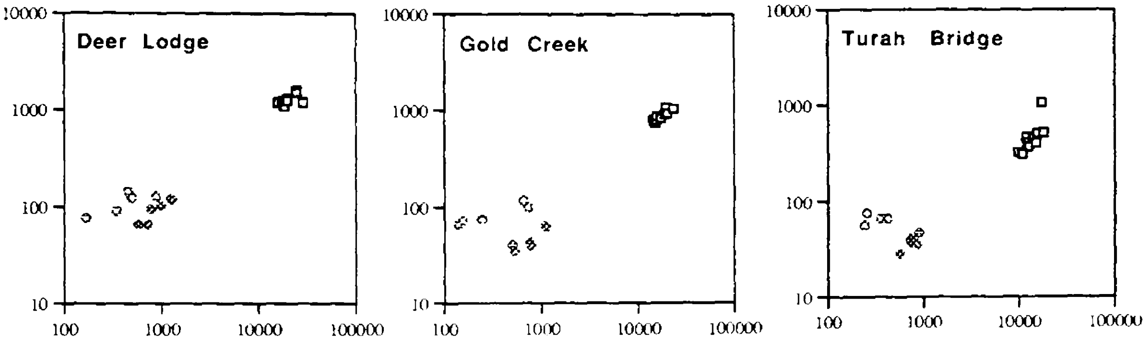
C: X-axis Fe. Y-axis Ni. (µg/g
)

□ Sediment ◆ *H. occidentalis* ○ *Isogenoids sp.*

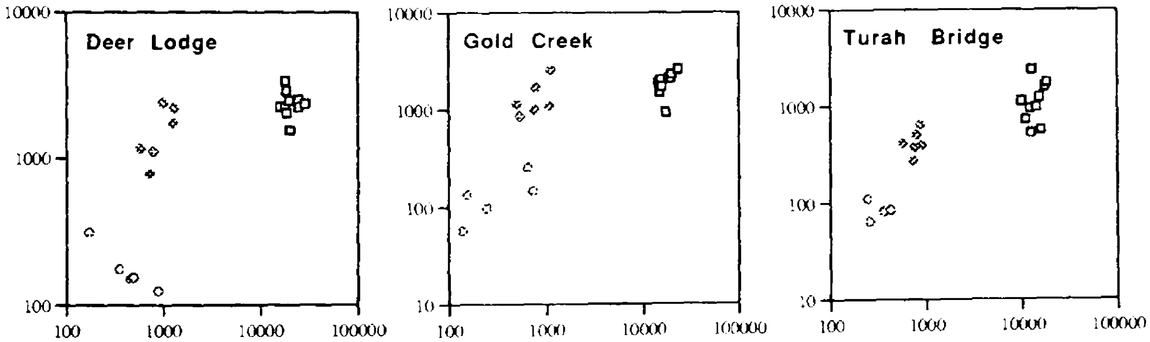
Plots of benthic insect and fine-grained sediment metal concentration ratios. (A) Cu:Zn, (B) Mn:Cu, (C) Fe:Ni..



A: X- axis Mn. Y-axis Ni. (µg/g)



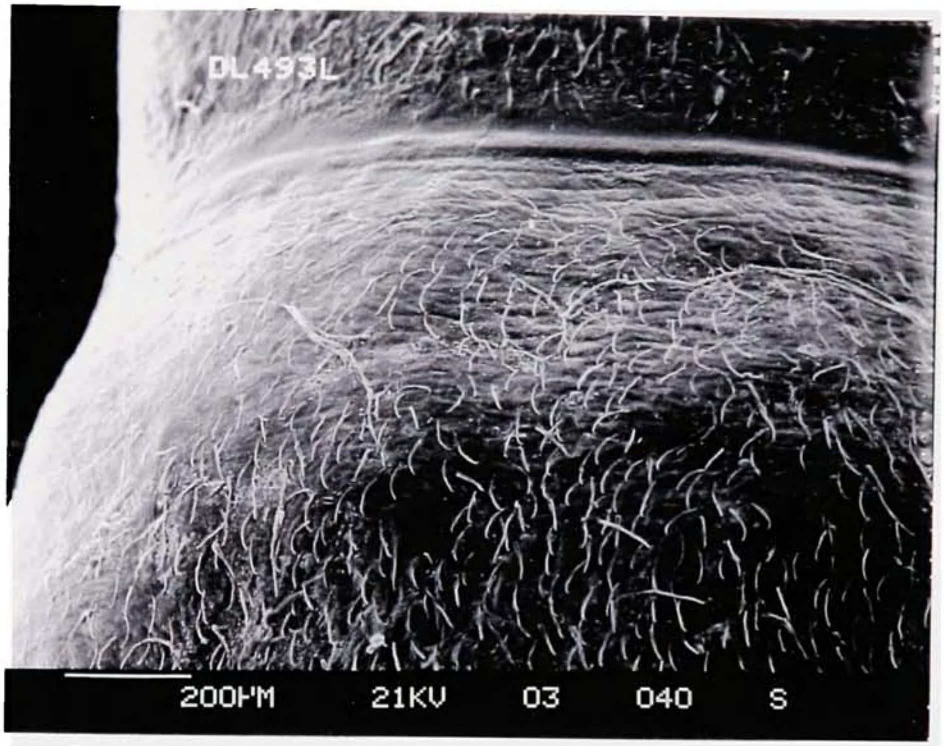
B: X-axis Fe Y-axis Cu (µg/g)

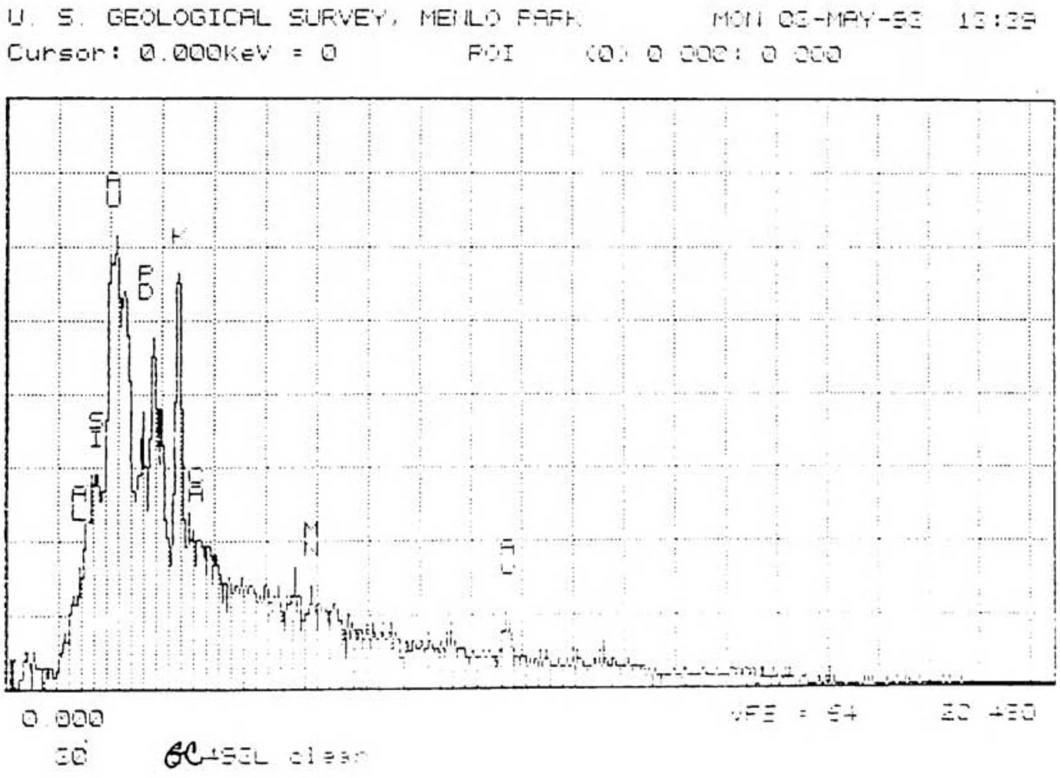


C: X-axis Fe Y-axis Mn (µg/g)

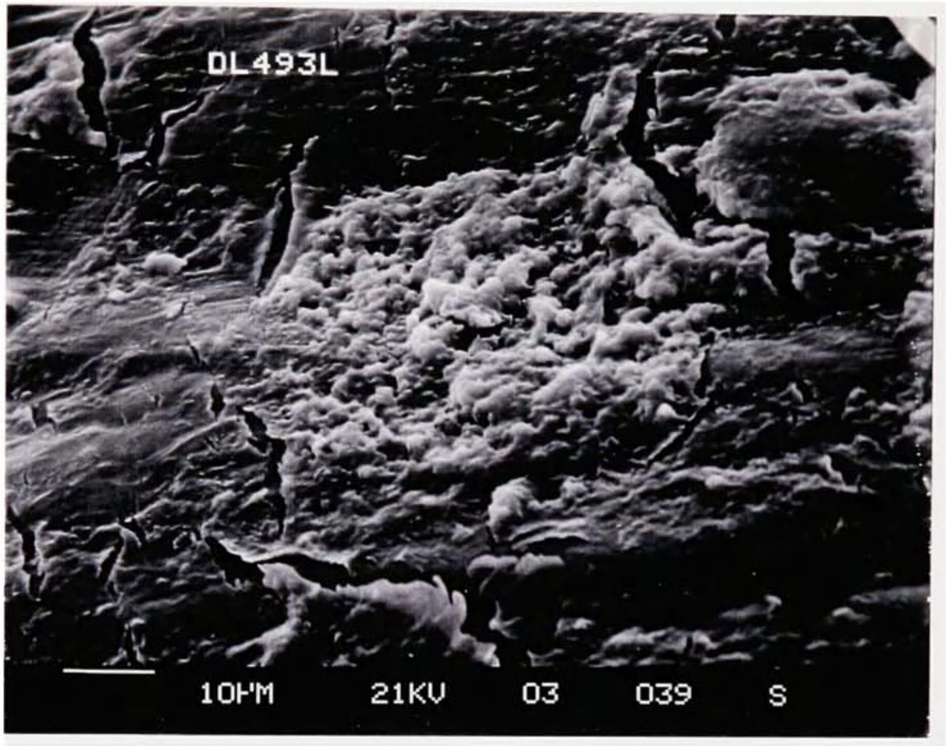
□ Sediment ◇ *H. occidentalis* ○ *Isogenoides sp.*

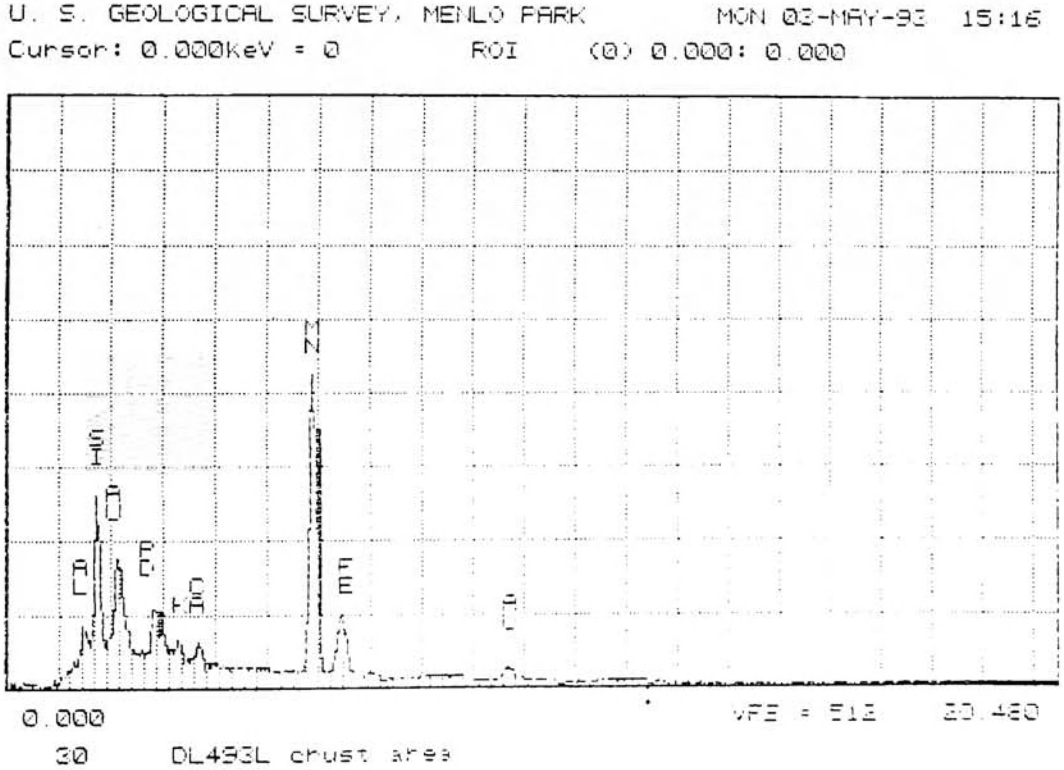
Plots of benthic insect and fine-grained sediment metal concentration ratios. (A) Mn:Ni, (B) Fe:Cu, (C) Fe:Mn.





SEM-EDX photomicrograph and accompanying scan
of relatively uncoated caddisfly.

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U. S. GEOLOGICAL SURVEY, MENLO PARK          MON 03-MAY-93  15:16
Cursor: 0.000keV = 0         ROI     (0) 0.000: 0.000
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30      DL493L crust area
```

SEM-EDX photomicrograph and accompanying scan
of coating patch on caddislfy on previous page

Constants and coefficients of determination for regressions of insect metal concentrations vs. sediment metal concentrations.

	H. occidentalis			*Isogenoides sp.*		
Metal	r2	m	b	r2	m	b
Deer Lodge						
Ca	0.33	0.04	611	0.05	-0.03	5391
Cd	0.5	-0.34	3.4	0.47	0.73	-3.6
Co	0	0.003	0.18	0.04	0.04	0.13
Cu	0.08	0.04	48	0.4	0.13	-45
Fe	0.08	0.02	557	0.68	0.04	-454
Mn	0.002	-0.06	1703	0.82	0.14	-172
Ni	0.05	0.03	0.77	0.28	0.03	0.1
Zn	0.18	-0.1	342	0.04	-0.08	405
Gold Creek						
Ca	0.32	0.24	-6259	0.56	-0.21	11874
Cd	0.31	0.25	-0.93	0.65	0.75	-3.6
Co	0.02	0.12	0.2	0.6	0.26	-1.9
Cu	0.57	0.07	-20	0.002	0.008	79
Fe	0.12	0.03	281	0.45	0.07	882
Mn	0.11	0.58	160	0.23	0.15	-195
Ni	0.04	0.04	0.44	0.17	0.04	-0.03
Zn	0.002	-0.02	204	0.017	-0.13	458
Turah Bridge						
Ca	0.06	0.02	1490	0.99	-0.08	7137
Cd	0.02	0.01	0.27	0.007	0.01	0.44
Co	0.5	-0.23	2.3	0.7	-0.22	1.9
Cu	0.58	0.02	29	0.62	-0.02	79
Fe	0.02	0.007	672	0.09	0.008	199
Mn	0.52	-0.14	627	0.1	0.01	69
Ni	0.1	-0.04	1.2	0.13	-0.02	0.66
Zn	0.06	-0.05	194	0.1	-0.1	336

Constants and coefficients of determination for regressions of insect metal concentrations vs. average monthly discharge.

	H. occidentalis			*Isogenoides sp.*		
Metal	r2	m	b	r2	m	b
Deer Lodge						
Ca	0.22	-8.8	3529	0.12	-14	5336
Cd	0.02	-0.001	1.1	0.56	0.01	0.63
Co	0.19	0.004	0.9	0.79	0.003	0.2
Cu	0.1	0.13	80	0.97	0.5	62
Fe	0.07	1.3	785	0.6	3.6	100
Mn	0.12	3.7	1131	0.61	-1.1	294
Ni	0.04	-0.001	1.3	0.01	0.0003	0.41
Zn	0.001	0.02	201	0.88	-1.4	433
Gold Creek						
Ca	0.16	-10	5237	0.02	2.5	3585
Cd	0	0	0.64	0.14	-0.003	1.9
Co	0	-0.0001	1.2	0.08	-0.001	0.62
Cu	0.51	0.1	26	0	0	87
Fe	0.2	1.2	525	0	-0.01	385
Mn	0.01	-0.78	1560	0.05	-0.19	182
Ni	0.01	0.0004	0.89	0.03	-0.0003	0.56
Zn	0.02	-0.06	197	0.49	-0.69	461
Turah Bridge						
Ca	0.58	-5.8	6202	0.61	5.7	-223
Cd	0.004	0	0.31	0.44	0.0004	0.19
Co	0.61	-0.001	1.5	0.82	-0.001	1.2
Cu	0.29	0.02	25	0.98	-0.06	105
Fe	0.002	0.03	748	0.06	-0.15	421
Mn	0.32	-0.44	713	0.99	0.13	-5.2
Ni	0.26	-0.001	1.1	0.47	-0.0004	0.73
Zn	0.54	-0.1	212	0.11	-0.1	307

Constants and coefficients of determination for regressions of insect metal concentrations vs. total suspended sediment (TSS).

	H. occidentalis			*Isogenoides sp.*		
Metal	r2	m	b	r2	m	b
Deer Lodge						
Ca	0.31	78	337	0.75	-364	15945
Cd	0.44	0.03	0.24	0.08	-0.04	2.9
Co	0.23	0.03	2.5	0.003	0.001	0.47
Cu	0	0.02	101	0.001	-0.15	115
Fe	0.01	-2.8	1059	0.02	-7.1	693
Mn	0.13	-23	2390	0.16	-5.9	383
Ni	0.06	0.01	0.97	0	0	0.45
Zn	0.12	1.7	164	0.13	5.9	98
Turah Bridge						
Ca	0.22	-158	4570	0.6	171	1563
Cd	0.05	0.004	0.29	0.18	-0.001	0.55
Co	0.03	-0.01	0.85	0.93	-0.04	0.89
Cu	0.69	1.4	21	0.98	-1.2	80
Fe	0.42	21	503	0.78	-16	572
Mn	0.02	-4.8	506	1	3.1	48
Ni	0.04	0.01	0.63	0.01	-0.001	0.47
Zn	0.08	-1.6	170	0.01	-0.65	236

(no TSS data available for Gold Creek)

Constants and coefficients of determination for regressions of insect metal concentrations vs. mean dry weight per individual.

	H. occidentalis			*Isogenoides sp.*		
Metal	r2	m	b	r2	m	b
Deer Lodge						
Ca	0.43	-493	4418	0.02	-28	4321
Cd	0.75	-0.2	1.7	0.07	0.02	1.4
Co	0.08	-0.1	1.9	0.62	0.01	0.3
Cu	0.62	-13	146	0.56	2	86
Fe	0.5	-138	1469	0.98	24	138
Mn	0.15	-166	2201	0.63	-5.6	262
Ni	0.36	-0.2	1.8	0.81	0.02	0.2
Zn	0.54	-23	293	0.87	-7.3	389
Gold Creek						
Ca	0.57	-20	10285	0.02	14	3873
Cd	0.01	0.003	0.52	0.01	0.005	1.1
Co	0	-0.01	1.2	0	0.004	0.4
Cu	0.007	1.1	43	0.004	-0.08	88
Fe	0.03	-52	983	0.05	3.7	301
Mn	0.007	-59	1609	0.17	-1.9	178
Ni	0.03	-0.09	1.3	0.01	-0.001	0.5
Zn	0.1	-12	229	0.81	-4.8	400
Turah Bridge						
Ca	0.6	-9	6475	0.001	1.4	3780
Cd	0.03	-0.01	0.38	0.02	-0.0005	0.47
Co	0.37	-0.1	1.3	0.11	-0.002	0.34
Cu	0.19	2.6	27	0.1	0.1	64
Fe	0	1.5	761	0.82	3.1	240
Mn	0.22	-58	681	0.1	-0.2	92
Ni	0.16	-0.07	1.1	0.06	-0.0007	0.47
Zn	0.62	-17	221	0.42	-1	267

Insect sample names by date and sampling station.

	Sampling Stations		
Date	Turah Bridge	Gold Creek	Deer Lodge
10/29/91	1TB	1GC	1DL
2/5/92	2TB	2GC	2DL
4/15/92	3TB	3GC	3DL
6/18/92		4GC	4DL
6/19/92	4TB		
8/20/92	5TB	5GC	5DL
10/22/92	6TB	6GC	6DL

Analysis summary for insect samples. TB = Turah Bridge, GC = Gold Creek, DL = Deer Lodge, C1 = Cheumatopsyche sp., HC = H. cockerelli, HO = H. occidentalis, S1 = Skwala sp., I1 = Isogenoides sp.

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
1TBC1-1	4311.36	0.67	0.70	73.29	1766.46	536.08	1.35	217.66
1TBHC-1	2055.30	0.32	0.57	39.47	701.22	306.68	0.60	125.92
1TBHC-2	1800.81	0.30	0.60	36.33	620.28	315.78	0.65	124.15
Average	1928.06	0.31	0.58	37.90	660.75	311.23	0.63	125.03
STDEV	179.95	0.01	0.01	2.23	57.23	6.43	0.04	1.25
1TBHO-1	2239.83	0.38	0.46	40.27	744.86	282.68	0.68	162.08
1TBHO-2	2251.17	0.36	0.44	38.87	719.78	266.32	0.50	147.98
1TBHO-3	2366.81	0.41	0.47	41.70	728.25	274.59	0.57	156.55
1TBHO-4	1813.57	0.33	0.42	38.14	672.18	238.03	0.61	134.99
1TBHO-5	2467.27	0.42	0.43	42.82	782.78	287.66	0.55	153.93
Average	2227.73	0.38	0.44	40.36	729.57	269.86	0.58	151.10
STDEV	249.47	0.03	0.02	1.94	40.17	19.55	0.07	10.34
1TBI1-1	2164.03	0.55	0.51	63.01	313.47	75.03	0.40	268.24
1TBI1-2	3399.45	0.57	0.57	70.48	377.28	83.20	0.45	288.66
1TBI1-3	2832.28	0.51	0.52	67.09	376.49	88.84	0.40	250.76
Average	2798.59	0.54	0.53	66.86	355.74	82.35	0.42	269.22
STDEV	618.40	0.03	0.03	3.74	36.62	6.94	0.03	18.97
2TBI1-1	2755.98	0.83	0.44	73.48	396.08	79.73	0.51	217.01
2TBI1-2	4699.89	0.34	0.38	62.61	406.11	82.29	0.48	156.61
2TBI1-3	5598.10	0.37	0.42	66.11	457.28	93.53	0.54	176.69
Average	4351.32	0.51	0.40	67.40	419.82	85.18	0.51	183.44
STDEV	1452.77	0.27	0.03	5.55	32.83	7.34	0.03	30.76

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
2TBHO-1	1320.00	0.36	0.67	46.28	780.00	494.80	0.61	124.10
2TBHO-2	1360.00	0.42	0.67	35.73	793.00	490.70	0.75	125.50
2TBHO-3	1290.00	0.38	0.73	35.72	798.00	520.00	0.65	128.30
Average	1323.33	0.39	0.69	39.24	790.33	501.83	0.67	125.97
STDEV	35.12	0.03	0.04	6.09	9.29	15.87	0.07	2.14
2TBHC-1	1180.00	0.28	0.68	39.52	657.00	488.90	0.69	122.30
2TBHC-2	1220.00	0.26	0.72	39.18	685.00	492.70	0.86	114.90
Average	1200.00	0.27	0.70	39.35	671.00	490.80	0.77	118.60
STDEV	28.28	0.01	0.03	0.24	19.80	2.69	0.12	5.23
3TBH-1	4910.00	0.52	0.16	57.10	243.00	110.40	0.45	228.30
3TBHO-1	1490.00	0.33	0.57	45.40	856.00	363.30	0.78	131.20
3TBHO-2	1760.00	0.38	0.63	48.76	950.00	403.00	0.82	145.30
3TBHO-3	1550.00	0.35	0.56	45.21	830.00	378.40	0.77	140.80
3TBHO-4	1580.00	0.34	0.64	50.11	940.00	421.70	1.01	136.30
3TBHO-5	1450.00	0.33	0.63	46.57	935.00	410.50	0.76	137.70
3TBHO-6	1530.00	0.33	0.64	48.30	897.00	408.80	0.84	137.10
Average	1560.00	0.35	0.61	47.39	901.33	397.62	0.83	138.07
STDEV	108.07	0.02	0.03	1.97	49.31	22.12	0.09	4.71
3TBHC-1	1080.00	0.26	0.66	42.37	680.00	401.30	0.70	124.10
3TBHC-2	1270.00	0.26	0.68	45.33	726.00	386.20	0.68	126.00
Average	1175.00	0.26	0.67	43.85	703.00	393.75	0.69	125.05
STDEV	134.35	0.00	0.02	2.09	32.53	10.68	0.01	1.34

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
4TBHO-1	3340.00	0.20	0.65	26.95	580.00	401.80	0.58	140.10
4TBHO-2	3160.00	0.20	0.62	29.46	578.00	436.20	0.65	141.30
4TBHO-3	3160.00	0.21	0.59	28.61	593.00	427.90	0.64	143.50
4TBHO-4	2570.00	0.21	0.62	27.33	576.00	383.20	0.63	135.50
4TBHO-5	2740.00	0.19	0.60	28.95	534.00	397.70	0.69	139.00
4TBHO-6	3060.00	0.22	0.70	29.55	576.00	438.10	0.71	136.70
4TBHO-7	2660.00	0.23	0.66	30.14	563.00	404.70	0.59	142.40
4TBHO-8	2760.00	0.27	0.60	28.92	547.00	393.80	0.61	136.00
Average	2931.25	0.22	0.63	28.74	568.38	410.43	0.64	139.31
STDEV	282.41	0.02	0.04	1.10	19.34	20.78	0.04	3.03
5TBHC-1	5130.00	0.39	0.87	32.66	872.00	476.20	1.04	167.30
5TBHC-2	5640.00	0.46	0.95	33.47	915.00	484.30	1.12	171.10
5TBHC-3	5820.00	0.46	0.99	36.00	974.00	563.00	1.20	183.00
5TBHC-4	6090.00	0.45	0.94	35.55	967.00	502.10	1.08	178.70
5TBHC-5	5710.00	0.43	0.90	35.28	948.00	492.60	1.10	175.10
Average	5678.00	0.44	0.93	34.59	935.20	503.64	1.11	175.04
STDEV	350.96	0.03	0.04	1.45	42.08	34.55	0.06	6.17
5TBHO-1	4890.00	0.33	1.13	35.33	878.00	636.50	1.17	195.40
5TBHO-2	4630.00	0.35	1.17	35.05	847.00	627.80	1.03	181.00
5TBHO-3	4630.00	0.36	1.15	37.43	867.00	652.20	1.04	191.80
Average	4716.67	0.35	1.15	35.94	864.00	638.83	1.08	189.40
STDEV	150.11	0.01	0.02	1.30	15.72	12.37	0.08	7.49
6TBS1-1	3700.00	0.49	0.52	46.51	448.00	111.30	0.70	258.10
6TBI1-1	2910.00	0.34	0.87	76.55	258.00	64.65	0.58	272.30

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
6TBHC-1	1350.00	0.18	0.73	45.73	589.00	393.60	0.62	98.60
6TBHC-2	1200.00	0.17	0.86	32.95	541.00	396.20	0.63	95.28
Average	1275.00	0.17	0.82	39.34	565.00	394.90	0.63	96.94
STDEV	106.07	0.01	0.08	9.04	33.94	1.84	0.01	2.35
6TBHO-1	2220.00	0.31	0.79	37.52	763.00	393.40	0.79	155.70
6TBHo-2	1950.00	0.24	0.79	37.88	735.00	372.90	0.76	135.20
6TBHO-3	2130.00	0.25	0.79	36.45	719.00	352.40	0.75	135.40
6TBHO-4	2470.00	0.34	0.01	37.80	785.00	383.00	0.78	159.30
Average	2192.50	0.29	0.00	37.41	750.50	375.43	0.77	146.40
STDEV	216.39	0.05	0.00	0.66	29.32	17.48	0.02	12.90
1GCC1-1	1649.20	0.71	1.07	69.92	962.38	1128.35	0.52	189.97
1GCH1-1	1165.55	0.39	0.59	41.06	503.26	1141.59	0.44	160.34
1GCHC-1	835.57	0.30	0.78	38.74	406.12	833.94	0.77	119.24
1GCHC-2	1215.84	0.31	0.65	36.36	339.11	793.46	0.50	114.50
Average	1025.70	0.31	0.72	37.55	372.61	813.70	0.63	116.87
STDEV	268.89	0.01	0.09	1.68	47.38	28.62	0.19	3.36
1GCI1-1	4135.11	1.35	0.76	135.90	779.20	307.46	0.87	440.52
1GCI1-2	3408.68	1.30	0.65	116.03	735.42	252.24	0.75	391.60
1GCI1-3	3744.08	1.12	0.55	119.15	605.66	265.83	0.55	383.77
1GCI1-4	2568.87	0.84	0.51	104.73	464.51	191.61	0.53	308.62
Average	3464.18	1.15	0.62	118.95	646.20	254.29	0.68	381.12
STDEV	666.62	0.23	0.11	12.89	141.78	47.94	0.17	54.47
2GCC1-1	1874.52	1.25	1.97	103.74	1568.20	1925.73	1.42	238.34

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
2GCHC-1	1319.32	0.79	1.75	55.63	832.33	1655.22	1.15	165.12
2GCHC-2	1234.37	0.80	1.72	54.19	791.00	1604.10	1.06	163.50
Average	1276.85	0.79	1.73	54.91	811.67	1629.66	1.10	164.31
STDEV	60.07	0.01	0.02	1.02	29.23	36.15	0.06	1.14
2GCHO-1	1588.83	1.21	2.46	62.35	1110.92	2561.12	1.71	245.60
2GCI1-1	2309.26	2.09	0.67	105.31	802.64	122.21	0.56	282.04
2GCI1-2	3022.20	2.60	0.76	114.79	738.47	147.40	0.60	327.71
2GCI1-3	4773.60	1.91	0.78	93.35	627.50	147.37	0.63	231.99
2GCI1-4	4308.48	1.82	0.73	92.04	714.82	149.41	0.60	232.07
2GCI1-5	4325.52	1.98	0.71	90.37	676.97	136.68	0.56	220.05
2GCI1-6	4999.70	2.25	0.82	102.07	781.96	181.65	0.70	258.81
Average	3956.46	2.11	0.76	99.66	723.73	147.45	0.61	258.78
STDEV	1058.52	0.28	0.05	9.49	65.36	19.63	0.05	40.56
2GCS1-1	5052.40	2.16	0.59	64.55	701.39	155.85	0.36	205.93
3GCI1-1	5309.65	4.81	1.55	242.13	1845.49	281.00	1.29	648.50
3GCI1-2	2981.95	2.57	0.76	113.26	728.63	145.44	0.60	323.35
3GCI1-3	6510.00	0.18	0.09	74.46	110.00	25.02	0.11	162.10
3GCI1-4	6960.00	0.26	0.05	62.25	126.00	28.69	0.15	149.40
3GCI1-5	6720.00	0.22	0.08	65.82	121.00	29.04	0.08	166.20
3GCI1-6	6660.00	0.22	0.07	67.05	130.00	31.53	0.12	136.80
3GCI1-7	6750.00	0.26	0.08	61.31	107.00	34.63	0.10	130.40
Average	5984.51	1.22	0.06	98.04	452.59	82.19	0.35	245.25
STDEV	1430.72	1.81	0.17	66.05	654.96	97.73	0.45	189.74

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
3GCCI-1	2980.00	0.77	1.50	71.85	1560.00	1580.00	1.47	180.50
3GCHC-1	1440.00	0.34	1.12	42.67	563.00	1124.00	0.80	125.00
3GCHC-2	1540.00	0.39	1.34	43.71	635.00	1306.00	0.97	139.00
3GCHC-3	1640.00	0.41	1.41	45.57	679.00	1386.00	0.98	143.00
Average	1540.00	0.38	1.29	43.98	625.67	1272.00	0.92	135.67
STDEV	100.00	0.04	0.15	1.47	58.56	134.27	0.10	9.45
3GCHO-1	3380.00	0.65	1.07	67.15	1140.00	1058.00	1.31	173.60
3GCHO-2	2650.00	0.57	1.07	60.86	1010.00	1132.00	1.02	159.60
Average	3015.00	0.61	1.07	64.01	1075.00	1095.00	1.17	166.60
STDEV	516.19	0.06	0.00	4.45	91.92	52.33	0.21	9.90
4GCI1-1	8740.00	1.08	0.26	91.60	127.00	113.70	0.37	323.60
4GCI1-2	5410.00	1.73	0.35	75.41	168.00	148.70	0.40	386.00
4GCI1-3	5460.00	1.45	0.22	76.06	144.00	130.00	0.28	374.90
4GCI1-4	5060.00	1.44	0.28	69.99	159.00	125.30	0.50	333.10
4GCI1-5	6770.00	1.47	0.33	68.00	158.00	142.20	0.26	380.20
Average	5675.00	1.52	0.29	72.37	157.25	136.55	0.36	368.55
STDEV	751.38	0.14	0.05	3.98	9.91	10.79	0.12	24.06
4GCHC-1	1700.00	0.51	0.57	47.00	551.00	574.90	0.73	138.60

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
4GCHO-1	1730.00	0.47	0.71	34.33	534.00	899.30	0.63	147.90
4GCHO-2	1670.00	0.46	0.67	31.71	503.00	790.80	0.66	141.20
4GCHO-3	1610.00	0.55	0.71	34.09	531.00	874.50	0.65	151.00
4GCHO-4	1730.00	0.47	0.69	35.40	525.00	865.80	0.62	147.70
4GCHO-5	1810.00	0.48	0.70	34.89	553.00	850.80	0.62	144.20
4GCHO-6	1760.00	0.53	0.74	36.30	557.00	891.30	0.63	155.40
Average	1718.33	0.49	0.70	34.45	533.83	862.08	0.63	147.90
STDEV	69.98	0.04	0.02	1.56	19.70	39.03	0.02	4.99
5GCHC-1	3820.00	0.46	0.78	30.87	597.00	1028.00	0.75	154.60
5GCHC-2	3720.00	0.47	0.76	31.08	616.00	964.20	0.65	154.40
5GCHC-3	4490.00	0.48	0.89	35.86	762.00	1099.00	0.96	164.30
5GCHC-4	4550.00	0.42	0.85	34.16	699.00	1123.00	0.72	159.30
Average	4145.00	0.46	0.82	32.99	668.50	1053.55	0.77	158.15
STDEV	435.62	0.03	0.06	2.43	76.47	71.94	0.13	4.68
5GCHO-1	8020.00	0.62	1.35	38.98	738.00	1840.00	1.13	203.00
5GCHO-2	10300.00	0.62	1.53	41.99	785.00	2016.00	1.28	206.10
5GCHO-3	4950.00	0.64	0.78	38.24	815.00	1203.00	0.99	205.60
Average	7756.67	0.63	1.22	39.74	779.33	1686.33	1.13	204.90
STDEV	2684.70	0.02	0.39	1.99	38.81	427.73	0.14	1.66
6GCI1-1	2000.00	0.31	0.28	74.65	222.00	92.95	0.46	301.70
6GCI1-2	2200.00	0.33	0.31	75.66	268.00	102.80	0.49	312.60
Average	2100.00	0.32	0.29	75.16	245.00	97.88	0.47	307.15
STDEV	141.42	0.02	0.02	0.71	32.53	6.97	0.03	7.71

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
6GCS1-1	2700.00	0.45	0.29	45.39	231.00	161.30	0.44	308.30
6GCS1-2	2500.00	0.51	0.39	55.09	337.00	220.30	0.51	335.70
Average	2600.00	0.48	0.34	50.24	284.00	190.80	0.47	322.00
STDEV	141.42	0.05	0.07	6.86	74.95	41.72	0.04	19.37
6GCHC-1	1860.00	0.30	0.71	38.84	605.00	730.50	0.61	151.40
6GCHO-1	2620.00	0.47	0.81	42.76	771.00	969.40	0.82	181.00
6GCHO-2	2450.00	0.47	0.91	43.45	761.00	1033.00	0.85	180.70
Average	2535.00	0.47	0.86	43.11	766.00	1001.20	0.84	180.85
STDEV	120.21	0.00	0.07	0.49	7.07	44.97	0.02	0.21
1DLC1-1	2999.21	1.57	1.49	146.11	1289.01	1762.12	1.16	236.23
1DLHC-1	1082.63	0.58	0.51	56.85	388.69	630.91	0.46	115.47
1DLHO-1	2602.30	1.11	1.14	121.34	944.67	1333.68	0.89	222.31
1DLHO-2	1995.89	0.84	0.85	83.15	687.80	1009.20	0.71	164.33
1DLHO-3	1699.35	0.75	0.81	85.09	657.41	987.98	0.74	158.09
1DLHO-4	2015.97	0.86	0.94	89.57	845.77	1100.60	0.97	174.12
Average	2078.38	0.89	0.93	94.79	783.91	1107.86	0.83	179.71
STDEV	378.09	0.15	0.15	17.90	135.29	158.28	0.12	29.15
1DLI1-1	2553.67	2.90	0.58	147.60	459.93	164.72	0.33	217.13
1DLI1-2	2806.00	3.30	0.66	167.63	505.08	172.70	0.34	276.70
1DLI1-3	1777.45	2.11	0.38	118.51	410.86	116.60	0.28	226.65
Average	2379.04	2.77	0.54	144.58	458.62	151.34	0.32	240.16
STDEV	536.05	0.61	0.14	24.70	47.12	30.35	0.03	32.00

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
1DLS1-1	3778.50	5.09	0.84	168.62	659.52	313.13	0.52	277.34
1DLS1-2	3159.30	3.79	0.65	142.10	932.65	260.90	0.49	245.37
Average	3468.90	4.44	0.74	155.36	796.09	287.02	0.50	261.36
STDEV	437.84	0.91	0.13	18.76	193.13	36.94	0.02	22.61
2DLHC-1	1153.02	0.56	1.06	73.84	626.82	1055.54	1.26	153.25
2DLHO-1	1779.45	1.24	2.46	108.72	1017.70	2588.73	1.58	268.75
2DLHO-2	1697.79	1.13	1.94	99.67	945.44	2165.85	1.27	236.56
Average	1738.62	1.18	2.20	104.19	981.57	2377.29	1.42	252.65
STDEV	57.74	0.08	0.36	6.40	51.10	299.02	0.23	22.76
2DLI1-1	4017.87	1.56	0.60	130.28	989.91	126.73	0.74	192.33
2DLI1-2	3236.56	1.35	0.49	128.35	668.42	92.91	0.56	185.22
2DLI1-3	5329.96	1.60	0.57	123.94	886.21	126.03	0.70	173.34
2DLI1-4	6331.45	1.59	0.57	135.56	902.80	150.95	0.75	169.17
2DLI1-5	6172.32	1.37	0.59	132.96	933.24	126.77	0.78	175.01
Average	5017.63	1.49	0.56	130.22	876.12	124.68	0.70	179.01
STDEV	1353.58	0.13	0.04	4.44	122.64	20.68	0.08	9.50
2DLS1-1	5416.77	1.81	0.38	85.14	739.77	114.30	0.56	157.79
3DLHC-1	2490.00	0.50	0.79	99.43	1030.00	819.30	0.76	161.00
3DLHC-2	2020.00	0.47	1.08	93.43	954.00	1101.00	0.91	155.30
Average	2255.00	0.49	0.94	96.43	992.00	960.15	0.84	158.15
STDEV	332.34	0.03	0.21	4.24	53.74	199.19	0.11	4.03

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
3DLHO-1	2560.00	0.76	2.23	118.60	1270.00	2363.00	1.35	214.40
3DLHO-2	2610.00	0.71	1.98	128.40	1360.00	2127.00	1.32	207.20
3DLHO-3	2520.00	0.79	2.29	125.90	1320.00	2426.00	1.55	221.80
3DLHO-4	2480.00	0.72	2.08	118.90	1270.00	2115.00	1.34	209.20
3DLHO-5	2340.00	0.73	2.09	115.30	1250.00	2101.00	1.32	208.30
3DLHO-6	2400.00	1.28	1.88	114.60	1220.00	1991.00	1.31	207.40
Average	2485.00	0.83	2.09	120.28	1281.67	2187.17	1.37	211.38
STDEV	100.75	0.22	0.15	5.64	50.37	168.93	0.09	5.75
4DLI1-1	7220.00	1.28	0.24	72.82	168.00	334.50	0.34	349.70
4DLI1-2	7780.00	1.43	0.24	72.13	179.00	310.20	0.25	363.60
4DLI1-3	7560.00	1.45	0.28	81.24	162.00	315.50	0.28	370.40
4DLI1-4	6470.00	1.24	0.25	81.17	168.00	307.40	0.53	381.10
Average	7257.50	1.35	0.25	76.84	169.25	316.90	0.35	366.20
STDEV	573.32	0.10	0.02	5.05	7.09	12.20	0.13	13.15
4DLHC-1	2080.00	0.48	0.55	59.91	480.00	570.80	0.57	135.50
4DLHC-2	2360.00	0.52	0.56	65.27	524.00	618.00	0.65	138.60
Average	2220.00	0.50	0.55	62.59	502.00	594.40	0.61	137.05
STDEV	197.99	0.03	0.01	3.79	31.11	33.38	0.05	2.19
4DLHO-1	2300.00	0.96	1.17	76.75	704.00	1320.00	1.16	182.80
4DLHO-2	1820.00	0.56	0.97	63.12	533.00	1083.00	0.92	154.30
4DLHO-3	1800.00	0.47	0.98	61.22	540.00	1115.00	0.91	147.60
4DLHO-4	1830.00	0.49	0.93	63.63	527.00	1047.00	0.92	151.30
4DLHO-5	1880.00	0.61	1.07	64.70	569.00	1244.00	1.04	167.80
4DLHO-6	2110.00	0.56	1.06	68.53	607.00	1183.00	1.00	167.10
Average	1956.67	0.61	1.03	66.33	580.00	1165.33	0.99	161.82
STDEV	203.24	0.18	0.09	5.65	67.59	103.67	0.10	13.22

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
5DLS1-1	1880.00	0.87	0.27	46.37	236.00	158.70	0.52	405.90
5DLS1-1	2040.00	1.02	0.43	56.26	310.00	225.50	0.30	410.90
Average	1960.00	0.95	0.35	51.32	273.00	192.10	0.41	408.40
STDEV	113.14	0.10	0.11	6.99	52.33	47.23	0.16	3.54
5DLI1-1	2330.00	0.72	0.25	90.60	391.00	171.50	0.30	398.70
5DLI1-2	2000.00	0.78	0.37	89.06	333.00	175.40	0.43	383.80
5DLI1-3	2120.00	0.76	0.39	92.76	316.00	183.80	0.37	344.50
Average	2150.00	0.75	0.34	90.81	346.67	176.90	0.37	375.67
STDEV	167.03	0.03	0.07	1.86	39.32	6.29	0.06	28.00
5DLHC-1	4140.00	1.18	0.80	109.20	1080.00	818.50	1.04	205.10
5DLHC-2	3770.00	1.15	0.85	111.90	1070.00	858.80	1.18	191.00
5DLHC-3	3850.00	1.12	0.90	109.40	1090.00	872.50	1.13	204.50
5DLHC-4	4230.00	1.27	0.88	116.30	1190.00	860.60	1.19	210.10
5DLHC-5	3950.00	1.21	0.85	110.50	1080.00	852.40	1.15	201.80
Average	3988.00	1.19	0.86	111.46	1102.00	852.56	1.14	202.50
STDEV	193.44	0.06	0.04	2.91	49.70	20.38	0.06	7.09
5DLHO-1	4430.00	1.22	1.09	114.50	1180.00	1407.00	1.33	237.30
5DLHO-2	5040.00	1.81	1.73	125.90	1330.00	2069.00	2.27	286.40
Average	4735.00	1.51	1.41	120.20	1255.00	1738.00	1.80	261.85
STDEV	431.34	0.42	0.45	8.06	106.07	468.10	0.66	34.72
6DLS1-1	3380.00	1.47	0.54	75.71	416.00	188.30	0.44	278.20
6DLS1-2	2890.00	1.45	0.48	58.27	229.00	120.50	0.32	221.20
6DLS1-3	2060.00	1.71	0.48	74.33	318.00	138.60	0.39	226.70
Average	2776.67	1.55	0.50	69.44	321.00	149.13	0.38	242.03
STDEV	667.26	0.15	0.04	9.70	93.54	35.11	0.06	31.44

Sample Name	Ca3179	Cd2288	Co2286	Cu3247	Fe2599	Mn2576	Ni2316	Zn2138
6DLH-1	3120.00	1.78	0.67	122.30	416.00	152.50	0.46	271.60
6DLH-2	2710.00	2.04	0.59	128.10	571.00	156.70	0.51	294.00
Average	2915.00	1.91	0.63	125.20	493.50	154.60	0.48	282.80
STDEV	289.91	0.18	0.06	4.10	109.60	2.97	0.04	15.84
6DLHC-1	1610.00	0.52	0.65	56.62	505.00	657.40	0.56	123.60
6DLHC-2	1860.00	0.51	0.65	59.15	573.00	662.20	0.57	125.40
6DLHC-3	1620.00	0.53	0.66	53.91	511.00	673.70	0.51	122.90
6DLHC-4	1930.00	0.56	0.80	56.45	521.00	831.70	0.65	133.00
6DLHC-5	1780.00	0.53	0.67	54.39	493.00	663.80	0.72	124.60
Average	1760.00	0.53	0.69	56.10	520.60	697.76	0.60	125.90
STDEV	142.65	0.02	0.07	2.09	31.00	75.11	0.08	4.08
6DLHO-1	2170.00	0.77	0.77	64.93	700.00	768.50	0.66	150.30
6DLHO-2	2120.00	0.78	0.84	70.78	784.00	839.20	0.72	157.40
6DLHO-3	1940.00	0.70	0.77	62.02	704.00	727.50	0.69	144.00
Average	2076.67	0.75	0.79	65.91	729.33	778.40	0.69	150.57
STDEV	120.97	0.04	0.04	4.46	47.38	56.50	0.03	6.70