GREAT LAKES FISHERY COMMISSION

1985 Project Completion Report[1]

Effects of the Lampricide, 3-triflouromethyl-4nitrophenol (TFM) on the Macroinvertebrates within the Hyporheic Region of a Softwater Creek

by:

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ORIGINAL REPORT

(For Duplication Only)

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ABSTRACT

The effect of the lampricide, 3-trifluoromethyl-4-nitrophenol (TFM), on the benthic macroinvertebrates within the hyporheic region of Dam Creek, Ontario was investigated. Samples were taken at 10 cm intervals, to a depth of 70 cm, at both an untreated and a treated site of the stream. Samples were collected 1 day before, and 1, 4, and 35 days after TFM application. Organisms were regularly found to a depth of 70 cm throughout the study period. Of the eight major taxa found at both sites only Tubificoidea exhibited a decrease in abundance attributable to TFM. Tubificoidea suffered significant declines ($p < 0.05$) in abundance to a depth of 30 cm 1 day after treatment and was also less abundant from 30-70 cm than previously. Tubificoidea did not recover to pretreatment levels 35 days after treatment.

One day after treatment TFM concentrations were greatest at a depth of 55 cm, the greatest depth to which water samples were taken. The movement of TFM into the hyporheic region during the present study may be due to the large convective forces created by the rapid decrease in surface water temperature. These convective forces are usually greatest in the late fall and winter when TFM is not applied. The hyporheic region may therefore act as a buffer zone during TFM treatments for the greater part of the application season and facilitate the quick recolonization of the upper substrate.

INTRODUCTION

Since the late 1950's 3-trifluoromethyl-4-nitrophenol (TFM) has been the main chemical used for the control of the parasitic sea lamprey, Petromyzon marinus Linnaeus, in the Great Lakes (Smith et al, 1974). TFM is selectively toxic to the larval, stream-dwelling stage of the lamprey and is administered regularly to a number of Great Lakes tributaries in both Canada and the United States (Applegate et al, 1958; NRCC, 1985). Lampricide treatments of streams range from 8 to 20 h in duration with concentrations of TFM ranging from 1 to 17 $mg.l^{-1}$ (NRCC, 1985).

The toxicity of TFM to nontarget lotic macroinvertebrates has been examined in both laboratory and field studies. Several taxa of Diptera, Ephemeroptera, Trichoptera, Annelida, Pelecypoda and Turbellaria are sensitive to field concentrations of TFM based on 24-96 h LC50 toxicity studies (Smith, 1967; Chandler & Marking, 1975; Maki et al, 1975). Reductions in the numbers of some Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Oligochaeta taxa have also been observed during field studies (Torblaa, 1968; Haas, 1970; Dermott & Spence, 1984; Kolton et al, 1985). Reestablishment of abundance of affected taxa occured within 19-42 days (Torblaa, 1968; Dermott & Spence, 1984; Kolton et al, 1985). Dermott & Spence (1984) found that only the most severely affected invertebrates, Oligochaeta and Philopotamidae, were not present at pretreatment levels 3 weeks after treatment. Further, the abundance of several taxa shortly following treatment was above that of pretreatment (Dermott & Spence, 1984; Kolton et al, 1985).

Benthic macroinvertebrates contributing to the recolonization of the top 5-10 cm of substrate may arrive via downstream drift, upstream migration, or vertical migration from within the substrate. Downstream

drift of organisms from untreated areas is undoubtedly a factor in recolonization (Waters, 1965; Williams, 1977); however, most taxon have peak recolonization rates through drift of 64 days (Shaw & Minshall, 1980). Upstream migration of organisms (Williams, 1977) may be discounted as a means of recolonization after TFM treatment as all of the stream below the application point is treated.

Kolton et al (1985) suggest that vertical migration may be the single most important factor in the recolonization of denuded stream areas following TFM treatment. In all previous field studies dealing with TFM toxicity, benthic macroinvertebrates were collected from within the top 5-10 cm of substrate. Benthic macroinvertebrates occur well below this level, often to a depth of 50 cm (Coleman & Hynes, 1970; Bishop, 1973; Williams & Hynes, 1974; Hynes, 1974; Poole & Stewart, 1976; Godbout & Hynes, 1982). The deep substrate, or hyporheic region, may act as a refugia where animals are protected from floods and washouts (Hynes, 1974) and therefore serve as a reservoir against natural as well as man-made perterbations. Invertebrates may migrate downward into the hyporheic region to escape TFM concentrations during treatment and then, along with the hyporheos, recolonize the upper regions of the substrate once TFM concentrations have declined.

It is also possible that TFM penetrates into the hyporheic region and affects the hyporheos as it does the invertebrates in the upper 5-10 cm of substrate. Water chemistry generally changes within the hyporheic region, with pH and dissolved oxygen declining with depth (Hynes, 1983; Whitman & Clark, 1982). TFM toxicity is inversely related to pH (NRCC, 1985). Fremling (1975) found TFM was 50 times more toxic at a pH of 6.5 then at 9.5. A decrease in dissolved oxygen can exert stress on organisms which may in turn lower their threshold to TFM. Hansen et al (1974) found the

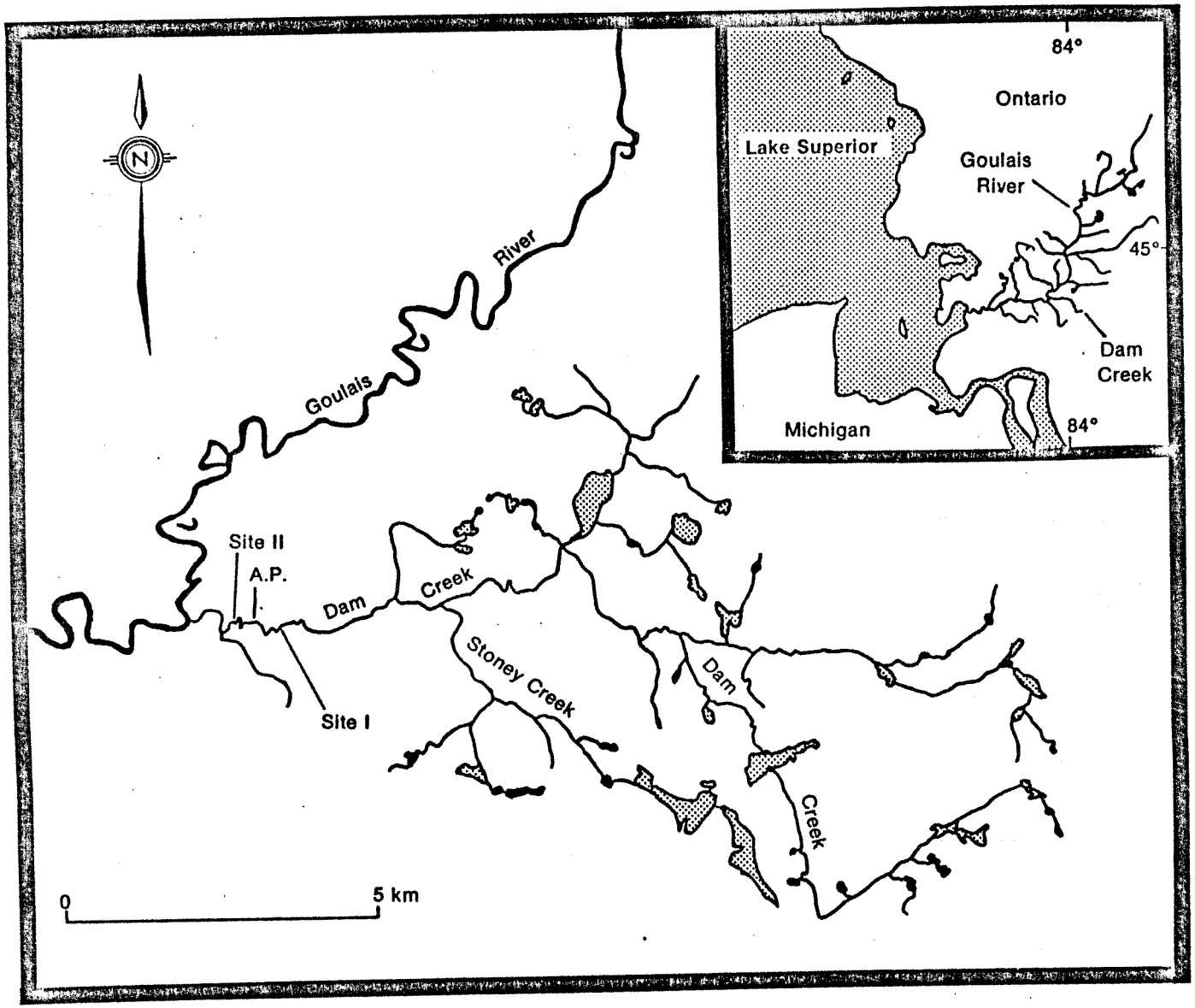
metabolic requirements of Chironomus tentans Fabricus to rise during exposures to TFM reflecting the catabolism and excretion of TFM residues. This would mean that penetration of TFM into the hyporheic region, even at concentrations lower than that of treatment levels, may prove toxic to animals in this region.

This study was undertaken to determine the extent to which the hyporheos is affected during TFM treatment and whether the hyporheic region is utilized by the macroinvertebrates as a refuge area for subsequent recolonization of the upper 5-10 cm of substrate.

MATERIALS AND METHODS

Dam Creek, a soft water creek situated within the Canadian Shield, is a tributary of the Goulais River which discharges into Lake Superior. The creek was treated with TFM on Oct. 18, 1984 near Searchmont, Ontario as part of the Department of Fisheries and Oceans sea lamprey control program. The control site (Site 1) was located approximately 0.9 km upstream, and the treatment site (Site 11) approximately 0.6 km downstream of the application point (Fiq. 1).

The two sampling sites were selected such that variations in water depth, substrate size, and stream flow were minimized. Sites I and II were riffle areas approximately 8 m wide, 15 m long, and 21-42 cm deep, and 7 m wide, 16 m long, and 18-44 cm in depth, respectively. The substrate at the two sites consisted of pebble size particles and smaller (Cummins, 1962). The top 10 cm of substrate was relatively the same at both sites, consisting of 70-82% pebble, 13-23% gravel, and 6-11% sand by weight. The amount of pebble decreased with depth and the proportion of gravel and sand increased until they were the major components by weight. Discharge before treatment was 0.916 $m^3.s^{-1}$ and increased slightly to 0.934 $m^3.s^{-1}$ during


N
Goulais River
Site II
A.P.
Dam
Creek
Site I
Stoney Creek
Dam
Creek
0
5 km
84°
Ontario
Lake Superior
Goulais River
45°
Dam Creek
Michigan
84°

treatment.

In the center of each sampling area a 4 x 12 grid, with intersecting points at 1 m intervals, was established to determine sampling locations, thus allowing for 48 sampling loci. Seven loci were selected at random for the collection of water samples throughout the experiment using a piezometer (Lee & Cherry, 1978). One sample was collected at the surface and the other six were taken at 10 cm intervals ranging from 5 to 55 cm in depth. The water samples were then analyzed for total hardness, calcium hardness, dissolved oxygen, pH, and TFM (APHA, 1974). Ten loci were chosen at random for benthic sampling on each of the 4 sampling dates (1 day before, and 1, 4, and 35 days after treatment). At each loci 7 samples were taken at 10 cm intervals ranging from 10-70 cm with a 100 ml standpipe corer (Williams & Hynes, 1974).

All benthic samples were preserved in 70% ethanol and transported to the laboratory where the macroinvertebrates were separated from the substrate by means of the swirling technique (Platts et al, 1983; Kolton et al, 1985). The macroinvertebrates were then sorted and identified to genus whenever possible. The identification was done using keys written by Brown (1972), Edmunds et al (1976), Klemm (1982), Mackie et al (1980), McAlpine et al (1981), Merritt and Cummins (1978), Oliver and Roussel (1983), Pennak (1978), Wiggins (1977), and Woods (1963). A reference collection of the macroinvertebrates identified is on file with the Department of Environmental Biology, University of Guelph.

RESULTS

At both sites pH declined significantly ($p < 0.05$) from approximately 6.9 to 6.5 between the surface and a depth of 55 cm. In addition, pH decreased slightly at all depths except 55 cm between Oct. 19 and Oct. 22

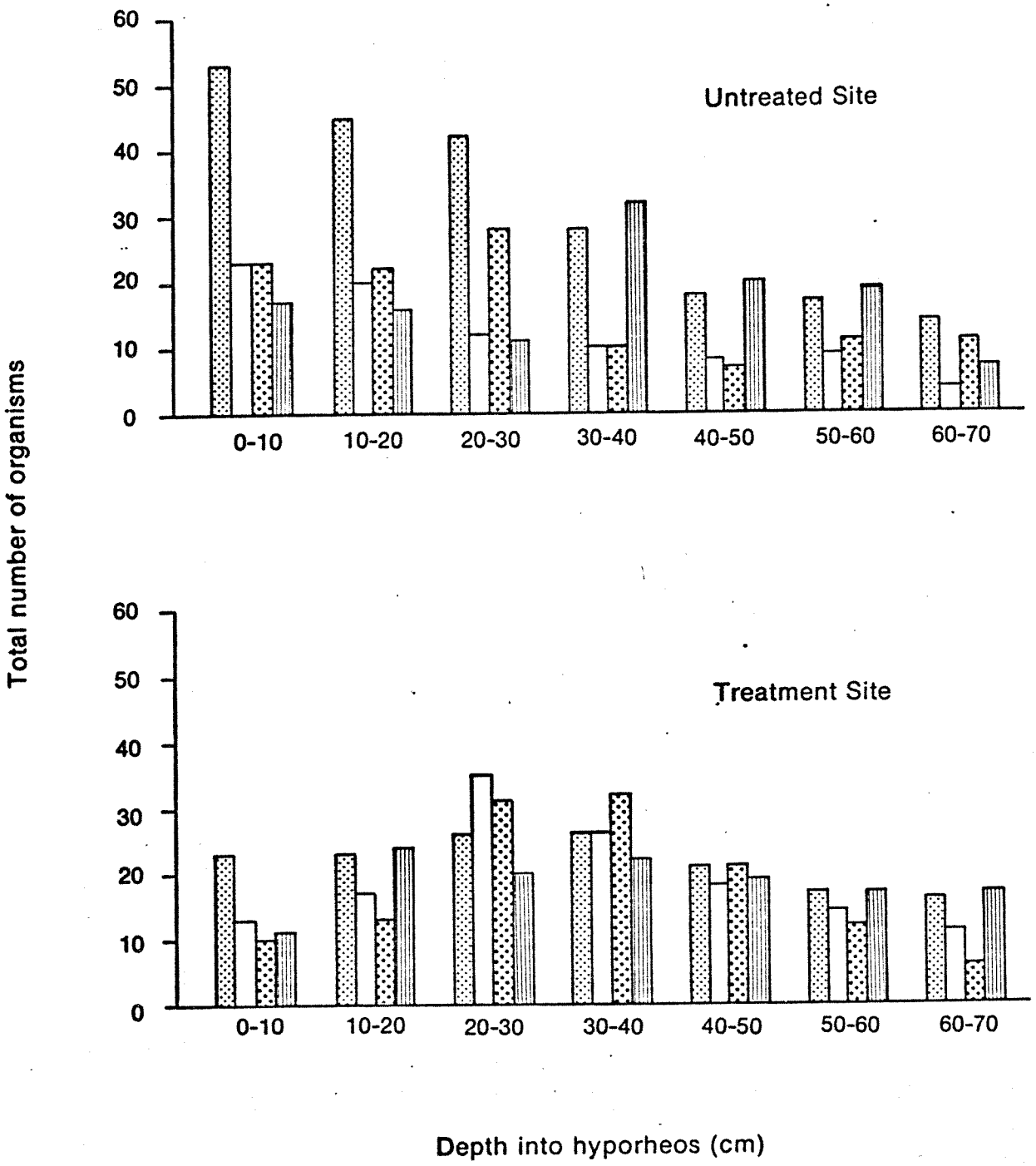
at site II. Dissolved oxygen also declined significantly ($p < 0.05$) with depth. At Site I the dissolved oxygen concentration was highest in the top 10 cm at 12.5 $mg.l^{-1}$ and decreased to approximately 7 $mg.l^{-1}$ at 55 cm. The treatment site displayed the same pattern with 11 $mg.l^{-1}$ at the surface and 6.5 $mg.l^{-1}$ at 55 cm. Total hardness and calcium hardness did not differ significantly ($p < 0.05$) with depth. Surface temperatures decreased from 12.3 - 9.0°C between Oct. 17 - 19 and then to 0°C on Nov. 20.

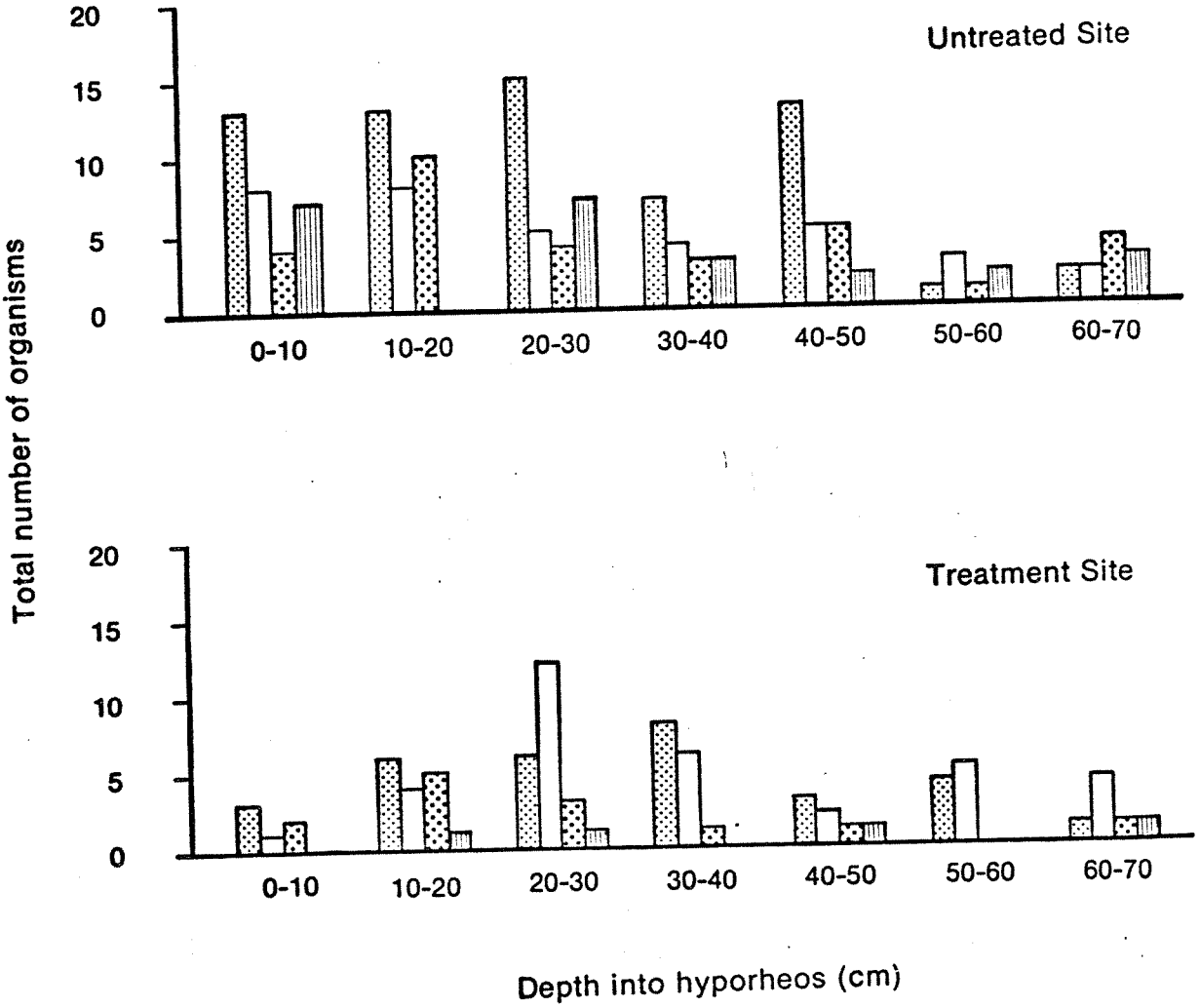
TFM was applied at a concentration of 1.1 $mg.l^{-1}$ for approximately 12 h. Eighteen hours after the TFM treatment had passed Site II, concentrations of TFM were undetected at 5 cm within the substrate. However, 0.01 $mg.l^{-1}$ was detected at a depth of 15 cm with concentrations steadily increasing with depth to 0.5 $mg.l^{-1}$ at 55 cm.

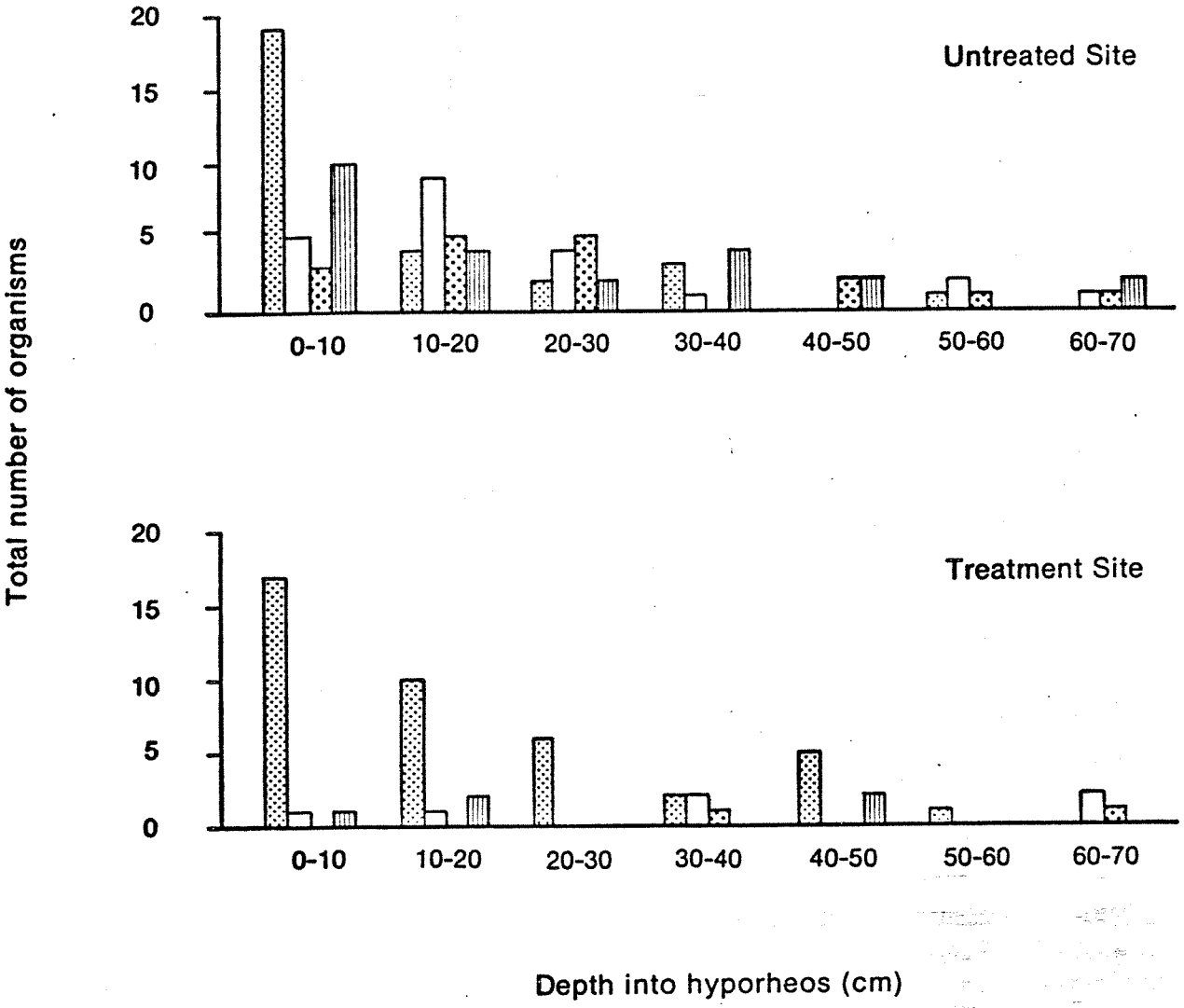
Composition of the benthic fauna was similar at the two sites throughout the study period. The distribution of macroinvertebrates between samples at each depth was found to be contagious using the chi-squared goodness of fit test for negative binomials. A log(x+1) transformation (Steel & Torrie, 1980) was used to normalize the data for further analysis. Lumbricidae was the only taxa prevalent at one site (Site I) and not at the other. The Chironomidae were the major group present at both sites, always contributing more than 60% of the total numbers found. Of the 42 taxa found at both sites only 8 were present in sufficient numbers to contribute more than 1% of the total fauna found at both sites during pretreatment sampling (Table 1). These included the Chironomidae, Microspectra sp. (Fig. 2), Rheotanytarsus sp., Stempellina sp., Polypedelium sp., and Tvetenia sp.; the Diptera, Chelifera sp.; the Trichoptera, Glossosoma sp. (Fig. 3); and Tubificoidea (Fig. 4). The effects of TFM on these eight major taxa were determined for each depth using a 2 x 4 (sites x times) ANOVA table. The differences between the

Table 1. Mean number ($\bar{x}$) and standard deviation (SD) of the major taxa of macroinvertebrates at each of the 10 cm intervals within the substrate, at each sampling site, on each of the four sampling dates.

CLASSIFICATION	SAMPLE Site	Time	SAMPLE DEPTH (cm) 0 - 10 $\bar{x}$	0 - 10 SD	10 - 20 $\bar{x}$	10 - 20 SD	20 - 30 $\bar{x}$	20 - 30 SD	30 - 40 $\bar{x}$	30 - 40 SD	40 - 50 $\bar{x}$	40 - 50 SD	50 - 60 $\bar{x}$	50 - 60 SD	60 - 70 $\bar{x}$	60 - 70 SD
Microspectra sp.	I	1	5.4	3.40	4.5	2.46	4.2	3.05	2.8	2.53	1.8	1.75	1.7	0.95	1.4	1.35
	I	2	2.3	3.56	2.0	2.16	1.2	1.03	1.1	1.60	0.8	1.03	0.9	1.19	0.4	0.70
	I	3	2.3	3.12	2.2	1.69	2.8	2.39	1.0	1.15	0.7	0.82	1.1	1.45	1.1	0.88
	I	4	1.7	1.89	1.6	2.59	1.1	1.97	3.1	3.63	2.0	1.63	1.9	2.47	0.7	0.82
	II	1	2.3	2.26	2.3	2.26	2.8	2.97	2.9	4.01	2.2	1.81	1.7	1.49	1.6	2.12
	II	2	1.3	1.34	1.7	1.70	3.5	3.31	2.6	2.95	1.8	1.69	1.4	1.26	1.1	1.20
	II	3	1.0	1.15	1.5	1.72	3.0	3.89	3.4	2.99	2.1	2.23	1.0	1.76	0.6	1.07
	II	4	0.9	1.60	1.3	1.25	1.7	2.16	2.6	3.06	2.4	2.17	1.8	1.48	1.7	2.87
Stempellina sp.	I	1	0.4	0.52	0.5	0.71	1.2	1.87	0.9	1.45	1.1	1.52	0.8	1.23	0.3	0.95
	I	2	0.4	0.97	0.2	0.63	0.8	1.23	0.3	0.48	0.2	0.63	0.3	0.48	0.5	0.53
	I	3	0.2	0.42	0.7	0.95	0.6	0.84	0.2	0.42	0.5	0.71	0.5	0.97	0.1	0.32
	I	4	0.2	0.42	0.4	0.70	0.2	0.63	0.1	0.32	0.1	0.32	0.5	0.71	0.2	0.42
	II	1	1.8	2.20	2.7	3.30	1.1	1.29	2.7	2.91	1.9	2.08	1.6	1.90	1.5	0.85
	II	2	1.2	3.46	1.6	3.72	2.7	3.30	2.5	4.95	1.6	2.55	1.1	1.60	1.1	1.97
	II	3	0.6	0.84	0.4	0.70	1.4	1.58	1.9	2.64	1.7	2.26	1.4	2.50	0.7	2.21
	II	4	0.4	0.70	0.2	0.42	0.7	1.25	1.0	1.49	0.6	1.35	1.4	2.76	0.9	1.10
Rheotanytarsus sp.	I	1	1.1	1.10	0.5	0.71	2.0	2.05	0.7	0.95	0.5	0.97	1.1	1.20	0.5	0.53
	I	2	0.3	0.48	0.5	0.71	0.6	0.70	0.7	1.06	0.4	0.70	0.0		0.3	0.67
	I	3	0.2	0.42	0.6	1.07	0.5	1.08	0.5	0.97	0.1	0.32	0.2	0.42	0.5	0.71
	I	4	0.1	0.32	0.2	0.42	0.1	0.32	0.4	0.70	0.2	0.42	0.4	0.70	0.1	0.32
	II	1	0.3	0.67	0.6	1.26	0.2	0.63	0.3	0.95	0.4	0.52	0.2	0.42	0.6	0.97
	II	2	0.0		0.5	0.53	0.2	0.42	0.4	0.70	0.2	0.42	0.5	1.58	0.2	0.42
	II	3	0.3	0.48	0.2	0.42	0.3	0.48	0.5	0.71	0.1	0.32	0.4	0.97	0.1	0.32
	II	4	0.0		0.1	0.32	0.0		0.4	0.70	0.2	0.42	0.1	0.32	0.0	
Polypedilum sp.	I	1	1.0	1.15	0.3	0.48	0.2	0.42	0.1	0.32	0.2	0.42	0.0		0.1	0.32
	I	2	0.5	0.85	0.0		0.1	0.32	0.1	0.32	0.0		0.1	0.32	0.2	0.63
	I	3	0.0		0.0		0.0		0.0		0.1	0.32	0.0		0.0	
	I	4	0.7	1.57	0.5	0.97	0.2	0.42	0.4	0.70	0.3	0.67	0.1	0.32	0.0	
	II	1	0.3	0.48	0.4	0.97	0.3	0.48	0.1	0.32	0.2	0.42	0.1	0.32	0.0	
	II	2	0.0		0.2	0.42	0.0		0.1	0.32	0.1	0.32	0.1	0.32	0.0	
	II	3	0.0		0.0		0.1	0.32	0.1	0.32	0.1	0.32	0.0		0.0	
	II	4	0.2	0.42	0.0		0.0		0.2	0.42	0.2	0.42	0.1	0.32	0.0	
Tvetenia sp.	I	1	0.4	0.52	0.2	0.42	0.2	0.42	0.3	0.67	0.1	0.32	0.1	0.32	0.1	0.32
	I	2	0.0		0.2	0.42	0.1	0.32	0.0		0.2	0.42	0.4	0.84	0.0	
	I	3	0.0		0.0		0.2	0.42	0.0		0.0		0.1	0.32	0.0	
	I	4	0.1	0.32	0.0		0.1	0.32	0.0		0.0		0.2	0.42	0.1	0.32
	II	1	0.0		0.1	0.32	0.1	0.32	0.1	0.32	0.3	0.48	0.1	0.32	0.3	0.67
	II	2	0.1	0.32	0.1	0.32	0.0		0.0		0.2	0.42	0.7	0.67	0.0	
	II	3	0.1	0.32	0.0		0.0		0.0		0.0		0.0		0.0	
	II	4	0.0		0.0		0.0		0.0		0.0		0.1	0.32	0.0	
Glossosoma sp.	I	1	1.2	0.79	1.4	1.65	1.5	1.27	0.7	0.82	1.3	1.57	0.1	0.32	0.2	0.42
	I	2	0.8	1.48	0.8	0.92	0.5	0.85	0.4	0.97	0.5	1.08	0.3	0.48	0.2	0.42
	I	3	0.4	1.26	1.0	0.94	0.4	0.70	0.3	0.48	0.6	0.70	0.1	0.32	0.4	0.84
	I	4	0.7	0.95	0.0		0.7	1.57	0.3	0.48	0.2	0.42	0.2	0.42	0.3	0.48
	II	1	0.3	0.48	0.6	0.70	0.6	0.84	0.8	1.03	0.3	0.48	0.4	0.70	0.1	0.32
	II	2	0.1	0.32	0.4	0.52	1.2	1.55	0.6	0.70	0.2	0.42	0.5	0.85	0.4	0.97
	II	3	0.2	0.42	0.5	0.85	0.3	0.95	0.1	0.32	0.1	0.32	0.0		0.1	0.32
	II	4	0.0		0.1	0.32	0.1	0.32	0.0		0.1	0.32	0.0		0.1	0.32
Chelifera sp.	I	1	1.2	1.14	1.1	1.10	0.5	0.71	0.2	0.42	0.4	0.97	0.2	0.42	0.0	
	I	2	0.2	0.42	0.3	0.48	0.1	0.32	0.3	0.67	0.3	0.48	0.1	0.32	0.0	
	I	3	0.3	0.67	0.4	0.84	0.4	0.52	0.3	0.48	0.3	0.48	0.2	0.42	0.0	
	I	4	0.9	2.51	0.5	0.71	0.1	0.32	0.6	0.70	0.2	0.42	0.5	0.52	0.2	0.42
	II	1	0.8	1.23	0.7	0.82	0.4	0.70	0.3	0.95	0.5	0.97	0.1	0.32	0.2	0.42
	II	2	0.2	0.42	0.2	0.42	0.0		0.2	0.63	0.0		0.2	0.42	0.1	0.32
	II	3	0.2	0.42	0.0		0.1	0.32	0.4	0.52	0.3	0.48	0.1	0.32	0.2	0.42
	II	4	0.1	0.32	0.3	0.48	0.3	0.48	0.2	0.42	0.2	0.42	0.2	0.63	0.4	0.52
Tubificoidea	I	1	2.0	1.63	0.4	1.26	0.2	0.42	0.3	0.67	0.0		0.1	0.32	0.0	
	I	2	0.5	0.97	0.9	1.29	0.4	0.70	0.1	0.32	0.0		0.2	0.63	0.1	0.32
	I	3	0.3	0.48	0.5	0.85	0.5	0.71	0.0		0.2	0.42	0.1	0.32	0.1	0.32
	I	4	1.0	1.89	0.4	0.70	0.2	0.42	0.4	0.70	0.2	0.63	0.0		0.2	0.42
	II	1	1.7	2.26	1.0	0.94	0.6	1.07	0.2	0.42	0.5	1.27	0.1	0.32	0.0	
	II	2	0.1	0.32	0.1	0.32	0.0		0.2	0.42	0.0		0.0		0.2	0.42
	II	3	0.0		0.0		0.2	0.42	0.3	0.67	0.0		0.0		0.0	
	II	4	0.0		0.0		0.0		0.1	0.32	0.0		0.0		0.0	


Total number of organisms
60
50
40
30
20
10
0
Untreated Site
0-10
10-20
20-30
30-40
40-50
50-60
60-70
60
50
40
30
20
10
0
Treatment Site
0-10
10-20
20-30
30-40
40-50
50-60
60-70
Depth into hyporheos (cm)


Untreated Site
Treatment Site
Total number of organisms
20
15
10
5
0
0-10
10-20
20-30
30-40
40-50
50-60
60-70
Depth into hyporheos (cm)


Untreated Site
Treatment Site
20
15
10
5
0
0-10
10-20
20-30
30-40
40-50
50-60
60-70
Total number of organisms
Depth into hyporheos (cm)

least square means were then compared to establish the effects of TFM. The remaining 34 taxa (Table 2) were not found in sufficient numbers to determine the effects of TFM on them.

Pretreatment sampling yielded a significantly greater ($p < 0.05$) total number of organisms at Site I than at Site II, however, the relative composition of taxa was comparable at both sites. Site I had a greater percentage of Trichoptera while Site II had a much greater percentage of Stempellina sp.. Organisms at Site I were slightly more concentrated within the top 20 cm of the substrate. The fauna at Site II was more evenly distributed over the depths. Site I did not have representatives of Diptera other than Chironomidae, Coleoptera, Ephemeroptera, and non-insects at 60-70 cm during pretreatment sampling. Ephemeroptera, Coleoptera, Trichoptera, and Plecoptera were rare in the 60-70 cm depth at Site II. Tubificoidea was found only to a depth of 50-60 cm at both sites. The top 10 cm of Site I always contained a greater number of organisms then the top 10 cm at Site II.

One day after treatment (Oct. 19), there was a significant decline ($p < 0.05$) in the total number of organisms found at both sites and all depths. Total numbers collected from the Site I declined by 63% while abundance at Site II decreased by 29%. The decrease in the Chironomidae at both sites was comparable to that of the total. Rheotanytarsus sp. was the Chironomidae most severely affected, declining by 75% and 37.5% at Sites I and II respectively. Other Diptera, including Chelifera sp., decreased by approximately the same amount at both sites. The Trichoptera at Site I were severely affected while at Site II no significant change was observed. In general, the response of Glossosoma sp. (Fig. 3) is comparable to that of the Trichoptera. Similarly, Plecoptera and Coleoptera were more adversely affected at the untreated site. Overall, non-insects decreased

Table 2. Mean number ($\bar{x}$) and standard deviation (SD) of the less abundant taxa of benthic macroinvertebrates collected at each of the 10 cm intervals within the substrate at the two sampling sites on the four sampling dates.

CLASSIFICATION	SAMPLING DEPTH (cm)													
	0 - 10		10 - 20		20 - 30		30 - 40		40 - 50		50 - 60		60 - 70	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
DIPTERA														
Hemerodromia sp.	0.38	0.74	0.63	0.74	0.25	0.46	0.88	1.36	0.00		0.13	0.35	0.00	
Bezzia sp.	0.63	1.06	0.88	0.84	1.25	1.98	0.75	0.89	1.00	0.76	0.50	0.76	0.13	0.35
Culicoides sp.	1.75	1.28	1.75	1.75	2.63	1.85	1.75	1.75	0.75	1.04	2.13	3.23	1.25	1.49
Dicranota sp.	0.13	0.35	0.13	0.35	0.00		0.13	0.35	0.00		0.00		0.13	0.35
Antocha sp.	0.50	0.54	0.13	0.35	0.13	0.35	0.63	1.06	0.25	0.46	0.00		0.25	0.46
Hexatoma sp.	0.25	0.46	0.13	0.35	0.25	0.46	0.25	0.46	0.13	0.35	0.13	0.35	0.13	0.35
Prosimulium sp.	0.50	0.76	0.63	0.74	0.00		0.25	0.46	0.00		0.13	0.35	0.13	0.35
Atherix sp.	0.00		0.00		0.00		0.13	0.35	0.00		0.00		0.00	
CHIRONOMIDAE														
Thienemannimyia sp.	0.63	1.06	1.50	1.41	0.75	1.17	1.50	1.20	0.75	1.04	0.25	0.46	1.13	1.89
Ablabesmyia sp.	1.00	2.07	0.13	0.35	0.75	1.04	0.25	0.71	0.63	0.52	0.50	0.76	0.13	0.35
Microtendipes sp.	0.50	0.76	0.75	0.89	0.88	0.64	1.38	1.19	1.13	1.13	0.88	0.84	0.63	0.74
Limnophyes sp.	2.63	2.33	1.88	1.46	1.46	0.84	1.50	2.07	0.88	0.99	0.75	0.89	0.63	1.06
Cricotopus sp. / *Orthocladius* sp.	0.13	0.35	0.25	0.71	0.25	0.46	0.25	0.71	0.00		0.00		0.25	0.71
TRICHOPTERA														
Hydropsyche sp.	0.50	0.54	0.75	0.71	0.50	0.76	1.00	1.07	0.25	0.46	0.25	0.46	0.38	0.52
Cheumatopsyche sp.	1.00	1.20	1.13	1.89	0.88	1.46	0.50	1.07	0.88	1.31	0.88	1.73	0.25	0.71
Dolophilodes sp.	0.25	0.46	0.25	0.46	0.00		0.13	0.35	0.25	0.46	0.25	0.46	0.00	
Hydroptiladae	0.13	0.35	0.25	0.71	0.75	1.17	0.25	0.46	0.75	2.12	0.00		0.00	
COLEOPTERA														
Optioservus sp.	0.63	0.74	0.25	0.46	0.38	0.74	0.38	0.58	0.50	1.07	0.75	0.89	0.50	0.76
Stenelmis sp.	0.13	0.35	0.00		0.00		0.00		0.00		0.00		0.00	
PLECOPTERA														
Brachyptera sp.	0.25	0.71	0.13	0.35	0.50	0.77	0.13	0.35	0.00		0.00		0.13	0.35
Isogenus sp.	0.13	0.35	0.00		0.00		0.00		0.13	0.35	0.00		0.00	
Alloperla sp.	0.13	0.35	0.13	0.35	0.50	0.54	0.00		0.13	0.35	0.00		0.13	0.35
EPHEMEROPTERA														
Paraleptophlebia sp.	0.63	0.92	0.25	0.46	0.50	0.54	0.00		0.75	0.71	0.13	0.35	0.00	
Ephemerella sp.	0.25	0.46	0.38	0.52	0.50	1.41	0.50	1.07	0.25	0.46	0.00		0.00	
Rithrogena sp.	0.88	1.13	1.13	2.10	1.00	1.07	1.50	2.27	0.75	1.04	0.63	1.06	0.63	0.74
Caenis sp.	0.00		0.00		0.25	0.46	0.00		0.00		0.00		0.00	
Baetis sp.	0.13	0.35	0.00		0.00		0.00		0.00		0.00		0.00	
Epeorus sp.	0.00		0.00		0.00		0.00		0.00		0.13	0.35	0.00	
CRUSTACEA														
Ostracoda	0.13	0.35	0.25	0.71	0.13	0.35	0.25	0.46	0.25	0.71	0.13	0.35	0.00	
Copepoda	0.00		0.00		0.00		0.00		0.00		0.00		0.13	0.35
ARACHNOIDEA														
Hydracarina sp.	0.75	1.04	0.50	0.54	0.50	0.76	1.25	1.75	0.25	0.71	0.75	0.89	0.38	0.52
OLIGOCHAETA														
Lumbricidae	3.63	4.96	3.25	4.65	3.75	5.04	2.13	2.64	1.25	1.75	1.25	1.83	0.63	1.19
NEMATODA	0.75	1.75	0.88	0.84	0.75	1.04	1.50	1.69	0.75	1.17	1.38	1.77	1.00	1.60

by 50% at both sites. The Tubificoidea were reduced by 85% at site II. The decline in Tubificoidea was significant ($p < 0.05$) between 0-30 cm. A decline was also observed between 30-70 cm but the numbers were not great enough to show any significance.

The depth distribution of the major taxa on Oct. 19 was similar to that found during pretreatment sampling. One exception was the slightly increased abundance of the Chironomidae in the 20-40 cm range of Site II. Pretreatment samples at depths of 20-40 cm contained 29% of the chironomids, while 1 day after treatment 41% of the chironomids were found at these depths. This is due to the increased presence of Microspectra sp., Rheotanytarsus sp., and Stempellina sp. in this depth range. The non-insects at Site I including Tubificoidea, were slightly more prevalent from 10-20 cm rather than 0-10 cm as they were before treatment. Tubificoidea was no longer present below 20 cm at Site II.

Four days after treatment (Oct. 22) the number of benthic macroinvertebrates found at the untreated site was greater than that found 1 day after treatment, although the number of organisms in each major group (Table 1) was still below that of pretreatment samples. Conversely, the number of organisms found at the treatment site on Oct. 22 was less than that found on Oct. 19. The total number of organisms found at Site II decreased by 45%, 4 days after treatment. All of the major groups at Site II continued to decline on Oct. 22. Only Polypedelium sp. decreased significantly at Site I, while experiencing no significant change at Site II. Chelifera sp. also did not decline at Site II. Tvetenia sp. was the chironomid most severely affected at Site II, declining by 92%. The total numbers of Glossosoma sp. and Tubificoidea found at Site I did not change from Oct. 19 to Oct. 22 while both decreased by 62% at Site II. The total number of non-insects at Site I increased significantly, by 79%, between 1

and 4 days after treatment.

The depth distribution of the major groups at Site I shifted slightly 4 days after treatment. Chironomidae were again concentrated in the 10-30 cm range but a greater number were found here on Oct. 22 than on Oct. 19. Non-insects at Site I were prevalent in the 20-30 cm area on Oct. 22, while at Site II their presence was greatest from 30-40 cm. Tubificoidea were evenly distributed over the depths at Site I while only 1 was found at each of 30-40 and 60-70 cm depths at Site II. Site II had the greatest numbers of organisms from 20-50 cm.

Thirty five days after treatment (Nov. 22), the total number of organisms found at sites I and II was greater then that found on Oct. 22. Polypedelium sp. increased significantly ($p < 0.05$) at Site I while no significant increases were exhibited by any of the major Chironomidae taxa at Site II. In fact, at Site II both Rheotanytarsus sp. and Stempellina sp. decreased significantly ($p < 0.05$) by 58% and 33% respectively. At Site II, the number of Diptera, excluding Chironomidae, was 32% greater 35 days after treatment than before treatment. Chelifera sp., however, did not increase greatly at Site II. The Trichoptera at Site II decreased from 4 days after treatment, including Glossosoma sp., while the Plecoptera and non-insects were decreased at Site I. The Tubificoidea increased at both Site I and Site II.

The major groups were evenly distributed throughout the hyporheic region 35 days after treatment. Tubificoidea were most prevalent in the top 10 cm at Site I while being most common from 10-20 cm at Site II. Site II continued to have most of its fauna within the depth range 20-50 cm.

DISCUSSION

The distribution of benthic fauna within the hyporheic region of Dam Creek was comparable to that found in previous studies (Coleman & Hynes, 1970; Bishop, 1973; Williams & Hynes, 1974; Hynes, 1974; Poole & Stewart, 1976; Godbout & Hynes; 1982). Many of these studies have found a hyporheal fauna to 50 cm, and sometimes more, with the greater percentage of the benthic macroinvertebrates occuring below the top 5-10 cm of substrate. Coleman and Hynes (1970) found that 20% of the total number of benthic macroinvertebrates were contained in the top 7.6 cm of the substrate. Similarly, benthic macroinvertebrates were consistantly found to a depth of 70 cm in Dam Creek with the upper 10 cm of both sites containing approximately 20% of the total numbers of organisms.

Williams and Hynes (1974) found that over a 13 month period the depth distributions of the hyporheos remained relatively constant. In contrast, within 2 days of the initial sampling of Dam Creek the relative distribution of organisms at each site was different. Site I contained a greater percentage of organisms in the 10-30 cm range than found previously while Site II had more in the 20-50 cm range. Macroinvertebrates at the untreated site continued to be more prevalent in the 10-30 cm range until 36 days after pretreatment sampling at which time the 0-10 cm level again contained 20% of the total organisms. The treatment site continued to have most of its organisms in the 20-50 cm range throughout the rest of the study.

The decrease in the abundance of organisms at the treatment site was often less severe than that observed at the untreated site. Increased water levels were observed on Oct. 19 and especially on Oct. 22. The effect of flooding may have been greater at the untreated site than at the

treatment site.

The significant decrease in abundance of Tubificoidea at the treatment site is the only one that can be attributed directly to the presence of TFM. Tubificoidea are extremely sensitive to TFM (Chandler & Marking, 1975) and have been virtually eliminated subsequent to lampricide treatment (Torblaa, 1968; Kolton et al, 1985; MacMahon et al, 1985). Other taxa that have been found to be TFM-sensitive such as Simulium sp., (Smith, 1967; Maki et al 1975), Lumbricidae (Maki et al, 1975) and Chimarra sp. were not present at Site II or were not present in sufficient numbers to evaluate their response.

The hyporheic region of Dam Creek did not function as a refuge zone for downward migrating organisms and showed a limited capacity in buffering the effects of TFM. Tubificoidea, the only taxa whose numbers declined in response to TFM treatment, exhibited significant decreases in abundance throughout the top 30 cm. Pretreatment sampling yielded few Tubificoidea below 30 cm and there was no apparent downward migration into or through the 30-70 cm zone immediately after treatment. One month after treatment there was no observed upward migration or recolonization of the surface regions by Tubificoidea at Site II.

Eighteen hours after treatment, TFM concentrations were highest at 55 cm, the greatest depth from which water samples were collected. This was the only time when TFM concentrations were measured. However, it is assumed that immediately following treatment, TFM concentrations in the upper 10 cm were close to that of treatment levels and decreased with depth. Eighteen hours after treatment the upper 5 cm were completely free of TFM while at 55 cm TFM concentration was half that of treatment levels.

The persistence of the lampricide at lower levels is probably due to slow interstitial water movement in concert with chemical stability.

Degradation of TFM by photolysis would not be expected to be significant at these depths (Carey & Fox, 1981). Binding to sediments is minimal in sandy substrate and microbial degradation of TFM is slow in the presence of oxygen (Bothwell et al, 1973), both of which characterized the conditions of Dam Creek. It is probable that TFM residues would persist longer in the hyporheic region, although at concentrations below that of treatment, and that water movement is the main factor in the elimination or dilution of residues from within the hyporheic region.

Although TFM concentrations at 55 cm may not have reached treatment levels other factors may compound the effect upon organisms such as Tubificoidea. Dissolved oxygen and pH decreased with depth which is in general agreement with other studies (Hynes, 1983; Whitman and Clark, 1982). TFM toxicity increases inversely with both pH and dissolved oxygen (NRCC, 1985). It was also observed that TFM concentrations persist for longer periods of time deeper within the substrate. These factors may be responsible in maintaining a relatively high TFM toxicity within the hyporheic region as found here with Tubificoidea.

It may be possible that the large influx of TFM into the substrate observed in this study was not common to previous studies. Hynes (1983) reports that studies on river pollutants, spawning sites, and the hyporheos have all indicated that there is some exchange of water between the hyporheic region, or interstitial water, and the surface. Whitman & Clark (1983) propose that the cooling of surface water in relation to the interstitial water creates thermal gradients that cause convective forces within the substrate. In this study surface water temperature declined by $3^{o}C$ during TFM treatment. This may account for the high TFM levels found at 55 cm one day after treatment and thus the decrease of Tubificoidea within the hyporheic region.

The results here probably indicate a more severe effect of TFM upon the hyporheos then would normally occur. Convective forces within the hyporheic region exhibit both diurnal and annual cycles but are greatest in the fall and winter (Whitman & Clark, 1983). TFM applications of the Great Lake tributaries generally commence in May and continue through to October. When convective forces are low, as they would be for much of the application season, it is probable that the hyporheos serves as a refuge or buffer zone during TFM treatment and therefore facilitate the recolonization of the upper substrate.

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