EFFECTS OF THE LAMPRICIDE 3-TRIFLUOROMETHYL-4-NITROPHENOL ON MACROINVERTEBRATE POPULATIONS IN A SMALL STREAM

Great Lakes Fishery Commission

TECHNICAL REPORT No. 55

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EFFECTS OF THE LAMPRICIDE 3-TRIFLUOROMETHYL-4-NITROPHENOL ON MACROINVERTEBRATE POPULATIONS IN A SMALL STREAM

by

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ABSTRACT

Following two seasons of benthic sampling, Watson Creek, a small tributary of the Pentwater River, Michigan, was treated with the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) to determine its effects on the stream macroinvertebrates. Sampling was continued for nearly six months after the treatment. Numbers of organisms decreased in 88% of the taxa immediately following the treatment. All affected populations recovered within five months and species richness and composition were not notably changed by treatment.

INTRODUCTION

The selective lampricide 3-trifluoromethyl-4-nitrophenol (TFM) has been successfully used to control the sea lamprey *(Petromyzon marinus)* in the Great Lakes since 1958 (Applegate et al. 1961). The history and status of the sea lamprey control program have been described by Smith and Tibbles (1980).

Several laboratory studies on the effect of TFM on aquatic invertebrates have been conducted (Smith 1967; Kawatski 1973; Kawatski et al. 1974; Chandler and Marking 1975; Fremling 1975; Kawatski et al. 1975; Maki et al. 1975; Sanders and Walsh 1975; Rye and King 1976). These studies determined the concentrations of TFM lethal to specific invertebrates, and usually indicated that these organisms would not be adversely affected by stream treatments. Because laboratory studies do not always simulate field conditions adequately, results from the foregoing studies are difficult to translate into the impacts expected from actual stream treatments. Laboratory toxicity test results may be influenced by the additional stresses to test organisms imposed by artificial conditions and handling. Furthermore, the tests are usually based on LC50 values for 24 or 96 h exposure of the invertebrates being tested, whereas streams are normally treated for a period of 8 to 14 h at concentrations based on the LC100 values for lamprey larvae. Some of these laboratory tests used the maximum allowable concentration (MAC) expressed as LC25 for fingerling rainbow trout *(Oncorhynchus mykiss)* as determined by range-finding toxicity tests. These concentrations are higher than treatment dosages, which are based on the minimum lethal concentration (MLC) to lamprey larvae as described by Howell and Marquette (1962). The MAC has been avoided in stream treatments in recent years.

A few field studies have been conducted in conjunction with stream treatments (Torblaa 1968; Haas 1970). More recently, an invertebrate drift study was made before, during, and following a stream treatment (Cawest 1980). Although these studies demonstrated minimal detrimental effects of TFM on lotic invertebrates, concern about the possible effect of TFM on nontarget organisms has intensified in recent years and more information is needed.

The present study is an effort to gain further information on the immediate and long-term effects of TFM treatments on aquatic macroinvertebrate populations. Watson Creek was selected for study because, having never harbored a sea lamprey population, its invertebrate fauna had not been exposed to TFM.

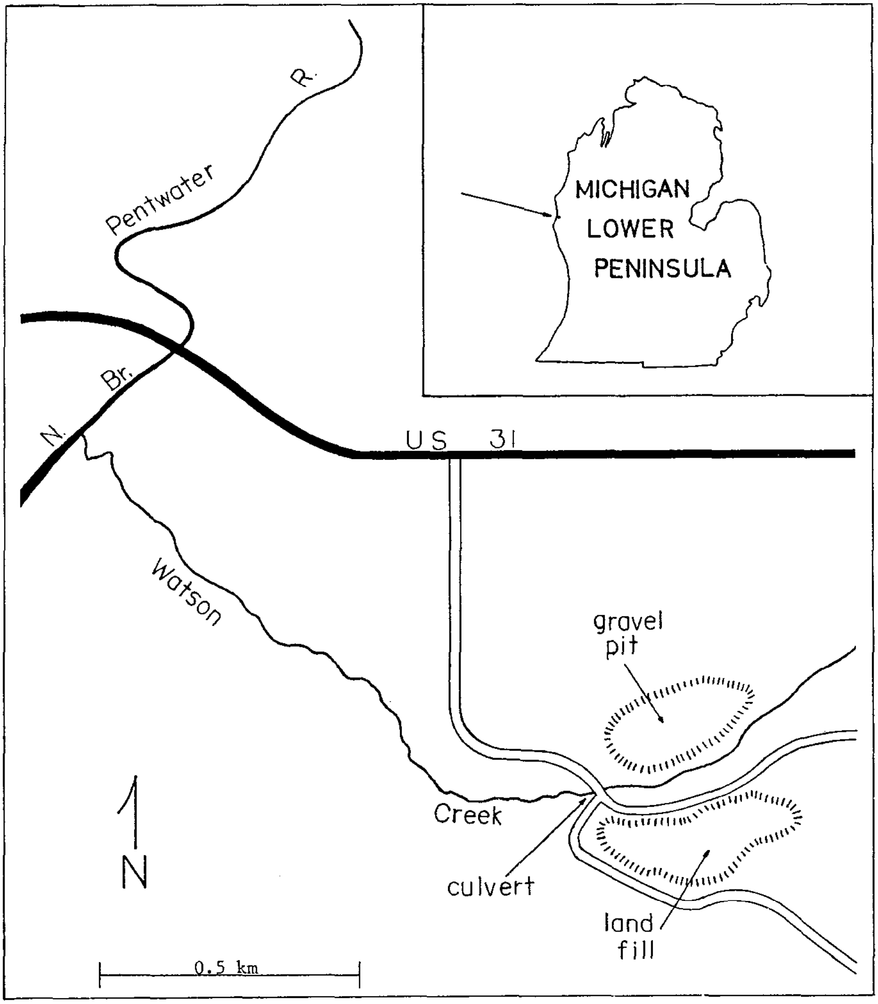

Fig. 1. The Watson Creek study area extends from the culvert to the North Branch of the Pentwater River.

THE STUDY AREA

Watson Creek is a first order tributary of the North Branch of the Pentwater River in the west-central portion of the Lower Peninsula of Michigan at approximately 43" 45' N, 86" 23' W (Fig. 1). The stream is approximately 4.8 km long; the upper two-thirds of which is characterized by seasonally intermittent flow through mixed woodlot, meadow, and farmland. The lower section, which includes the study area, flows through a wooded valley dominated by red maple *(Acer rubrum),* bigtooth aspen *(Populus grandidentata),* trembling aspen *(Populus tremuloides),* and red *oak (Quercus rubra),* with some eastern hemlock *(Tsuga canadensis)* and red pine *(Pinus resinosa)* on the higher ground. Stream and riparian vegetation includes marsh marigold *(Caltha palustris),* watercress *(Nasturtium officinale),* moss and algae on exposed surfaces of cobbles, and speckled alder *(Alnus rugosa),* willow *(Salix* sp.), cattail *(Typha latifolia),* and sedge *(Carex* sp.) near the mouth. Continuous flow in the lower part of the stream is maintained by groundwater seepage and numerous springs.

The lower 1.2 km of the stream was selected for study.. At the head of this section, the stream flows through a culvert under a dirt road. Just upstream from the culvert there are two gravel pits, one of which was converted to a sanitary landfill in 1965. In the study area the stream is approximately 1.2 to 2.8 m wide, about 15 cm deep, and its substrate is composed of a mixture of silt, sand, gravel, and cobbles up to 15 cm in diameter. The study area contains many riffles and pools, and slackwater areas with silt deposits are common along the edges of the: stream. A few productive cobble riffles are present. However, most riffle areas are composed of a mixture of sand and pea gravel, which is relatively unproductive as evidenced by sampling such sites.

The vertebrate fauna of Watson Creek is not diverse compared to larger streams in the area (U. S . Fish and Wildlife Service, unpubl . data). Ammocoetes of the American brook lamprey *(Lampetra appendix)* are common. The bony fishes include brown trout *(Salmo trutta),* brook trout *(Salvelinus fontinalis),* johnny darter *(Etheostoma nigrum),* and mottled sculpin *(Cottus bairdi).*

MATERIALS AND METHODS

COLLECTION OF SAMPLES

In conjunction with macroinvertebrate samples, water temperature, conductivity, pH, and carbonate and bicarbonate alkalinity were measured biweekly. Other physical and chemical parameters (Table 1) were tested less regularly. Water discharge was calculated from measurements obtained using a Price AA current meter, and dissolved oxygen was determined by a Hach modified Winkler method. The pH was measured with a Beckman Zeromatic pH meter, and conductivity was measured with an Industrial Instruments conductivity bridge. Carbonate and bicarbonate alkalinities were determined by titration with phenolphthalein and methyl purple indicators. Other chemical parameters were measured with a Hach DR calorimeter.

Macroinvertebrate samples were taken at approximately two-week intervals with a Surber square-foot bottom sampler from April to September in 1966-67 and from April to October in 1968. Meehan (1974) and Allan (1975) concluded that a small number of samples taken with a Surber sampler is adequate to determine species diversity and relative abundance.

TABLE 1. Ranges and means of physical and chemical parameters measured in the Watson Creek study area, 1966-68.

Parameter	No. Measurements	Min.	Max.	Mean
Temperature (C)	47	8.9	17.8	12.6
Oxygen (mg/L)	22	8.6	11.0	10.1
Oxygen (% saturation)	22	80	11.5	97.7
PH	31	7.1	8.3	7.9
Alkalinity (mg $CaCo_3$) at culvert	19	71	143	125
(HCO,) at culvert	19	0	0	0
Alkalinity (mg $CaCO_3$) at mouth	22	95	168	146
(HCO,) at mouth	22	0	0	0
Conductivity (µmhos at 25°C) at culvert	17	170	322	293
Conductivity (µmhos at 25°C) at mouth	19	219	373	325
Aluminum	3	0.02	0.13	0.19
Calcium	3	104	112	109
Chloride	3	4.0	5.5	4.4
Copper	3	0.17	0.25	0.21
Iron	3	0.05	0.06	0.058
Nitrate (mg/L)	3	3.250	3.795	3.523
Nitrite	3	0.003	0.013	0.007
Ortho phosphate	3	2.8	5.9	4.4
Meta (poly) phosphate	3	0.1	0.2	0.15
Total phosphate	3	3.0	6.0	4.5
Silicon	3	9.0	12.5	10.4
Tannic acid	3	0.3	1.2	0.78

In sampling benthic organisms in a small stream, it is possible to change significantly various spatially limited habitats through destruction or removal of physical constituents, and to deplete populations in small areas. These possibilities were addressed by Waters (1964) and MacKay (1969). MacKay sampled one of 12 substations per station each month, and Waters found that the rate of recolonization of many organisms by drift was sufficient to justify a biweekly sampling frequency.

In the present study, one sample was taken in each of three habitat types (silt, sand, and gravel/cobble riffles) on most sampling dates. Samples were taken randomly throughout the study area and although the most productive sites were sampled more frequently than others, no site was sampled on consecutive sampling dates, thus ensuring a minimum of one month for recolonization. Many sites were sampled only once during the study period. Because replicate samples were not obtained, statistical analysis was not performed. Cobbles were removed from riffles and returned after being scraped and washed. All sample sites were excavated to a depth of 7.5 cm. Initially, each site was 0.279 m^2 in area; however, after the first three sampling dates, samples were restricted to 0.186 m^2 for silt and sand, and 0.093 m^2 for gravel, because of the size limitation of some sites. All sample counts were adjusted to sample areas of 1.0 m^2. In both 1967 and 1968, 33 samples were taken, whereas 29 were collected in 1966. One sample from a gravel habitat and three from a sand habitat were not evaluated in 1966 due to loss of sample or lack of collection. Because sand habitat generally contained few organisms, the total organism count for 1966 was probably affected only slightly and is therefore considered comparable to counts in other study years. Organism counts from the three habitat types were combined for each sampling date because species overlap was too great to allow clear delineation of taxa by habitat. Much of this overlap may be due to variations in the substrate composing the sampling sites.

To determine which taxa were available for recolonizing the treated stream section by drift, two consecutive drift samples with a total duration of 24 h were taken on April 25-26, 1968 in the upstream opening of the culvert. In addition, single Surber samples were taken on four days in 1967 from silt deposits located immediately upstream from the culvert. The stream becomes intermittent above this point and no gravel is present.

Organisms were separated from debris by three repetitions of a flotation process using a saturated solution of CaCl. Remaining organisms were retrieved by sorting the debris with the aid of a hand magnifier. All organisms were fixed in 5% formalin and later transferred to an aqueous solution of 5% formalin, 5% glycerin, and 60% 2-propanol.

The Lampricide Application

Information for planning the Watson Creek treatment was collected on April 29, 1968. A. toxicity test indicated a MLC (LC100) of 4.0 mg/L for 7 h and a MAC (LC25) of 14.5 mg/L for 20 h. Water discharge was 0.062 m^3/s at the culvert and 0.217 m^3/s at the mouth, with an average velocity of 0.22 m/s. It was determined from the discharge measurements that a concentration of 14.0 mg/L TFM was needed at the application site to obtain 4.0 mg/L at the mouth, because of dilution.

The stream was treated with TFM on April 30, 1968 using techniques described by Smith and Tibbles (1980). The lampricide was applied at the head of the study section for 9.5 h (11:00 a.m.-8:30 p.m. EST). The concentration of TFM at the application site was maintained at about 14.0 mg/L and averaged 4.2 mg/L for 8.5 h at the mouth.

RESULTS AND DISCUSSION

Water Quality

Watson Creek is a cool, well oxygenated stream with an average total alkalinity (mg/L $CaCO_3$) of 125 at the culvert and 146 at the mouth, and a pH range of 7.1 to 8.3. Conductivity averaged 293 µmhos at the culvert and 325 ymhos at the mouth (Table 1). Other chemical parameters showed little variation in concentration.

From April to October 1966-68, water temperature ranged from 8.9 to

17.8°C at the culvert (avg. 13.1°C), and 8.9 to 13.3°C at the mouth (avg. 11.6°C). The reduction in temperature from culvert to mouth resulted from the influx of groundwater below the culvert and the shading effect of the forest canopy.

MACROINVERTEBRATE COLLECTIONS

A total of 92 macroinvertebrate taxa from within the study area were identified (Table 2). Because individuals of similar genera are difficult to differentiate when small, genera represented by few individuals are grouped under the name of the dominant taxon. Nine annelid taxa were identified and were grouped as oligochaetes or hirudinids, for convenience. The four samples collected above the culvert with a Surber sampler (Table 3) contained three taxa not collected below the culvert and 25 taxa found in the study area. The drift samples (Table 4) consisted of 30 taxa occurring in the study area and eight taxa not collected in the study area. One of the eight taxa was an adult hemipteran and three were adult coleopterans - all very motile organisms not targeted for capture with a Surber sampler.

Of the taxa found in the study area, 53 (64%) were collected in very low numbers, contributing only 1.4% of the total organism count for 1966, 0.8% for 1967, and 0.9% for 1968.

Total numbers of organisms increased from 1966 through 1968 (Fig. 2GG). Of the 30 taxa used for comparisons, 21 (70%) were most numerous in 1968 and of these, 19 (63.3%) increased annually from 1966 through 1968. Only three (10%) of the taxa showed an annual decline. A unidirectional trend in annual totals in 22 (73.3%) of the taxa suggests a change in some aspect of the stream environment. This change may have been due to a slight increase in nutrient enrichment of Watson Creek either from natural or agricultural sources, or as a consequence of the establishment of the landfill at the head of the study area. In an incidental observation in Watson Creek in 1971, a large silt bed near the mouth of the stream was covered with an extensive red mat of the hemoglobin-bearing midge *Stictochironomus,* partially emerged from the substrate and exposed to the current. This phenomenon had not been previously observed for any chironomid found in Watson Creek. A conservative estimate of numbers was placed at 50,000/m^2 - roughly six times greater than the previous peak sample of 8,500/m^2.

Numerically, the most important taxa were *Micropsectra,* Cnephia, and *Gammarus,* which collectively constituted about 70% of all organisms counted in each of the three study years (Table 5). *Micropsectra* was the most numerous organism in 1968, masking the combined contributions of all other taxa that year (Figs. 3CC, FF, and GG). Over the three-year period, *Micropsectra* increased in numbers (Fig. 2CC) and in percent of total numbers of organisms collected (1966, 13.1%; 1967, 43.6%; 1968, 56.9%). During the same period, Cnephia declined in numbers (Fig. 2DD) and percentage (1966, 42.0%; 1967, 20.0%;

TABLE 2. Total numbers of organisms and their frequency of occurrence in 95 samples (expressed as m^2) from the study area of Watson Creek during the period April 1966 to October 1968.[1]

Taxon	Total no. of organisms	Frequency of occurrence
Hydra	11	1
Nematoda	694	32
Oligochaeta[2]	3,438	55
Hirudinea[3]	523	17
Physa	141	12
Limnaea	4	1
Valvata	9	2
Pisidium	8,440	36
Ostracoda[4]	1,026	16
Copepoda[4]	16	2
Asellus	6,605	35
Gammarus	58,938	91
Acari	451	25
Isotomidae	61	5
Sialis	876	26
Nemoura	5,452	23
Paracapnia	1,250	27
Baetis	26,223	48
Paraleptophlebia	9	2
Molanna	7	1
Diplectrona[5]		
Parapsyche	11,754	30
Agapetus[5]		
Glossosoma	13,919	35
Ptilostomus	20	4
Lepidostoma	679	16
Rhyacophila	5	1
Limnephilus	306	10
Frenesia	221	4
Neophylax	3,320	27
Hesperophylax	16	2
Pseudostenophylax	149	14
Nemotaulius	5	1
Hebrus	22	1
Merragata	5	1
Pleidae	11	1
Cenocorixa	21	3
Trepobates	11	1
Optioservus	274	10
Agabus	64	6
Hygrotus	10	2
Lepidoptera	5	1
Dolichopodidae	5	1
Psychodidae	4	1
Syrphidae	4	
Heliinae	2,615	44
Clinocerinae	3,398	28
Hemerodromia	2,557	48
Cnephia	129,904	36
Dixa	27	3

TABLE 2. (Cont.)

Taxon	Total no. of organisms	Frequency of occurrence
Limnophora	42	5
Liriope	63	5
Tipula	232	14
Limonia	4	1
Holorusia	11	1
Pedicia	29	4
Dicranota	3,096	47
Limnophila	799	27
Pilaria	111	9
Helius	16	2
Trimicra	24	5
Tabanus	3,889	35
Podonomus	8,011	38
Procladius	18,771	37
Pentaneura	866	30
Diamesa	566	25
Prodiamesa olivacea	25,350	63
Prodiamesa bathyphila	8,890	48
Psectrocladius	693	19
Nanocladius	10,515	35
Trichocladius	2,293	36
Cricotopus	10,393	48
Smittia	1,362	23
Metriocnemus	14,301	60
Corynoneura	236	20
Chironomus (Chironomus)	59	3
Chironomus (Cryptochironomus)	22	2
Chironomus (Tribelow)	4	1
Stictochironomus	15,419	41
Microtendipes	197	13
Paratendipes	4,292	26
Polypedilum (Polypedilum)	1,247	37
Polypedilum (Pentapedilum)	4	1
Paralauterborniella	1,207	30
Micropsectra	335,903	69

[1]Posttreatment samples are included in the totals because, while the tint posttreatment sample, in many cases shows a decrease in numbers, subsequent samples indicate recovery and often, increases over previous seasons.

[2]*Lumbriculus variegatus*, Enchytraeidae, *Rhyacodrilus* sp., *Limnodrilus hoffmeisteri, Limnodrilus udekemianus, Iliodrilus templetmi,* and *Sparganophilus* sp.

[3]*Helobdella elongata* and *Nephelopsis obscura.*

[4]Specimens were not retrieved from all samples in which they were encountered.

'Very small specimens of *Diplectrona* and *Parapsyche* are difficult to differentiate, and because of numerical insignificance in these collections, *Diplectrona* was included with *Parapsyche. Agapetus* and Glossosoma were treated in the same manner, with Glossosomo being the numerically dominant organism.

TABLE 3. Organisms and numbers/m* collected in four silt habitat samples taken immediately above the study area in 1967 with a Surber sampler.

Organism	Date collected			
	April 5	May 5	May 19	June 2
Nematoda	5	5	11	-
Oligochaeta	54	732	27	161
Hirudinea	22	32	226	75
Pisidium	5,250	8,203	134	5,417
Ostracoda	43	86	-	11
Gammarus	1,592	2,598	2,114	1,759
Sialis	48	38	54	38
Ptilostomus	5	-		
Lepidostoma	-	-	5	
Limnephilus	11	5	-	11
Frenesia	11	-		
Pseudostenophylax	5	-		-
Donacia’	5		-	
Brachydeutera’	-		16	
Heliinae	285	86	-	22
Hemerodromia	5		5	
Euparyphus’	-		-	5
Pilaria	-	5		-
Procladius	38	167		86
Pentaneura	22		-	
Prodiamesa olivacea	888	974	-	129
Psectrocladius	-	16		
Smittia	134	-		-
Metriocnemus	140	16		-
Stictochironomus	-	11		-
Paratendipes	-	393	5	1,625
Polypedilum (Polypedilum)	301	97	-	5
Micropsectra	9,946	5,589	-	145

‘Not collected in the study area.

1968, 5.9%), and *Gammarus* increased in numbers (Fig. 2B) and decreased in percentage (1966, 12.1%; 1967, 8.1%; 1968, 6.1%).

EFFECTS OF THE LAMPRICIDE

The study showed that an immediate decline in the numbers of organisms in many macroinvertebrate taxa occurred after the stream treatment (Fig. 3). Some of the decline, (e.g. *Baetis* and *Nemoura)* may have been associated with seasonal life cycle events. Torblaa (1968) noted that reductions in numbers of organisms of some taxa at various times after treatment were more easily explained by natural cycles of emergence.

The four noninsect macroinvertebrate taxa showed an immediate reduction in posttreatment numbers (Fig. 3 A-D, Table 6). However, subsequent posttreatment abundance similar to or greater than that found in 1966 or 1967 was

ABLE 4. Organisms and numbers collected during a 24-hour drift sample taken on April 25-26, 1968.

Taxon	Number collected	Taxon	Number collected
Oligochaeta	1	***Haliplus***[1]	1
Hirudinea	3	Lepidoptera	4
Asellus	2	Psychodidae	1
Gammarus	209	Syrphidae	2
Atari	6	*Hemerodromia*	1
Isotomidae	176	*Cnephia*	1
Sialis	1	*Dixa*	2
Nemoura	134	*Limnophora*	1
Baetis	57	***Tetanocera***[1]	7
Paraleptophlebia	4	***Euparyphus***[1]	21
Parapsyche	9	***Eulalia***[1]	29
Lepidostoma	16	*Tipula*	1
Limnephilus	47	*Helius*	1
Neophylax	2	Phoridae’	2
Hesperophylax	3	*Trichocladius*	7
Pseudostenophylax	14	*Metriocnemus*	12
Gerris’	1	*Paratendipes*	1
Notomicrus[1]		*Polypedilum (Polypedilum)*	2
Pronoterus[1]	1	*Micropsectra*	5

[1]Not collected in the study area

achieved, e.g., numbers of *Gammarus* (Fig. 3B) showed a posttreatment decline through May but began a steady increase in June and peaked at 5233/m^2 in September.

Most insect populations recovered after the initial posttreatment decline, and all except *Cnephia* (Fig. 3DD) subsequently reached levels of abundance similar to or greater than those found in 1966 or 1967. The 1968 peak sample for *Cnephia* was lower than the 1966 and 1967 peaks and the total number collected in 1968 was less (Fig. 2DD). Although TFM is highly toxic to blackflies (Smith 1967), the low numbers of *Cnephia* in 1968 may not be entirely the result of the effects of TFM because numbers were comparably low in 1966 and 1967 until late June. Before the TFM treatment in 1968, *Micropsectra* (Fig. 3CC) showed a decline which continued after treatment through May, but samples of *Micropsectra* in June and July displayed a strong resurgence in numbers, exceeding the combined totals for 1966 and 1967 (Fig. 2CC). The apparent increase immediately after treatment is attributed to differences in productivity among the sites sampled on April 29 and May 5, 1968. *Nemoura, Paracapnia,* and *Procladius* (Fig. 3E, F, and Q) generally declined in numbers in 1968, but the trends are also evident in 1966 and 1967 and are probably seasonal. Although the abundance of *Micropsectra* strongly influenced the total organism count in 1968 (Fig. 3CC, FF, and GG), the general posttreatment recovery of other taxa is demonstrated. These results generally agree with the findings of Torblaa (1968)) Cook and Moore (1969) and other workers, who have reported significant

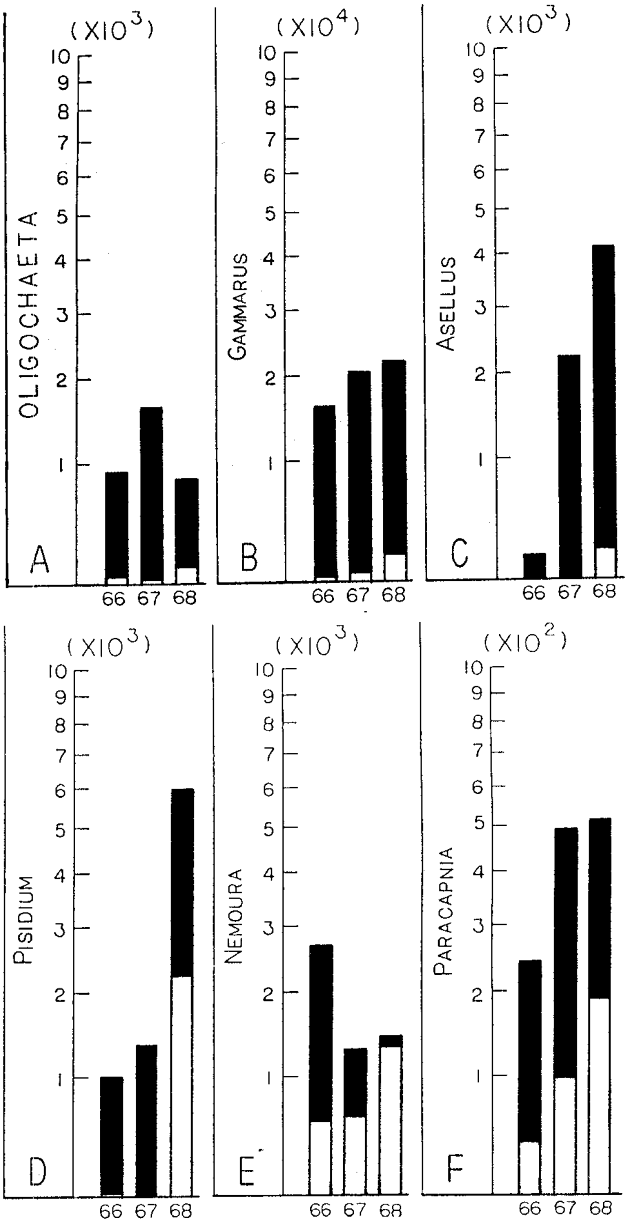

Fig. 2. Yearly numerical totals for selected Watson Creek macroinvertebrate taxa. Numbers of organisms on the ordinate are multiplied by the factor at the top. Light portions of the bars represent numbers collected prior to May 2 (equivalent to the pretreatment period) in each year.

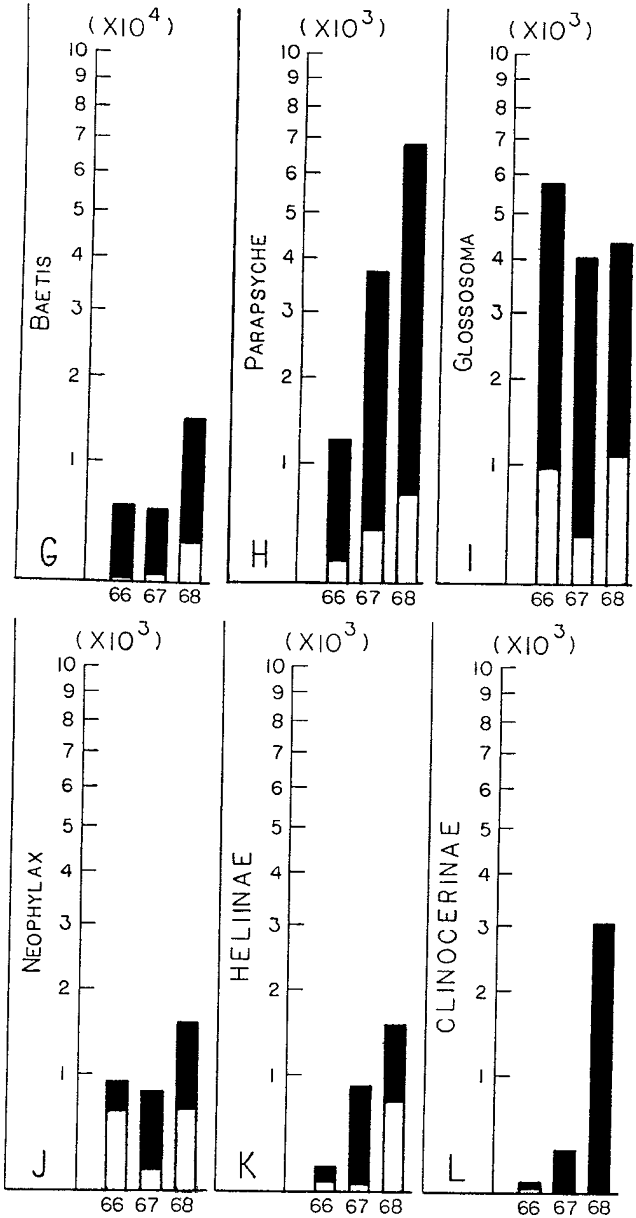
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Fig. 2 (Cont.)

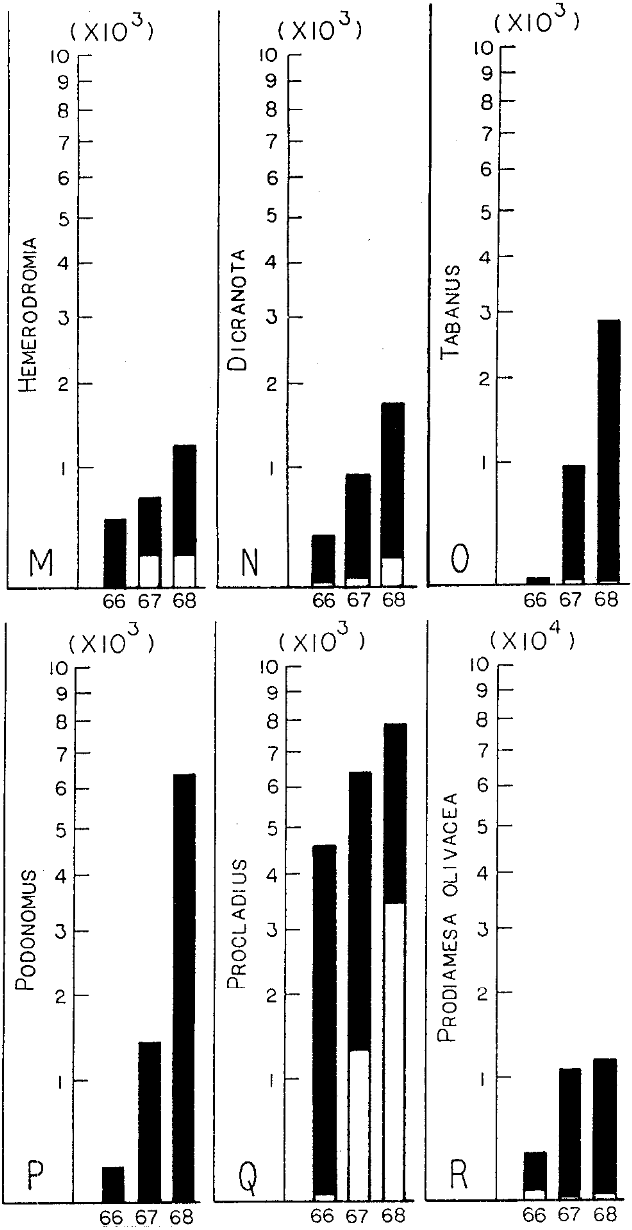
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Fig. 2. (Cont.)

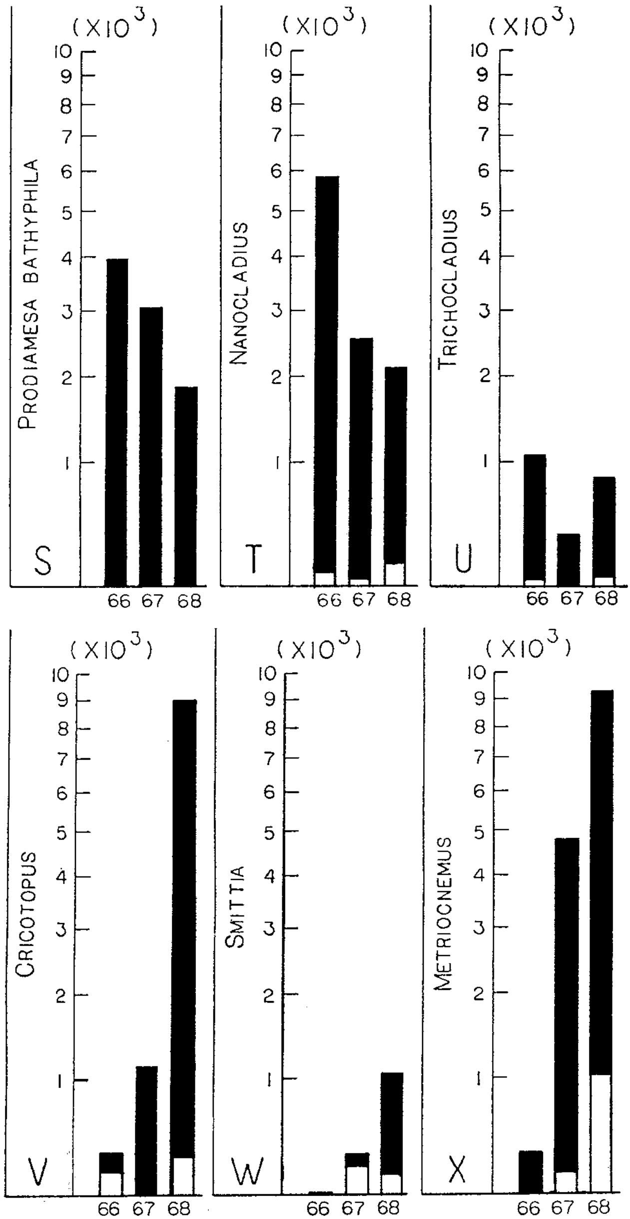
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Fig. 2. (Cont.)

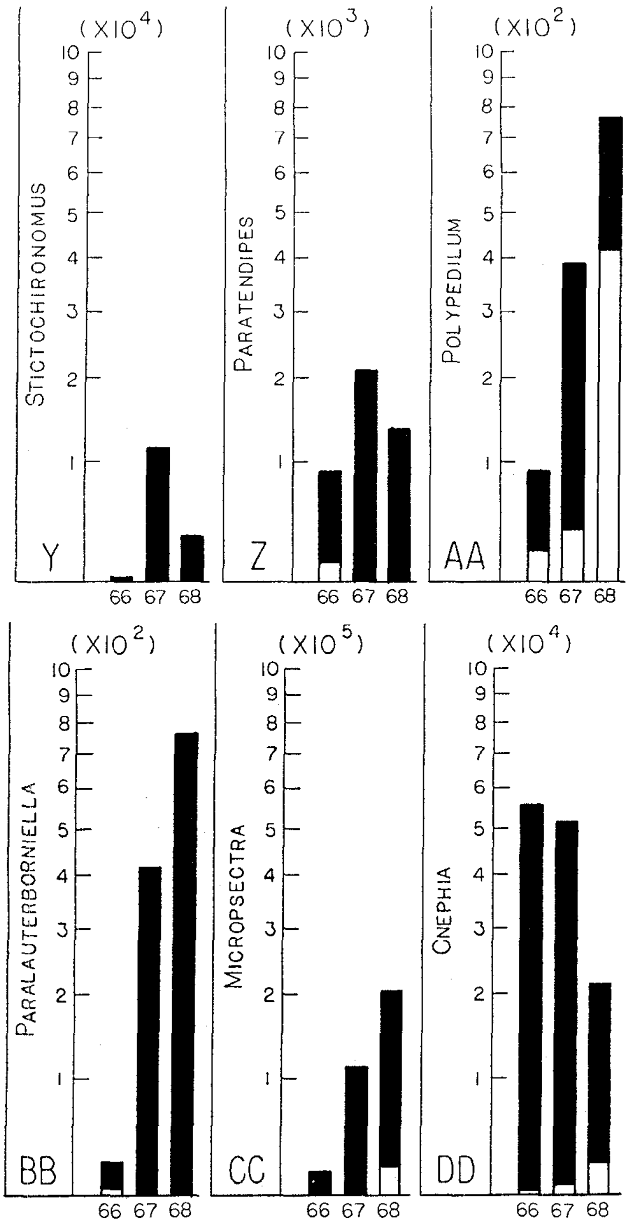
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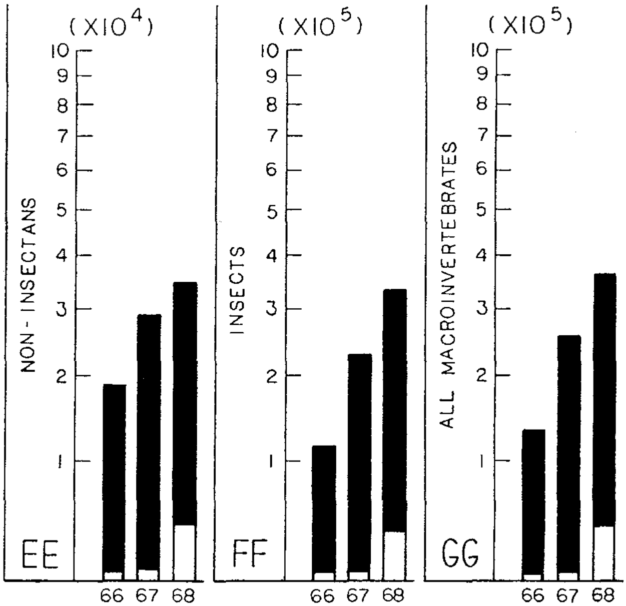
Fig. 2. (Cont.)



recovery of severely reduced macroinvertebrate populations after pesticide applications .

Torblaa (1968) found that the total number of organisms showed complete recovery at all three of the stations which he sampled one year after treatment, and that the major taxa that were present before treatment were well represented. Species richness and composition in Watson Creek remained relatively stable during 1966-68. The number of taxa collected in the study area was 62 in 1966, 63 in 1967, and 69 in 1968 after TFM treatment. In all three study years, 52 taxa were common to collections. In only one or two years, including five that were absent only in 1967, 31 taxa were collected. However, all of these were relatively uncommon members of the Watson Creek community, or were of a type (e.g., adult Hebrus, *Cenocoryxa,* and *Merragata)* resistant to capture by the methods employed.

Recolonization of Treated Streams

Larimore et al. (1959) listed the criteria which affect the rate of recolonization of streams after a drought as follows: (1) the extent of the affected area, (2) sources of new organisms, (3) degree of habitat damage and recovery, (4) water levels, and (5) season. These criteria are also applicable to streams treated with TFM, as was Watson Creek.

Streams are seldom treated with TFM during periods of very low or high

TABLE 5. Total numbers of organisms and average number per m^2 (shown in parentheses) of selected taxa collected during three years from the Watson Creek study area.

Taxon	1966	1967	1968
Oligochaeta	944 (86)	1,634 (149)	860 (78)
Pisidium	1,024 (93)	1,388 (126)	6,028 (548)
Asellus	183 (17)	2,239 (204)	4,183 (380)
Gammarus	16,087 (1,463)	20,805 (1,891)	22,046 (2,004)
Nemoura	2,699 (245)	1,301 (118)	1,452 (132)
Paracapnia	242 (22)	492 (45)	516 (47)
Baetis	5,987 (544)	5,578 (507)	14,658 (1,333)
Parapsyche	1,198 (109)	3,734 (340)	6,822 (620)
Glossosoma	5,784 (526)	4,069 (370)	4,066 (370)
Neophylax	923 (84)	827 (75)	1,570 (143)
Heliinae	183 (17)	882 (80)	1,550 (141)
Clinocerinae	75 (7)	326 (30)	2,997 (273)
Hemerodromia	535 (49)	787 (72)	1,235 (112)
Cnephia	57,054 (5,187)	51,435 (4,676)	21,415 (1,947)
Dicranota	397 (36)	939 (85)	1,760 (160)
Tabanus	53 (5)	984 (90)	2,852 (259)
Podonomus	266 (24)	1,403 (128)	6,342 (577)
Procladius	4,582 (417)	6,359 (578)	7,830 (712)
Prodiamesa olivacea	3,418 (311)	10,093 (918)	11,839 (1,076)
Prodiamesa bathyphila	3,949 (359)	3,059 (278)	1,881 (171)
Nanocladius	5,852 (532)	2,549 (232)	2,114 (192)
Trichocladius	1,073 (98)	370 (34)	850 (77)
Cricotopus	309 (28)	1,128 (103)	8,956 (814)
Smittia	12 (1)	300 (27)	1,050 (96)
Metriocnemus	308 (28)	4,777 (434)	9,216 (838)
Stictochironomus	385 (35)	11,613 (1,056)	3,421 (311)
Paratendipes	910 (83)	2,107 (192)	1,275 (116)
Polypedilum	91 (8)	392 (36)	765 (70)
Paralauterborniella	21 (2)	418 (38)	768 (70)
Micropsectra	17,393 (1,582)	112,338 (10,213)	206,172 (18,743)
Non-insectans	18,238 (1,658)	26,066 (2,370)	33,117 (3,011)
Insects	113,669 (10,334)	228,260 (20,751)	323,372 (29,397)
Combined macroinvertebrates	131,907 (11,992)	254,326 (23,121)	356,489 (32,408)

discharge and no streams have been treated in their entirety. Although portions of streams may be affected by the treatments, usually there are extensive untreated headwater and tributary sections which remain as potential sources of new organisms, either by drift or by ovipositing adults. Some of the untreated portion of Watson Creek is similar environmentally to the study section, with many invertebrate taxa common to both areas (Tables 3 and 4); therefore, drift into the treated portion would likely contain organisms capable of recolonization. Ovipositing adult invertebrates from untreated nearby streams can also assist in the recolonization of treated streams. For Watson Creek this includes the lower North Branch, of the Pentwater River.

Invertebrate drift during treatment may also constitute a source of recolo-

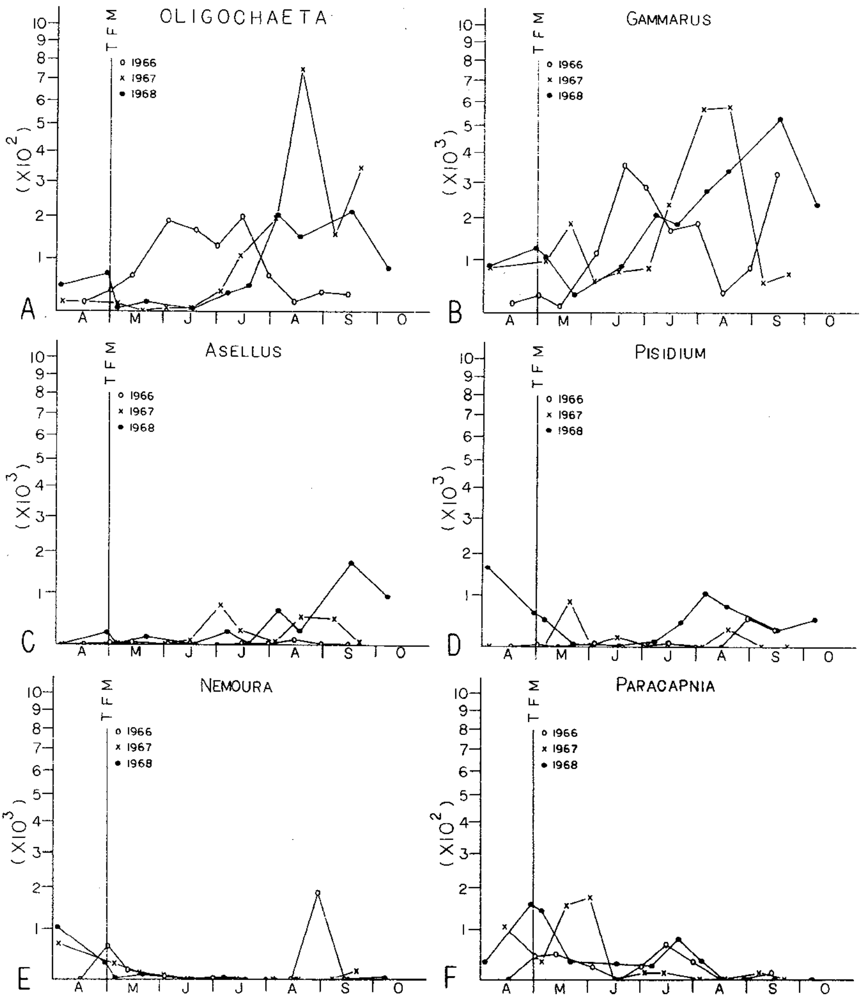


Fig. 3. Sampling dates and numbers collected of selected Watson Creek macroinvertebrate taxa during the years 1966-68. Numbers of organisms on the ordinate are multiplied by the factor to the left. The vertical line represents the April 30, 1968 TFM application date. Numbers per sample adjusted to m^2.

nization. Increased drift rates occur during some pesticide treatments (Reed 1966; Hatfield 1969; Maki et al. 1975; Cawest 1980; Dermott and Spence 1984) and some species, such as the burrowing mayfly *Hexagenia,* abandon their burrows when exposed to TFM (Fremling 1975) and drift downstream. Since the highest concentration of TFM is found immediately below the application site, organisms may drift to less toxic areas where recovery and survival may be

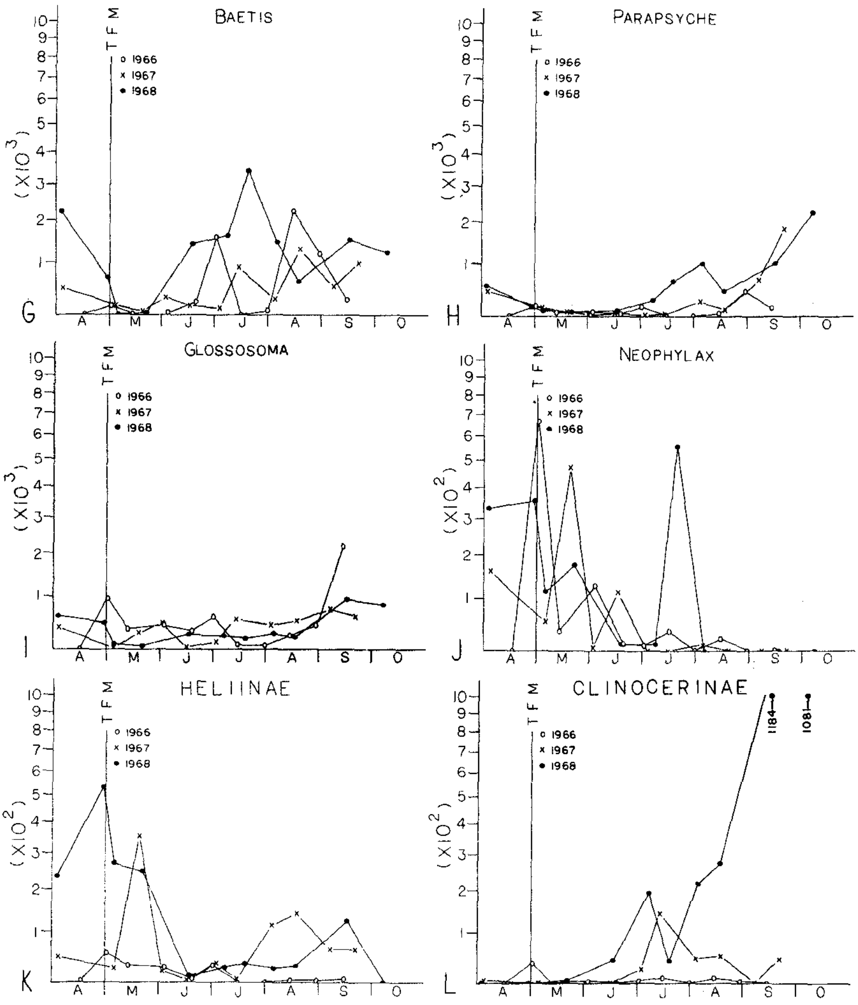


Fig. 3. (Cont.)

possible. Dermott and Spence (1984) concluded that increased drift rates rather than mortality may be the major impact of lampricides on invertebrate communities.

The survivors of a treatment may contribute also to the recolonization of a treated area. Several studies (Smith 1967; Kawatski 1973; Chandler and Marking 1975; Cawest 1980) have shown that invertebrates are generally not as sensitive as lamprey larvae to TFM and should not be severely affected at the concentra-

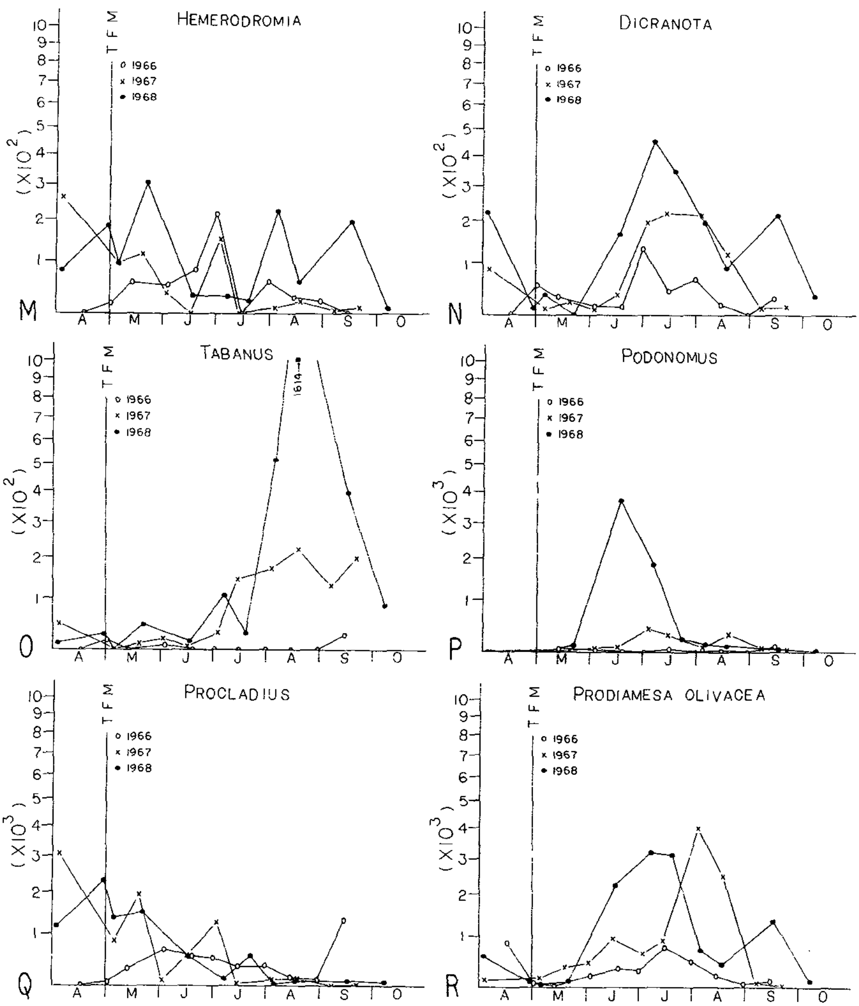
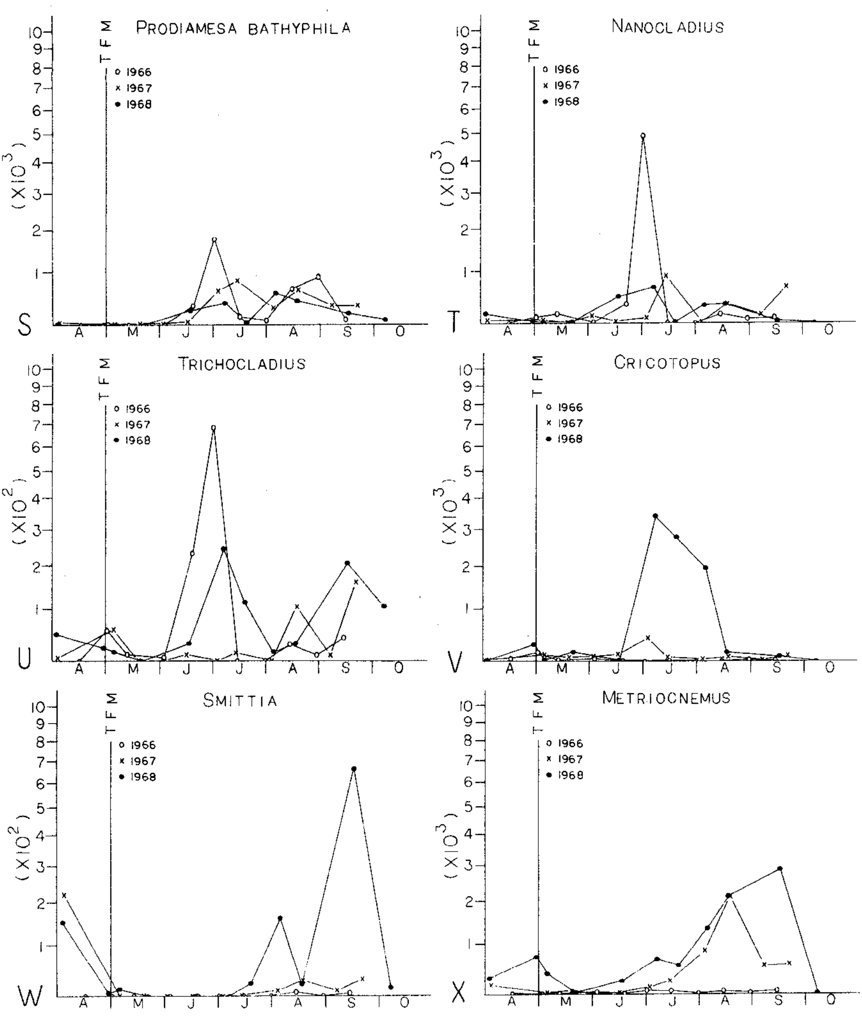


Fig. 3. (Cont.)

tions and exposure times commonly used in lampricide treatments. Significant ability to biotransform and excrete TFM has been demonstrated for oligochaetes, gastropods, crayfish, and various insects (Gilderhus et al. 1975); the mussel *Anodonta* sp. (Maki and Johnson 1976a); *Chironomus tentans* (Kawatski et al. 1974, 1975); the ostracod *Cypretta kawatai* (Kawatski 1973); and *Gammarus* (Sanders and Walsh 1975). Sanders and Walsh have shown also that *Daphnia* suffers no reproductive impairment after exposure to 10.0 mg/L TFM for three generations.



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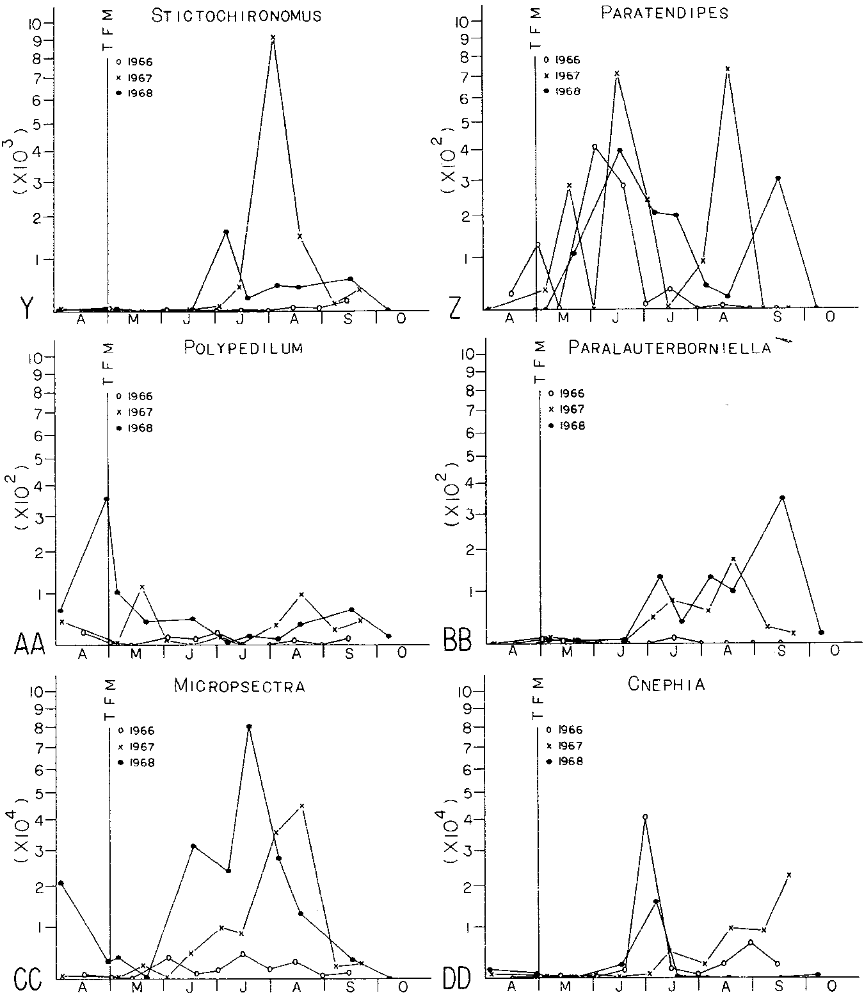
There is minimal damage and rapid recovery of stream habitats subjected to TFM (Gilderhus et al. 1975; Maki and Johnson 1977). Residues of TFM in sediment are effectively reduced to harmless materials through the action of microorganisms (Bothwell et al. 1973; Kempe 1973; Thingvold and Lee 1981). Another important pathway of TFM degradation may be photolysis (Carey and Fox 1981). Maki and Johnson (1976b) demonstrated that while gross biological production declined to low or undetectable levels during a TFM treatment, gross production, respiration, and P:R ratios returned to pretreatment levels within two days.



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SUMMARY

Results of the 1968 posttreatment samples showed no lasting deleterious effects of TFM on the Watson Creek macroinvertebrate community. Total numbers of organisms from the combined taxa were greatest in 1968, and 21 of the 30 numerically most important taxa in the study were most numerous in 1968 (Fig. 2). These 30 taxa were present after treatment (Table 5), as well as in the

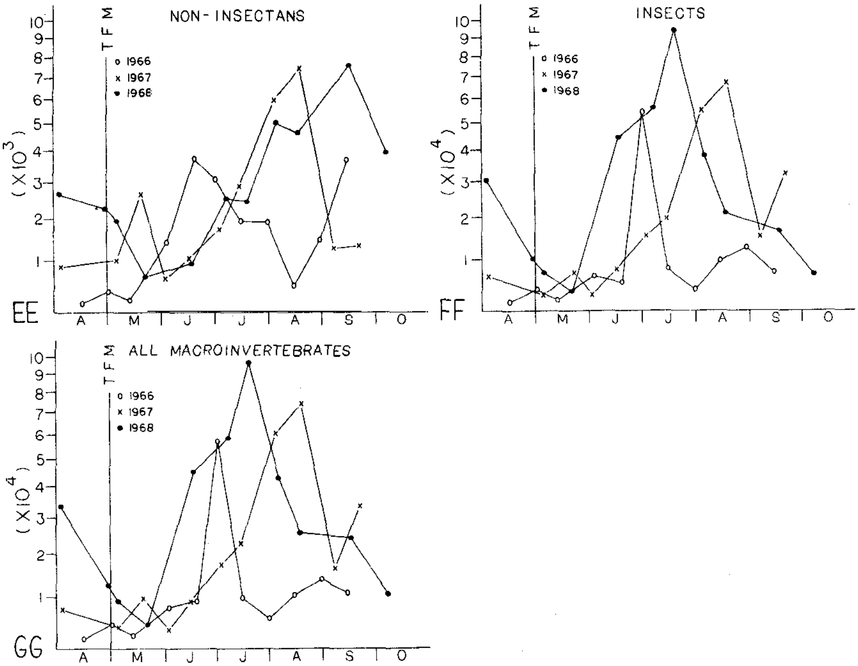

Fig. 3. (Cont.)

previous two years. In samples taken five days after treatment, 22 of these taxa were reduced in numbers from the samples taken one day before treatment. Subsequent samples in 1968 indicated recovery to numbers which compared favorably with or exceeded those in 1966 and 1967 collections (Table 6).

ACKNOWLEDGMENTS

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TABLE 6. Immediate and long-term effects of TFM on Watson Creek macroinvertebrate populations in 1968.

Taxon	Collected before and after treatment	Not collected before	Reduction after treatment	No apparent effect	Good post-treatment recovery[1]
Oligochaeta	X	-	X	-	X
Gammarus	X	-	X	-	X
Asellus	X	-	X	-	X
Pisidium	X	-	X	-	X
Nemoura	X	-	X	-	X
Paracapnia	X	-	X	-	X
Baetis	X	-	X	-	X
Parapsyche	X	-	X	-	X
Glossosoma	X	-	X	-	X
Heliinae	X	-	X	-	X
Clinocerinae		X	-	X	X
Hemerodromia	X	-	X	-	X
Dicranota	X	-	-	X	X
Tabanus	X	-	X	-	X
Podonomus	X	-		X	X
Procladius	X	-	X	-	X
Prodiamesa olivacea	X	-	X	-	X
Prodiamesa bathyphila	X	-	-	X	X
Nanocladius	X	-	X	-	X
Trichocladius	X	-	X	-	X
Cricotopus	X	-	X	-	X
Smittia	X	-		X	X
Metriocnemus	X	-	X	-	X
Stictochironomus	X	-	X	-	X
Paratendipes	-	X		X	X
Polypedilum	X	-	X		X
Paralauterborniella	X	-		X	X
Micropsectra	X	-	-	X	X
Cnephia	X	-	X	-	X

[1]Numbers compare favorably with 1966 and 1967 collections.

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