THE EFFECTS OF AN EXPERIMENTAL INJECTION OF METHOXYCHLOR ON AQUATIC INVERTEBRATES: ACCUMULATION, STANDING CROP, AND DRIFT

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Abstract

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A single 0.3 ppm injection of methoxychlor into the Athabasca River, Alberta on 4 June 1974 for 15 min caused catastrophic drift for a distance of over 400 km, and a subsequent large decrease in the drifting population. This decrease, when expressed as a percentage reduction from pretreatment drift, is in close agreement with percentage reduction of standing crop recorded by other sampling methods. The time required for the pesticide to affect different species varied considerably but was not related to the mode of feeding. Methoxychlor residues above ambient levels in water were recorded in all the invertebrate populations sampled. Caged animals had significantly different residues than the natural populations. The use of caged animals as indicators of environmental damage is therefore questioned.

Methoxychlor (1,1,1-trichloro-2,2-bis(p-methoxyphenyl)ethane) injection directly into streams is an experimental technique for controlling blackfly larvae, particularly *Simulium arcticum* Mall., at their growing sites (Fredeen 1974, 1975). *S. arcticum* is not a direct threat to man but has been blamed for the death of some 1100 livestock during 1944–47 in Saskatchewan (Fredeen 1974). Following this period DDT was used for some 20 years in the Saskatchewan River to control the larvae (Fredeen *et al.* 1971) and with the recent restrictions in the use of DDT, it was replaced by methoxychlor.

Various authors (Burdick *et al.* 1968; Fredeen 1972; Merna and Eisele 1973) have shown that methoxychlor is at least as acutely toxic to non-target aquatic invertebrates as DDT. However, the use of methoxychlor has continued because it is supposedly non-persistent in the environment (but see Merna and Eisele 1973); does not readily accumulate in fish (Kapoor *et al.* 1970; Fredeen *et al.* 1975); and is thought to be selective to blackflies because it is adsorbed onto suspended particles in rivers and thus selected by the filter feeding simuliid larvae (Fredeen *et al.* 1975). Wallace and Hynes (1975) and Wallace *et al.* (1976) have shown catastrophic drift (as defined by Waters 1966) of non-target aquatic invertebrates associated with methoxychlor treatments in clear streams in Quebec, and Fredeen (1974, 1975) indicated major, but apparently short-lived effects, on the fauna of the Saskatchewan River, Saskatchewan.

The following study was carried out to assess the impact of a blackfly larviciding program on non-target aquatic invertebrate fauna of the Athabasca River, Alberta and to develop methods to provide impact assessment of the effects of chemical treatment of large, fast flowing rivers. A more thorough statistical analysis of the data contained in this paper will be given in de March *et al.* (in prep.).

Methods

The Athabasca River is a large, fast glacial river draining north-east from the Rocky Mountains into Lake Athabasca. The mean flow at the town of Athabasca in 1974 was 572 m^3/sec, the maximum flow was 2520 m^3/sec recorded on 28 April. The flow in early June was around 750 m^3/sec (Water Surveys of Canada 1975).

On the morning of 4 June 1974, 786 ℓ of 24% emulsifiable concentrate methoxychlor were poured into the Athabasca River from the bridge at the town of Athabasca, Alberta. The liquid was dispensed simultaneously from a number of points across the bridge at a rate calculated to give a 15 min pulse of 300 μg methoxychlor/ℓ.

Four stations were established on the Athabasca River: I– the control station, upstream of the treatment point and approximately $^7/_8$ of the way across the river from the town of Athabasca; II–about 200 m downstream from the treatment point; III–67 km downstream; and IV–approximately 400 km downstream. Stations III and IV were just upstream of the confluence of the Athabasca River and the Calling and Clearwater rivers respectively. All three downstream stations were near the left bank of the river.

Methoxychlor Residue Sampling

Benthos samples were collected at each of the stations, downstream from the drift nets (see next section), using a dip net. These samples were sorted live to Order, wrapped in aluminum foil, frozen, and returned to the Freshwater Institute for methoxychlor analysis (Solomon and Lockhart 1977). Two groups of animals, the clam, *Lampsilis radiata* (Barnes), which occurs naturally in the river, and the crayfish, *Orconectes virilis* (Hagen), which does not, were suspended in cages in the river at each station (≃20 cages/station:4 clams/cage, 3–6 crayfish/cage). Crayfish were used because they were available, locally, in large numbers and are currently being developed as a bioassay animal in the Freshwater Institute. To avoid accidental introduction of an exotic animal into the river only male crayfish were used in the experiment. Animals were monitored regularly for mortality and general health (activity, posture, etc.) and were sampled at various times before and after treatment at each station. Crayfish blood was analyzed for calcium while the remaining body together with the clam samples were wrapped, frozen, and shipped to Winnipeg for methoxychlor analyses as previously described. The clam gill–marsupium tissue was analyzed separately from the remaining soft body tissues, while whole-body (less blood) analyses were carried out on the crayfish.

Benthos Population Studies

Drift sampling was carried out every 4 h starting 24 h before the treatment time (i.e. on 3 June) at stations I, II, and III, and 48 h after treatment time at station IV (to allow time for the methoxychlor to reach this station) and continued for 4 days. At each station two drift nets were used, a 400μ mesh "bomb" (Burton and Flannagan 1976) and a standard 400μ drift net. Both were suspended from an anchored buoy to sample at about ½ m above the river bed as described by Burton and Flannagan (1976). At station IV the "bomb" sampler was lost in the evening of the first day of sampling and could not be replaced until 1500 h on the third day of sampling. During this time it was replaced by another standard drift net.

Artificial substrate samplers consisting of barbeque baskets filled with 5–7 cm diameter stones, as described by Anderson and Mason (1968) but with a pan of fine sediment attached below the basket to simulate the rock over sand situation common in the Athabasca River, were set on the river bed, at each station shortly after ice-out (ca. 1–5 May). The samplers were all recovered from station III; some were lost at stations I and II; and all were lost at station IV. The remaining 60 samplers were removed from the three stations in groups of threes at various times before and after the treatment.

Triplicate bottom samples, using a modified Ekman grab (Burton and Flannagan 1973) at stations I and II and, because we had only one Ekman, Ponar grabs (Powers and Robertson 1967) at stations III and IV, were taken before, during, and 3 to 5 times after the calculated arrival time of the treatment at each station.

The grab and artificial substrate samples were sieved to remove the silts or sugar floated (Flannagan 1973) and then sieved. Drift, grab, and artificial substrate samples were all preserved in 10% formalin solution and sorted in the laboratory under the low magnification of a dissecting microscope.

After individual artificial substrate samples from each station were sorted, they were grouped into a pretreatment group (before any one station was influenced by the pesticide); a treatment group (including the first day the station was influenced by the pesticide, plus at least two other sampling days within 5 days of treatment) and a post-treatment group (samples taken 5 to 20 days after treatment). These three temporal groups allowed a relatively large number of samples to be used to estimate population densities. The numbers of samples in each temporal group are indicated on Fig. 3.

Since more grab samples were available than artificial substrates, the grab samples were sorted into one of five temporary groups viz. 24 May – 3 June (T1); 4 and 5 June (T2; 7 and 8 June (T3); 11 and 18 June (T4); and 24 to 27 June (T5). Each temporal group contained a minimum of six Ekman or Ponar samples, the larger number of samples available allowing a better coverage of the sampling period than with the artificial substrates. All data were converted to no./m^2 to facilitate comparisons. Preliminary analyses of the material indicated that means and variances were nearly always equal because of wide variability in the data. The raw data was therefore transformed as ln (no./m^2+1) which according to Bartlett (1947) makes the variances homogeneous and thus gives "truer" values of statistical significance. The transformed data were then compared using t-tests.

Results

Methoxychlor Residues

No mortalities attributable to the methoxychlor treatment were observed in the caged *Orconectes virilis* or *Lampsilis radiata*. Methoxychlor residue data (Fig. 1) indicates that this chemical was concentrated above the treatment's level (300 μg/ ℓ) by all the animals sampled. The maximum concentration factor is about ×33 for the naturally occurring animals, about ×3 for caged *L. radiata*, and ×1.6 for *O. virilis*. It is worthy of note that the caged animals accumulated proportionately less methoxychlor than the wild ones at station II but proportionately more at station III. At station II the Trichoptera and Plecoptera, mainly predaceous species, show methoxychlor levels at about the same maxima as the herbivorous Ephemeroptera. However, the Ephemeroptera seem to have taken up the insecticide faster than the other two groups since the first post-treatment mayfly samples were an order of magnitude higher than those for the caddis or stoneflies.

In all cases the methoxychlor residues which were at trace levels or undetectable in all the control situations (station I + pretreatment samples at the other three stations), returned to these levels within 23 days after treatment.

Grab Samples

The results from the Ponar and modified Birge-Ekman samples are presented in Fig. 2. Only the Chironomidae, Ephemeroptera, Plecoptera, and Trichoptera and totals for these four taxa are presented since the remaining animals were not consistently caught at all four stations. With the exception of the Ephemeroptera at T4, the populations densities at station I either remained stable or had a tendency towards increasing over the sampling period. This is substantiated by the results of t-tests comparing the pretreatment (T1) with the various post-treatment densities (T2, T3, T4, T5) (Table I) where the only significant changes ($p < 0.05$) in the densities were increases in chironomids and total benthos. Station II results show very large standard deviations in all the sets of samples with only the Plecoptera and Ephemeroptera showing significant changes from the T1 samples. The Ephemeroptera were totally eliminated for one sampling period (T2) and then apparently recolonized. The Plecoptera showed a temporary increase at T3 followed by total elimination at T4 with some evidence of recovery at T5.

All taxa at station III, and the Ephemeroptera and total benthos at station IV, show a similar pattern – an initial decline in population following treatment, an increase at

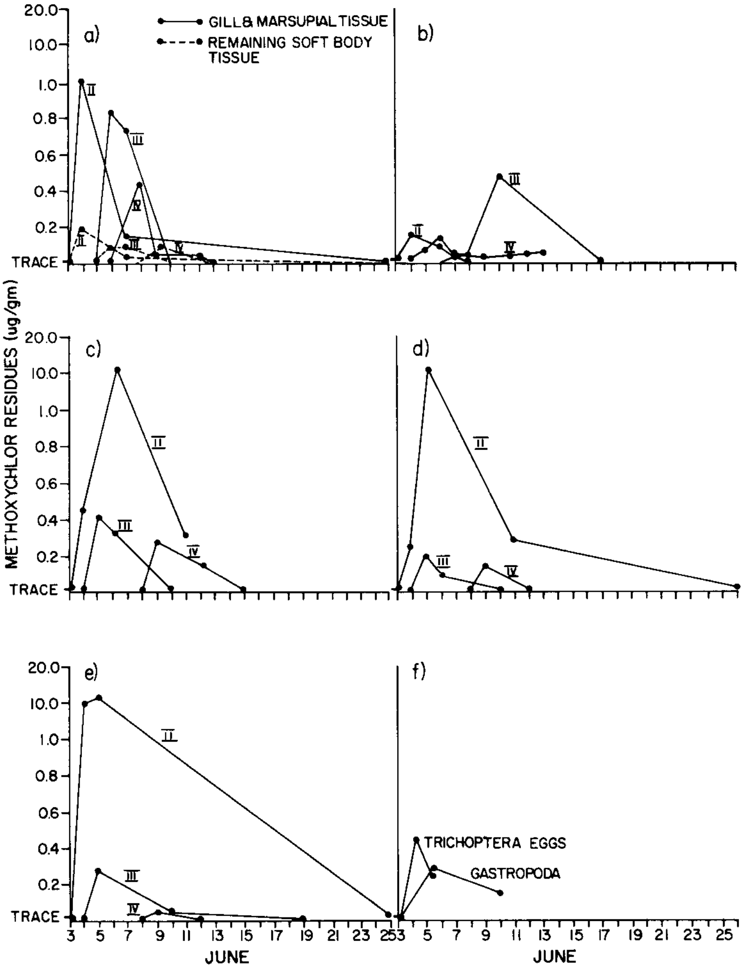

FIG. 1. Concentrations of methoxychlor in surviving non-target invertebrates after treatment: (a) clams, (b) crayfish, (c) Plecoptera larvae, (d) Trichoptera larvae, (e) Ephemeroptera larvae at stations II, III, and IV; (f) station II, miscellaneous samples.

T4, then a decline at T5. This phenomenon is probably the result of disturbed and drifting animals from upstream temporarily colonizing the downstream stations and then, because of population pressures or because of a delayed toxic effect, a partial or total collapse of the population occurs. Trichoptera and Plecoptera populations at station IV appear to react differently since they do not show the temporary post-treatment population increases.

It is of interest to note that, except for the chironomids at station IV, the mean densities of all the taxa at the three treated stations were always lower at T5 than at T1 (Fig. 2) while the reverse was true for the control station.

Artificial Substrate Samples

Invertebrate populations at station I essentially double over the sampling period while the populations at stations II and III decrease markedly over the same period with

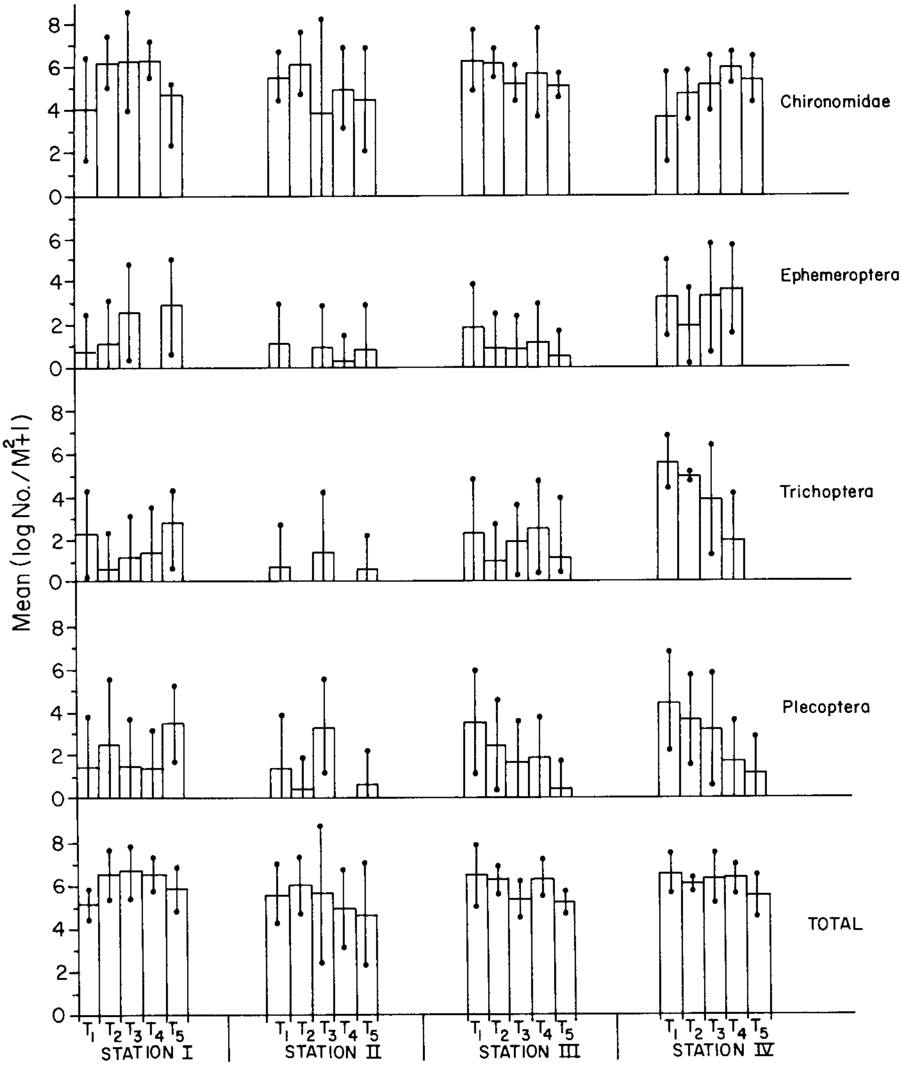

FIG. 2. Mean numbers [*ln*number/m^2+1)] and standard deviation of benthic animals collected in grab samples (Ponar, FRB, Ekman) at stations I–IV over T1–T5.

perhaps some post-treatment recovery at station II (Fig. 3). Similar to the results from the grab sample data, Plecoptera and Ephemeroptera are the most seriously affected taxa, reductions in numbers at station III being more extreme than at station II (Fig. 4). Some signs of recovery in Ephemeroptera, Plecoptera, and hydropsychid Trichoptera are evident at station II and in the hydropsychid at station III. Chironomids were apparently unaffected at station II but showed drastic decline with time at station III. Simuliids, Crustacea, and Oligochaeta were recorded only at station III thus no upstream control results are available. However, it is evident that very drastic reductions in numbers of these animals occurred over the sampling period at station III.

Table I. *t* values comparing mean densities of the various taxa of invertebrates estimated from Ponar and modified Birge-Ekman T1 samples with those at T2, T3, T4, and T5 at the various stations

	T1 vs. T2	T1 vs. T3	T1 vs. T4	T1 vs. T5
Station I				
Ephemeroptera	0.321	1.576	1.392	1.699
Plecoptera	0.676	0.088	0.231	1.682
Trichoptera	1.574	0.981	0.764	0.374
Chironomidae	2.191↑	1.707	2.674↑	0.497
Total of above taxa	2.127↑	2.337↑	3.433↑	0.458
Sample No.	13	15	15	11
Station II				
Ephemeroptera	1.885↓	0.171	1.059	0.204
Plecoptera	1.037	1.804↑	1.976↓	0.675
Trichoptera	1.215	0.778	1.282	0.104
Chironomidae	0.948	1.059	0.773	1.349
Total	0.814	0.072	0.784	0.817
Sample No.	17	13	18	13
Station III				
Ephemeroptera	1.139	1.210	0.753	1.454
Plecoptera	1.080	1.883↓	1.682	2.821↓
Trichoptera	1.352	1.163	0.221	0.080
Chironomidae	0.210	2.007↓	0.639	1.809↓
Total	0.350	2.022↓	0.308	1.823↓
Sample No.	19	19	19	14
Station IV				
Ephemeroptera	1.279	0.036	0.322	4.173↓
Plecoptera	0.596	1.010	2.250↓	2.651↓
Trichoptera	1.095	1.603	3.515↓	9.889↓
Chironomidae	0.969	1.978↑	2.553↑	1.866↑
Total	1.197	0.366	0.343	1.813↓
Sample No.	11	18	12	11

↑significant increase ($P < 0.05$) from pretreatment number.
↓.significant decrease ($P < 0.05$) from pretreatment number.

Drift

Catastrophic drift, especially of Ephemeroptera (Fig. 6), Trichoptera (Fig. 7), and Plecoptera (Fig. 5) were recorded at stations III and IV more or less simultaneously with the expected arrival of methoxychlor at these stations. In most cases the non-target insect drift continued at above normal densities for periods of 4 to 12 h then dropped to below pretreatment amounts. An exception to this was the Trichoptera drift, which exhibited large increases in densities coincident with the insecticide arrival at station III; however, the post-treatment numbers remained above the pretreatment ones throughout the remaining sampling time (Table II). This continued drift suggests that the effect of the treatment on Trichoptera is much longer lasting or that some Trichoptera are slower to react than other groups of invertebrates. Comparison of the individual species making up the drift indicates only small differences in the sensitivities of the various species to the methoxychlor: at station III, the stoneflies *Isogenus expansus* (Banks) and *Peltoperla* sp. reached peak numbers approximately 4 h before *I. frontalis* (Newman) and *Hastaperla* sp. (Fig. 5), and at station IV, *I. expansus* peaked 8 h before *Hastaperla* sp. Similar differences are evident among the mayfly species (Fig. 6) with *Rhithrogena* sp., *Ametropus neavei* McD., and *Ephemerella invaria* (Walker) peaking 4 h before *Heptagenia flavescens* Walsh and *Baetis* sp. at station III. It is also of interest to note that the latter two species showed little or no increase in drift at station IV while the first three species showed a decided disturbance.

Among the species of Trichoptera (Fig. 7) the catastrophic drift appears to be synchronous at station III but as much as 8 h apart even within one family, the Hydropsychidae (*Cheumatopsyche* sp. and *Hydropsyche* sp.) at station IV.

Small fish, mainly alevins and fry of the white sucker, *Catostomus commersoni* (Lacépède), appeared sporadically in the drift at the first three stations and, bearing in mind the inefficiency of the standard drift net (see Burton and Flannagan 1976), exhibited at station IV a very large increase in numbers, coincidentally with the increase in invertebrate drift, followed by a steady increase in numbers until the end of the sampling period (Fig. 8). It is possible that this first peak is due to a disturbance or kill of these animals by the methoxychlor followed by a disturbance or kill due to the lack of food items. However, since little is known of the migratory habits of the young of this species the steady increase, but not the initial increase recorded, may be a natural distributional phenomenon.

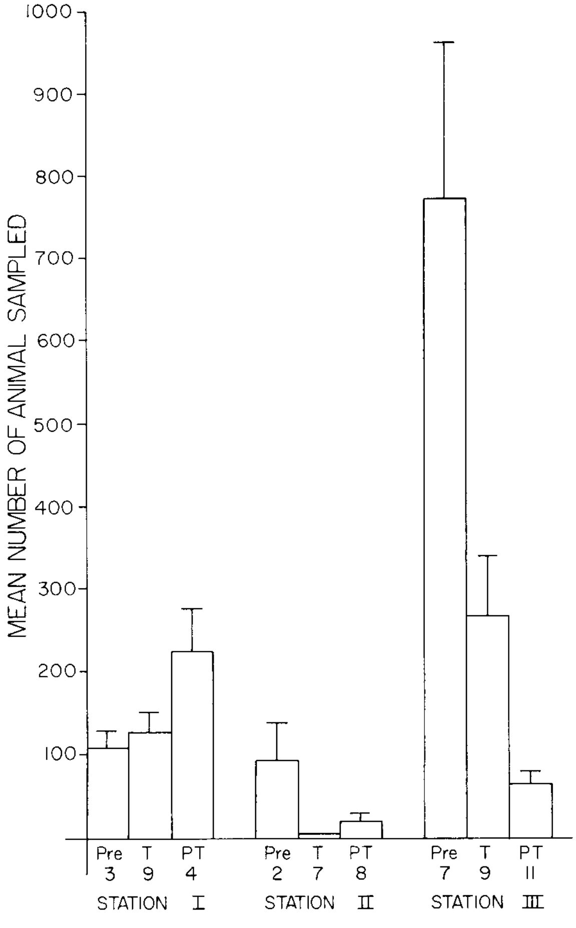

FIG. 3. Mean numbers and standard deviations of total animals sampled from artificial substrates at the upper three stations. (Pre, T, PT = pretreatment, treatment, and post-treatment samples respectively.)

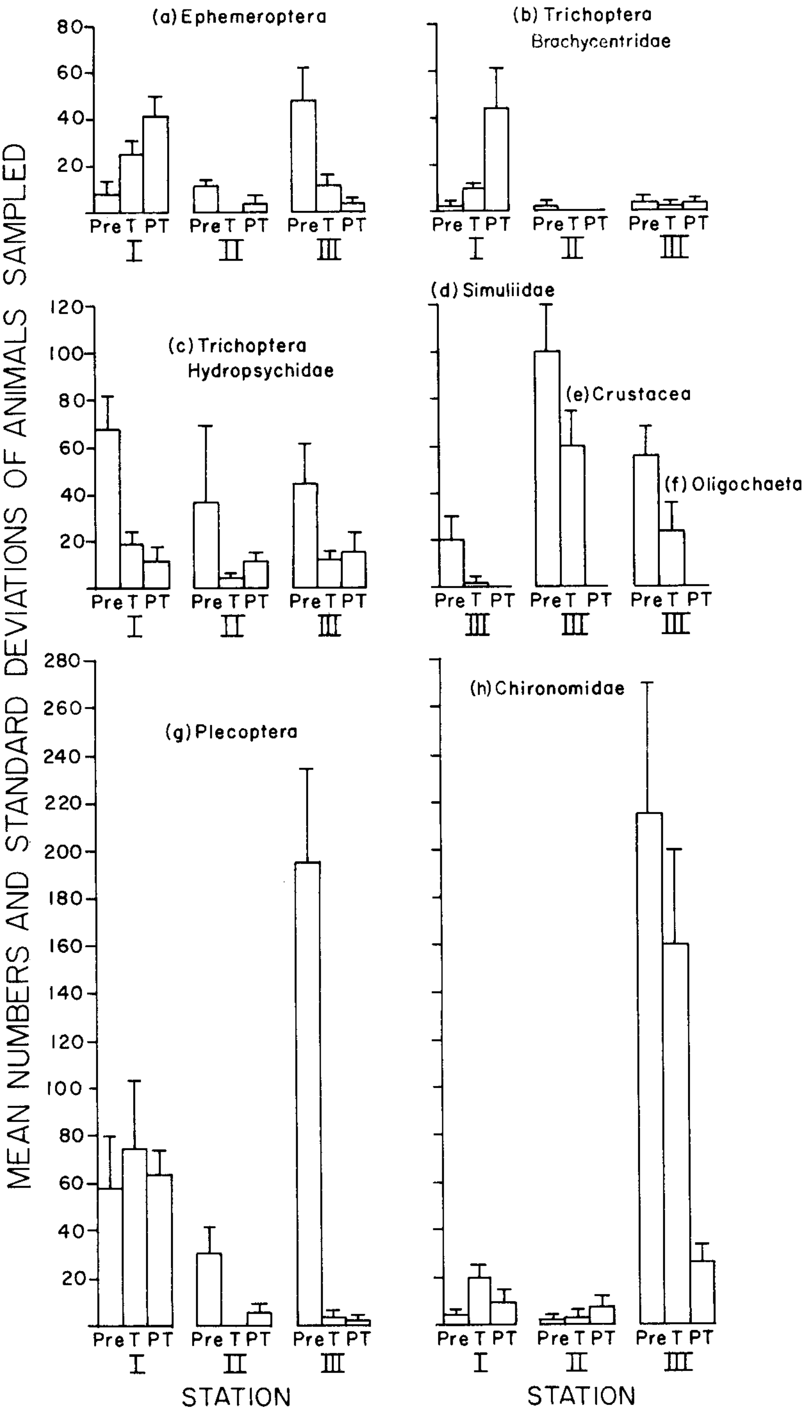

FIG. 4. Mean numbers and standard deviations of the various animal groups sampled at the upper three stations in artificial substrates. (Pre, T, PT = Pretreatment, treatment, and post-treatment samples respectively.)

Table II. Percentage change between pre- and late post-treatment numbers in the drift, grab, and artificial substrate samples at the various stations

	Ephemeroptera	Plecoptera	Trichoptera	Chironomidae	*S. arcticum*	Other inverte-brates
			Station I (control)			
Drift	+31.5	+2.65	+16.05	-	+32.5	+9.1
Grabs	+364.9	+455	+265	+660.3	-	+503.5
Art. subs.	+362.5	+20.7	+1200	+275	-	-
			Station II			
Drift	+35.5	+19.9	−3.75	-	−12.3	+7.35
Grabs	−27.6	−73	−8.8	+38.9	−94.5	-
Art. subs.	−66	−83.3	−100			-
			Station III			
Drift	−83.8	−95.45	+5.15	-	−8.5	−20.1
Grabs a)	−63.6	−89.0	−51.6	−41.1	+100.5	−14.1
Art. subs.	−90	−99.0	0	−88.2	−100	−100
			Station IV			
Drift	−49.0	−85.6	+180	-	+664.7	−32.3
Grabs	−100	−95.4	−100	+98	−100	−9.2

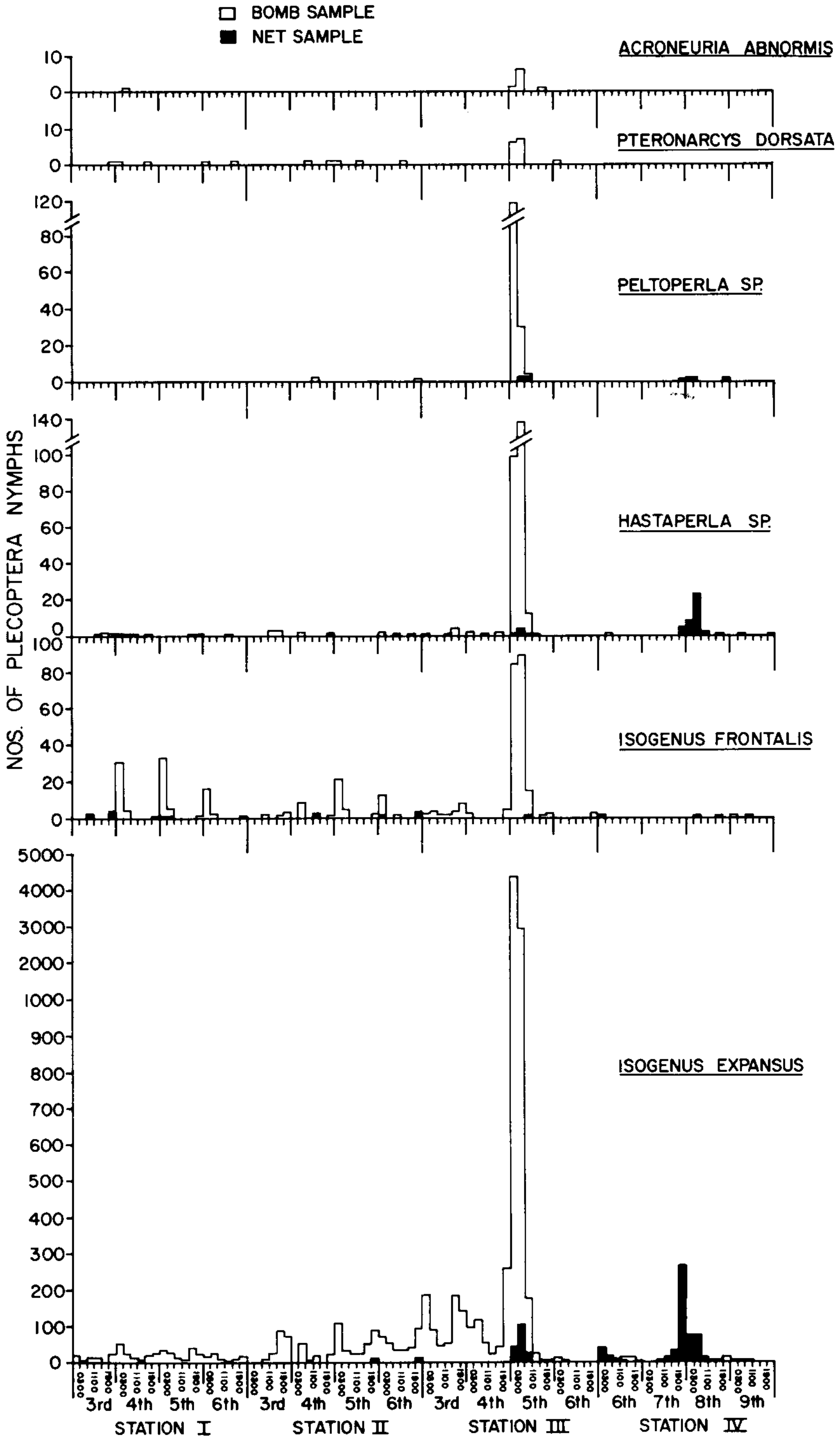

FIG. 5. Numbers of each species of Plecoptera caught every 4 h by drift samplers on 3–6 June at stations I–III and 6–9 June at station IV.

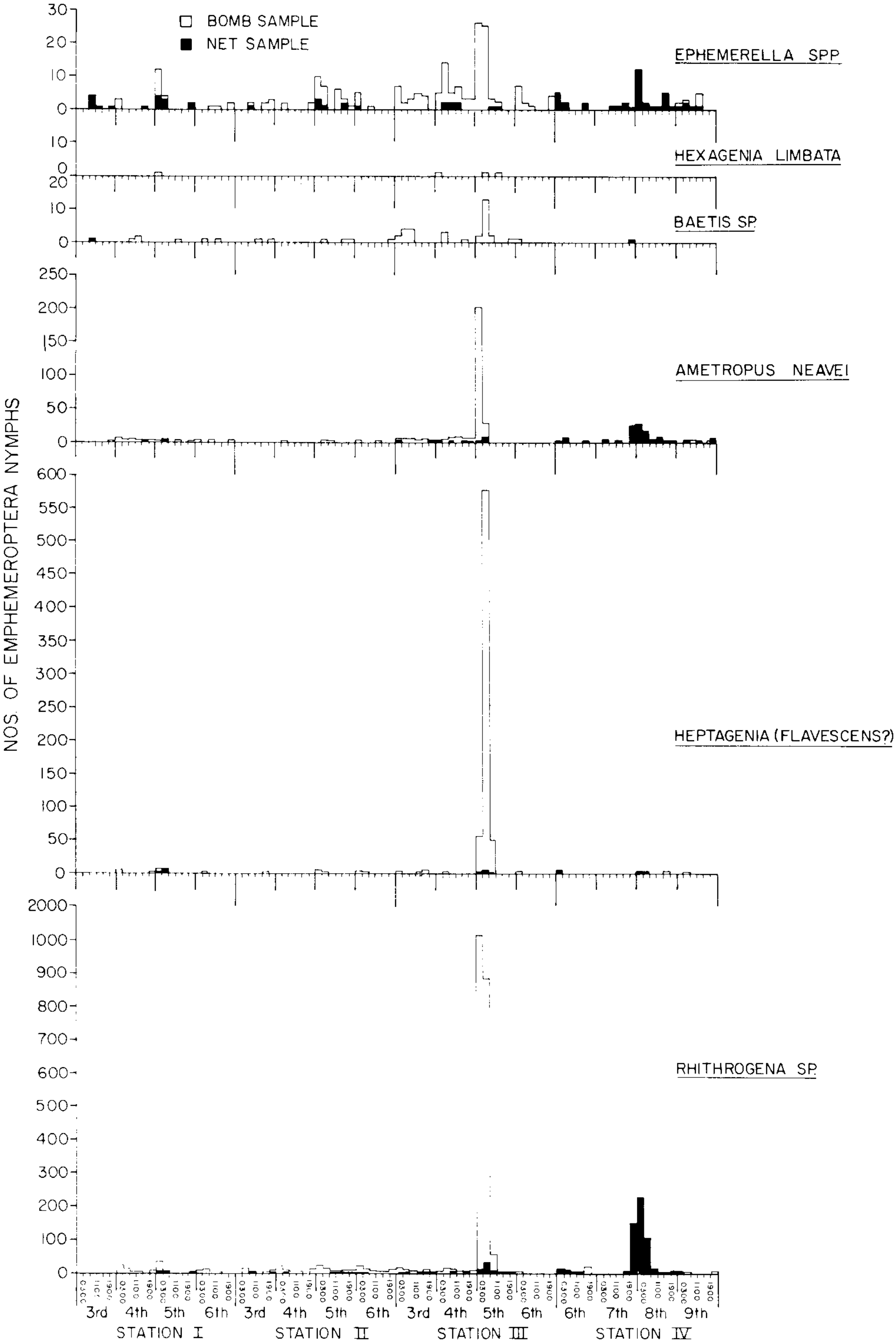

FIG. 6. Numbers of each species of Ephemeroptera caught every 4 h by drift samplers 3–6 June at stations I–III and 6–9 June at station IV.

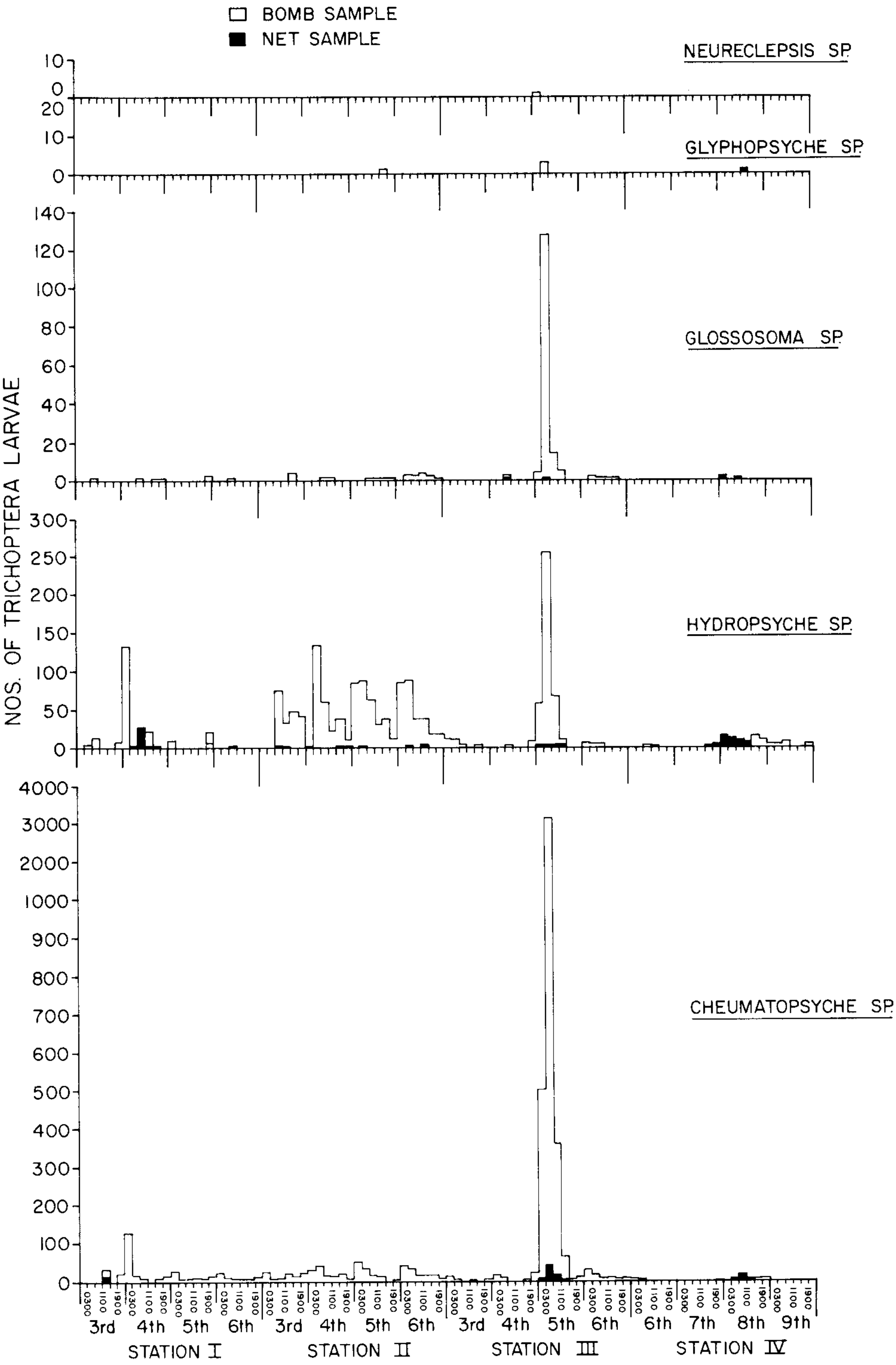

FIG. 7. Numbers of each species of Trichoptera caught every 4 h by drift samplers on 3–6 June at stations I–III and 6–9 June at station IV.

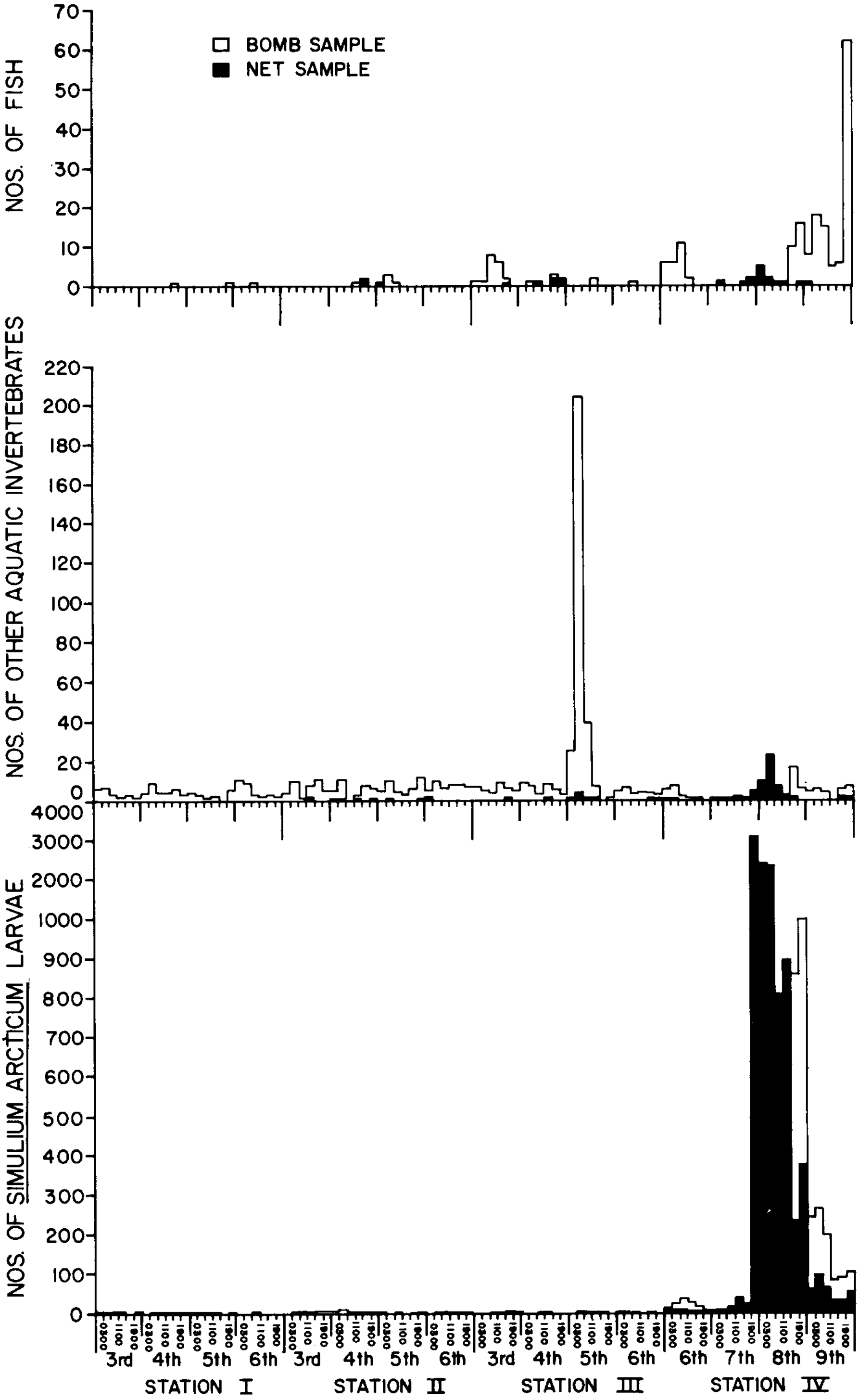

FIG. 8. Numbers of fish alevins, *S. arcticum* and other aquatic insects caught by the drift samplers on 3–6 June at stations I–III and 6–9 June at station IV.

Simulium arcticum appeared in the drift at stations I, II, and III relatively consistently but in very low numbers (Fig. 8). At station IV they showed a decided and long lasting catastrophic drift which, although still above the pretreatment levels (Table I), declined towards the pretreatment levels by the last day of sampling. The distribution of *S. arcticum* in the pretreatment drift suggests that although this species is present along most of the river, the largest concentrations occur between station III, 67 km downstream from the treatment injection point, and station IV, 400 km downstream. This area contains several rapids which are likely to be the main growing areas for *S. arcticum*.

A comparison of pretreatment mean numbers of the various taxa of aquatic invertebrates caught in the artificial substrate and grab samples, and pretreatment mean number per 24 h in the drift samples with the last set of post-treatment samples, is presented in Table II. Increases in population density, many of them very large, occurred in all the taxa at station I. Reductions, in some taxa almost total, occurred in most taxa from the treated areas. Further, the general rise in standing crop which occurred at the control station, makes the percentage decreases even larger at the treated stations. It therefore seems clear that post-catastrophic reductions in both drift and standing crop of benthic invertebrates occurred downstream from the injection site.

Discussion

Waters (1965) divided observed drift into three categories: constant, behavioural and catastrophic, depending on the shape of the drift pattern and the cause of the drift. The rapid, short term increases in drift associated with insecticide treatments in rivers (e.g. Wallace and Hynes 1975) most closely resembles, in magnitude and cause, Waters (1965) catastrophic drift. This term might, for the purposes of this paper, be defined as significant change in the time of day of maximum drift or an increase of more than an order of magnitude in drift densities related to the treatment, at any particular time of day.

In this study station II drift does not show any clear signs of increased post-treatment drift resulting from the methoxychlor addition. However, there seems to be no doubt that the invertebrates in the area of this station were severely depleted since collections of 1 g of animals required for the methoxychlor analyses took one person only a few minutes before treatment but took four people several hours after treatment. Also the artificial substrate samples show decided population decreases after treatment at this station. It would therefore seem likely that in a large, fast river such as the Athabasca, drift populations are recruited from areas at least several hundred meters upstream. Invertebrates normally drift only a few meters or tens of meters (Waters 1964, 1965). The failure to demonstrate catastrophic drift at this station is thus probably related to the origin of the drifting animals caught being upstream of the injection site. Also the distance between the injection point and station II was probably insufficient to allow the dead animals to be lifted the 0.5 m from the bottom to be caught in the drift samplers. The results at the remaining two stations clearly show that the methoxychlor treatment varied in time of maximum effect, in duration of effect, and in effective distance, depending on the species involved. Serious, and in some cases almost total reduction, occurred in many species.

Fredeen (1974) suggested that methoxychlor was adsorbed onto suspended particles carried in the water and was thus selective to filter feeding animals, while Wallace and Hynes (1975) have shown this insecticide to be totally non-selective in small clear streams. The present data support the latter suggestion since the predaceous Plecoptera, the detritus feeding Ephemeroptera, and the filter feeding animals all appeared to be affected by methoxychlor at about the same time. This similarity in reaction time among animals of differing trophic levels suggests that methoxychlor is not necessarily an internal poison (as suggested by Fredeen *et al.* 1975) but may kill or disable on contact.

Fredeen (1974, 1975) suggested that river treatment with methoxychlor was acceptable because no species of non-target invertebrates was eliminated and all Orders had repopulated the treated area in a few weeks. Wallace and Hynes (1975) and Wallace *et al.* (1976) have suggested that these two criteria are not necessarily the criteria with which the acceptability of this or any other method of control should be measured. It seems likely that significant reductions in bottom fauna will cause a reduction in the food supply of insectivorous fish, birds, and mammals; however, until these relationships and the dynamics of river ecosystems are better understood no definitive criteria can be set. Our grab and artificial substrate samples showed short term reductions similar to those indicated by the drift method (Table II) and no significant recovery in 4 weeks especially of the furthest downstream station. The apparent anomalies between the studies mentioned above and this one are perhaps partially related to differences in the rivers studied but are also largely affected by different methodologies used to measure the treatment effect on the system. For instance, the artificial substrates of Fredeen (1974, 1975) and ours all differ from each other, and the drift "bomb" used in this study (Burton and Flannagan 1976) has been shown to be considerably more efficient, especially in sampling the non-target taxa involved here, than the standard drift net utilized by both Fredeen (1974, 1975) and by Wallace and Hynes (1975). The distances over which the effect was measured also varied considerably in the various studies and it is obvious from this study that disturbances extend much further downstream than was previously realized.

Residues of methoxychlor in the animals analyzed (Fig. 1) appear to have been relatively short lived, very similar among all the free living taxa sampled, and decreased with distance downstream. However, one should remember that here we were sampling surviving animals and the affected ones may have had much higher residues. The caged animals show concentrations of methoxychlor lower than in the natural populations at station II, but much higher at station III. The concentration of methoxychlor in the clam tissues follows the natural populations in that maximum concentration decreases with distance downstream while the crayfish show peak concentrations at station III, 67 km downstream. Similar differences between caged and wild fish have been recorded by Lockhart *et al.* (1977). None of the caged animals died and the series of measurements taken as indices of sublethal effects (see Leonhard 1978) showed no conclusive evidence that the methoxychlor had any effect on these animals. Although the reasons for the difference in concentration between the caged and wild animals are unknown the crayfish, which were exotic to the system, may not be representative. Alternatively, and perhaps more likely, the reasons may be related to factors like stress produced by captivity and the resultant interference with normal feeding and other behavioural patterns. However, the results do indicate the unreliability of using caged animals, especially exotic ones, as indicators of ecosystem effects, at least in this system. Fredeen *et al.* (1975) in a study of methoxychlor residues of various components of the ecosystem in the Saskatchewan River following a treatment of the same concentration as in this study, found detectable residues in invertebrates only during the treatment time. In studies of five species of fish they found detectable residues only in goldeye and attributed this to the high lipid levels in the species; however, it is interesting to note that of the five species, goldeye and suckers are the only ones which are mainly insectivorous and of these two, only goldeye consistently feeds in mid or surface waters and would therefore be the species most likely to take advantage of the catastrophic drift of invertebrates caused by the treatment.

The remaining three sampling methods (drift, grab, and artificial substrate) appear to demonstrate similar decreases as a result of treatment. However, the drift sampling should have been extended by at least 2 days in order to investigate the possibility of an eventual reduction of densities of Trichoptera and *Simulium* shown by the other two methods.

The grab sample results are more variable than the artificial substrates partly because the grabs sample a variety of substrates and not just the 5–7 cm stones. Thus variation in numbers and kinds of animals should be expected. Further, in a large river like the Athabasca the only areas effectively sampled with grabs of this kind are those with finer sediments, e.g. the wide calm areas of the river proper, in backwaters, behind islands, etc. Slow flowing areas of the river may get a higher concentration of methoxychlor than ambient while the backwaters get lower than ambient concentrations because of differential deposition of substrates, and the fauna may be showing the difference.

Conclusions

Methoxychlor treatment for blackfly larvae control removed blackfly larvae for long distances downstream. Catastrophic drift of non-target invertebrates followed by large decreases in both drift and standing crop occurred to a distance of 400 km downstream from the injection point. All non-target invertebrates, regardless of trophic level, appeared to be affected at about the same time. The results suggest that methoxychlor is not selective for blackfly larvae. Little recolonization of non-target invertebrates was recorded within 4 weeks after treatment. Methoxychlor levels well above ambient water levels were recorded in natural populations of invertebrates, generally different levels being recorded in caged clams and crayfish. The caged animal method is therefore not recommended for studies of this nature. Measurements of drift and estimates of changes in standing crop using artificial substrate samplers appeared to give the most consistent indications of environmental perturbation.

Acknowledgments

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