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Project Summary

Seasonal Variability in Prickly Pear Creek Water Quality and Macroinvertebrate Communities

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Prickly Pear Creek, Montana, was sampled during four seasons in 1982 and 1983 to attempt to relate biological responses to fluctuations in discharge, in-stream toxicity and metal concentration in the water column. The biota (macroinvertebrate) were definitely impacted directly downstream from a metal source during all seasons, but no definite relationships among discharge, metal concentration and biological response could be established on a seasonal basis.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Prickly Pear Creek, Montana, was studied by the U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV), during 1980 through 1983. This stream was of interest because healthy biota were observed throughout much of the system even though concentrations of zinc, copper and cadmium exceeded the acute aquatic life criteria several fold. Stream surveys and on-site toxicity tests were conducted to investigate factors that enable sensitive organisms to tolerate exposure to waters containing concentrations of metals well in excess of acute national aquatic life criteria. Additional studies examined persistence and degradation of metal toxicity in Prickly Pear Creek as revealed by the downstream distribution of toxic metals and the resultant response of the resident biota.

These studies cited above and others identified factors that affect organism-ecosystem toxic responses. However, not all factors are equally influential in all aquatic systems, and it is important to be able to identify the principal factors controlling metal availability and toxicity in a given system.

One factor that has generally been ignored in relating metal concentrations to in-stream toxicity and biological responses is seasonal variability in flow and associated changes in water quality and in the biota. In some waterways, toxicity may be greatest during periods of high flow when metals are most susceptible to mobilization and transport to surface water (e.g., streams receiving drainage from mine tailings). Conversely, in the same system during low flow periods, metal loading to the stream may be minimal, and the toxicity may be greatly reduced. Knowledge of these factors is crucial to enable water managers to make intelligent decisions regarding the issuance of permits, the allocation of waste loads, the designation of beneficial uses, and the establishment of site-specific criteria and standards.

Consequently, a study was conducted on Prickly Pear Creek to assess seasonal variability in discharge, in water quality, and in the biota. This summary and the project report address that study.

Study Area

Prickly Pear Creek forms its headwaters in the Elkhorn Mountains approximately 32 km southeast of Helena, Montana and flows north for 64 km before entering Lake Helena and the Missouri River (Figure 1). Tailing and settling ponds remain as prominent features of historical gold mining operations within the Corbin and Spring Creek drainages and release high concentrations of zinc, copper, and cadmium which are carried into Prickly Pear Creek. Prickly Pear Creek also underwent extensive mining operations in the early 1900's during which time over 75 percent of the stream was subjected to stream-bed modifications and dredging.

The present study reach was generally characterized by riffle flow and cobble and gravel substrate. The Prickly Peak Creek annual discharge at the U.S. Geological Survey (USGS) gaging station (Figure 1) ranged from 30 to 343 cubic feet per second (cfs) with a mean of 55 cfs during the 1982 to 1983 water year. Spring Creek discharge during this study ranged from approximately 1 to 5 cfs.

Four principal stations on Prickly Pear Creek and one station on Spring Creek were utilized in this study (Figure 1). Spring Creek was considered an "effluent" site (012). Station 011, upstream from the confluence of Spring Creek and Prickly Pear Creek, was used as a control. Stations 013 and 014 were designated impact zone sites, and station 018 (and occasionally 014) was designated as a downstream recovery zone site.

Prickly Pear Creek, Montana

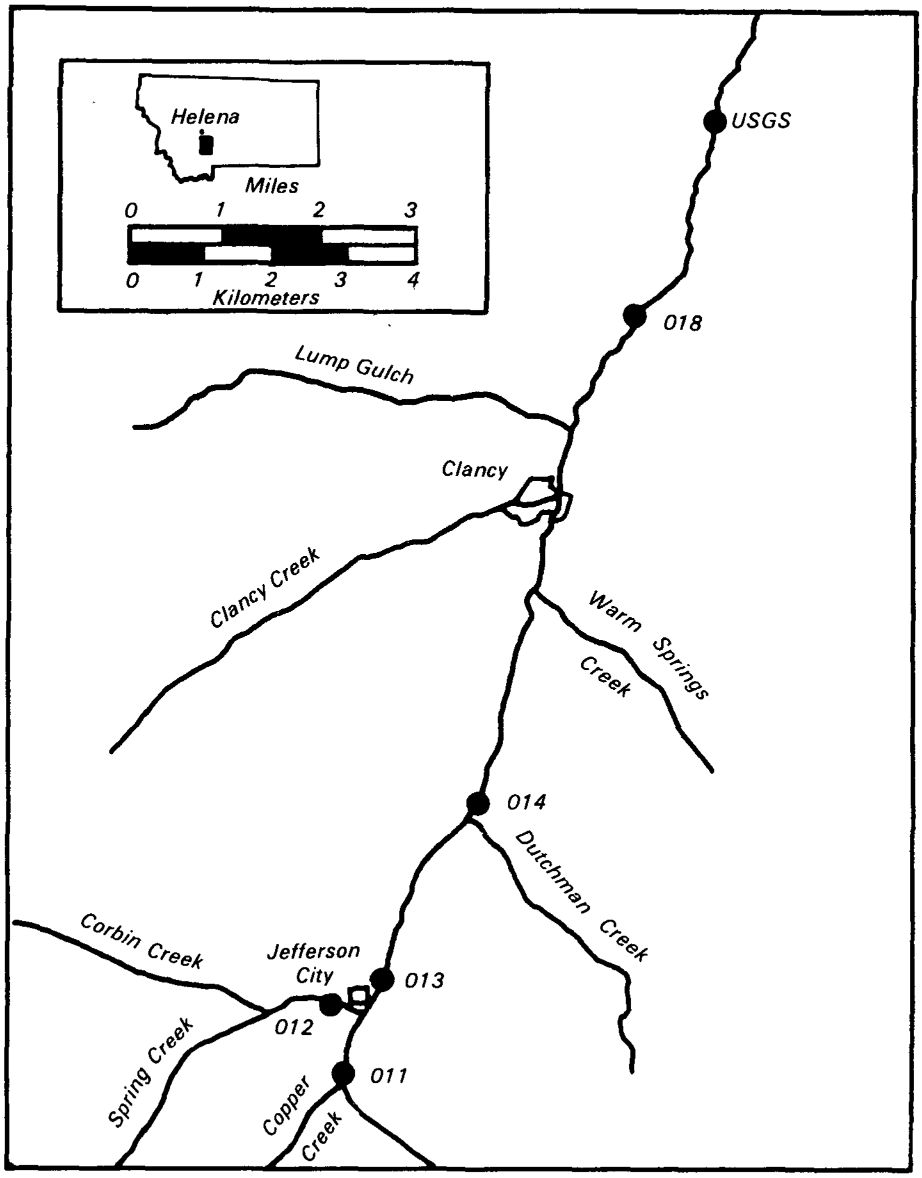

Figure 1. *Station locations on Prickly Pear Creek, Montana.*

Methods

Invertebrate populations and stream water metal concentrations from Prickly Pear Creek control, impact, and recovery sites were sampled during 1982 and 1983. Collections were made during July and December 1982 and April and October 1983 to assess seasonal variations in discharge, temperature, runoff, metal concentrations, and invertebrate communities. Water samples were also collected from Spring Creek during all seasons, however, invertebrate samples were only taken during July 1982. Commonly measured water quality parameters, were also recorded during all seasons.

Water Quality

During July 1982, triplicate water samples for metals analyses were collected at each station. Because very little variability among replicates was observed in these samples, during subsequent samplings single samples were collected from each station. All metal samples were preserved with Ultrex grade HNO_3 to pH $\leq$2.0. July 1982 samples were analyzed by Inductively Coupled Plasma Optical Emission Spectrometric (ICP) methods. The detection limits of the ICP for all metals except zinc and copper approached or exceeded ambient levels in the water column, during July 1982, hence, the July data for cadmium, lead, silver and arsenic should be viewed with this in mind. For the other three periods zinc and copper were analyzed by AA Flame; cadmium, lead, and arsenic via AA Furnace; and silver via ICP.

Hydrology

Stream discharge was measured at each station during the July and October surveys using a Marsh-McBirney Model 57 current meter. At each station flow at each of 20 intervals along a transect was measured at 6-tenth depth. The December 1982 and the April 1983 discharge was extrapolated from July and October data and from USGS gauge values for these periods taken about 3 km downstream from Station 18.

Macroinvertebrates

A Portable Invertebrate Box Sampler (PIBS) was used to collect five replicate samples at each station from riffle zones of uniform flow and velocity. Samples were preserved and processed following conventional techniques. Sorted invertebrates were identified to the lowest possible taxon, counted, and the data entered into computer storage and tabulated. A reference collection of identified specimens is maintained at EMSL-Las Vegas.

Results

Water Quality

Data for metals of concern in Prickly Pear Creek, i.e. cadmium, lead, zinc, copper, silver, and arsenic, are summarized in Table 1. This table suggests that cadmium, lead, silver and arsenic contamination during July 1982 did not originate from Spring Creek because control Station (011) concentrations exceeded those of the effluent (012) and/or the receiving stream impact zones (sites 013 and 014). This apparent anomaly is probably attributed to analytical limitations of the ICP instrument used for analyses of the July 1982 samples. The three metals that commonly exceeded National Criteria were Cadmium, Z inc, and Copper, hence, these results concentrate principally on these metals.

Cadmium levels in July of 1982 (Table 1) appeared elevated over those which occurred during the other three periods, but were undoubtedly a function of the analytical methods because the values reported for July approached the detection limits of the ICP instrument used for these analyses. However, cadmium concentrations measured by AA furnace were clearly elevated in Spring Creek and impact Station 013 over the other stations during the other seasons as well. Spring Creek produced elevated levels of cadmium in Prickly Pear Creek impact site 013, but a gradual reduction to near control (011) levels was observed at sites 014 and 018 (Table 1). The highest concentrations at all stations (excluding July 1982) occurred in October 1983 during low flow. April (1983) and December (1982) concentrations were considerably lower at the downstream sites (014, 018) than summer and fall values. Correlation analysis of USGS gauging station discharge data and cadmium concentrations produced correlation coefficients at sites 012 and 018 of r = 0.94 and r = 0.93, respectively.

Very high zinc levels in Spring Creek (1128 to 2227 μg/l) resulted in substantial increases in zinc concentrations in Prickly Pear Creek (Table 1). Concentrations downstream were progressively reduced, but they never reached control site levels. The highest concentrations of zinc in Spring Creek occurred in July, the period of highest discharge, and October the lowest discharge period. Discharge values and zinc concentrations at sites 012 and 018 did not correlate strongly (r = 0.53 and r = 0.43, respectively).

Copper responded similarly to zinc (Table 1). Variations in concentrations between sample periods within the same sites were not pronounced. Impact site (013) concentrations ranged from 25 to 37 μg/l, approximately twice the control and final recovery site concentrations. July concentrations in Spring Creek were slightly higher than those of other seasons (Table 1). Correlation coefficients for copper concentrations and discharge values for stations 012 and 018 were r = 0.11 and r = 0.67, respectively.

No consistent correlation with discharge (positive or negative) was noted with these three metals at the other stations. Spring Creek (012) concentrations of all three metals correlated positively with discharge, but possibly this was extraneous because of the small number of paired data points.

Hydrology

During July 1982 flow was approximately two times greater than during the other three periods. Flow during the last three sampling periods was essentially uniform and ranged from 38 to 42 cfs at the USGS gauge downstream from site 018.

Macroinvertebrates

Fifty-two macroinvertebrate taxa were collected in Prickly Pear Creek during the four seasons. Estimates of Shannon-Wiener diversity (H'), Evenness (J) and Simpson's Dominance (D) are provided in Table 2 for comparison purposes.

Table 1. *Total Metal Concentrations From Prickly Pear Creek and Spring Creek Sites During the Four Sampling Periods*

	Date	011	012	013	014	018
Cadmium	07/22/82	13	17	19	10	10
	12/21/82	0.2	5.4	2.4	0.7	0.3
	04/08/83	<.3	6.0	2.6	0.9	0.2
	10/09/83	2.0	7.6	5.0	4.0	3.0
Lead	07/22/82	64	29	119	52	51
	12/21/82	2.4	242.5	84.3	16.4	8.6
	04/08/83	<1	246.6	66.1	18.1	5.7
	10/09/83	13	72	30	19	15
Zinc	07/22/82	71	2227	454	221	128
	12/21/82	21.9	1128	431.1	212.2	134.5
	04/08/83	40.5	1595	640.7	320.9	138.4
	10/09/83	100	2119	580	236	203
Copper	07/22/82	20	119	33	13	15
	12/21/82	<9	80.7	37.0	22.0	13.0
	04/08/83	11.0	67.8	25.3	11.7	<9
	10/09/83	12.0	84	28	14	12
Silver	07/22/82	25	24	9	6	4
	12/21/82	<7	<7	<7	<7	<7
	04/08/83	<7	<7	<7	<7	<7
	10/09/83	0.6	1.6	1.9	0.2	0.1
Arsenic	07/22/82	163	90	87	61	126
	12/21/82	<2	46.4	16.7	4.0	5.3
	04/08/83	<2	26.9	10.3	4.5	5.0
	10/09/83	<2	27	6	4	10

Table 2. *Mean Invertebrate Community Indices From Prickly Pear Creek During the Four Sampling Periods (Coefficients of Variation [Percent] are Noted in Parentheses).*

	July 1982				*December 1982*				*April 1983*				*October 1983*			
Parameter	*011*	*013*	*014*	*018*	*011*	*013*	*014*	*018*	*011*	*013*	*014*	*018*	*011*	*013*	*014*	*018*
Mean Count	*411 (53)*	*130 (51)*	*103 (86)*	*226 (15)*	*578 (21)*	*238 (17)*	*171 (34)*	*230 (23)*	*774 (10)*	*460 (9)*	*556 (15)*	*516 (8)*	*298 (17)*	*219 (24)*	*126 (33)*	*76 (26)*
Richness	*21 (36)*	*15 (14)*	*10 (43)*	*19 (8)*	*27 (10)*	*15 (17)*	*13 (23)*	*16 (19)*	*29 (17)*	*19 (20)*	*16 (10)*	*22 (16)*	*20 (16)*	*11 (6)*	*15 (26)*	*9 (26)*
Diversity (H')	*2.82 (12)*	*2.44 (5)*	*2.48 (18)*	*2.92 (7)*	*3.36 (4)*	*2.59 (8)*	*2.90 (11)*	*3.12 (7)*	*3.62 (3)*	*2.81 (13)*	*2.40 (12)*	*2.97 (9)*	*3.43 (8)*	*2.08 (18)*	*3.15 (17)*	*2.68 (15)*
Evenness (J)	*0.67 (9)*	*0.64 (9)*	*0.79 (11)*	*0.69 (5)*	*0.71 (5)*	*0.66 (5)*	*0.78 (10)*	*0.79 (2)*	*0.75 (5)*	*0.66 (7)*	*0.60 (12)*	*0.67 (7)*	*0.79 (4)*	*0.60 (18)*	*0.81 (13)*	*0.84 (4)*
Dominance (D)	*0.77 (5)*	*0.69 (5)*	*0.77 (9)*	*0.80 (6)*	*0.84 (2)*	*0.73 (5)*	*0.81 (7)*	*0.84 (3)*	*0.88 (1)*	*0.80 (6)*	*0.65 (12)*	*0.74 (9)*	*0.86 (4)*	*0.62 (18)*	*0.83 (12)*	*0.82 (7)*

Control Zone (Station 011)

Thirty-nine taxa were collected from the riffles in the control zone during the four sampling seasons. This station consistently provided higher mean total numbers of individual organisms per sample and higher mean and total number of taxa per season than the other sampling stations (Table 2, Figures 2 and 3).

Thirty-two taxa were collected from the riffle at station 011 during July when the flow was greatest. The ubiquitous *Baetis tricaudatus* was very common, comprising 38 percent of the total invertebrate numbers at this site. Other common taxa (6 percent to 30 percent relative abundance) at this site included the mayfly, *Epeorus longimanus*, and the midge subfamily, Orthocladiinae.

The spring, pre-runoff sampling (April) produced both the highest total number of taxa at 37 (Figure 2) and the highest mean number of taxa per sample at 29. The highest mean number of individuals per sample encountered during the study (n = 774) (Figure 3) were collected during April at this station. The most common organism collected in April was the filter feeding caddisfly *Arctopsyche grandis*, which comprised 22 percent of the total invertebrate numbers at this site. Other common taxa in the spring included the mayfly, *Beatis tricaudatus*, with a mean relative abundance of about 16 percent, and the midge subfamily, Othrocladiinae (11 percent), *Glossosoma* sp. (9 percent), and *Ephemerella tibialis* (8 percent).

The pattern of results for December was similar to that observed in April, although the mean total number of individuals per sample dropped by approximately one-third (Figure 3). Several rare or occasional stoneflies captured in April were not observed in December. The composition of the dominant functional groups changed little from December to April.

The macroinvertebrate community at Station 011 appeared most depressed during fall (October) sampling. The mean total number of individuals per sample was down approximately 60 percent from the spring, (Figure 3) and total number of taxa (Figure 2) and mean taxa per sample were reduced by about one-third. This may be a natural seasonal occurrence caused by recent adult emergence and by the inability of the PIBS net to retain minute nymphal instars. Nine taxa were found at Station 011 during the study that were not collected at any other station.

Spring Creek (012)

In July (1982) Spring Creek (012) was sampled to ascertain the presence or absence of fauna. Only five taxa and a total of nine organisms were collected from five replicate samples. These included Orthocladiinae midges and a single stonefly (Chloroperlidae), the caddisfly, *Arctopsyche grandis*, the crane fly, *Tipula* sp., and the water mite, *Sperchon* sp. The low number of taxa and individuals in Spring Creek reflect the extremely disturbed nature of the watershed and the concomitant ele vated metal levels.

Impact Zone (Stations 013 and 014)

Thirty-three taxa were collected dur ing the four sampling seasons at Statior 013. The total number of taxa were rela tively uniform at this station durinç April, July, and December (Figure 2) However, during October the total num ber of taxa was substantially reduced a Station 013, and differences in the num ber of taxa between control Station 01 and impact station were most pro nounced during the October samplin (Figure 2). As was the case at contro site 011, the mean number of individu als per sample was highest in Apri (n = 460) (Table 2, Figure 3). Decembe October and July values did not diffe greatly in terms of numbers of individu als (Table 2, Figure 3).

Two species, *Baetis tricaudatus* an *Arctopsyche grandis*, predominated a this station during all sample season Combined, they made up 54 percent o the total standing crop in July, 65 per cent in December, 49 percent in April and 72 percent in October. The onl other organisms that contributed sub stantially were *Antocha* sp., the Di amesinae midges, and the caddisfly *Brachycentrus* sp.

Twenty-eight taxa were collected du ing the four seasons at Station 014, bu unlike Station 013 no difference in tot number of taxa was evident on a sea sonal basis (Figure 2). As was the cas on the upstream stations, the averag

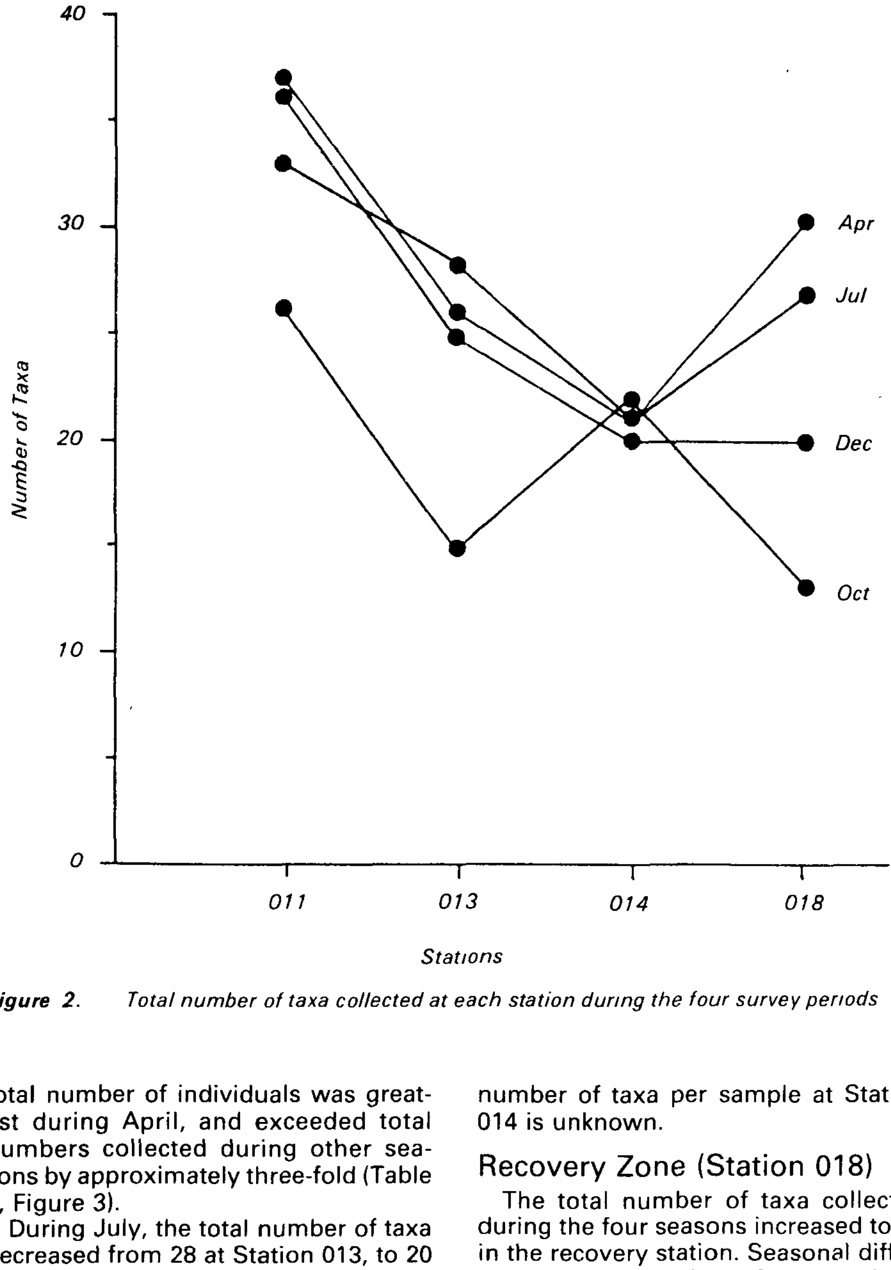

Figure 2. *Total number of taxa collected at each station during the four survey periods*

total number of individuals was greatest during April, and exceeded total numbers collected during other seasons by approximately three-fold (Table 2, Figure 3).

During July, the total number of taxa decreased from 28 at Station 013, to 20 at 014, when 8 of the 11 upstream mayfly species were eliminated. Mean total numbers of invertebrates collected dropped from 130 at Station 013 to 103 at Station 014. Three out of five replicates at Station 014 contained fewer than 100 total animals. Orthoclad midges were very common at this site (32 percent total relative abundance). *Brachycentrus* sp., the crane fly, *Antocha* sp. and the snipe fly, *Atherix variegata*, were also all common. In all seasons except October, Station 014 had the lowest total taxa and the lowest mean number of taxa per sample of any station sampled (Figure 2). The reasons for the October increase in the total number of taxa per sample at Station 014 is unknown.

Recovery Zone (Station 018)

The total number of taxa collected during the four seasons increased to 31 in the recovery station. Seasonal differences in the number of taxa and the mean total number of individuals was the most pronounced at this site of any station sampled during the study (Table 2, Figures 2 and 3).

The total number of taxa collected during the July sampling period was 26 (Figure 2). However, some stonefly and mayfly species present in the control zone and absent from impact stations did not reappear here (e.g., *Ephemerella inermis* and *Doroneuria theodora*). This may be a function of downstream physical changes in the stream (e.g. substrate, flow). Relative abundances of the orthoclad midges fell to 25 percent of the total invertebrate densities. *Baetis tricaudatis* increased to 28 percent relative abundance from 4 percent within the impact zone. *Brachycentrus* sp. and *Atherix variegata* remained common. The number of taxa for December varied little between 014 and 018, but the mean total number of organisms per sample was slightly greater at Station 018 (Table 2, Figure 3). During October, both the total number of taxa and mean total number of individuals was the lowest of any station sampled during the entire study (Table 2, Figures 2 and 3).

Discussion

The goal of this study was to examine the relationships of the biota and pollutant (metals) variations to fluctuations in discharge during four seasons. The main emphasis of the goal was to describe the seasonal variations in macroinvertebrate communities in Prickly Pear Creek and to provide a data base for future comparisons. Community response in Prickly Pear Creek was generally assumed to be related directly to toxic levels of metals. Metals are contributed primarily from leachate supplied via Spring Creek. This contribution varies presumably as a result of changes in discharge levels in both creeks. Biological response is also related directly to community tolerance which changes throughout the year because of natural succession and because of exposure of different invertebrate life stages to pollutants. Our principal hypotheses were that water column metal concentrations in Prickly Pear Creek were related to discharge, and that instream toxicity and resultant community responses correspond to seasonal variations in both discharge and metal concentrations

That concentrations of metals in Spring Creek and the resultant levels in Prickly Pear Creek change between seasons is shown by the data (Table 1). However, an obvious feature of these data is the very high concentrations of cadmium, silver and arsenic during July as compared to concentrations during the other seasons, thus, one must suspect the integrity of the July data. Values presented for these metals approach the detection limits of the instrument used for these analyses and this may account for the seemingly abnormally high values. Most of the variance in these data were attributable to analytical variability among replicates which ranged from 56 to 80 percent. The analytical capability of the ICP for analysis

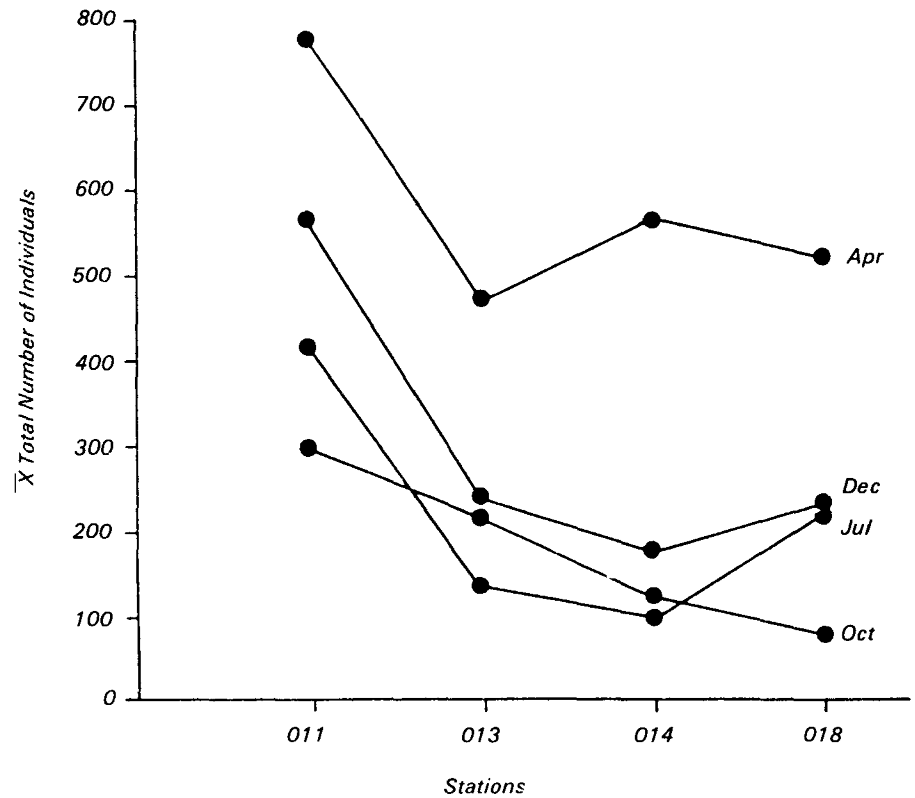

Figure 3. *Mean total number of individuals collected at each station during the four survey periods.*

of copper and zinc, however, appears adequate for levels reported, as they are well above the detection levels. Variability among stations accounted for 100 percent of the total zinc variability during the July sampling and for 94 percent of the variability in copper concentrations for this same period. Considering only the zinc and copper data then, the only obvious trends that emerge are that zinc in Prickly Pear Creek, reached its highest concentration during the period of lowest discharge (October 1983), whereas copper concentrations were highest at the impact station during the December 1982 period of stable flow. Concentrations of both metals in Spring Creek were greatest during the July 1982 period of high discharge. The lack of consistent correlation between metal concentration and discharge may be attributable primarily to variations in the amount of rain that fell in tributary watersheds that feed Prickly Pear Creek. Because each tributary has received differing amounts of disturbance, and because each produced either a dilution effect or an increase in metals leached during events, small rainstorms that affect flow at the USGS gauge downstream from Station 018 may not have necessarily produced a consistent increase or decrease in metals at all stations on Prickly Pear Creek.

Hydrologic flow during our study period did not provide a good discharge gradient, hence, expected changes in chemical and toxic conditions were not well defined. Studies of seasonal variability might better be conducted during the months of January, April, May, June and August, or September for more predictable flow character as based on historical information.

Macroinvertebrate community response, on the whole, was predictable, with well-defined control, impact, and recovery sites. Reductions in the number of individuals, diversity, evenness, and dominance were evident during all four seasons at the impact sites where concentrations of zinc and copper were consistently highest (Tables 1 and 2, Figures 2 and 3). Trends toward recovery at Station 018 were evident, but recovery to control station type communities was not complete. This was undoubtedly more a function of habitat changes than of toxic influence.

The pattern of changes in the number of taxa across stations was similar during April, July, and December (Figure 2). In each instance the control and recov ery zone stations supported the highes number of taxa and the second impac zone station (014), the fewest. For rea sons that are not clear this pattern dic not hold during October, when the num ber of taxa at Station 014 approachec those at the control station, and densit) was markedly reduced at Station 01: and 018. In terms of numbers of individ uals, the impact at Station 013 and 01 is very apparent. Evidence of recover) at Station 018 was apparent during al seasons except October when number: of individuals showed a progressive re duction downstream.

The deviation in seasonal strean metal concentrations because of unde fined factors in Prickly Pear Creek wa: evident. Whether the differences wer significant cannot be ascertained by th current study. Biological systems ar known to vary naturally on a seasona basis. It is difficult to precisely defin natural biological variability, and ex tremely difficult to integrate into thi variability the effects of a variable toxi discharge on an aquatic system. Th present study shows a trend for correla tion between discharge and cadmiun concentrations in the impact and cor trol sites of Prickly Pear Creek, howeve the cadmium data for July 1982 are sus pect. This trend was not consistently ap parent for other metals or at other sta tions. It is evident that a more intensiv study would be necessary to clarify rela tionships among discharge, metal cor centration, instream toxicity and cor munity response. Such a study shoul incorporate consistent water quality ar alytical methods with sufficient sensiti ity, accuracy and precision to reliabl measure levels of toxic metals encour tered in Prickly Pear and Spring Creek The macroinvertebrate sampling cor ducted during this study was adequat and additional sampling using the sam methods should be followed in futur studies. Discharge measurements take at the time each site is sampled chem cally and biologically would provide r liable data for future correlations. Th sampling locations described in th study are adequate to demonstrat spatial variations in water quality, h drology and the biota and they shoul be maintained in future studies for co sistency in the data base.

Conclusions

Toxic metals originating from aba doned mine tailings in the Corbin ar Spring Creek drainage reached Prick

Pear Creek via Spring Creek near Jefferson City, Montana. Principal metals of concern were cadmium, copper and zinc because their concentrations in Prickly Pear Creek waters exceeded the national water quality criteria limits for the protection of aquatic life. Elevated levels of these three metals were present in Prickly Pear Creek waters during four seasons in the impact zone immediately downstream from the Spring Creek and Prickly Pear Creek confluence. Concentrations downstream in the recovery zone approached, but did not quite reach, levels in the unimpacted control zones.

Stream discharge during the winter, spring and fall sampling periods was nearly uniform within each station. During the summer sampling, however, discharge levels were approximately twice those during other periods. During this high flow period, the highest concentrations of the three metals in Spring Creek water were recorded. Cadmium and zinc concentrations reached their next high levels during October 1983, which was a period of low, stable flow. No pronounced trends in copper concentration were apparent on a seasonal or flow related basis.

Macroinvertebrate communities were definitely affected by the high levels of metals in the impact zones. Reduction in numbers of individuals, numbers of taxa and related parameters were apparent during all seasons in the reach downstream from the Spring Creek discharge. Recovery of communities to control station levels was not complete, but this was judged to be a function of different habitats in the downstream reaches rather than a direct impact of metals. October data were somewhat anomalous in that the second impact site showed an increase in total number of taxa and the recovery site showed a reduction in number of taxa. In terms of numbers of individuals, the fall data were also somewhat anomalous as total numbers of individuals progressively decreased downstream, reaching their lowest densities in the recovery zone.

Additional studies would be needed to clarify relationships among discharge, seasons, water quality and the biota. Refinement of hydrological measurements, use of consistent techniques for metals analyses and some adjustment of sampling periods would be required to assure a high probability of success in future studies.

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The complete report, entitled "Seasonal Variability in Prickly Pear Creek Water Quality and Macroinvertebrate Communities," (Order No. PB 87-129 300/AS; Cost: $11.95, subject to change) will be available only from:

National Technical Information Service
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