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Population and Community Effects of Sediment Contamination from Residential Urban Runoff on Benthic Macroinvertebrate Biomass and Abundance

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Levels of sediment contamination from nonpoint source urban runoff often exceeds that of point source discharges (Cole et al. 1984; Liston and Maher 1986; Muschack 1990; Winner et al. 1980). Nonpoint source runoff is frequently regarded as a low-level and less intense, though more widespread type of contamination. Benthic macroinvertebrates are particularly useful in evaluating the presence of this type of low-level chronic contamination because of their relatively limited mobility and sufficiently long life span (some up to a year or more) (Plafkin et al. 1989, Winner et al. 1980).

Difficulties in biomonitoring studies can arise from the need to use a separate unimpacted community for comparison. Finding two discrete systems with the same biotic and abiotic characteristics can prove difficult. Studies are often conducted in two systems that appear superficially similar but have subtle and important differences. This procedure can produce variation not attributable to the impact of the contaminant. Studying a lake with two distinct basins provides an opportunity to examine the impact of two types of runoff on a single benthic community. The goal of this study was to evaluate whether residential urban runoff influences the benthic macroinvertebrate community.

MATERIALS AND METHODS

Campus Lake, Carbondale, Illinois, has a surface area of 15 ha and total drainage area of 82 ha. The drainage is divided into two sub-basins, vegetated and residential. Half of the lake receives runoff from residential areas, comprising parking lots, sidewalks, and dormitories, while the other half receives runoff from forested and old field successional areas. Sample sites were located in two physically similar bays; one receiving runoff from a storm sewer and overland flow in the residential basin; the other receiving only overland flow from the vegetated basin.

Sediment samples for trace metal analyses were collected from 5 cores, 4 cm deep and 5 cm wide, extracted from an Ekman grab sample at 0.5 m deep sites in each sub-basin. Five replicate cores were taken from each Ekman sample and dried at 60 °C for 24 hr. Five gram sub-samples of each replicate were ground to a fine powder and weighed to +/- 0.0001 mg, heated in a muffle furnace to 550 °C 1 hr to volatilize all organic matter, then reweighed. Loss on ignition was then calculated. The remainder of each sample was digested and refluxed in concentrated nitric acid for 16 hr, filtered through a Whatman 0.45-μm glass microfiber filter, and stored at 4°C until atomic absorption analysis was performed (American Public Health Association 1989). Total metal concentrations for Fe, Mn, Ni, Pb, and Zn were gener

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ated by means of atomic absorption spectroscopy following APHA(1989) procedures. Detection levels were down to 0.001 mg/L. Standards for trace metal analysis were suppliedby the Illinois EPA laboratory certification program. Percent recoveries for Fe, Mn, Ni, Pb, and Zn were 98, 95 99, 98, and 97%, respectively.

Benthic macroinvertebrates were sampled on 17 December 1991 and 29 February 1992 with an Ekman grab. Five samples per basin type were collected and washed through a U.S. standard No. 60 sieve (250-μm). Samples were sorted using Anderson's (1959) sugar flotation technique and preserved in 85% ethanol. Macroinvertebrates were sorted and identified to genus, excluding Oligochaeta which were taken to family. Taxa where then analyzed based on abundance per m^2 and total grams wet weight of the taxa per sample site. No transformations or other manipulations were conducted on the data before ANOVA (α = 0.05) for metals and macroinvertebrates were computed using the SYSTAT version 5 software package (Wilkinson 1989).

RESULTS AND DISCUSSION

Of the five trace metals analyzed, only manganese (F = 38.742, p = 0.001), lead (F = 11.463, p = 0.001), and zinc (F = 9.96, p = 0.001) had significantly greater concentrations in the residential sub-basin (Table 1). Fifteen taxa were found in the residential sub-basin samples, while only 11 were found in the vegetated. Six of the 11 taxa shared by the basin types had significantly different totals of abundance and biomass ($p < 0.05$, Table 2). Species richness, total site abundance, and total site biomass were all greater in the sediments of the residential basin. No significant differences were detected in functional feeding groups, as defined by Merritt and Cummins (1984), between sub-basin types.

Table 1. Sediment metal concentrations (mg/kg dry sediment) in Campus Lake at 0.5 m depth (N=10, 5 per site). Superscripted letters that are different indicate statistically significant (α = 0.05) differences among sites.

Metal	Site	Mean	SE	Minimum	Maximum
Iron	Urban	396000.4	3404.6	26621.3	46393.5
	Vegetated	48643.7	10598.6	16853.3	75220.9
Manganese	Urban	1464.1	157.4	1065.2	1825.6
	Vegetated	1.6	0.6	0.2	3.6
Nickel	Urban	131.5	28.8	45.4	222.2
	Vegetated	366.5	238.4	45.1	1306.2
Lead	Urban	579.8	50.3	460.8	753.1
	Vegetated	262.6	95.1	64.4	622.5
Zinc	Urban	558.1	131.2	208.9	911.1
	Vegetated	2.2	0.8	0.6	4.1

Six of the moderately to very pollution tolerant taxa (Plafkin et al. 1989) common to both sites, *Caenis*, *Chironomus*, *Dicrotendipes*, *Naididae*, and *Natarsia*, exhibited a positive response in abundance or biomass associated with the residential sub-basin (Table 2). The alderfly *Sialis*, ranked as pollution intolerant, was present but statistically less abundant and had statistically lower site biomass in the residential sub-basin.

Differences in concentrations of manganese, lead and zinc in sediments are clearly associated with sub-basin type. Their enrichment in the residential sediments is indicative of differences

Table 2. Site mean abundance (per m^2) and mean biomass (g wet weight/m^2) of benthic macroinvertebrates in the residential and vegetated basins of Campus Lake, Carbondale, Illinois. (α = 0.05, Standard Error in parenthesis).

	Abundance			Biomass		
Taxa	Residential	Vegetated	F(p)	Residential	Vegetated	F(p)
Bezzia	506 (5)	373 (7)		0.631 (0.103)	0.152 (0.158)	
Caenis	107 (2)	169 (1)		4.218 (1.013)	0.552 (0.204	26.991 (0.0001)
Chaoborous	80 (4)			0.187 (0.241)		
Chironomus	302 (8)	71 (3)		4.786 (1.020)	0.321 (0.169	6.344 (0.023)
Dicrotendipes	266 (5)	71 (4)	6.841 (0.019)	0.293 (0.161)	0.007 (0.232	16.945 (0.001)
Gastropoda	45 (3)			0.196 (0.434)		
Glyptotendipes	240 (6)	71 (4)		1.031 (0.393)	0.894 (0.397)	
Hyalella	258 (10)	124 (6)		2.078 (0.813)	0.623 (0.249)	
Mystacides	18 (2)			0.039 (0.108)		
Niadidae	178 (3)	18 (2)	8.641 (0.010)	0.408 (0.136)	0.041 (0.245)	
Natarsia	417 (6)	115 (46)	7.864 (0.013)	0.028 (0.065)	0.127 (0.218)	
Penteneura	160 (4)	142 (52)		0.746 (0.363)	0.586 (0.060)	
Perithemis	36 (2)			2.408 (0.649)		
Procladius	151 (4)	62 (28)		0.552 (0.132)	0.081 (0.143)	
Sialis	71 (2)	293 (2)	10.16 (0.001)	1.353 (0.441)	4.835 (0.065	65.069 (0.0001)

in runoff received by the 2 sub-basins. Species richness and abundance do not show residential runoff as having an overall negative impact. However, the previously mentioned differences in abundance and biomass characteristics between sites within a taxon do show that there is a subtle shift within the community that can be associated with sub-basin type.

Previous authors have shown that reduction of macroinvertebrate predator numbers can lead to increases in macroinvertebrate prey (Paine 1966; Petersen 1986; Fairchild et al. 1992). The 76% decrease in abundance of *Sialis* (the dominant macroinvertebrate predator sampled and a pollution-intolerant taxon) at the residential sub-basin site has the potential to free the other taxa present from the constraints of predation, thus allowing for increases in abundance and biomass at the residential site. It should be noted that while *Sialis* is the dominant macroinvertebrate predator present, it is unlikely to be the main predator of Campus Lake. Fish predation is likely to be more important. However, if the mobility of fish and the fact that both sample sites are located in the same small water body are taken into account, it is doubtful that fish would exert greater pressure at one location over another. A second possibility is that the residential runoff is supplying greater mounts of nutrients to the benthos, thus allowing for increases in population abundance and biomass. If there were no toxic impact this should also lead to increases for *Sialis*. Table 2 shows instead that the abundance and biomass of pollution-intolerant *Sialis* decreased while the pollution-tolerant taxa increased at the residential site.

The results of this study indicate that residential runoff and associated contamination is not great enough to eliminate taxa from the community or depress the overall community abundance and biomass. However, the results do suggest that residential runoff can be associated with significant differences in abundance and biomass of intolerant taxa like *Sialis*. While the causal mechanism is not clear, the resulting shifts in the overall community, in this case an increase in species richness and population abundance and biomass of pollution-tolerant prey taxa, are significant.

REFERENCES

Anderson RO (1959) A modified flotation technique for sorting bottom fauna samples. Limnol Oceanog 4:223-225

American Public Health Association (1989) Standard methods for the examination of water and wastewater. 17th edition, APHA, Washington D.C.

Cole RH, Frederick RE, Healy RP, Rolan RG (1984) Preliminary findings of the priority pollutant monitoring project of the nationwide urban runoff program. J Wat Pollut Con Fed 56:898-908

Fairchild JF, La Point TW, Zajicek JL, Nelson MK, Dwyer FJ, Lovely PA (1992) Population, community, and ecosystem level responses of aquatic mesocosms to pulsed doses of a pyrethroid insec ticide. Environ Toxicol Chem 11:115-129

Liston P, Maher W (1986) Trace metal export in urban run-off and its biological significance. Bull Environ Contam Toxicol 36:900-906

Merritt RW, Cummins KW (1984) An introduction to the aquatic insects of North America. Second edition. Kendall Hunt publishing Co., Dubuque IA

Muschack W (1990) Pollution of street run-off by traffic and local conditions. Sci Tot Environ 93:419-31

Paine RT (1966) Food web complexity and species diversity. Amer Nat 100:65-75

Petersen RC, Jr (1986) Population and guild analysis for interpretation of heavy metal pollution in streams. In: Cairns J Jr (ed), Community Toxicity Testing. American Society for Testing and Mate rials, Philadelphia, PA, pp. 180-188.

Plafkin JL, Barbour MT, Porter KD, Gross SK, Hughes RM (1989) Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. USEPA Pub.EPA/444/4-89-001

Wilkinson L (1989) SYSTAT: The system for statistics. Evanston IL; SYSTAT, Inc.

Winner RW, Boesel MW, Farrel MP (1980) Insect community structure as an index of heavy metal pollution in lotic ecosystems. Can J Fish Aquat Sci 37:647-655