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Shifts in Caddisfly Species Composition in Sacramento River Invertebrate Communities in the Presence of Heavy Metal Contamination

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The results reported in this study document a change in invertebrate species composition that may be due to exposure to increasing levels of toxic metals in the environment. This is a gradual response which could only be documented because of the long-term and extensive data base accumulated over 18 years. This study is unique in this respect and may also reveal an example of the unexpected side benefits which accrue from a monitoring program such as this.

The study area was the upper Sacramento River, which extends from near Anderson, California, to the vicinity of Red Bluff, California.

During a routine program conducted to monitor resident benthic invertebrate communities, unusual shifts in species composition of two indigenous caddisfly larvae were observed. These occurrences were not associated with any point source, nonpoint source, or seasonal event for which data were available. However, there is reason to suspect that heavy metals in this ecosystem had a role in the changes seen.

METHODS AND MATERIALS

Macroinvertebrates were collected with a Surber square-foot bottom sampler from gravel substrate in riffle habitats. Four replicate samples were collected at each site and treated separately. Substrate was collected in pails, brushed and scraped to remove organisms, and sieved through a U.S. Standard 30-mesh screen. Organisms were preserved with 10% buffered (NaOH) formaldehyde and stored in glass containers. Samples were subsampled, counted, and organisms identified according to conventional techniques and taxonomic references.

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Analyses for cadmium, copper, and zinc were conducted on sieved samples preserved in 10% formaldehyde and stored for one-half to four and one-half years. Invertebrates were hand sorted, washed with distilled water, air dried, and analyzed by perchloric acid digestion followed by atomic absorption spectroscopy.

RESULTS

Macroinvertebrate Community Structure The invertebrate riffle community in this portion of the Sacramento River is moderately diverse and is made up of taxa from several orders including Oligochaeta, Plecoptera, Ephemeroptera, Coleoptera, Trichoptera, and Diptera. During any single sample period the Diptera were represented by more taxa, but the Trichoptera were numerically dominant. The average number of taxa at any station was 19. During the course of sampling at all stations for any single annual study, as many as 35-50 taxa were observed. The total number of taxa identified in this portion of the river for data collected during October, 1980, was 37.

The Sacramento River is moderately productive, and invertebrate densities may reach 2,500 individuals per square foot of substrate. Of this number, 35-68% of the individuals present are Trichoptera larvae. Of the caddisfly larvae which inhabit this portion of the river, two are overwhelmingly dominant. The filter - feeding/grazing *Brachycentrus americanus*, with its chimney-shaped case, occurs in all riffle samples. So also does the caseless filter-feeding *Hydropsyche* sp. The specific Hydropsychidae, specimens collected from the Sacramento River are described by Shuster as *Symphotopsyche* sp. [SCHUSTER and ETNIER 1978]; however, this taxonomic delineation is not universally accepted, and *Hydropsyche* is the genus name used in this report.

Throughout the monitored portion of the river, the relative community composition remained consistent from station to station. There was some fluctuation in total numerical diversity, which is a function of habitat differences between riffles. In Fig. 1 the histogram illustrates the distributions of taxa at each station for 1980 data and compares the 1980 annual distribution to an average of the data collected during the five preceding sampling periods. There are no meaningful differences between stations for the 1980 data and between the 1980 and average data. These data are further broken into "intolerant" and "facultative" components to reflect those organisms which are sensitive or resistant to changes in water quality. The community structure described would not seem to indicate water quality perturbations according to the conventional interpretation of comparative community density and diversity data.

However, an inspection of the relative distribution of individual species over the long time interval spanned by this study shows a marked change in the relative abundance of *Brachycentrus americanus* and *Hydropsyche* sp. In Fig. 2 the mean number of individuals per square foot for all stations sampled is plotted by year.

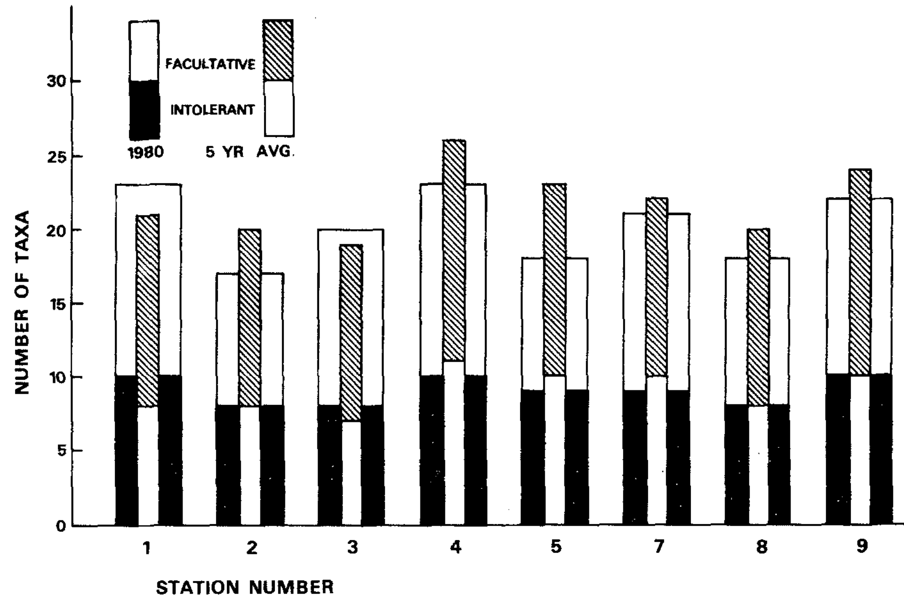

Figure 1. Number of invertebrate taxa in Sacramento River communities for 1980 compared to an average of the five preceding sample periods.

During the late 1960's and early 1970's Brachycentrus americanus was the dominant trichopteran; although Hydropsyche sp. was not rare, it was only about half as abundant as Brachycentrus americanus and represented only a third of the total density for those two dominant trichopterans. In 1972 a shift in distribution began, and by 1978 there was a clear reversal in distribution.

During the past 18 years, the benthic invertebrate standing crop has steadily increased in this portion of the Sacramento River, accompanied by a constant taxonomic diversity and a relatively constant species composition. The Hydropsyche and Brachycentrus reversal were the only significant changes in community structures. This is not a typical response to organic pollutants and therefore indicates that the biological community is responding to some other perturbation.

A likely explanation for these observed changes in species abundance may be a selective susceptibility to the toxicity of heavy metals, specifically zinc, copper, and cadmium. In 1979 the California Department of Fish and Game surveyed benthic invertebrates in Keswick Reservoir and discovered significant reductions in density and diversity in sites located downstream from Spring Creek tributary [CALIFORNIA DEPARTMENT OF FISH AND GAME 1979]. Spring Creek drains one of four mining areas which the State describes as causing severe impacts on water quality in the Sacramento River and its headwater impoundment. Power generation causes intermittent discharges of water containing accumulated heavy metals into the Sacramento River.

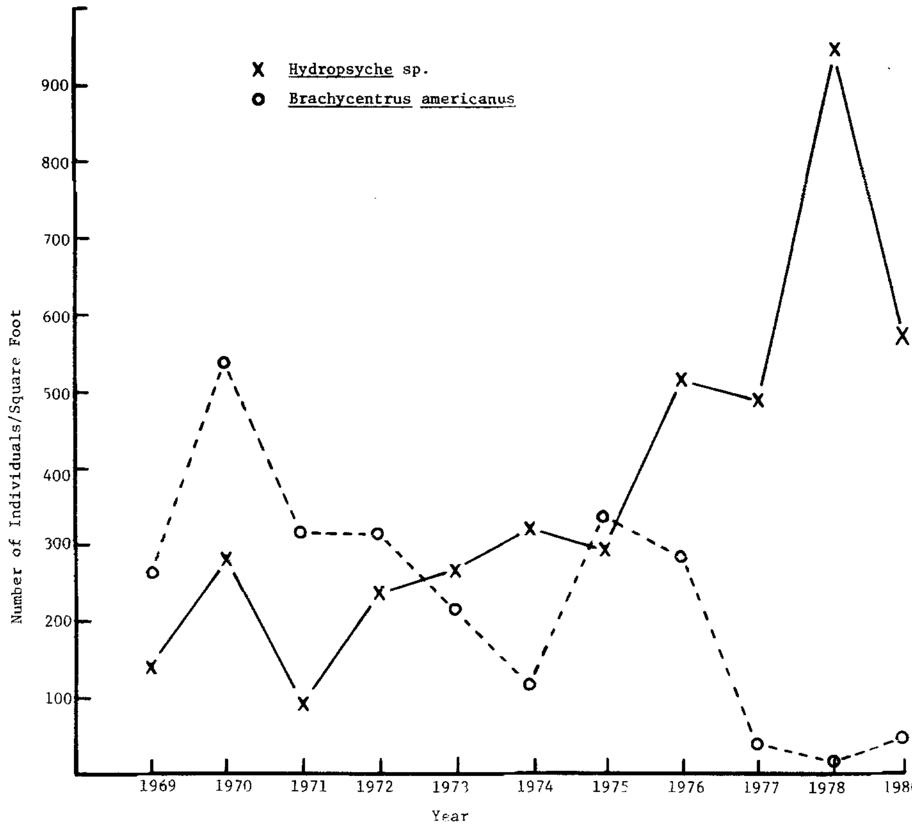

Figure 2. Distribution of Hydropsyche sp. and Brachycentrus americanus in Sacramento River Communities from 1969 to 1980.

In the vicinity of Redding, California (at the upstream end of the invertebrate study area), the California Department of Fish and Game has measured levels of metals in the river water for dissolved cadmium at 1.0 μg/L, dissolved copper at 26 μg/L, and dissolved zinc at 59 μg/L (Table 1).

Storet data for the same metals sampled in 1976 indicate that mean values for total copper and total zinc were lower in 1976 than dissolved metal levels found in 1979. Comparable data for cadmium were unavailable.

Table 1. Metals in Sacramento River Water Sampled at Redding, California, in μg/L, for 1973, 1976, and 1979

	1973[a]			1976[a]			1979[b]
	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Dissolved cadmium	--	--	--	--	--	--	1.0
Total cadmium	--	--	--	7.7	1.0	10.0	-
Dissolved copper	19.8	6.0	34.0	--	--	--	26.0
Total copper	--	--	--	8.0	2.0	44.0	-
Dissolved zinc	40.8	2.0	110.0	--	--	--	59
Total zinc	--	--	--	16.0	2.0	120.0	-
Totals							
Dissolved	60.6	8.0	144				86
Total				31.7	5.0	174	

[a]Storet data.
[b]California Department of Fish and Game data.

These available data indicate that opportunity for invertebrate exposure to these metals was greater in 1979 than in 1976, at the time when the species changes occurred.

Samples of invertebrates collected from three locations in the river during the 1980 sampling period were analyzed for cadmium, copper, and zinc. These results are summarized in Table 2, which also includes a sample of the aquatic moss Hygrohypnum ochraceum, an abundant organism throughout the Sacramento River from Keswick Dam to Red Bluff [SANFORD et al. 1974].

The invertebrate community showed very high levels of copper and zinc and relatively high levels of cadmium. The H. ochraceum metal contents were by far the highest for copper and zinc, with zinc 2.5 times greater than the zinc level found in invertebrates.

The distribution of heavy metals in the tissues of the two caddisfly larvae Hydropsyche sp. and Brachycentrus americanus was also determined for combined individuals in the remaining samples from each site. Samples collected in 1980 and samples collected in 1976 are compared in Table 3. The Hydropsyche larvae had higher levels of copper and zinc in all samples except the Station 9, 1980 sample. Zinc was the predominant metal, and *Hydropsyche* from Station 2 contained the highest animal burden measured.

Table 2. Copper, Zinc, and Cadmium in Mixed Invertebrates and Plants from 1980 Samples in μg/g (ppm)

Metal	Station 2	Station 5	Station 9	Plants Station 2
Cadmium	8.9	6.8	4.9	7.6
Copper	146	122	103	880
Zinc	719	556	697	1791
Total	874	685	805	2678

Table 3. Copper, Zinc, and Cadmium in Caddisfly Larvae and Mixed Invertebrates with Stations Combined for 1976 and 1980 (in μg/g)

	1980							1976					
	Station 2		Station 9		$\bar{x}$ River Values			Station 2		Station 9		$\bar{x}$ River Values	
	B	H	B	H	B	H	Mixed	B	H	B	H	B	H
Cadmium	5.8	5.5	7.2	<2.0	6.5	5.5	6.9	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Copper	155	241	74	91	114	166	125	301	403	159	168	230	285
Zinc	682	1096	761	493	721	794	708	271	280	92	178	181	178
Total	843	1342	842	584	841	965	840	572	683	251	346	411	463

B = *Brachycentrus*
H = *Hydropsyche*

Differences also occurred between species for copper and to a lesser extent for zinc. The *Hydropsyche* larvae in all samples contained more copper than did the *Brachycentrus* larvae. For zinc, the *Hydropsyche* contained more for two of the stations sampled but less at Station 9 in 1980 and at Station 2 in 1976. *Hydropsyche* and *Brachycentrus* showed no differences.

Cadmium has apparently increased in the insects since 1976; copper appears to have decreased; and zinc has increased at about 4 times the levels found in 1976 samples. A similar pattern exists for the two species monitored.

Unfortunately, no literature on the relative sensitivity of these two species to the metals in question could be found. Levels of cadmium found in the river water were below levels found to be acutely toxic to fathead minnows [PICKERING and GAST 1972; HOHREITER 1980] and below levels (57 μg/g) which caused decreased embryo survival. Copper levels were also below the 10.6-18.4 mg/L MATC levels determined for fathead minnows [MOUNT and STEPHAN 1969] but exceeded acceptable criteria for fish and aquatic life of 0.02 mg/L [HOHREITER 1980]. Of the three metals, only zinc has been tested against caddisfly larvae. WARNICK and BELL (1969) determined that at an exposure of 32 mg/L for each of the metals - copper, cadmium, and zinc - it would take 14 days to reach an LC_{50} for copper, 11 days for zinc, and 10 days for cadmium. No data for Brachycentrus were obtained. With the high exposure to zinc evidenced by uptake in the Sacramento river invertebrates, a difference in susceptibilty between the two invertebrates probably accounts for the decline in Brachycentrus and increase in Hydropsyche numbers.

Acknowledgments

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