THE EFFECT OF FENITROTHION FROM LARGE-SCALE FOREST SPRAYING ON BENTHOS IN NEW BRUNSWICK HEADWATERS STREAMS

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Abstract

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Kills of arthropods in three streams containing fenitrothion up to 6.38 ppb were measured using drift nets. Stoneflies and some species of mayflies were most affected. The drift responses of various taxa to the insecticide and to stream discharge are documented. The benthos was not seriously depleted.

Résumé

Des arthropods morts furent prit aux filets dans trois ruisseaux contenant du fenitrothion jusqu'au niveau 6.38 ppb. Des plécoptères et certains éphéméroptères étaient le plus touchés. L'auteur décrit les réactions des différents taxons à l'insecticide et au débit des ruisseaux. La faune du fond ne fut pas épuisée.

Aerial spraying for forest protection against the spruce budworm, *Choristoneura fumiferana* Clem., deposits fenitrothion in stream water (Eidt and Sundaram 1975). D. J. Wildish and R. L. Phillips (1972) found that fenitrothion was lethal to some aquatic insects at concentrations such as those found by Eidt and Sundaram. Banks (1973) found increases in drift with spray concentration in a New Brunswick stream, but did not determine if it represented mortality. In this paper I will relate benthos kills to fenitrothion concentrations and its persistence in stream water. Interactions with spates will be described.

This work is part of the Nashwaak Experimental Watershed Project, a cooperative project of the Canada Department of the Environment, the University of New Brunswick, the Province of New Brunswick, and the St. Anne-Nackawic Pulp and Paper Co. Ltd. The project is concerned with terrestrial and aquatic impacts of chemical and physical changes resulting from forest clear cutting and fertilization. The effects of insecticides on aquatic fauna may be profound (Cope 1966; Holden 1972; Muirhead-Thompson 1971), and may mask the effects of the prescribed treatments. It was impractical to exempt the area from aerial spraying, therefore the effects of the insecticide on the aquatic fauna had to be determined.

Three brooks, Middle,* Hayden, and a small branch of Lake, were studied. All are tributaries of the Nashwaak River, a tributary of the St. John River, and are located in the uplands of west-central New Brunswick.

The area, which ranges in elevation from 200 to 425 m, is completely forested, the principal trees being *Acer* spp., *Fagus grandifolia* Ehrh., *Abies balsamea* (L.) Mill., and *Picea rubens* Sarg. Hardwoods and softwoods occur in about equal numbers, the softwoods predominating in lower areas. Except at some beaver ponds and openings caused by beaver activity, the forest canopy closes over the streams. Hayden Brook has a catchment area of about 700 ha, Middle Brook about 400 ha, and Lake Brook, with the least relief, about 125 ha. Precipitation is about 125 cm fairly evenly distributed throughout the year, but because most accumulates as snow for 5 months, a heavy spring runoff occurs.

Methods

Drift organisms were collected in nets constructed of nylon bolting cloth with 0.6 mm apertures. The nets (31 cm wide, 20 cm high, 66 cm long) were affixed to sample a column of water from the stream bottom, to and including the surface. They were set for

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*Name changed to Narrows Mountain Brook, March 1975.

15 min every 3 h. Each catch was emptied into a holding cage constructed from a plastic dishpan with screened holes (0.6 mm apertures) at each end. They were placed in the same stream so that water could pass through, and were weighted with rocks which also provided some refuge for the animals. The drift was held in these cages for 24 h to allow fatally poisoned animals to die. Within the next 2 h it was sorted into living and dead fractions.

Stream discharge at the sample site on Middle Brook was measured with a propeller-type flow meter to determine the proportion flowing through the nets. Obstruction by the nets was estimated to be 15%.

Water depth, being a function of discharge, was measured at each sample station every time a drift sample was taken. Water level and discharge on Middle and Hayden brooks were measured hourly by the Canadian Water Survey. Water samples for fenitrothion analysis were collected according to a sequential schedule following each spray. Data on water depth, discharge, and fenitrothion concentration in the stream water are given by Eidt and Sundaram (1975).

Benthos was sampled with artificial substrates located above the drift sample stations. Two pot samplers after the design of Coleman and Hynes (1970) were installed in each stream and sampled at 4-week intervals. They were 20 cm deep by 21.3 cm diameter, and constructed of perforated sheet aluminum. Two artificial substrates, stoneman samplers, after a design used by the Fisheries Research Board Biological Station, St. Andrews, N.B., were sampled in each stream at 3-week intervals. They were 39 cm in diameter, of 0.64 cm (¼ in.) steel boiler plate with 2 cm raised rims, and two discs of coarse screen in the cavity. They were similar to the sampler described by Beck (1970) but without the cover.

Effects on Total Drift

In all three streams drift fluctuated, with the greatest catches at night, as is normal (Waters 1972). The amplitude of the diel fluctuations varied among streams, but the patterns were similar except during spates and when fenitrothion was present. The data on drift, both living and dead, are shown in Figs. 1 to 3, the time scales being the same as for the water depth, discharge, and fenitrothion concentration curves of Eidt and Sundaram (1975, figs. 2 to 4).

Middle Brook (Fig. 1)

A brief increase in living drift occurred at 1800 h on 9 June, probably because the fenitrothion concentration in the water had been 0.16 ppb 4 h earlier. A greater increase that occurred at midnight and at 0300 on 10 June was due to the spate that occurred that night.

From 1500 h 12 June to 2400 h 13 June, drift was high. It contained a large dead component that still persisted on 15 June. Following the treatment of the spray block containing Middle Brook, between 0657 and 0755 h on 12 June, fenitrothion concentrations in the stream water rose as high as 5.25 ppb (Eidt and Sundaram, fig. 2). This was the direct cause of the kill which, although high after 1300 h 12 June and all day 13 June, showed nighttime peaks as in normal diel fluctuations of living drift.

Drift samples during a 24-h period, 20–21 June, yielded less living drift than any comparable period before the 12 June fenitrothion peak.

Hayden Brook (Fig. 2)

The amount of living drift rose sharply on the night of 9–10 June due to a spate. The spate was more abrupt and intense than that in Middle Brook; the rate of discharge increased nearly 5-fold in only 5 h.

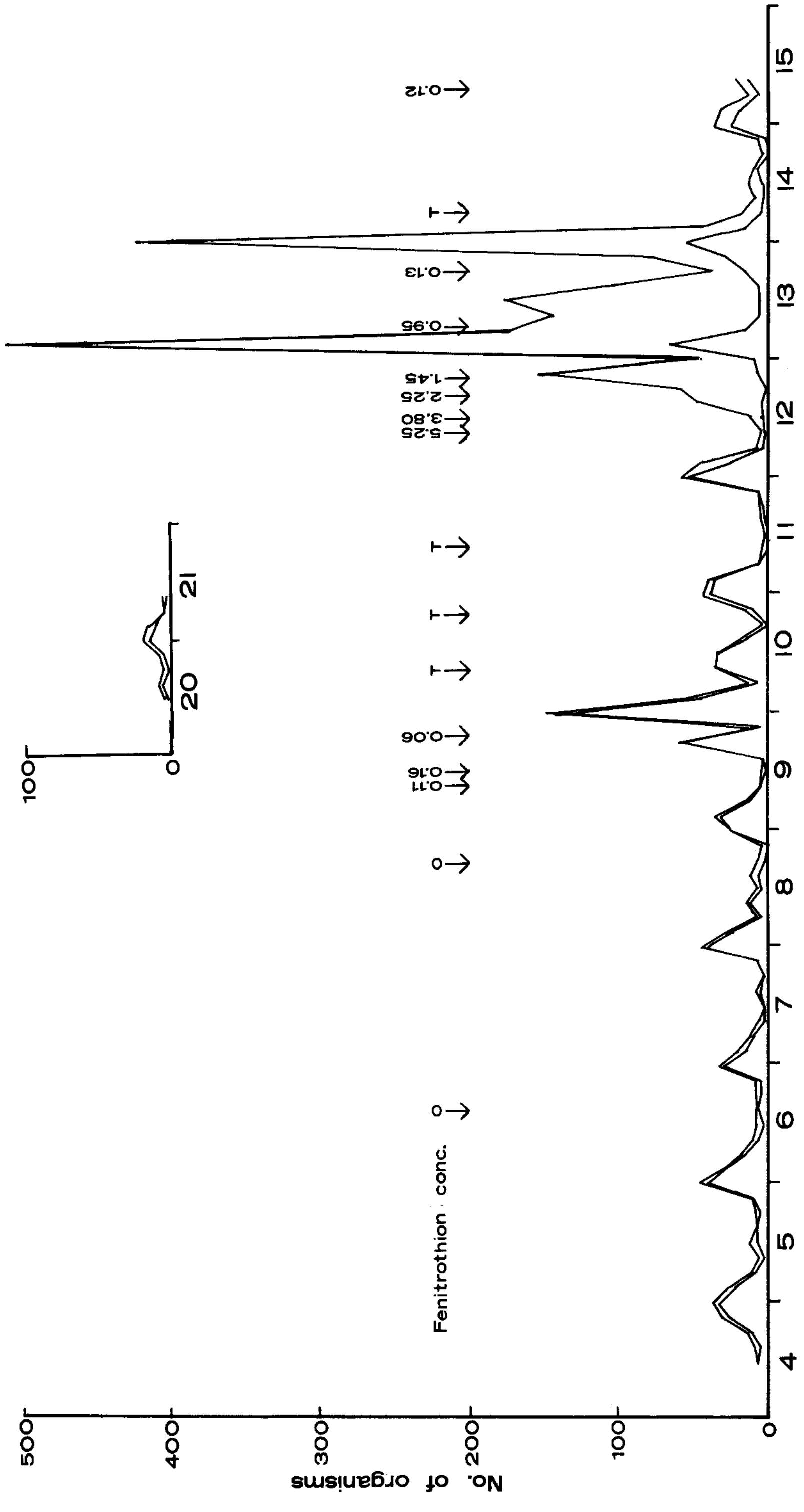


FIG. 1. Numbers of organisms in 15-min drift samples from Middle Brook (lower line = living, upper line = living + dead). Fenitrothion concentrations in the stream water are given in parts per billion (T = trace, O = none detected).

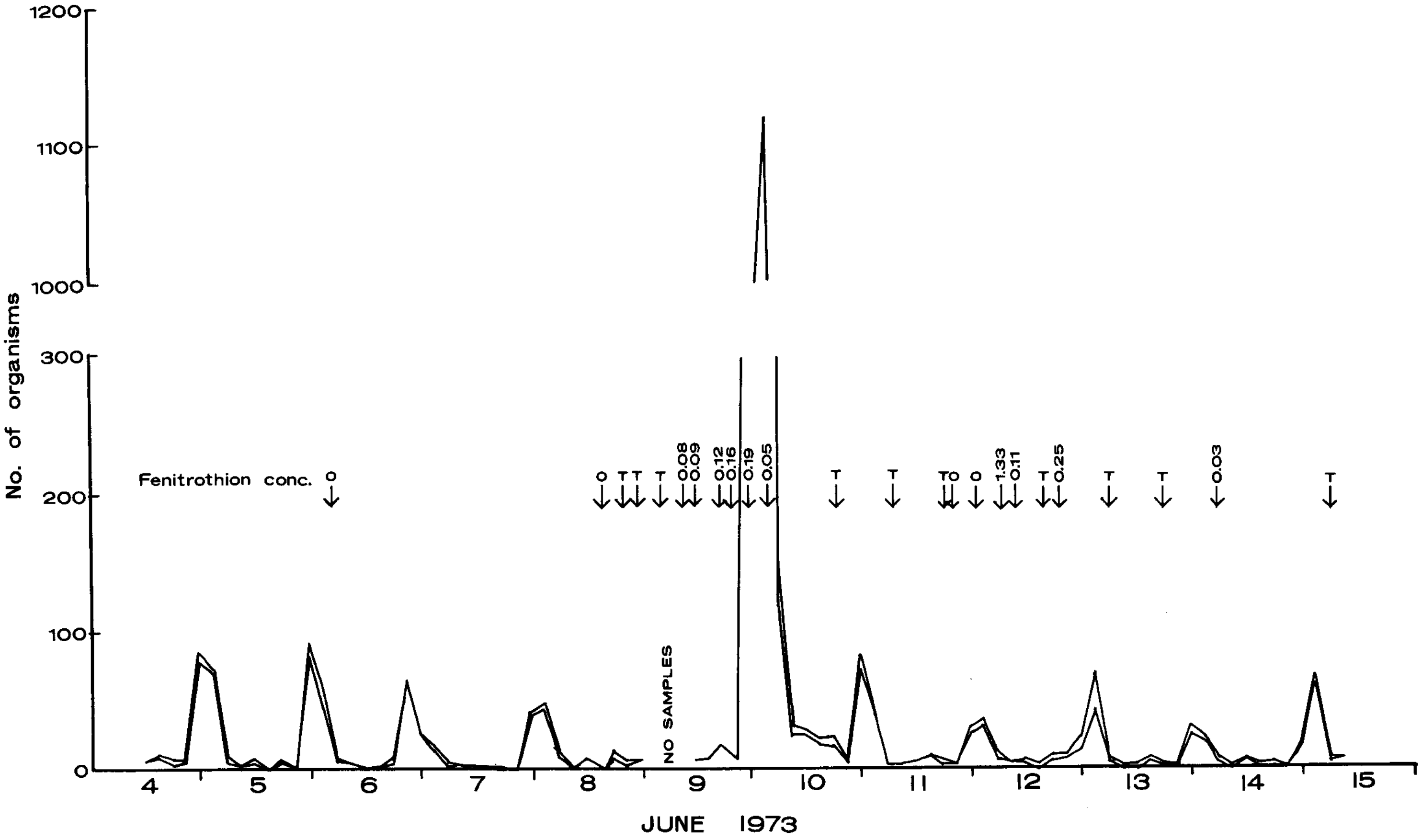


FIG. 2. Numbers of organisms in 15-min drift samples from Hayden Brook. Legend as Fig. 1.

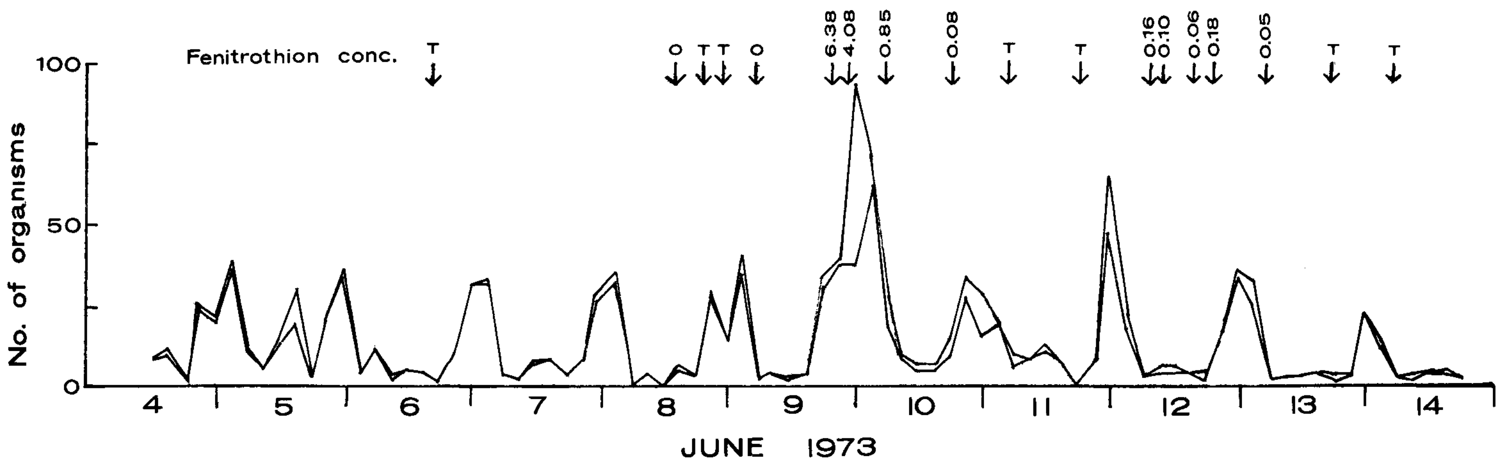


FIG. 3. Numbers of organisms in 15-min drift samples from Lake Brook. Legend as Fig. 1.

Figure 2 indicates that the numbers of dead drift insects twice rose slightly above background levels. The first time was 10 June when fenitrothion concentration rose to 0.12 ppb and remained above 0.05 ppb for 20 h despite dilution by the spate (Eidt and Sundaram, fig. 3). The second time was at 2400 and 0300 h the night of 12–13 June following a brief rise in fenitrothion concentration to 1.33 ppb the morning of 12 June.

Lake Brook (Fig. 3)

Increase in drift occurred the night of 9–10 June when the stream was in spate. There was also a larger than usual dead component during each of the next three nights which, at least the night of 9–10 June, was due to the high fenitrothion concentration (6.38 ppb) that evening. Although this concentration was higher than that recorded in Middle and Hayden brooks, it dropped much faster because of the spate (Eidt and Sundaram, fig. 4). The dead drift during the nights of 10–13 June could be caused by persisting low concentrations affecting already weakened animals.

The midday increase in drift on 5 June with its large dead component at 1500 h is unexplained. No samples for fenitrothion concentration were taken that early, but I know of no way that fenitrothion might have entered the stream that day.

Effects on Various Taxa

Plecoptera

There was a large increase in drift of Plecoptera in Middle Brook after the peak concentration of fenitrothion on 12 June. Plecoptera in benthos samplers apparently declined on Middle Brook from 4 June to 2 July (Table I), but both *Amphinemoura* spp. and *Leuctra* spp. were emerging during the period, thus obscuring any possible depletion due to fenitrothion.

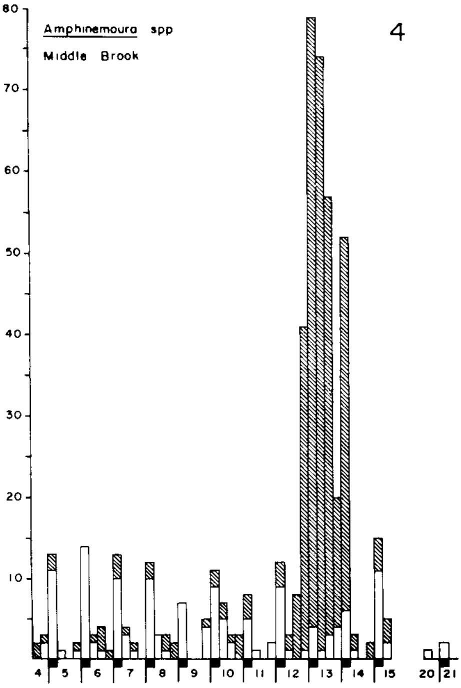
Amphinemoura spp. in Middle Brook (Fig. 4), mostly *A. wui* (Claassen) but some probably *A. nigritta* (Provancher), were abundant in drift and in benthos samples from rubble and coarse gravel. Pretreatment drift peaked at night and about a quarter of the daily catch was dead. There was no response to the spate of 9 June. With the high fenitrothion concentrations of 12–13 June, drift increased up to 12-fold and most was dead. The very high kill lasted 2 days after which drift returned to near normal levels. Living *Amphinemoura* spp. were still present in drift on 20–21 June, but in lower numbers possibly due to emergence and very low water levels. In Hayden Brook (Fig. 5), *Amphinemoura* spp. responded to the more intense spate of 9 June, but there was no effect of fenitrothion on drift. In Lake Brook (Fig. 6), *Amphinemoura* spp. increased in drift during the spate of 9 June and kill coincided with the high fenitrothion concentration of 10 June. In stoneman samplers (Table II), there was no clear indication that *Amphinemoura* spp. populations changed in any of the streams.

Leuctra spp. in Middle Brook (Fig. 7), including *L. fenella* Provancher and *L. tenuis* (Pictet), did not show pronounced nocturnal drift peaks, and were much scarcer in normal drift than *Amphinemoura* spp. *Leuctra* spp. numbers increased slightly following the spate the evening of 9 June. With the occurrence of a high fenitrothion concentration on 12 June the daily drift, most of it dead, increased more than 100-fold, and was still abnormally high on 15 June when sampling was stopped. No *Leuctra* spp. were taken 20–21 June. In Hayden Brook (Fig. 8) *Leuctra* spp. showed strong nocturnal peaks, with a response to the spate of 9 June but an insignificant increase in the dead component on 10 June. In Lake Brook (Fig. 9) *Leuctra* spp. drift increased from 10 June to 13 June, again with small but insignificant increases in the dead component. Benthos samplers showed an apparent decrease in *Leuctra* spp. in Middle Brook (Table II) from 28 May to 18 June, which, at least in part, was due to emergence. In Hayden and Lake brooks, *Leuctra* spp. in benthos increased or remained

Table I. Numbers and biomass of invertebrates from Coleman–Hynes pots, taken before and after the 1973 budworm spray program

						Total invertebrates less crayfish	
Brook	Date	Plecoptera	Ephemeroptera	Trichoptera	Chironomidae	Number	Biomass (mg)
Middle	4 April	216	92	8	25	347	238
(stn. 4)	4 June	235	187	16	51	494	599
	2 July	117	298	10	67	494	800
	30 July	100	356	8	69	545	503
Hayden	4 April	924	95	55	210	1330	1335
(stn. 2)	4 June	579	128	6	11	733	694
	2 July	676	277	7	75	1059	903
	30 July	189	22	4	58	285	124
Lake	2 May	116	2	1	32	156	109
(stn. 3)	4 June	239	24	1	29	315	305
	2 July	470	31	19	37	558	1162
	30 July	184	52	4	26	270	114

Numbers of Organisms per 30 min sample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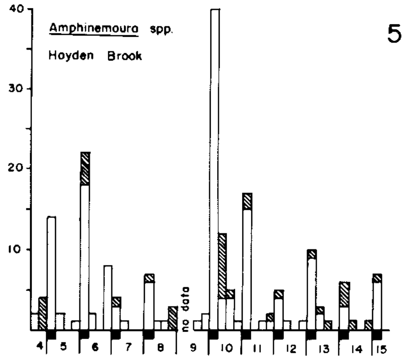
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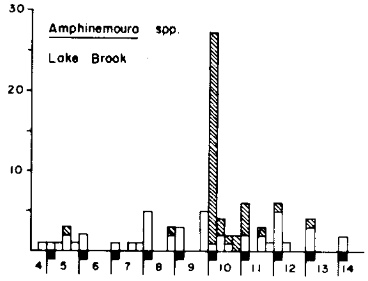
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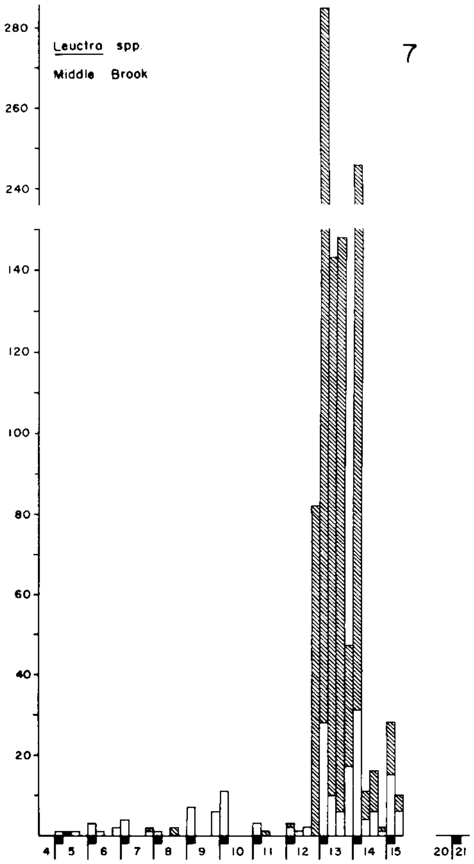
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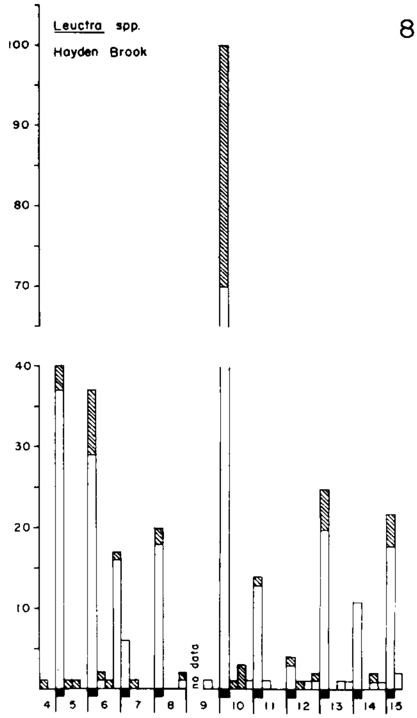
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Date, June 1973

constant over the same period. It was not determined if the same species were involved in the three brooks.

Phasganophora capitata (Pictet) (Fig. 10) did not appear in drift except in Middle Brook where numbers of dead and dying followed the high fenitrothion concentration of 12 June. It was not found in Hayden or Lake brooks. It lives on rocks (Hilsenhoff 1970) but it was not collected in benthos samplers at sites with rubble bottoms.

Ephemeroptera

Ephemeroptera varied in response to the spate and to fenitrothion concentration among and within genera.

A *Caenis* sp. was found consistently in Middle Brook (Fig. 11) and showed some drift response to the spate of 9 June, but no mortality or drift response to fenitrothion.

The Heptageniidae in Middle Brook (Fig. 12), including at least three species, showed nocturnal peaks, no drift response to the spate of 9 June, and high mortality as a result of the high fenitrothion concentration of 12 June. In Hayden Brook there was a weak response to the more intense spate and a small midday dead component on 10 June that may have been caused by the insecticide. Heptageniidae were scarce in Lake Brook drift.

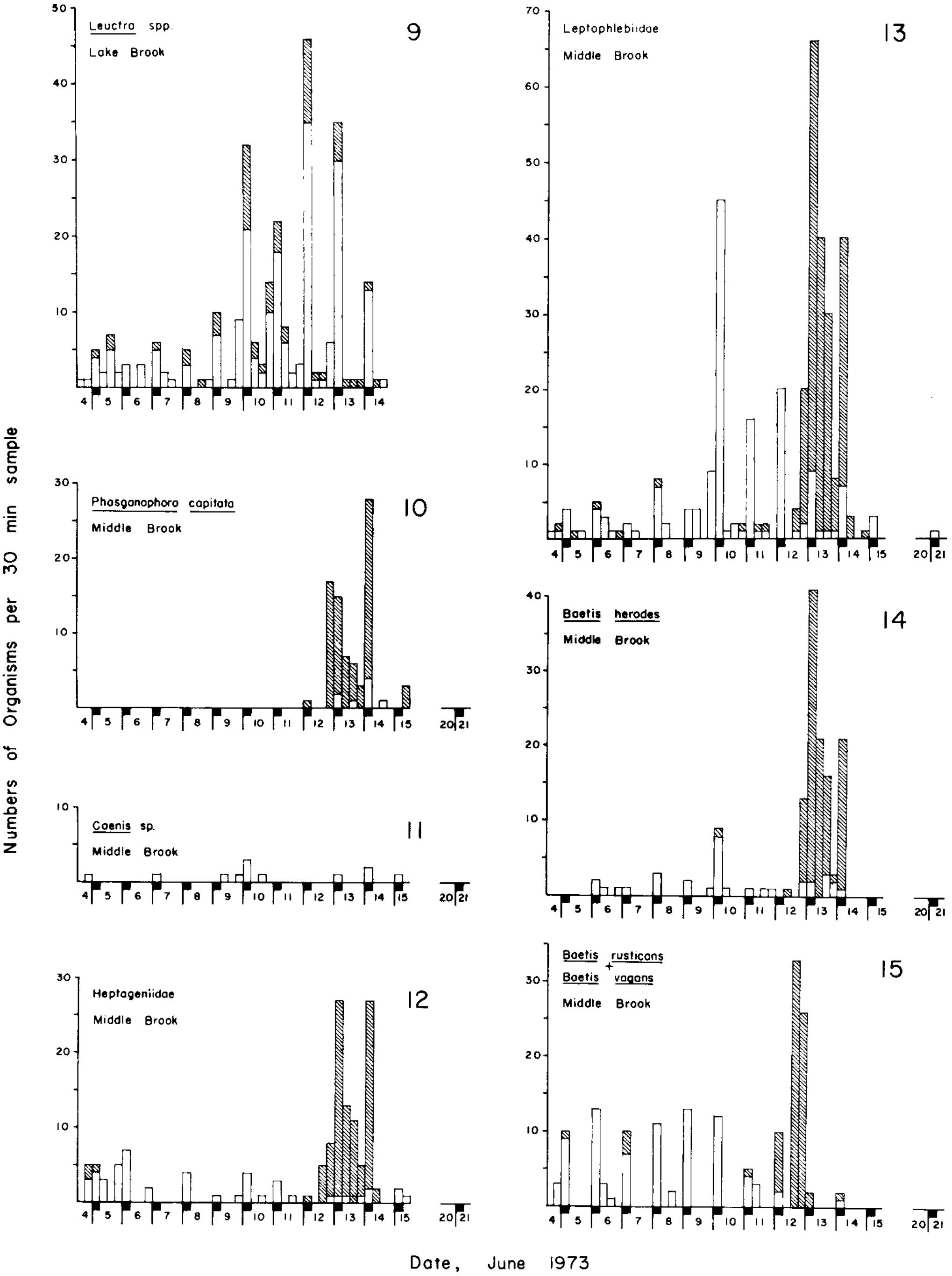
The Leptophlebiidae in Middle Brook (Fig. 13), which included at least three species, showed diel periodicity, a drift response to the spate of 9 June, a large kill following the high fenitrothion concentration of 12 June, and a lone survivor on 21 June. They showed the usual drift response to the intense spate of 9 June in Hayden Brook. Only three specimens were taken in Lake Brook over the 10-day sampling period.

The genus *Baetis*, of which there were at least six species, showed varied responses in Middle Brook, but all showed some kill. *B. brunneicolor* McD., *B. levitans* McD., and *B. pluto* McD. were rare in drift. Most other *Baetis* spp. from Middle Brook were

Table II. Numbers of invertebrates from stoneman samplers taken before and after the 1973 spray program

Taxon	Date	Middle		Hayden		Lake	
		Stn. 1	Stn. 2	Stn. 1	Stn. 2	Stn. 1	Stn. 2
Plecoptera							
Amphinemoura spp.	28 May	9	3	1	3	20	0
	18 June	13	2	0	4	9	0
Leuctra spp.	28 May	11	23	12	10	1	3
	18 June	6	10	54	68	0	4
Ephemeroptera							
Ephemerella subgenus *Ephemerella*	28 May	13	2	5	5	9	0
	18 June	44	5	13	18	1	0
Baetis spp.	28 May	10	22	6	4	37	3
	18 June	18	6	8	18	22	0
Total invertebrates	28 May	113	147	44	64	148	23
	18 June	98	74	117	156	291	98

FIGS. 4–8. Fluctuations in living (open) and dead (hatched) drift. Each bar represents the catch of two 15-min samples. Samples taken at 3-h intervals, night samples indicated by black squares below the abscissa.



FIGS. 9–15. Fluctuations in drift. Legend as Figs. 4–8.

either *B. herodes* Burks, or a mixture of *B. rusticans* McD. and *B. vagans* McD., which were difficult to distinguish except as fully grown nymphs bearing intact caudal filaments and cerci.

B. herodes (Fig. 14) was not abundant in normal drift, but responded to the spate of 9 June. It showed a large kill following the fenitrothion peak of 12 June, followed by a complete absence in drift. *B. rusticans + vagans* (Fig. 15) on the other hand was abundant in normal drift, had pronounced nocturnal peaks, and showed no drift response to the spate of 9 June. Kill of *B. rusticans + vagans* due to high fenitrothion concentration began 6 h earlier than that of *B. herodes*, and lasted only 12 h, whereas that of *B. herodes* lasted 36 h. There was also a large dead component in drift collected during the night of 11–12 June, before the fenitrothion peak, which was probably due to fenitrothion received in the holding cages. One living specimen was found after the fenitrothion concentration subsided. *Baetis* spp. showed no consistent trend in population from 28 May to 18 June in stoneman samplers (Table II).

Baetis spp. from Hayden and Lake brooks were not identified beyond genus. In Hayden Brook (Fig. 16) kills occurred 10 and 13 June, following two rises in fenitrothion concentration. After 10 June the daily dead component was larger and the amplitude of the diel fluctuations decreased. A steady decline in daily drift occurred throughout the sample period, apparently independently of the spate or the insecticide. *Baetis* spp. drift in Lake Brook (Fig. 17) increased in quantity and had an increased dead component with the coincidence of the spate and high fenitrothion concentration of 9 June. Daily drift apparently also declined independently of stream discharge and fenitrothion concentration.

The genus *Ephemerella* increased in drift in Middle Brook during the spate and, for no known reason, during the early morning darkness of 12 June. The dead component increased following the high fenitrothion concentration of 12 June but not as dramatically, nor did it decrease as rapidly about 14 June as did *Baetis* spp. and the Plecoptera. A large dead component was found every sampled day after 12 June, including 20–21 June. The species identified in drift in order of abundance were *invaria* (Walk.), *funeralis* McD., *cornutella* McD., and *lata* Morgan. Many could only be determined to subgenus because they were not fully grown. *E. rotunda* Morgan and *E. aurivillii* (Bengt.) were found in benthos samples in Middle Brook, but usually not in drift. Nymphs of *E. invaria* and *E. rotunda* are very difficult to distinguish in northeastern North America (Allen and Edmunds 1965), and *invaria* as used here probably includes some *rotunda*.

E. funeralis (Fig. 18) was taken in Middle Brook drift throughout the sampling period, usually at night, and responded to the spate of 9 June. Only one dead specimen was taken. The evidence suggests that the fenitrothion had no effect.

E. subgenus *Eurylophella* (Fig. 19), which by implication from fully grown nymphs collected by other means, includes *funeralis*, *temporalis* McD., and *aestiva* McD., occurred erratically in Middle Brook drift, responded to the spate of 9 June, but not to the insecticide.

E. invaria (Fig. 20) responded weakly to the spate of 9 June, but not to the insecticide.

Most *Ephemerella* were young nymphs (Fig. 21) of the subgenus *Ephemerella*, and by implication from fully grown, identifiable nymphs, were *invaria*, *rotunda*, and *aurivillii*. They showed weak nocturnal peaks and a drift response to the spate of 9 June. The numbers of dead rose sharply on 13 June following the appearance of fenitrothion in the water, and continued high even on 20–21 June. The declining numbers of living nymphs after 13 June are apparently due to emergence, and on 20–21 June, to low water levels. These young nymphs, along with *E. invaria*, account for the increase in *Ephemerella* drift in the night samples of 12 June, in the absence of spate and a measurable concentration of fenitrothion. As with *Baetis rusticans* + *vagans* there was a large dead component at that time.

Ephemerella spp. were not identified beyond genus in Hayden Brook (Fig. 22) and Lake Brook drift (Fig. 23) except to note that the living specimens in Lake Brook, following the high insecticide concentration beginning the night of 9 June, were all *Eurylophella*. *Ephemerella* spp. drift in Hayden Brook showed strong nocturnal peaks, responded strongly to the spate of 9 June, and contained larger numbers of dead during some periods from 10 to 14 June that were probably due to the insecticide.

Ephemeroptera increased in numbers in artificial substrates in all the streams from 4 June before the spray to 2 July after the spray (Table I). I cannot explain the drastic drop in numbers on 30 July in Hayden Brook. *Ephemerella* spp. of the subgenus *Ephemerella* generally increased in stoneman samplers in Middle and Hayden brooks between 28 May and 18 June (Table II).

Hyalella azteca (Saussure), an amphipod, occurred only in drift in Middle Brook (Fig. 24). It showed nocturnal peaks and increased in drift with the spate of 9 June and again the following night. It increased following the high fenitrothion concentration during the night of 12 June but was not killed. The species has not been taken from benthos samples, all of which were from rubble and gravel, because *H. azteca* is associated with vegetation.

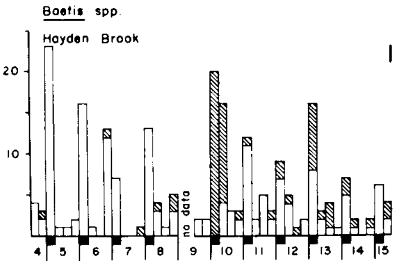
Chironomid larvae were most abundant in Lake Brook drift and least abundant in Hayden Brook drift, but never sufficiently numerous to determine if they responded to the spate or the insecticide. Simulid larvae on the other hand, although never numerous, were equally abundant in drift in Lake and Middle brooks but less so in that of Hayden Brook. The spate and the insecticide clearly had no effect on either live or dead drift of Simuliidae. (The specimens from Middle Brook drift were 1 ♂ *Prosimulium fuscum* D. & S., 28 immature *P.* probably *fuscum*, 1 ♀ *Simulium venustum* Say, and 28 immature *S.* probably *verecundum* S. & J.) Trichoptera larvae were consistently seen in drift only in Lake Brook, where they were most numerous in benthos, but there was no drift response to the insecticide.

Discussion

Increases in drift above the diel rhythm were due to both fenitrothion and spates. There was a general decline in daily drift catches during the sampling period, perhaps because of heavy emergence of many species. A full moon—moonlight has a depressant effect on drift (Bishop and Hynes 1969)—occurred 15 June; cloud cover and the influence of moonlight on drift catches were not evaluated, but were probably negligible because of the high forest canopy.

Increases in drift catches result from more animals entering drift, increased times and distances, or a combination of both. Whereas increases in numbers of animals entering drift are undoubtedly important in diel fluctuations, increased drift times and distances are probably mainly responsible for increases due to spates and fenitrothion poisoning. Increased discharge carries suspended objects, living or dead, longer distances. Dead or dying animals should resettle later and drift longer distances than active ones. Peterson and Zitko (1974) found, in fact, that post-fenitrothion treatment catches on drift screens in a stream stretch without long pools increased in rough proportion to the distance below a point of fenitrothion introduction.

Figs. 16–24. Fluctuations in drift. Legend as Figs. 4–8.



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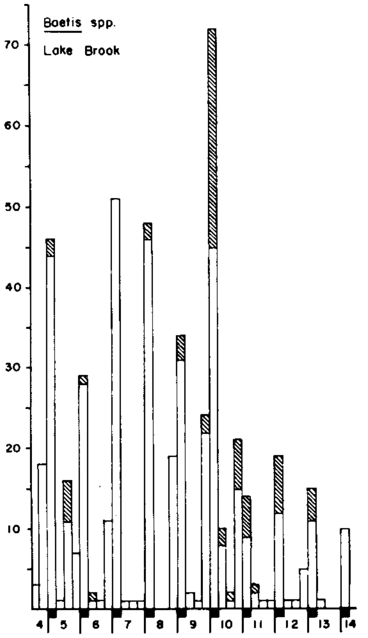

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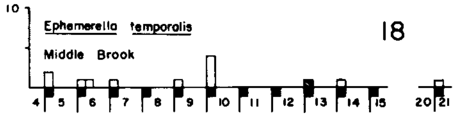

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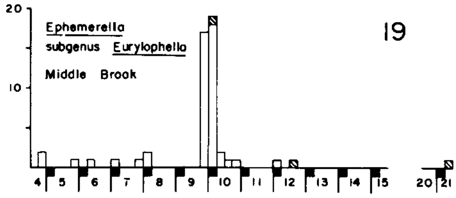

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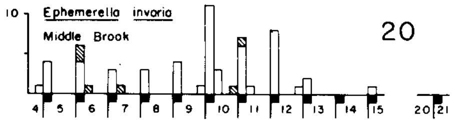

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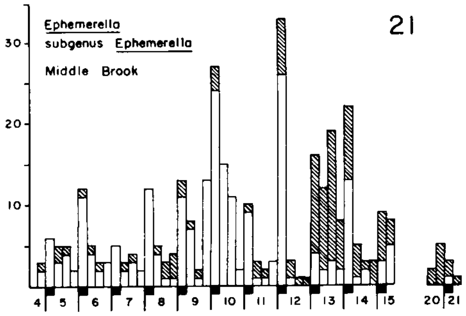

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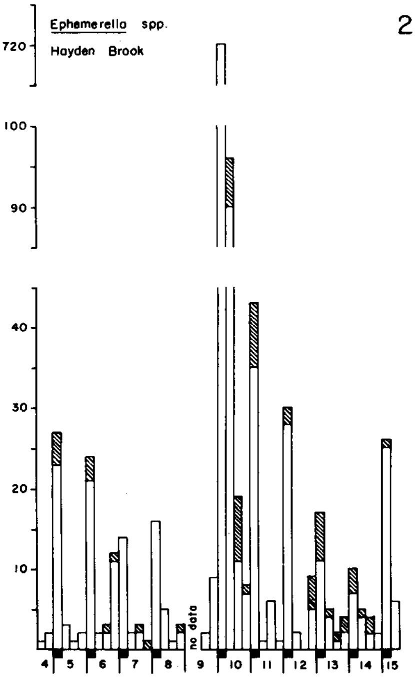

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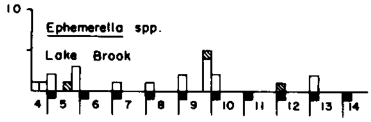

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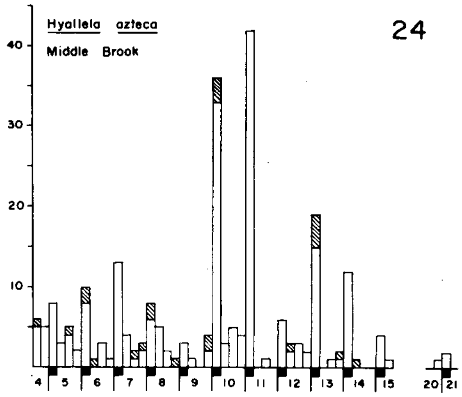

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Numbers of Organisms per 30 min sample

Date, June 1973

The effects of spates were clear: the increases in living drift were roughly proportional to the increases in discharge among the three streams. In the absence of fenitrothion the numbers of dead drift animals were low, and the daily numbers in each stream were remarkably uniform in spite of changes in stream discharge. The proportion of dead animals therefore diminished with spates. In expressing mortality due to fenitrothion it is better to use numbers of dead animals rather than percentages; although the percentage of dead drift increases, the measure is deceptive.

It was essential that the dead and living drift animals be separated and that time be allowed for the insecticide to act. Holding drift for 24 h in cages in the stream was adequate; only a small portion of the sample was difficult to classify as alive or dead. The water in the cages should have had a similar fenitrothion content to that in the stream, and animals collected just before the treatment should therefore have received a dose of fenitrothion while being held in the cages. With the exception of *Baetis* spp. and young nymphs of *Ephemerella* spp. subgenus *Ephemerella*, there was not time enough for a toxic effect, because there was no unusual amount of mortality in the drift collected during the 24 h before the fenitrothion peak.

Mortality depends on insecticide concentration and exposure time. Although the peak concentration in Lake Brook was higher than that in Middle Brook, the benthos kill was relatively insignificant. This is explained by the short exposure time, a consequence of the more rapid rate of decline in concentration of fenitrothion in Lake Brook.

At the peak of the kill in Middle Brook on 12 and 13 June, it was estimated that over 80,000 dead insects per 24 h drifted past the sample point. This was the standing crop of 3 m^2 of rubble stream bottom using estimates from Coleman–Hynes pots. Total pre-spray drift was about 13,000 arthropods per day. Drift/discharge ratios (Waters 1972) increased about 10-fold in the two days following the spray, but there was little if any increase during the spate (Table III). The difference was due to the increase in the dead component.

In spite of this increase in drift and mortality with increase in fenitrothion concentration, there was no evidence of benthos depletion. Neither was there evidence that some taxa were selectively depleted. *Leuctra* spp., *Amphinemoura* spp., and the *Baetis* spp. were strongly affected, but benthos samples indicated no decline in numbers. *Phasganophora capitata*, which is found on rocks, was rarely collected in benthos samplers, and *Hyalella azteca*, which lives among vegetation, was never collected.

It is virtually impossible to establish an order of sensitivity to fenitrothion for the taxa considered, because of the rapidly changing fenitrothion concentrations, the widely differing samples, and diverse drift behavior among taxa. But it is clear that the

Table III. Drift rates, proportion dead, and drift–discharge ratios* for Middle Brook

	Numbers/ 24 h	Dead (%)	Discharge (m^3/sec)	Drift/discharge (1000's)	
				Living	Total
Prespray (5–day av.)	13,028	25.9	0.10	97	130
Spate (9–10 June)†	30,233	6.2	0.19	149	159
Postspray (12–13 June)†	92,907	90.3	0.09	112	1,032
Postspray (13–14 June)†	95,660	83.9	0.09	152	1,063

*The total number of organisms drifting past the sample point per 24 h, divided by the stream discharge in m^3/sec at that point (Waters 1972).

†24 h, noon to noon.

Plecoptera (*Leuctra*, *Amphinemoura*, and *P. capitata*) and *Baetis* spp. were most affected. This agrees with the findings of Wildish and Phillips (1972) that a plecopteran, *Acroneuria* sp., was most sensitive (24-h LC_{50} = 2 ppb) among five species tested. The others, in descending order of sensitivity, were *Ophiogomphus* sp. (Odonata), *Nigronia serricornis* (Say) (Neuroptera), *Pycnopsyche* sp. (Trichoptera), and *Eriocera spinosa* (O.S.) (Diptera) but no Ephemeroptera.

Langer and Taylor (1974) inferred mortality of aquatic invertebrates from an 8-fold increase in benthos drift following an aerial fenitrothion spray at 2 oz/ac (140 g/ha), with a 600 ft wide (186 m) buffer strip along the stream. They imply that a decrease in benthos resulted, but are careful to point out that their Surber sampling was inadequate to be certain. From the maximum residue found on one of their stream side glass plates and their 6-in. average water depth, the water probably contained less than 0.6 ppb of fenitrothion and its breakdown product. Since I have demonstrated that an increase in drift can occur without kill at low fenitrothion concentrations, it is probable that neither benthos kill nor depletion occurred.

Flannagan (1975) found a 7- to 8-fold increase in drift of chironomid larvae and a 2- to 5-fold increase in drift of other aquatic invertebrates after a recorded peak concentration of 64 ppb followed by a rapid decline in concentration. His study stream was entirely different from the New Brunswick streams discussed in this paper; it had an invertebrate community essentially limited to chironomids and oligochaetes associated with a rather unstable sandy substrate. He found no decrease in standing crop, and reasonably assumes that the effect could have been very serious had the whole stream been sprayed. In that case, a higher concentration of fenitrothion in the water would have persisted longer.

Peterson and Zitko (1974) counted insects caught on flat screens (30 cm square, 16 meshes/in.) in the Waweig River, N.B., where they measured a peak fenitrothion concentration of 4.84 ppb after an operational spruce budworm spray. Although flat screens have low catch efficiency with time, and the sampling times and durations were not uniform, they found a small increase in catch of Plecoptera, but not of Ephemeroptera, Trichoptera, aquatic Diptera, or Coleoptera. They postulated 10% mortality on the basis of decreased drift of nymphal exuviae.

Peterson and Zitko (1974) also dosed a stream with fenitrothion for 24 h, maintaining concentrations from 50 to 511 ppb. Using their 30-cm square screens, they recorded sharp increases in drift of larvae or nymphs of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera (also adults), Simuliidae, Chironomidae, and Tipulidae. Ephemeroptera nymphs appeared to them most sensitive because the catch peaked earliest, but diel behavior patterns could account for this apparent conflict with observations that Plecoptera are most sensitive. My results suggest that there is too much variation among genera, species, and even larval and nymphal stages to generalize about orders.

With differential mortality, some change in the species composition of the benthos should be expected. It is possible, however, that the insecticide is merely affecting that drift which would have been lost by attrition, if the production hypothesis of Waters (1972) is correct. Lending support to this possibility is the observation that insecticide-killed drift shows the same periodicity as normal drift. The insecticide apparently did not enter the interstices in the substrate in sufficient concentration to kill benthos or the animals would have died there, been trapped there and not continued to enter drift. This is suggested by Flannagan's (1975) failure to find fenitrothion in substrate material of a treated stream. The animals were affected by the insecticide when they entered the drift, causing them to remain suspended for a longer time and to drift a greater distance, thus increasing the catch during the 15-min net set. The taxa most affected were not just those most susceptible to fenitrothion, but like *Baetis* spp. those which live at the surface of the substrate and are common in drift.

Differential sensitivity of taxa suggests that *Leuctra* spp. and *Baetis* spp., which are widespread and abundant in forested headwaters streams, would be the best indicator organisms of the presence of fenitrothion in streams. Holden (1972) suggested *Daphnia* and *Gammarus* as test animals for insecticides in fresh waters, but their close relationship with *Hyalella azteca*, which was little affected, suggests they would not be suitable for fenitrothion. *Daphnia* was occasional and *Gammarus* absent in drift from Middle, Hayden, and Lake brooks.

Middle and Hayden brooks supported healthy populations of brook trout, *Salvelinus fontinalis* (Mitchill), and other fish in early August 1972 and 1973 (P. F. Elson,[1] pers. comm.). The more sensitive aquatic insect nymphs, because they live near the surface of the substrate and are normally common in drift, are important fish foods, but no data are available on fish growth rates for Middle Brook. Symons and Harding (1974) have evidence that fenitrothion in streams can result in reduced growth of brook trout. Selective benthos kill is a possible mechanism, because spruce budworm sprays are applied at the time of year when trout growth is normally fastest.

All or part of the catchment areas of these three streams have been sprayed with fenitrothion every year since 1969 (Table IV). DDT was used in the area in 1966 and 1967. The actual residues to which the benthos was exposed are not known, but data from other studies (Dimond 1967; Ide 1967; Muirhead-Thompson 1971, chap. 6) leaves little doubt that DDT had a serious impact. The fenitrothion concentrations, as Eidt and Sundaram (1975) demonstrated, would have varied widely. Nonetheless, the benthos communities in these streams in 1973 had survived this long history of insecticide treatment in spite of the apparent sensitivity of some taxa. On the other hand, there is no way of knowing what the composition of the benthos community would have been if there had been no forest spraying in the area. Comparisons among Middle, Hayden, and Lake brooks suffer for lack of a control stream. Because of stream variability, diverse spray histories, and the caprices of spray drift, adequate controls for such experiments are difficult to find, but the different doses received by the three streams partly compensate.

Table IV. Spray history of the area including Middle, Hayden, and Lake brooks. Coverage was never complete; all or parts of some streams were exempted each year

Year	Insecticide	Rate (g/ha)	Applications
1966	DDT	280	2
1967	DDT	280	2
1968	None	–	–
1969	Fenitrothion	280	1
1970	Fenitrothion	140	2
1971	Fenitrothion	210	1
1972	Fenitrothion	210	1
1973	Fenitrothion	210	1
1974	Fenitrothion	210	1

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[1] Fisheries and Marine Service, Environment Canada, St. Andrews, N.B.

H. A. Hall[2] (personal communication) and Banks (1973), who studied drift and benthos in Cove Stream, near Sussex, N.B., have evidence that benthos was somewhat depleted by fenitrothion (peak concentrations published by Eidt and Sundaram 1975). The high concentrations probably occurred because the entire basin was sprayed and the stream, with a wide shallow cross section, was less sheltered by trees than Middle, Hayden, and Lake brooks.

Conclusions

Living drift increases with stream discharge but the dead component does not. The numbers of dead animals therefore must be used, not the proportion in drift, in assessing the effects of fenitrothion in stream water. The dead fraction must be identified to separate the effects on drift of spates and of the insecticide, and time must be allowed for the insecticide to act.

Leuctra spp. and *Amphinemoura* spp. (Plecoptera) and *Baetis* spp. (Ephemeroptera) were most affected by the insecticide. These genera were among the most abundant in drift and live at or near the surface of the substrate. They are important food of brook trout.

Survival may be higher in streams having a higher concentration of fenitrothion than in others if the insecticide concentration diminishes faster through dissipation and breakdown.

Although a large kill of aquatic insects occurred in one of the study streams, it was small in relation to production and there was no noticeable depletion of benthos. Because of a long spray history, the pretreatment condition of the streams is not known, but it is unlikely that fenitrothion spraying in the area has reduced the benthic fauna or drastically changed the benthic community.

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