EFFECT OF A METAL PLATING PLANT EFFLUENT ON LEAF PROCESSING RATES IN A STREAM

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ABSTRACT

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The purpose of this study was to determine if previously documented negative impact of a metal plating plant on macroinvertebrate populations in the Red Cedar River in southern Michigan affected leaf processing rates. Five gram leaf packs were placed in stream and periodically sampled. Water samples were analyzed for chromium, copper, nickel, and zinc. Zinc content of leaf packs was determined and found to be greater in leaf packs below outfall, but not at levels which would have detrimental impact on macroinvertebrate populutions. Except for the particularly fast breakdown rate at a gravel control site, leaf breakdown rates were similar for matching habitat sites above and below outfall. Macroinvertebrate fauna was similar for matching habitat sites. Lack of negative impact of effluent on leaf processing rates was attributed to improved water quality and macroinvertebrate faunal composition.

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INTRODUCTION

Small temperate woodland streams are characteristically heterotrophic, with allochthonous input as the major source of energy (Nelson and Scott 1962, Hynes 1963, Egglishaw 1964, Minshall 1967, Fisher and Likens 1972,1973, Cummins 1974). A large portion of this input is leaves. Thus, processing of leaves is an important function of these streams. Perturbations of this process may have major impact on stream function and quality.

Decomposition of leaves is largely a biological process in which insects, which are sensitive to heavy metal pollution, play a significant role by shredding of leaves (Cummins 1973, 1974, Petersen and Cummins 1974, Boling *et al*. 1975). Previous studies on the Red Cedar River, a warm-water stream in southern lower Michigan, have shown that effluent from the Utilex metal plating plant had a significant impact on invertebrates (Garton 1968, Harrington 1974, Sylvester 1978). Below outfall, there was a reduction in numbers and types of insects, crustacea, and mollusks, with an increase in tubificids. The purpose of this study was to determine if this biological degradation significantly reduced the rate of leaf processing.

DESCRIPTION OF STUDY AREA

The Red Cedar River is a warm-water stream originating at Cedar Lake, Livingston County, in south central Michigan. It flows northwesterly approximately 73 km (45 miles) before entering the Grand River in Lansing. It drains an area of approximately 1220 square kilometers (472 square miles). Section of the river studied is tree-lined and located in an agricultural and residential area. Sources of residential and industrial contamination to the river are concentrated in Fowlerville (population 2000). Two major sources of pollution in this section are Hoover Universal-Utilex Division metal plating plant, which manufactures decorative plated zinc die castings and is located in Fowlerville, and domestic sewage from Fowlerville sewage treatment plant. Metal plating process and cooling water effluent enters the river 0.3 km (0.2 mi) north of Grand River Road Road bridge. Fowlerville sewage treatment plant utilizes a lagoon system, discharging wastes twice a year in spring and fall. Sewage is discharged 1 km (0.65 mi) below Utilex plant discharge.

Six sites were selected, three above outflow of plating plant effluent and three below. Sites were selected to enable those above discharge to match, as closely as possible, habitats of those below discharge. Sites below discharge were located as follows: 0.2 km (0.1 mi) below discharge near Grand River Road; 2.1 km (1.3 mi) below discharge at Gregory Road and 4.3 km (2.7 mi) below discharge at Nicholson Road (Figure 1). Grand River Road site had a soft black muck substrate with slow flow. Gregory Road site had a silt and sand substrate with moderate flow. Nicholson Road site had a sandy bootom with macrophytes and a shallow, fast flow. Matching habitat sites for Grand River and Gregory Road sites were located at end of Garden Lane Road, 0.3 km (0.2 mi) above Utilex discharge point. These sites closely matched their downstream counterparts at Grand River and Gregory Roads. No sandy bottom site could be found above Utilex plant discharge to match Nicholson Road site, thus a site which most closely matched it was selected. This site was located at the railroad bridge 0.1 mile above discharge. It had a gravel substrate, but like Nicholson Road site had macrophytes and shallow, fast flow.

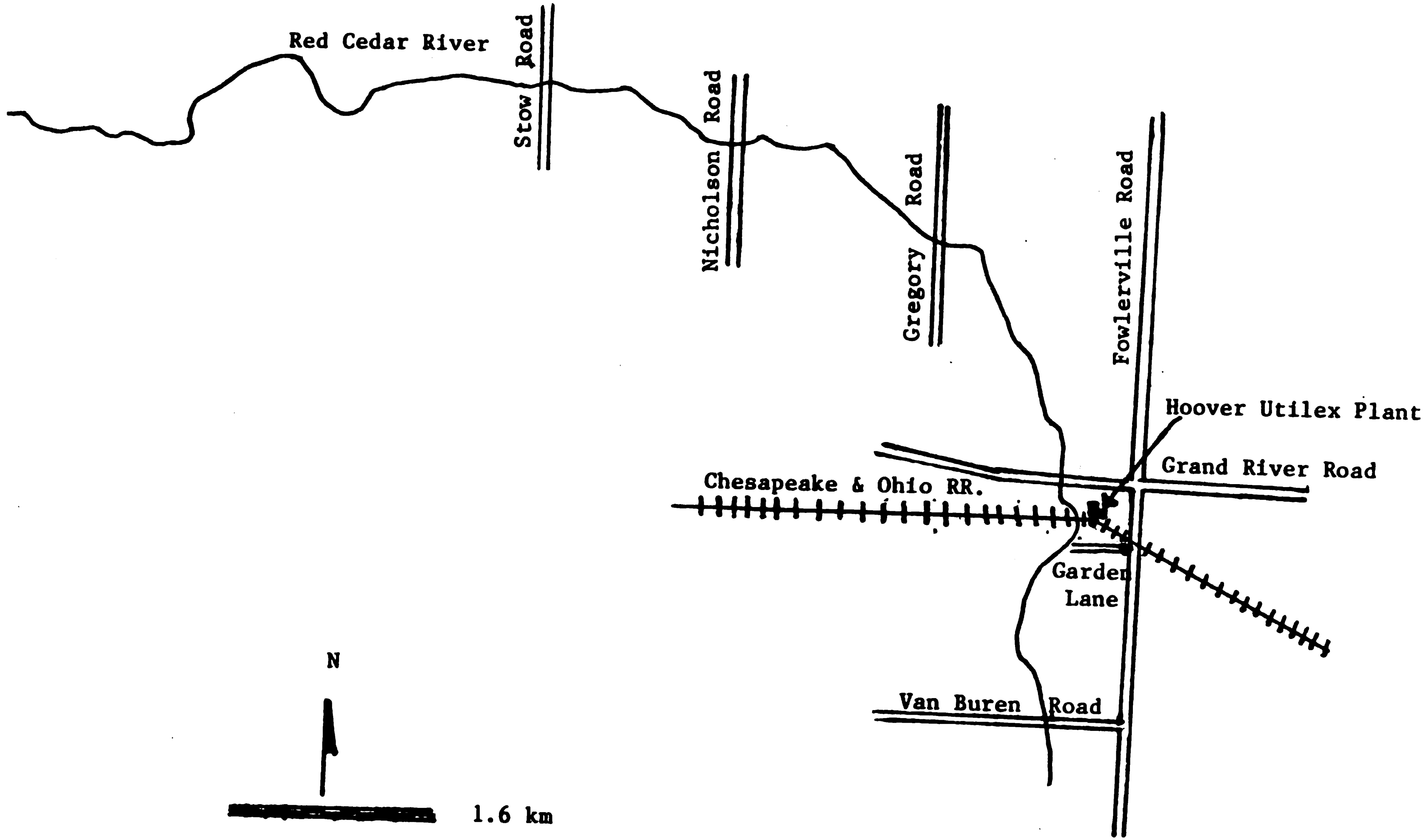

Figure 1. Map of Study Area.

METHODS

The experimental unit was a leaf pack composed of sugar maple (*Acer saccharum*) leaves. Leaves were collectd from a single tree at autumnal abscission, air-dried and weighed to 5.0 grams. Leaves were then soaked for a few minutes in water until they could be manipulated without breakage. Leaves were fastened together with a Buttoneer (Dennison Corp.) utilizing plastic I-bars. Bundles of leaves were then placed against brick faces and attached with an elastic garter.

Bricks were placed in stream so that attached leaf packs faced upstream into current. This arrangement simulates natural leaf packs which form against objects obstructing the current, such as rocks, branches, logs, etc. Leaf packs were placed in stream June 28, 1978, and the last packs were removed August 13, 1978. Leaf packs were sampled approximately every 125 degree-days. Degree-days are a measure of stream temperature multiplied by time. There were eight pick-ups and three replicates per pick-up per site. Replicate leaf packs are designated A,B, and C in tables. A total of 144 leaf packs were used (6 sites X 8 pick-ups X 3 replicates).

Sampling procedure was as follows. Bricks with attached leaf packs were lifted from the stream bed. Individual leaf packs were slid off of bricks into a small Zip-Loc (Dow Corp.) storage bag and transported to laboratory. Leaf packs were disassembled and organisms visible by eye were rimoved and preserved in alcohol for later identification. Organisms were identified using keys in Ross (1944), Pennak (1953), and Hilsenhoff (1975). Leaves were gently rinsed in water to remove attached sediments, air-dried, and then weighed.

Three water samples were taken at each site in polyethylene pint bottles. Three samples were also taken from the effluent. To prevent precipitation, 1 ml of nitric acid was added to each sample bottle. Samples were analyzed for total zinc, copper, nickel, and chromium levels using atomic absorption spectrophotometry. Before analysis, samples were pretreated with nitric acid to digest organic matter using a method suggested by D'Itri (pers. comm.). Each sample bottle was rinsed a few times with nitric acid to remove material which may have adhered to walls of sample bottle. Each sample was boiled with excess nitric acid, then diluted to original volume with distilled water.

To determine if increased metal concentrations below the discharge point substantially increased metal contents of leaves, thereby possibly having a deleterious impact on insect populations through the food chain, leaf packs were analyzed for zinc content. Leaf packs from second, fourth, sixth, and eighth pick-ups were analyzed following a method suggested by Ellis (pers. comm.). Duplicate 1 gm samples of ground leaf material were taken from each leaf pack, except that 0.5 gm samples were taken from leaf packs which had insufficient material remaining to form two 1 gm samples. Samples were ashed at 500°C. for 4 hr. Residue was dissolved in 5 ml of 2 N hydrochloric acid and filtered into a 50 ml volumetric flask. Beakers were repeatedly rinsed with 0.1 N hydrochloric acid. Rinsings were filtered into flasks until volumes were near graduations, and flasks were then brought to volume with distilled water. Zinc content of samples was determined using an atomic absorption spectrophotometer.

RESULTS

Concentrations in river water of chromium, nickel, and copper were below detection limits of 0.1-0.2 ppm at all sites for all samples. Chromium concentration in effluent was 0.4 ppm in the first sample and undetectable in the other samples. Copper concentrations in effluent samples were 2.0, 0.75, and 0.65 ppm. Concentrations of nickel in effluent samples were 0.65, 0.2, and 0. 2 ppm. Zinc concentrations in river water were below detection limit of 0.01 ppm for many samples and were barely detectable at levels of 0.01-0.02 ppm for the other samples. Zinc concentrations in effluent samples were 1.1, 1.2, and 1.1 ppm. These results were similar to those obtained in a Michigan Department of Natural Resources survey conducted May 22-26, 1978. Range in values in effluent for 24-hr composite samples were 0.28-0.47 ppm chromium, 0.81-1.2 ppm copper, 0.50-0.87 ppm nickel, and 0.8-1.6 ppm zinc (Saalfeld 1979).

Although variable, zinc content of leaf packs tended to increase with time while in the stream (Table 1). At all sites, average zinc content of leaf packs was higher than control samples of leaves not placed in stream for the sixth and eighth pick-up samples. Zinc levels in terrestial leaf litter have also been found to increase with time (Lawry 1978). Zinc content was significantly higher for

Table 1. Zinc content of leaves (mg/kg)

Garden Lane - Grand River Control

Pick-up	Leaf Pack A		B		C	
7/11	5	5	32	56	5	35
7/22	6	6	35	33	20	21
8/2	43	44	15	23	70	66
8/13	35	39	44	36	29	29

Garden Lane - Gregory Road Control

Pick-up	Leaf Pack A		B		C	
7/11	11	6	8	9	11	22
7/22	8	7	6	6	8	7
8/2	16	15	24	25	52	35
8/13	42	21	106	111	15	36

Railroad Bridge

Pick-up	Leaf Pack A		B		C	
7/11	16	18	9	14	24	18
7/22	10	21	7	8	8	8
8/2	7	5	5	5	53	70
8/13	69	62	62	85	46	50

Grand River Avenue

Pick-up	Leaf Pack A		B		C	
7/11	14	13	27	33	31	28
7/22	9	13	10	12	15	23
8/2	43	54	42	32	35	58
8/13	85	63	54	63	100	87

Gregory Road

Pick-up	Leaf Pack A		B		C	
7/11	6	7	32	35	10	7
7/22	24	15	14	48	18	27
8/2	43	54	42	32	35	58
8/13	81	62	21	31	48	37

Nicholson Road

Pick-up	Leaf Pack A		B		C	
7/11	6	14	34	7	7	14
7/22	18	15	33	33	24	31
8/2	39	43	48	58	108	112
8/13	23	23	13	24	58	44

leaf packs collected below Utilex discharge point than for leaf packs from above discharge ($P>.01$, planned contrast single degree of freedom F test). However, these levels were still relatively low, were will within normal range, and unlikely to have been having an adverse impact on insect populations.

Leaf breakdown rates were very similar for the site immediately below discharge and its matching habitat site above discharge (Figure 2, Table 2). Macroinvertebrates collected in leaf packs were also similar for these two sites. Chironomids and oligochaetes were predominant, with a few caddisflies, mayflies, amphipods, and flatworms also present at both sites. Leaf breakdown rate for the site 2.1 km below Utilex plant discharge was variable and generally slower than its matching habitat site above discharge (Figure 3, Table 2). Macroinvertebrate fauna was also similar at these two sites. Chironomids were most abundant and oligochaetes were also numerous. Oligochaetes were more abundant at the site above discharge than at the site below discharge. Numbers and types of other taxa were similar and typical of sand-silt substrates.

Rate of leaf breakdown was considerably slower at the site 4.3 km below discharge than at its matching habitat site above discharge, which had a processing rate considerably faster than the other habitat sites (Figure 4, Table 2). This result is typical for a gravel habitat. Gravel habitats usually have the fastest leaf breakdown rates (Reice 1974).

Table 2. Leaf pack biomass remaining in grams

	Grand River Avenue			Garden Lane-Grand River Control		
	Leaf Pack			Leaf Pack		
Pick-up	A	B	C	A	B	C
7/4	4.07	4.01	4.02	4.05	3.92	4.02
7/11	3.95	3.92	3.54	3.79	3.67	3.77
7/17	3.36	3.46	3.54	2.97	3.41	2.81
7/22	3.43	2.75	3.23	3.49	3.22	3.23
7/27	2.92	3.03	3.27	3.28	2.96	2.88
8/2	2.45	2.82	2.69	3.13	3.03	2.93
8/8	2.85	3.01	2.64	2.22	2.57	2.57
8/13	2.31	2.60	2.52	2.35	2.95	2.96
	Gregory Road			**Garden Lane-Gregory Road Control**		
	Leaf Pack			Leaf Pack		
Pick-up	A	B	C	A	B	C
7/4	3.78	3.74	3.67	3.95	4.08	3.80
7/11	3.63	3.54	3.60	3.48	3.13	3.51
7/17	3,50	3.45	2.38	3.30	3.13	2.84
7/22	3.18	3.28	3.04	2.98	2.88	2.81
7/27	3.18	2.88	3.15	2.52	2.74	2.63
8/2	2.59	2.34	2.62	2.76	2.89	2.65
8/8	2.62	2.70	3.11	2.39	2.48	2.04
8/13	2.71	3.02	2.37	2.15	2.26	2.26
	Nicholson Road			**Railroad Bridge**		
	Leaf Pack			Leaf Pack		
Pick-up	A	B	C	A	B	C
7/4	3.83	3.80	3.89	3.81	3.89	3.80
7/11	3.76	3.33	3.83	3.42	3.52	3.60
7/17	3.32	3.52	3.26	3.24	2.90	2.60
7/22	3.20	3.06	3.20	1.87	2.88	2.81
7/27	2.78	2.69	3.25	1.68	2.68	1.93
8/2	2.67	2.73	2.87	1.58	2.40	2.32
8/8	2.40	2.44	2.65	2.25	2.24	1.57
8/13	2.26	2.36	2.01	1.76	1.76	2.19

Although Nicholson Road and railroad bridge sites were closely matched with respect to current flow and presence of macrophytes, these two sites had different substrates, one sandy and the other gravel. This difference in substrate resulted in different macroinvertebrate fauna and leaf breakdown rates. Nicholson Road site had a greater number of caddisflies and oligochaetes than railroad bridge site. It also had a greater number of mayflies, especially Caenis sp., a genus which is adapted to a sprawling existence on the surface of fine sediments (Merritt and Cummins 1978). Railroad bridge site had more elmid beetles.

In the analysis of variance, site as a source of variation was found to be highly significant ($P > .01$) (Table 3). This is to be expected, regardless of impact of discharge, since leaf processing rates vary in different habitats (Reice 1974). The five degrees of freedom for sites can be partitioned to analyze effect of discharge. A planned contrast, single degree of freedom F test comparing sites above discharge to sites below discharge found this comparison to be highly significant ($P > .001$), indicating that discharge may be slowing leaf processing rate. However, two degree of freedom F tests of variation within site groupings found variation within above discharge sites to be very highly significant, while variation in below discharge sites was not significant. The sum of squares for sites above effluent discharge point was over two-thirds of site sum of squares. This high degree of variation can be attributed to the particularly fast breakdown rate at railroad bridge site.

Table 3. Analysis of Variance - Leaf Pack Biomass

Source	SS	DF	MS	F	P
A (Week)	36.45	7	5.21	89.06	.001
B (Site)	6.06	5	1.21	20.68	.001
AB	3.88	35	.111	1.89	.05
Error	5.62	96	.059		
Total	52.01				

DISCUSSION

Effluent from Utilex metal plating plant does not appear to be having an appreciable effect on leaf processing rates. The site nearest discharge, where one would expect the greatest impact on leaf breakdown rates, had a rate very similar to its matching habitat site above discharge. Although rates above effluent were significantly greater than rates below effluent, much of this difference can be attributed to the especially fast breakdown rate at the gravel railroad bridge site. This site, although the best available, was not a good control site, for its different sustrate type and community structure affected breakdown rates and complicated overall analysis of breakdown rates. Due to this complication, it would not be appropriate to attribute the statistically significant difference in breakdown rates in above effluent sites versus below effluent sites to effects of effluent, especially since the difference was very small for the site closest to effluent and its control site.

Previous studies have shown that effluent was having a negative impact on insect populations (Garton 1968, Harrington 1974, Sylvester 1978). Since shredding of leaves by insects is important in leaf processing, the negative impact of effluent could result in slower leaf breakdown rates below effluent. One reason that effluent did not have a demonstrable impact on leaf breakdown rates may be improvement in water quality from previous studies. In 1966, Garton (1968) found elevated metal concentrations as far as 10.3 miles (15.5 km) below discharge. In the present study, levels of copper, nickel and chromium were below detection limits at all locations. In a series of samples in summer 1966, effluent levels were 0.9-2.2 ppm copper, 1.4-9.5 ppm nickel, 0.85-4.3 ppm zinc and 0.17-3.4 ppm total chromium (Garton 1968) compared to 0.7-2 ppm copper, 0.2-0.7 ppm nickel, 1.1-1.2 ppm zinc and a maximum of 0.4 ppm chromium in present study. In 1966, macroinvertebrate fauna near discharge was almost entirely tubificids, which occurred in very high numbers (Garton 1968). Macroinvertebrate fauna was mostly tubificids in large numbers in June 1972 before new pollution control equipment became operational (Harrington 1974). By June 1973, one year after pollution control equipment went into operation, there had been a considerable recovery of macroinvertebrate populations. Numbers of organisms other than tubificids increased while numbers of tubificids substantially decreased (Harrington 1974). In September 1976, no mayflies or caddisflies were collected in a 30-minute qualitative sampling at Grand River Road near Utilex discharge point (Sylvester 1978). In contrast, in this study mayflies and caddisflies were collected at Grand River Road site. Chironomids were numerous at this site, while in previous studies macroinvertebrate fauna was mostly tubificids. Number and variety of organisms were very similar to matching habitat site above discharge point, indicating discharge was not appreciably affecting faunal composition. Since insects were not as severely affected as previously, it is not surprising that little impact on leaf breakdown rates was observed.

Metal concentrations in effluent, especially copper concentrations, were at levels which are detrimental to some macroinvertebrate populations. In a static bioassay, 96-hr TLm's (concentrations producing 50% mortality) for *Gammurus sp*. were 0.91, 8.1, 13.0 and 3.2 ppm for copper, zinc, nickel and chromium, respectively (Rehwoldt *et al*. 1973). Corresponding values for *Chironomus sp*. were 0.03, 18.2, 8.6 and 11.0 ppm. These are levels which are acutely toxic. Levels which are chronically toxic, by means such as reduced growth and reproduction, would be even lower. In an on-site continuous-flow bioassay conducted May 22-26, 1978 in a mobile laboratory, testwater containing Utilex plant effluent concentrations as low as 12 per cent produced total mortality of *Daphnia magna* (Saalfeld 1979). Thus, effluent is likely to be having negative impact on macroinvertebrates in the immediate area of outfall. However, dilution of effluent in river water produced levels below detection limits in areas studied. At these levels, a negative impact could not be distinguished in parameters studied, *i.e*. leaf breakdown rates and faunal composition.

Although effluent and river metal concentrations have substantially decreased from previous levels, sediments are still considerably contaminated. Sediment samples collected in January, 1978 had the following levels, in mg/kg, of chromium, copper, nickel and zinc, respectively: 1,300, 1,700, 200 and 2,000 immediately below discharge, 530, 430, 290 and 500 100 yards below discharge, 1,700, 1,500, 580 and 250 at Gregory Road, and 630, 590, 340 and 360 at Nicholson Road (Sylvester 1978). Elevated levels at Gregory Road may be due to an increased amount of organic matter, which has greater metal adsorption than mineral matter. Gregory Road is located 0.65 mi. below the discharge point of Fowlerville sewage treatment plant. Levels in sediment samples above Utilex discharge point ranged from 5.8-25 mg/kg for chromium, 9.1-36 mg/kg for copper, 12-35 mg/kg for nickel and 50-200 mg/kg for zinc. However, metal concentrations in sediments below discharge point have substantially decreased from earlier levels of 5,150 mg/kg chromium, 4,450 mg/kg copper, and 2,050 mg/kg nickel in samples collected in September 1967 (Sylvester 1978). The 1978 levels were below threshold avoidance levels of 4,000-8,000 ppm zinc and 800-1,500 ppm chromium for the midge *Chironomus tentans* (Wentsel *et al*. 1977).

SUMMARY

Metal concentrations in effluent were at levels which can detrimentally affect macroinvertebrate populations at immediate area of outfall. However, dilutions in river water reduced metal concentrations in water samples below 0.1-0.2 ppm at all sites. Zinc concentrations of leaves increased while leaf packs were in stream. Although increased adsorption of zinc occurred on leaf packs located below Utilex plant discharge, zinc content of leaves remained at levels which would not have been deleterious to macroinvertebrate populations.

Leaf processing rates in Red Cedar River were not substantially affected by effluent from the metal plating plant. Leaf breakdown rates and macroinvertebrate populations were similar for sites below outfall and matching habitat sites above outfall, except for the gravel control site which had a particularly fast breakdown rate. Rate of leaf processing was significantly lower below outfall, but much of this statistical significance can be attributed to fast breakdown at the gravel control site above outfall. Lack of a demonstrable negative impact on leaf processing can be attributed to water quality improvement and concommitant improvement in macroinvertebrate community structure

and numbers. Levels of heavy metals in effluent and in the river have considerably decreased during the past decade. Consequently, there has been an improvement in macroinvertebrate fauna, with a decrease in tubificids and an increase in number and variety of insects. Metal concentrations in effluent remain at levels which are detrimental to some invertebrate populations and are a cause for concern, but the river no longer has the severe biological degradation documented previously.

LITERATURE CITED

Boling, R.H., E.D. Goodman, J.A. VanSickle, J.O. Zimmer, K.W. Cummins, R.C. Petersen, and S.R. Reice. 1975. Toward a model of detritus processing in a woodland stream. Ecology 56:141-151.

Cummins, K.W. 1973. Trophic relations of aquatic insects. Ann. Rev. Entomol. 18:183-206.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24:631-642.

Egglishaw, H.J. 1964. The distributional relationship between the bottom fauna and plant detritus in streams. J. Anim. Ecol. 33:463-476.

Fisher, S.G. and G.E. Likens. 1972. Stream ecosystem: organic energy budget. BioScience 22:33-35.

Fisher, S.G. and G.E. Likens. 1973. Energy flow in Bear Brook, New Hampshire: an integrative approach to stream ecosystem metabolism. Ecol. Monogr. 43:421-439.

Garton, R.R. 1968. Effect of metal plating wastes in the ecology of a warm-water stream. Ph.D. Dissertation, Mich. State Univ., E. Lansing. 83p.

Harrington, H.F. 1974. The effects of heavy metals on species composition in a warm-water stream. M.S. Thesis, Mich. State Univ., E. Lansing. 54p.

Hilsenhoff, W.L. 1975. Aquatic insects of Wisconsin; with generic keys and notes on biology, ecology, and distribution. Wisconsin Dept. Natural Resources, Technical Bulletin No. 89. 52p.

Hynes, H.B.N. 1963. Imported organic matter and secondary productivity in streams. Proc. XVI Int. Congr. Zool. 3:324-329.

Lawry, J.D. 1978. Trace metal dynamics in decomposing leaf litter in habitats variously influenced by coal strip mining. Can J. Bot. 56:953-962.

Merritt, R.W. and K.W. Cummins, eds. 1978. An Introduction to the Study of Aquatic Insects. Kendall/Hunt.

Minshall, G.W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48:139-149.

Nelson, D.J. and D.C. Scott. 1962. Role of detritus in the productivity of rock-outcrop community in a piedmont stream. Limnol. Oceanogr. 7:396-413.

Pennak, R.W. 1953. Fresh-water Invertebrates of the United States. Ronald Press.

Petersen, R.C. and K.W. Cummins. 1974. Leaf processing in a woodland stream. Freshwat. Biol. 4:343-368.

Rehwoldt, R., L. Lasko, C. Shaw, and E. Wirhowski. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contam. Toxicol. 10:291-294.

Reice, S.R. 1974. Environmental patchiness and the breakdown of leaf litter in a woodland stream. Ecology 55:1271-1282.

Ross, H.H. 1944. The caddisflies, or Trichoptera, of Illinois. Illinois Natural History Survey Bull. vol. 23. 326p.

Saalfeld, G. 1979. Report of a toxicity evaluation and industrial wastewater survey conducted at the Hoover Universal-Utilex Division (outfall 470003), Livingston County, Fowlerville, Michigan, May 22-26, 1978. Michigan Dept. Natural Resources, Point Source Studies Section Report. 14p.

Sylvester, S. 1978. Water quality and biological investigation of the Red Cedar River in the vicinity of the Hoover Universal Die Cast Co., Fowlerville, Michigan, September 9, 1976 and January 24, 1978. Michigan Dept. Natural Resources, Water Quality Division Report. 21p.

Wentsel, R., A. McIntosh, W.P. McCafferty, G. Atchinson, and V. Anderson. 1977. Avoidance response of midge larvae (Chironomus tentans) to sediments containing heavy metals. Hydrobiology 55:171-175.

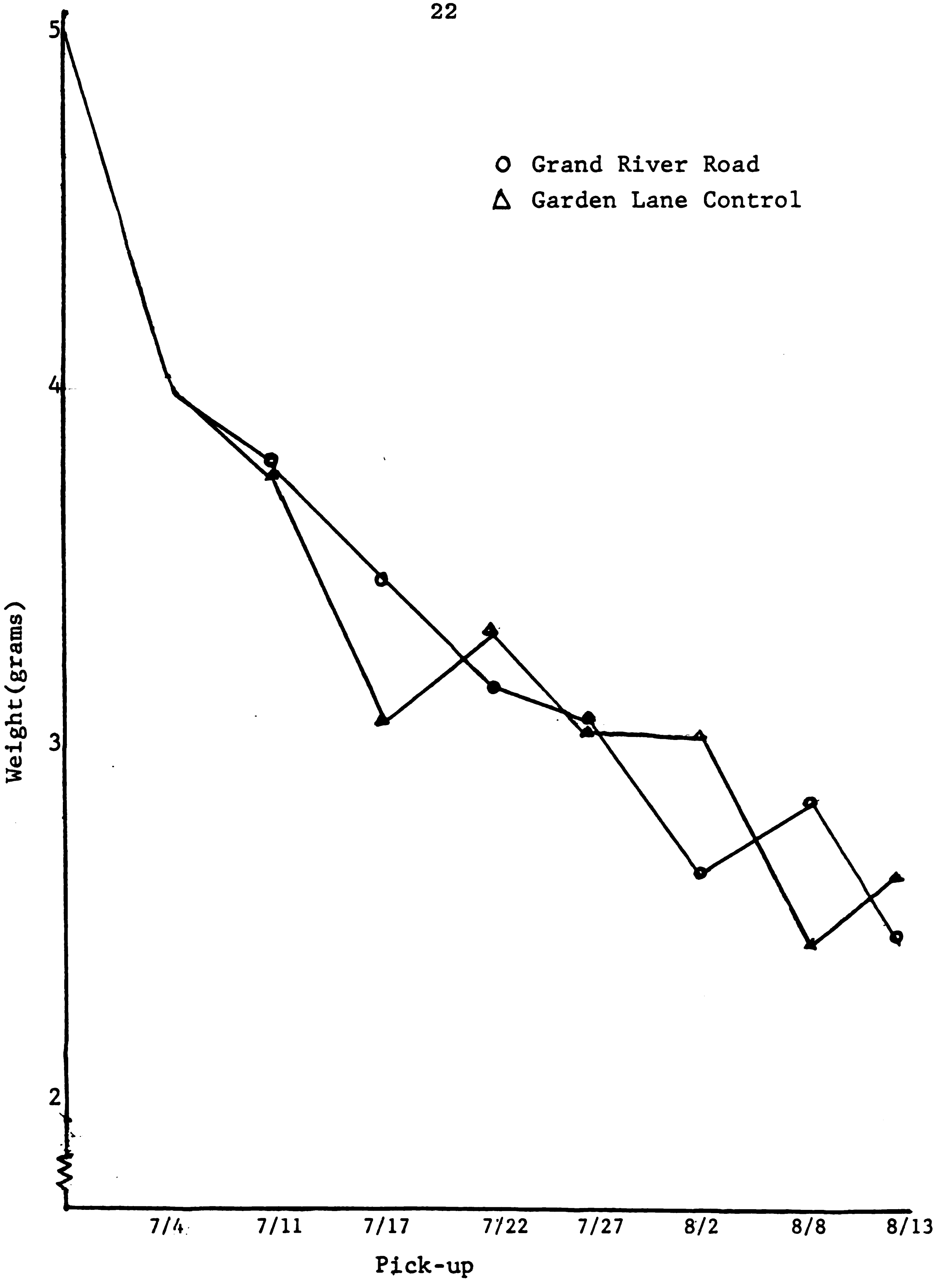

Figure 2. Leaf pack biomass-Grand River Road and Control

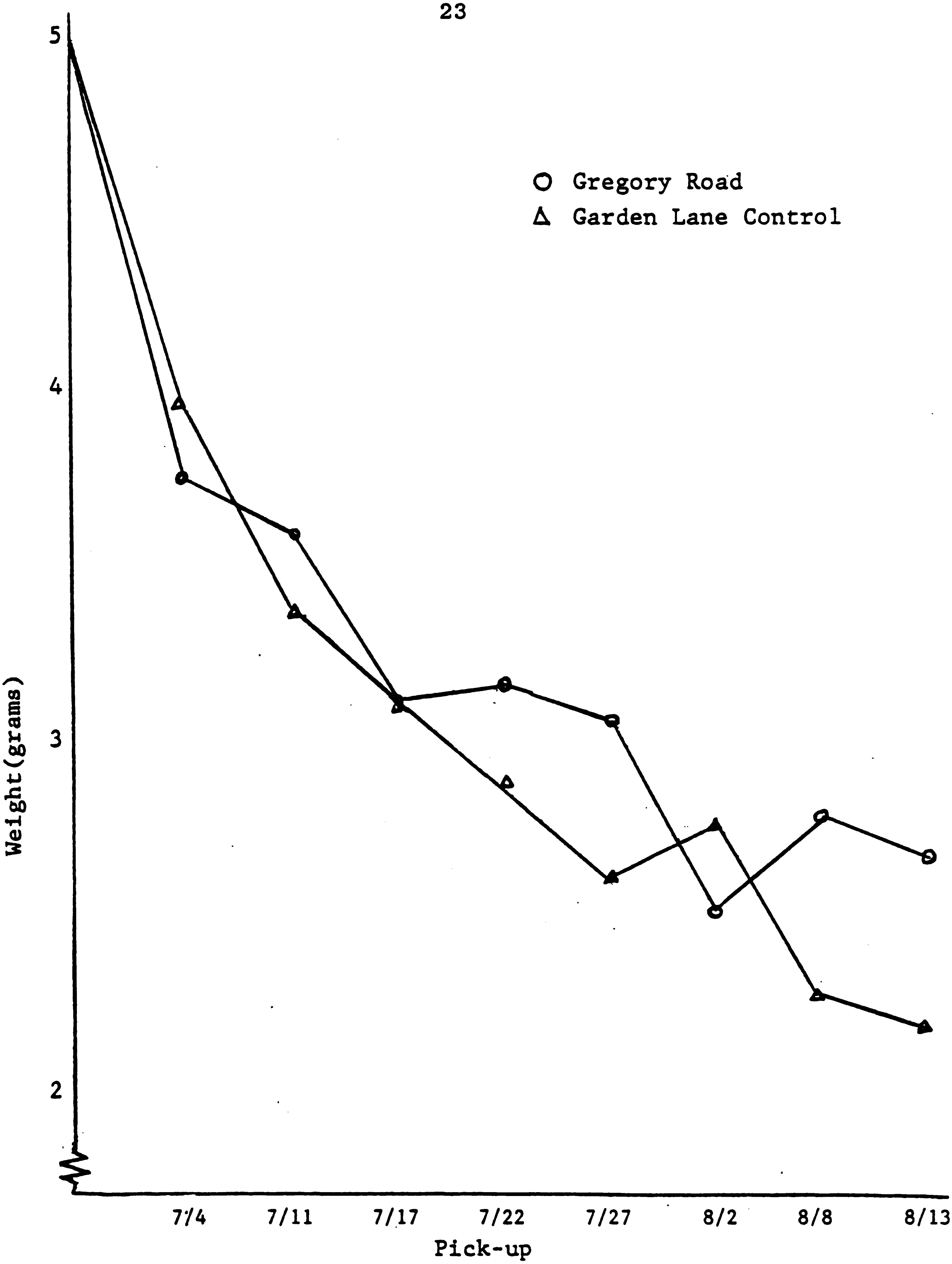

Figure 3. Leaf pack biomass-Gregory Road and Control

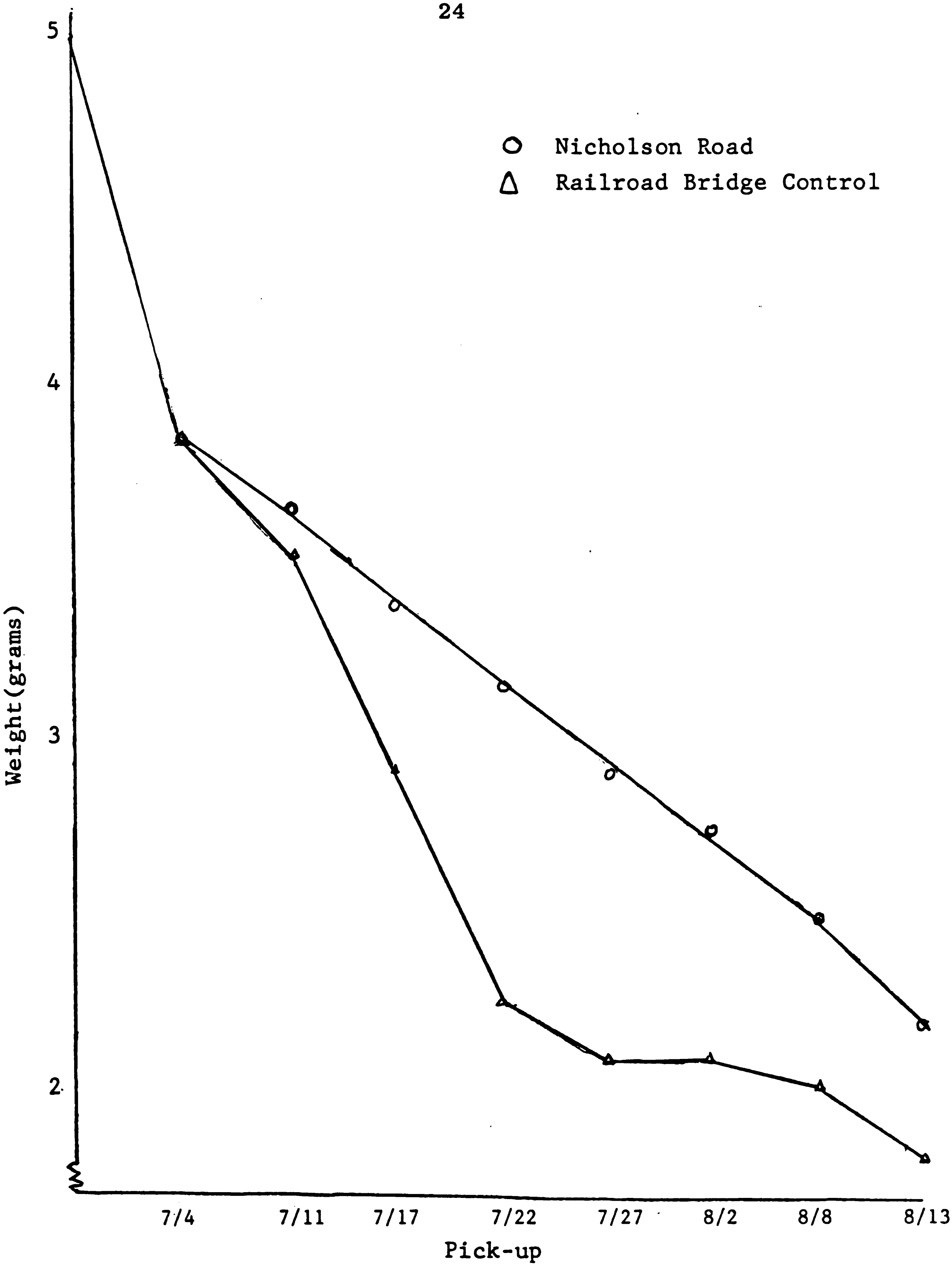

Figure 4. Leaf pack biomass-Nicholson Road and Control

Table A1. Macroinvertebrates collected from three leaf pack samples
Grand River Road Site - 0.2 km below effluent

Taxonomic Group Pick-up	1	2	3	4	5	6	7	8
Turbellaria								
Dugesia sp.	1				1			
Oligochaeta	44	71	30	32	4	35	31	13
Acari		1						
Isopoda								
Asellus sp.			2					
Amphipoda								
Gammarus sp.							1	
Hyalella azteca								1
Ephemeroptera								
Stenacron sp.		1	3	2			1	3
Odonata								
Argia sp.						1		
Megaloptera								
Sialis sp.			1		3			
Trichoptera								
Polycentropus sp.		1	3		2			
Coleoptera								
Dubiraphia sp. (larva)						1		
Macronychus sp. (larva)				1				
Dytiscidae (Hydroporinae)		1						
Diptera								
Chironomidae	5	24	53	77	111	108	47	58
Total number of organisms	51	100	94	112	121	145	80	75
Total number of taxa	4	6	6	4	5	4	4	4

Table A2. Macroinvertebrates collected from triplicate leaf pack samples
Garden Lane - Grand River Control Site - 0.4 km above effluent

Taxonomic Group Pick-up	1	2	3	4	5	6	7	8
Turbellaria								
Dugesia sp.				3				
Gastropoda								
Physa sp.								1
Pelecypoda								
Pisidium sp.			1					
Oligochaeta	14	15	4	34	11	9	8	
Amphipoda								
Hyalella azteca				1				
Ephemeroptera								
Stenacron sp.			2	2	5			1
Megaloptera								
Sialis sp.	1							
Trichoptera								
Hydropsyche sp.			1					
Polycentropus sp.		2						
Coleoptera								
Dubiraphia sp.						1		
Diptera								
Chironomidae	21	72	108	115	103	50	21	10
Total number organisms	36	89	116	158	129	60	29	12
Total number taxa	3	3	5	6	3	3	2	3

Table A3. Macroinvertebrates collected from triplicate leaf pack samples
Gregory Road Site - 2.1 km below effluent

Taxonomic Group Pick-up	1	2	3	4	5	6	7	8
Hydrazoa								
Hydra sp.	5		1					
Turbellaria								
Dugesia sp.	4	3	7					
Oligochaeta	12	4	8	51	9	9	19	10
Hirudinea	1			1			1	
Gastropoda								
Physa sp.		1						
Somatogyrus sp.						1		
Pelecypoda								
Pisidium sp.							1	
Isopoda								
Asellus sp.	1							
Amphipoda								
Hyalella azteca	1				1			
Ephemeroptera								
Caenis sp.	1	4	7	10	6	24	6	7
Stenacron sp.		12	11	5		3		
Plecoptera								
Perlodidae		1						
Megaloptera								
Sialis sp.	3		6	6	3	4	3	2
Trichoptera								
Polycentropus sp.	1	3	1	1		1		1
Coleoptera								
Dubiraphia sp.		4		2		1	1	1
Diptera								
Ceratopogonidae			1	1	1			
Chironomidae	12	46	42	104	103	66	44	64
Total number organisms	41	86	88	181	123	109	75	87
Total number taxa	10	10	11	9	6	8	7	7

Table A4. Macroinvertebrates collected from triplicate leaf pack samples
Garden Lane - Gregory Road Control Site - 0.3 km above effluent

Taxonomic Group Pick-up	1	2	3	4	5	6	7	8
Turbellaria								
Dugesia sp.						1		
Oligochaeta	2	3	85	30	50	50	51	10
Acari							1	
Isopoda								
Asellus sp.	2	1	3		1		2	
Amphipoda								
Gammarus sp.	1							
Hyalella azteca					1		1	
Ephemeroptera								
Caenis sp.		1	1	1	1	1	1	
Stenacron sp.	2		3	1	4		3	5
Megaloptera								
Sialis sp.	5	5	1					
Trichoptera								
Cheumatopsyche sp.	5	2	2					
Hydropsyche sp.		1						
Cyrnellus sp.		1						
Lepidostoma sp.		1						
Neophylax sp.		1	2					
Limnephilidae				1				
Polycentropus sp.	1	2	3	1		1		
Dolophilodes sp.		1						
Coleoptera		1						
Dubiraphia sp. (larvae)			1	2		1	1	1
Macronychus sp. (adult)			1					
(larvae)	2					1		
Diptera								
Chironomidae	56	96	135	43	125	88	56	53
Total number organisms	76	120	237	80	182	143	117	69
Total number taxa	8	13	11	7	6	7	9	4

Table A5. Macroinvertebrates collected from triplicate leaf pack samples Nicholson Road - 4.3 km below effluent

Taxonomic Group	Pick-up	1	2	3	4	5	6	7	8
Hydrazoa									
Hydra sp.			5	2	1				
Turbellaria									
Dugesia sp.			2			1			
Oligochaeta		42	155	138	133	73	140	94	30
Hirudinea						5	1		
Gastropoda									
Physa sp.				17					1
Somatogyrus sp.			1						
Pelecypoda									
Pisidium sp.					1				
Amphipoda									
Gammurus sp.		4							
Hyalella azteca		7	5	126	39	45	22	6	3
Ephemeroptera									
Caenis sp.			4	10	6	7	15	6	1
Stenacron sp.			6	7	14	7	3		
Megaloptera									
Chauliodes sp.						1			
Sialis sp.			3	6		1			
Trichoptera									
Cheumatopsyche sp.					7	7		2	10
Polycentropus sp.			2	2	3	2			
Limnephelidae					2	4			
Phryganeidae					1				
Odonata									
Boyeria sp.				1					
Coleoptera									
Berosus sp.				3					
Dubiraphia sp.	(adult)			1					1
	(larvae)		2	1	3		2	2	4
Dytiscidae		1		2					
Diptera									
Empididae					1				
Ceratopogonidae				1	1		3		
Chironomidae		51	152	123	105	120	119	87	30

Table A5 continued.

Pick-up	1	2	3	4	5	6	7	8
Total number organisms	105	337	440	317	271	305	197	80
Total number taxa	5	11	15	14	12	8	6	7

Table A6. Macroinvertebrates collected from triplicate leaf pack samples
Railroad Bridge Site - 0.1 km above effluent

Taxonomic Group Pick-up	1	2	3	4	5	6	7	8
Hydrazoa								
Hydra sp.								1
Turbellaria								
Dugesia sp.			2	1	2	1	5	1
Oligochaeta		1	1	3	10	3	2	10
Hirudinea				1				
Gastropoda								
Physa sp.		2	4					
Amphipoda								
Gammarus sp.		1	1	2	1			
Hyalella azteca		8	12	2	12	21	9	7
Ephemeroptera								
Stenacron sp.		2	2	2	5	3	9	5
Odonata								
Argia sp.								1
Boyeria sp.					1			
Megaloptera								
Sialis sp.		2			1			
Trichoptera								
Cheumatopsyche sp.	1	2	1				2	
Hydropsyche sp.		1						
Polycentropus sp.			3	1		1		
Coleoptera								
Dubiraphia sp. (adults)		10	11	4	14	9	10	1
Macronychus sp.								
adults		6	5	3	1	2	1	
larvae		3		3		2	4	3
Diptera								
Chironomidae	82	163	156	138	218	215	176	154
Total number organisms	83	208	198	163	265	257	218	183
Total number taxa	2	11	11	10	10	8	8	9