Effects of Fenitrothion on Benthos in the Nashwaak Project Study Streams in 1976

by

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ABSTRACT

Fenitrothion concentration in water of the Nashwaak Project study streams, benthos drift, and benthos populations were monitored before and after the forest was sprayed. In one of three streams, a small kill of aquatic insects occurred after a recorded peak of 21 ppb fenitrothion in the water. Benthos populations were not affected. Insect larvae in cages buried in the streambed and fenitrothion concentrations in the interstitial water gave weak evidence that there was refuge from insecticide deep in the streambed.

RESUME

La concentration de fénitrothion dans l'eau des ruisseaux du Projet Nashwaak, ainsi que la dérive de benthos, et les populations de benthos, furent mesurées avant et après la pulvérisation forestière. Un des trois ruisseaux démontra une légère mortalité d'insectes aquatiques suivant une cime enregistrée de 21 ppb fénitrothion dans l'eau. Les populations de benthos ne furent pas atteintes. Des larves d'insecte dans des cages enterrées dans le fond du cours d'eau et les titres de fénitrothion dans l'eau de fond témoignèrent, avec certaines reserves, du refuge contre l'insecticide bien au-dessous du ruisseau.

Every year since 1973, the incidence of insecticides aerially sprayed for control of spruce budworm, Choristoneura fumiferana Clem., and the effects of these insecticides on benthic invertebrates have been monitored in the three experimental streams of the Nashwaak Experimental Watershed Project. This has had two purposes: (1) to elucidate the relationship between the concentration and persistence of insecticide in stream water and the effect on benthic invertebrates, and (2) to explain possible insecticide-induced variance in evaluating the effects on benthos of the prescribed clear-cutting and fertilization treatments of the Nashwaak Project.

The history of spraying in the area is as follows:

1966	DDT, two sprays 280 g/ha, each
1967	DDT, two sprays 280 g/ha, each
1968	no treatment
1969	fenitrothion, 280 g/ha
1970	fenitrothion, two sprays, 140 g/ha, each
1971	fenitrothion, 210 g/ha
1972	fenitrothion, 210 g/ha
1973	fenitrothion, 210 g/ha
1974	fenitrothion, 210 g/ha
1975	fenitrothion, 175 g/ha + phosphamidon, 175 g/ha
1976	fenitrothion, two sprays, 210 g/ha each

In none of these years were the entire watersheds sprayed because some of the forest was not susceptible to the spruce budworm and in some years not all the susceptible forest was sufficiently threatened to warrant spraying.

The experimental streams are described in earlier papers (Eidt 1975a, b); all are clear, slightly acid, headwaters streams of the Nashwaak River. In 1972, when monitoring post-spray effects began, the streams supported large, diverse, and apparently healthy benthos communities.

In 1973, there was some kill of aquatic insects, especially of stonefly larvae in one of the brooks, but there was no detectable depletion of benthos, even at the generic level (Eidt 1975a). In 1974, lower concentrations of insecticide were found in the water than in 1973 and no kill occurred (Eidt 1975b). In 1975, higher concentrations of fenitrothion in relation to previous experience were recorded, but there was no kill of benthos and little or no effect on drift; the phosphamidon had no effect on benthos (Eidt 1976).

This work is part of the Nashwaak Experimental Watershed Project (Anon, undated), a cooperative study of environmental impacts of forestry practices involving Environment Canada, the University of New Brunswick, the New Brunswick departments of Natural Resources and Environment, and the St. Anne Nackawic Pulp and Paper Co. Ltd.

OBJECTIVES

As in previous years, the streams were monitored in three ways: 1. To measure the concentrations of insecticide in the water. 2. To determine if aquatic invertebrates are killed, by monitoring invertebrate drift. 3. To determine from bottom samples if depletion of benthos occurs. Two additional objectives in 1976 were: 4. To establish the relationship between insecticide concentrations in the streamwater and those in water of the streambed interstices. 5. To determine if sensitive insect larvae deep in the streambed are less likely to be poisoned than those at or near the top of the streambed.

METHODS

The study area was sprayed twice with fenitrothion at 210 g (active ingredient)/ha each time. An aqueous emulsion was formulated of 150 parts of technical fenitrothion, 50 parts of the emulsifier, Atlox 3409F, and 2 parts of a solvent oil, CFTX107 Aerotex 3470. Technical fenitrothion varied from 95 to 97% active ingredient, but was mixed with water as if it were 97%.

Three spray blocks were involved; each was sprayed twice. Block numbers for the first spray began with a 6 and those for the second spray began with a 7. Blocks 637 and 737 included only a part of the west branch of Hayden Brook (Fig. 1); blocks 640 and 740 included a middle reach of the mainstem of Narrows Mountain Brook; blocks 645 and 745 included most of the mainstem and middle and east branches of Hayden Brook, most of the lower mainstem of Narrows Mountain Brook and the lower reaches of Lake Brook. The spraying times and conditions are given in Table 1.

Table 1. Spray times and conditions

Block	Date	Time	Wind (km/h)	Spray cloud
640	30 May	0825-0910	SW 16	Settling, breaking
637	31 May	0709-0744	NE 3-6	Settling, slight drift
645	31 May	0807-0844	NE 3-6	Settling
740	4 June	0750-0825	N 0-3	Settling
745	4 June	1942-2023	W 5-8	Settling
737	6 June	2030-2110	SW 8	Settling

Streamwater samples were collected from affected streams at the sites shown in Fig. 1 before and about 1, 4, 10 and 24 h after sprays. These were taken at midstream where the water was turbulent, by moving a 1.5 ℓ container from the bottom to the surface of the stream to ensure a well mixed sample.

Interstitial water was sampled with lengths of black rubber tubing through which water was withdrawn by gravity. One end of each tube was screened to prevent obstruction, and was carefully buried in the streambed by a technician wearing a skin-diving mask and snorkel, and using a ruler and a garden trowel. The other end of the tube was led downstream and adjusted so that water flowed slowly into a 300-mℓ amber bottle. Four tubes were installed at each of 5, 10, 15, and 20 cm depth and the collections from each depth were combined. Sample variance was reduced by this procedure, but it could not be measured because of limitations on the number of samples that could be analysed for fenitrothion.

All water samples were washed with chloroform within an hour of their collection to remove fenitrothion. Later the chloroform fraction was analysed for fenitrothion using essentially the same procedure described by Eidt and Sundaram (1975). Most surficial water samples were analysed by Dr. K.M.S. Sundaram, Chemical Control Research Institute, Canadian Forestry Service, Ottawa. The remaining surficial and all the interstitial samples were analysed by G.L. Brun, Water Quality Laboratory, Environment Canada, Moncton, N.B. Only one duplicate sample was taken because of limitations of time in the field, but agreement between the analysts was good (Narrows Mountain Brook, 30 May, 0920 hrs: Ottawa, 0.22 ppb; Moncton, 0.17 ppb).

Drift of invertebrates was sampled in each stream at the locations indicated on Fig. 1. Nets of nylon bolting cloth with 0.6 mm apertures were constructed on a metal frame. They were 31 cm wide, 66 cm long, and affixed to sample a column of water from the bottom to and including the surface of the stream. The nets were set for 15 min every 4 h. At night, when drift peaks, net sets on Hayden and Narrows Mountain brooks were reduced to 10 min and catches multiplied by 1.5. Catches were held in floating flow-through cages for 24 h, to allow fatally poisoned animals to die. They were then sorted into living and dead fractions, preserved in alcohol, and later identified and counted in the laboratory. Benthos was sampled as described by Eidt (1975a), using artifical substrates.

Preliminary stream discharge data for Narrows Mountain and Hayden brooks were obtained from the Water Survey of Canada. Flume readings, from which discharges were calculated, were taken each time a drift sample was taken on Lake Brook.

Insects were collected in nighttime drift, well before spray treatment began, for caging in Narrows Mountain Brook. These were sorted, identified as well as possible without excessive handling, and placed in cages on the bottom and 10 and 20 cm deep in the streambed gravel of Narrows Mountain Brook. The cages were constructed of black plastic pipe 2.6 cm ID x 9 cm long. A piece of nylon cloth with 0.2 mm apertures was fastened over each end of the cage with an elastic band. Five or 10 insects, depending on size, with a piece of dead leaf for substrate, were placed in each cage. Six cages were installed at each of 0 cm and 20 cm depth and 5 cages at 10 cm depth and were marked by a different colored plastic tape for each depth.

RESULTS AND DISCUSSION

Stream monitoring

Only low concentrations of insecticide were found 30 May in Narrows Mountain Brook (Fig. 2) after block 640 was sprayed. They were comparable with a low concentration found 27 May, which could only have resulted from drift from a distant spray block. Coverage of the north end of block 640 was poor because the aircraft were seen from the ground to turn at least 3 km south of Narrows Mountain Brook; the navigator's report confirms this. Insecticide concentration rose again 3 May following treatment of block 645, which included the lower part of Narrows Mountain Brook. The highest concentration found, 3.13 ppb (μg/ℓ), was certainly not the highest that occurred, as will be explained later, but there was no detectable effect on drift (Fig. 3). Two later peaks of 3.75 ppb were found within a 24-h period following treatment of blocks 740 and 745 on 4 June. Although this resulted in the presence of the insecticide in the water for a longer time than usual, the dose received by the benthos was not enough to kill or cause an increase in drift.

Peaks of insecticide concentration were found in Hayden Brook following the treatment of blocks 637 and 645 on 31 May and blocks 740 and 745 on 4 June (Fig. 2). The bimodal curve that is drawn for 31 May and 1 June in Fig. 2 is based on the assumption that the first peak was from block 645 and the second lesser peak was due to insecticide that came from the west branch after block 637 was sprayed. The navigator's report shows clearly that parts of Hayden Brook were sprayed; the lower part by a diversion to spray the band of softwoods along the Nashwaak River. There is no evidence in the results of drift sampling to indicate an effect of the insecticide (Fig. 4).

The highest concentrations of insecticide were found in Lake Brook (Fig. 5), 5.25 ppb on 31 May and 21.00 ppb on 4 June. Only one spray block was involved each time and only the lower part of the stream was sprayed, thus the presence of high concentrations was brief. Following the treatment of block 745 between 1942 h and 2023 h on 4 June and a concentration of 21.00 ppb at 2100 h, the drift catch at 2300 h was normal (Fig. 6). However, at 0300 h on 5 June, the drift catch increased 5-fold over the normal nighttime peak and consisted mainly of dead aquatic insects. Of 97 dead insects, 63 were *Baetis* spp. (mayflies) and 24 were *Simulium* sp. (black flies). The stoneflies, *Leuctra* spp. and *Amphinemoura* spp., which were shown by Eidt 1975a to be more sensitive to fenitrothion, were represented in the drift by one dead *Amphinemoura* larva. Both genera are abundant in Lake Brook, and their near absence in the drift can only be attributed to the nature of the sample site, which was ca. 15 m below a beaver dam with a long deep pool above the net. At 0700 h, and in subsequent samples, drift catches and the dead component dropped to normal. Benthos samples at four sites at 3- or 4-wk intervals indicated no depletion of stoneflies, black flies, *Baetis*, or benthos standing crop.

During the entire sampling period there had been a general decline of discharge in the streams (Fig. 2), and hence a minimal effect on benthos drift. A slight increase in discharge on 1 June is reflected in higher nighttime drift in all three streams (Figs. 3, 4, and 5), but otherwise, daily peak drift catches have a downward trend, at least on Hayden and Narrows Mountain brooks. Thus the effects of insecticides are not complicated by streamflow.

Fenitrothion in streambed interstitial water

The insecticide concentration data (Table 2) do not indicate a diminuation of concentration with depth in the substrate. It is not possible to directly compare the interstitial and surficial water samples because they were not collected at the same times. However, if there is no difference, all the concentrations, surficial and interstitial, should fall on a curve describing the usual rapid increase followed by a negative exponential decay curve.

On 30 and 31 May, it seems that this is what happened (Fig. 8); three interstitial samples fell approximately on the same line described by three surficial samples. On 31 May, the first of two interstitial samples showed that a higher concentration had been missed by the surficial samples; a second sample extended the descending part of the curve about as much as would be expected if a surficial sample were taken at that time. On 4 June, the relationship does not hold (Fig. 9) because the interstitial concentrations are too low to fall on the curve described by the surficiai samples. On the other hand, 50% higher values for the interstitial samples of 30 and 31 May would not change the interpretation for those dates, and it may be that the interstitial concentrations are lower. There is weak evidence of diminuation of

Table 2. Fenitrothion concentrations (ppb) in interstitial water at various depths in the streambed and in the surficial streamwater of Narrows Mountain Brook at various intervals after completion of treatment of the spray blocks indicated T < 0.01

		Concentrations of fenitrothion (ppb)				
			Depth in streambed (cm)			
Spray Block	Lapsed time after spray	Stream water	5	10	15	20
640	0.10	0.22	–	–	–	–
	2.35	–	T	0.17	T	0.16
	4.15	0.08	–	–	–	–
	7.05	–	0.14	T	0.01	0.01
	9.57	0.08	–	–	–	–
	16.20	–	T	T	T	T
645	0.15	3.13	–	–	–	–
	2.01	–	5.56	5.50	4.03	4.93
	5.22	2.40	–	–	–	–
	8.26	–	0.81	0.74	0.64	0.80
740	1.18	1.30	–	–	–	–
	2.03	–	1.00	0.84	0.65	1.00
	4.00	3.75	–	–	–	–
	6.35	–	1.40	1.50	0.78	0.91
	10.25	1.95	–	–	–	–

concentration with depth following the spraying of blocks 645 and 640 (Table 2) if the data for 20 cm depth are omitted.

The evidence for a lower insecticide concentration in the interstitial water is weak. It is reasonable to expect that water circulates freely in the coarse gravel, and no matter how carefully water is withdrawn from the streambed, it may be drawn from above. However, there should be a lag in dispersion into the streambed just as there is from the center and top of an idealized stream channel to its edges and bottom.

Caged insects

There was a high survival of insect larvae in cages, both on the stream bottom and buried 10 to 20 cm in the streambed (Table 3). The survival rates, if missing insects are regarded as dead, were 78, 66, and 70%, respectively. If the missing insects are presumed escaped and alive, which is more probable, the survival rates were 88, 76, and 88%. Neither set of survival rates suggest any difference. If *Leuctra* spp. are considered alone, the percent survival increases the deeper they are buried:

Depth (cm)	0	10	20
Missing *Leuctra* presumed dead	62	65	70
Missing *Leuctra* presumed alive	79	85	97

Whereas *Leuctra* spp. have been shown to be the most sensitive of the insects used, the data suggest there may be some refuge from fenitrothion in the stream bed.

Table 3. Numbers of caged invertebrates in Narrows Mountain Brook and their fate

Depth in streambed	Species	No. of insects			
		Starting	Dead	Missing	Finishing
0 cm					
	Leuctra spp.	29	6	5	18
	Amphinemoura spp.	18			18
	Ephemerella spp.	5			5
	Total	52	6	5	41
10 cm					
	Leuctra spp.	20	3	4	13
	Amphinemoura spp.	5			5
	Ephemerella spp.	7	3	1	3
	Total	32	6	5	21
20 cm					
	Leuctra spp.	30	1	8	21
	Amphinemoura spp.	12	4		8
	Ephemerella spp.	4	1	1	2
	Total	46	6	9	31

CONCLUSIONS

Fenitrothion was found in the waters of Narrows Mountain, Hayden, and Lake brooks as a consequence of the 1976 spruce budworm spray program. Peaks of concentration were found following treatment of each spray block that included part of a stream. Only in Lake Brook was the concentration sufficiently high (21 ppb) to kill benthic animals, but the kill was minor and did not measurably change the benthos population.

Analysis of water samples from the interstitial water in the coarse gravel streambed of Narrows Mountain Brook suggested that fenitrothion concentrations were lower in the streambed than in the stream. Because water circulates rather freely in gravel it is reasonable to suppose that a considerable gradient would occur in finer streambed materials.

The highest mortality of *Leuctra* spp. stonefly larvae occurred in cages on the bottom of Narrows Mountain Brook, and the lowest in the cages buried deep in the streambed. This is weak evidence that there is some protection from poisoning for larvae buried deepest. Unlike interstitial water samples it is certain that the water at the cage sites was not diluted by water from the stream above. The question is not resolved, however, and should be investigated further at greater depths and in finer bottom materials.

ACKNOWLEDGEMENTS

The cooperation of Forest Protection Limited, who applied the sprays, is gratefully acknowledged. Provisional data on stream discharge

for Narrows Mountain and Hayden brooks were provided by the Water Survey of Canada. Water samples were analysed for fenitrothion by Dr. K.M.S. Sundaram, Chemical Control Research Institute, Canadian Forestry Service, Ottawa and by the Water Quality Laboratory, Inland Waters Directorate, Environment Canada, Moncton, New Brunswick.

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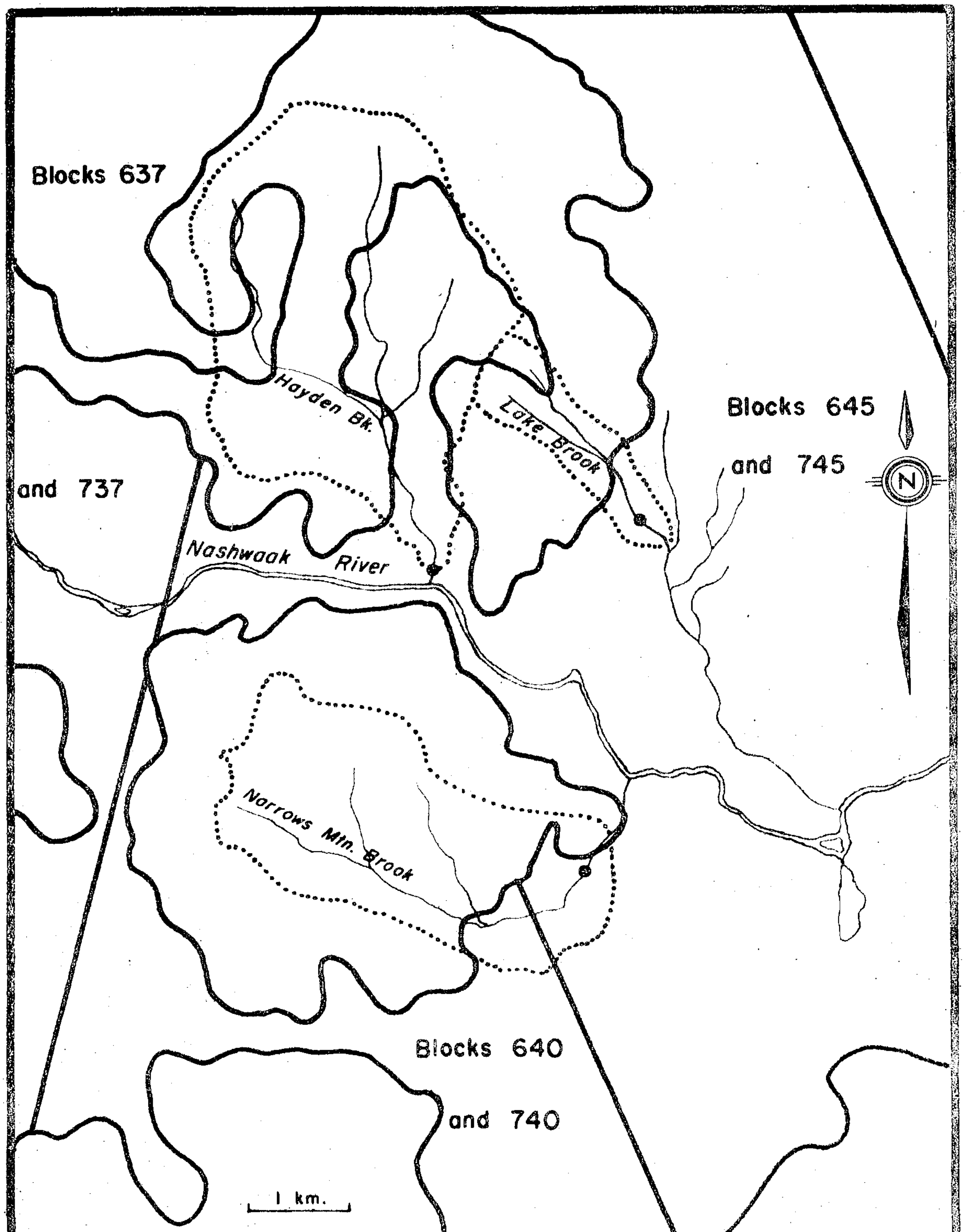

Fig. 1. Study area showing spray block boundaries, heavy lines; unsprayed areas not susceptible to spruce budworm, irregular areas enclosed by heavy lines; watersheds, dotted lines; and sample stations, dots.

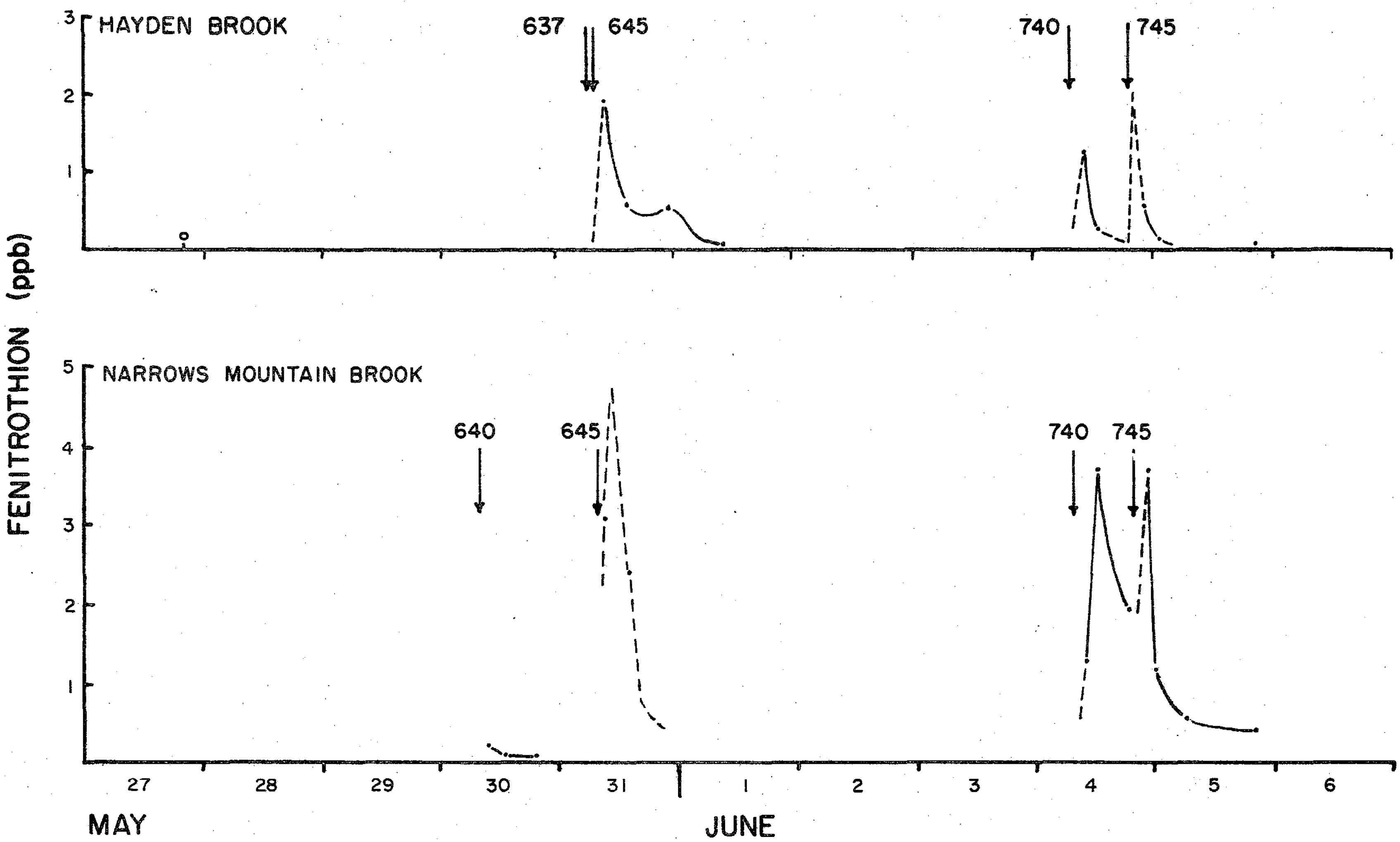

Fig. 2. Fenitrothion concentrations in Hayden Brook (above) and Narrows Mountain Brook (below).
0 = negative sample.

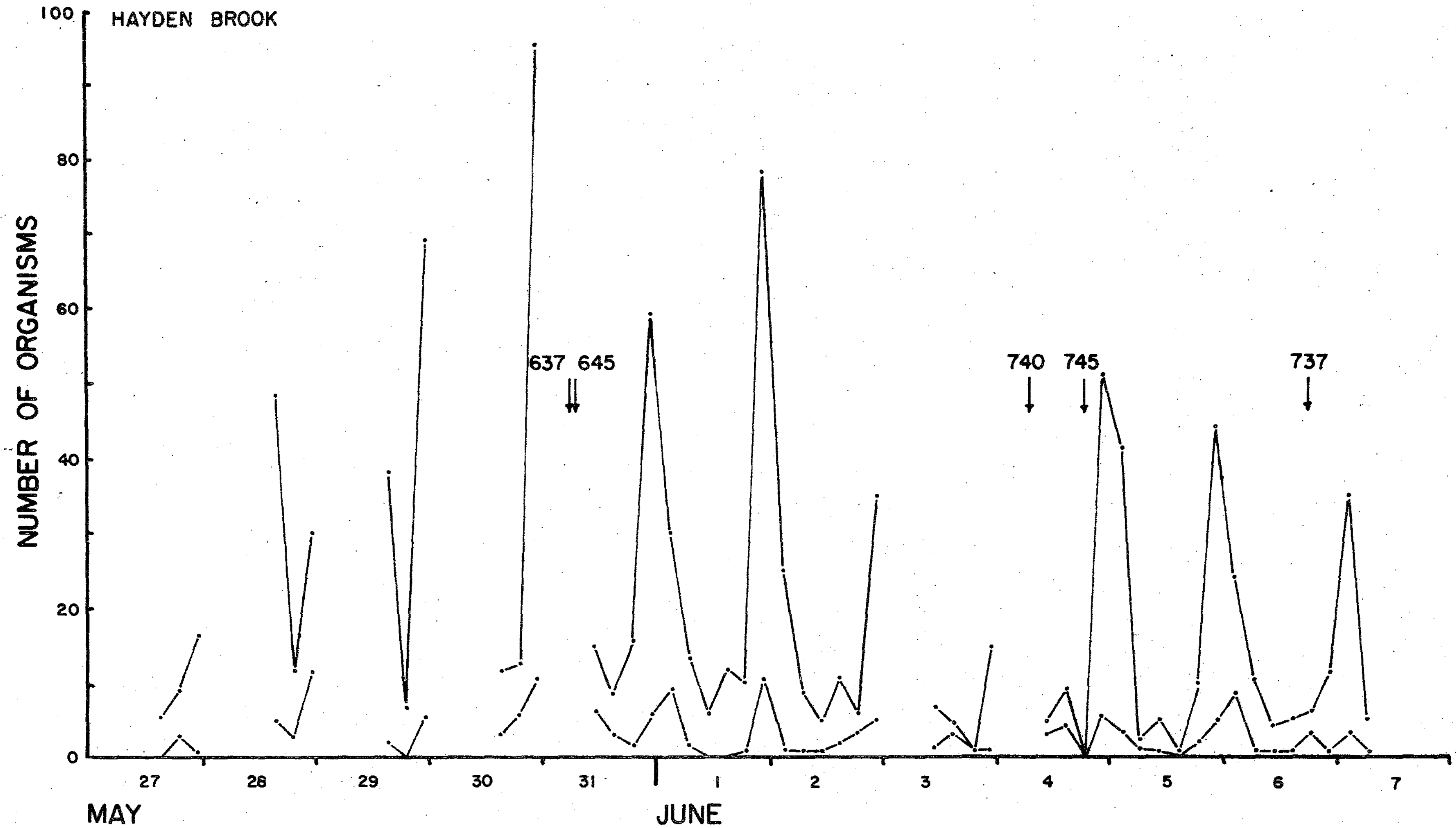

Fig. 3. Fifteen-minute drift samples at 4-h intervals, Hayden Brook. Upper line, total; lower line, dead.

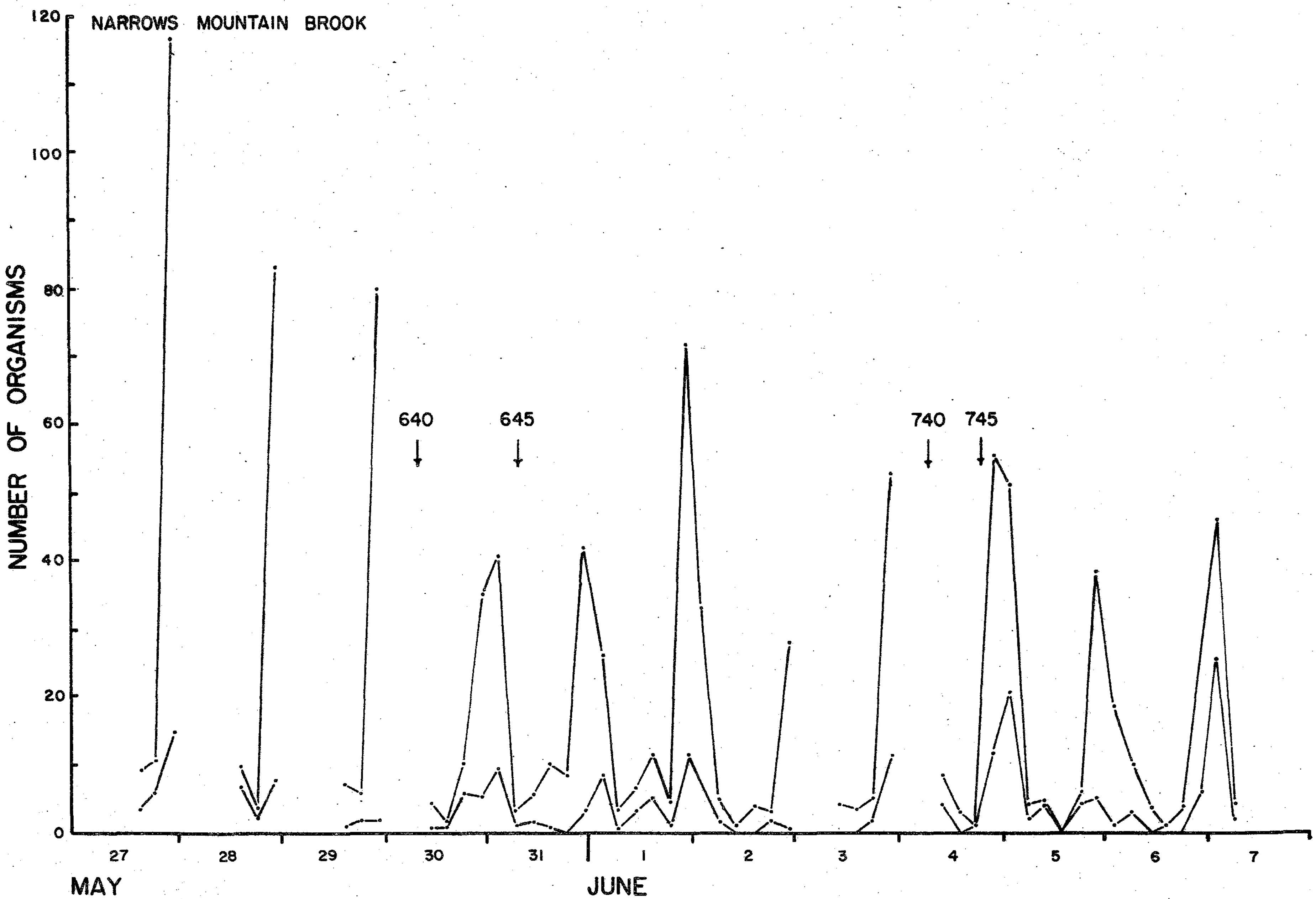

Fig. 4. Fifteen-minute drift samples at 4-h intervals, Narrows Mountain Brook. Upper line, total; lower line, dead.

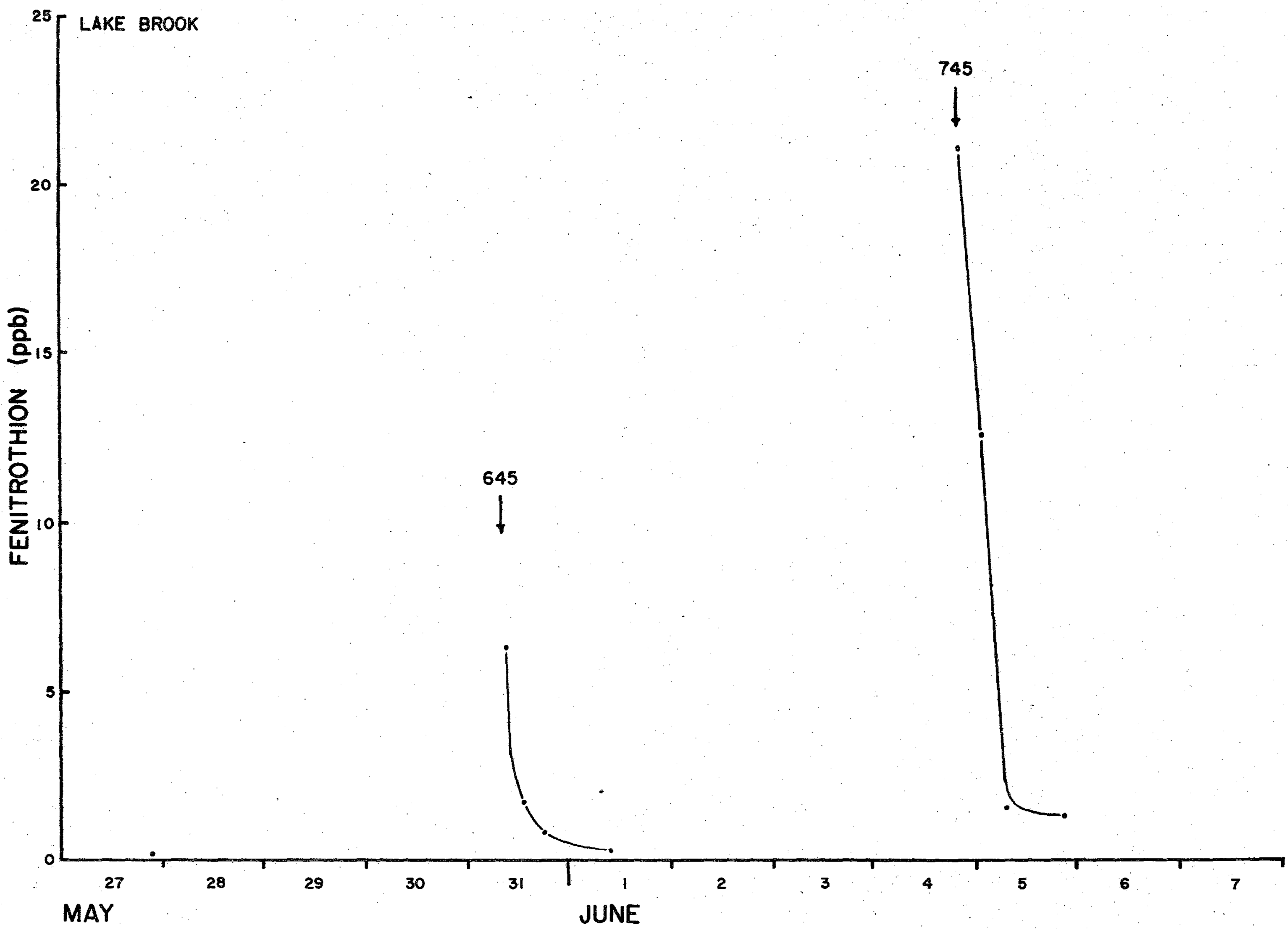

Fig. 5. Fenitrothion concentrations in Lake Brook.

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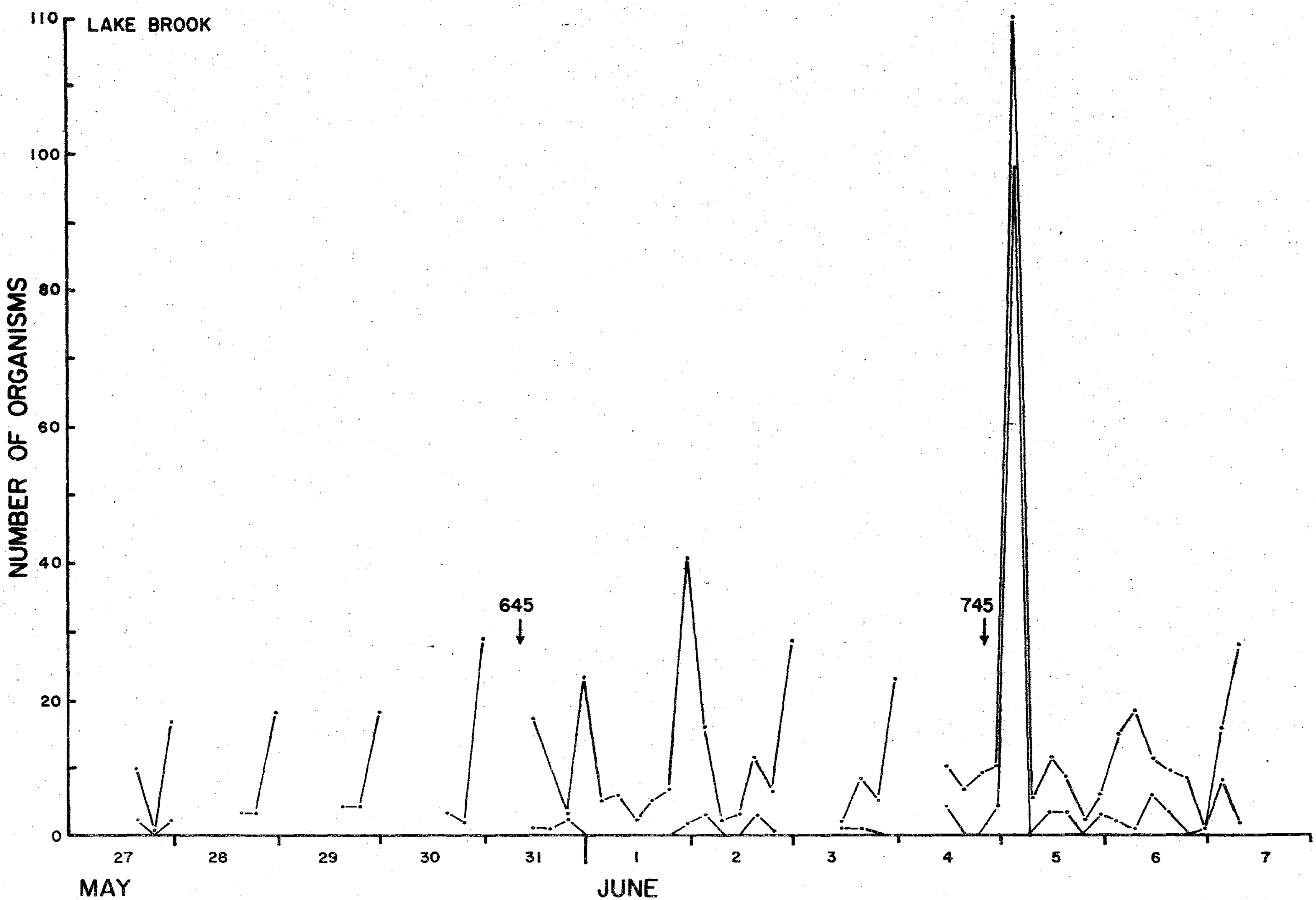

Fig. 6. Fifteen-minute drift samples at 4-h intervals, Lake Brook. Upper line, total; lower line, dead.

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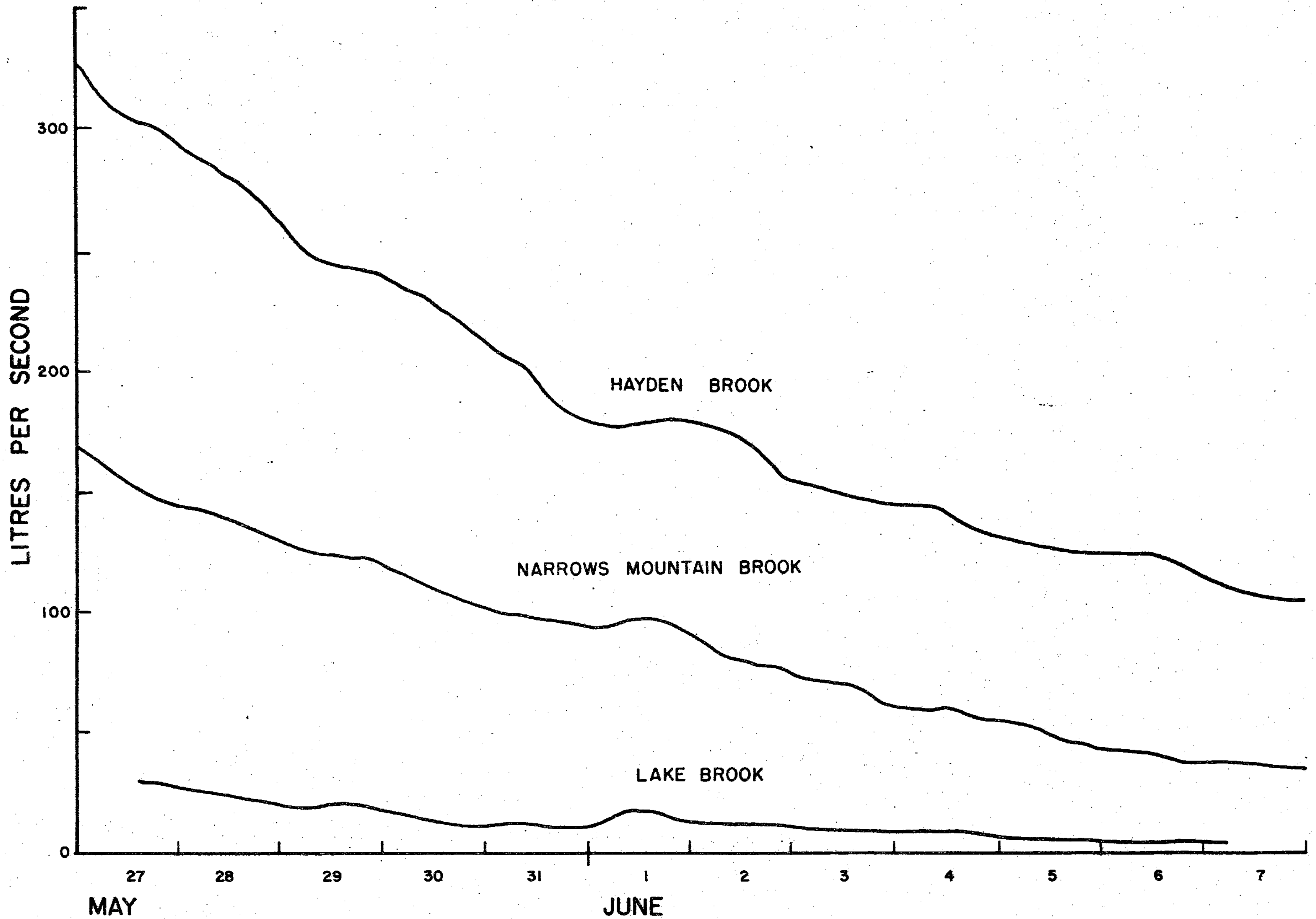

Fig. 7. Stream discharge of Hayden, Narrows Mountain and Lake brooks.

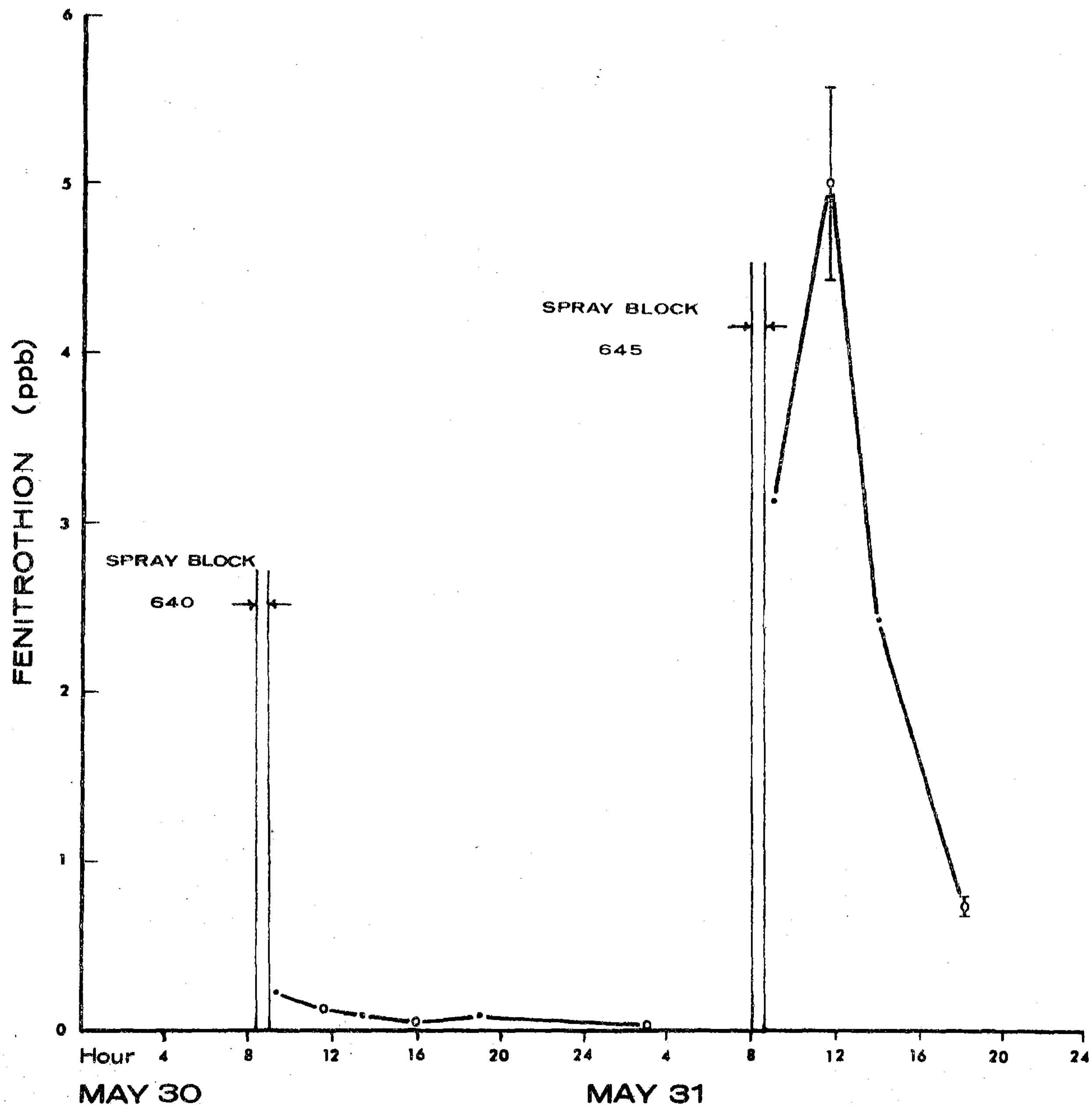

Fig. 8. Fenitrothion concentration in Narrows Mountain Brook, 30 and 31 May. Solid dots, surficial water samples; open dots, averages with one standard deviation of 4 interstitial water samples at 5, 10, 15, and 20 cm deep in the streambed.

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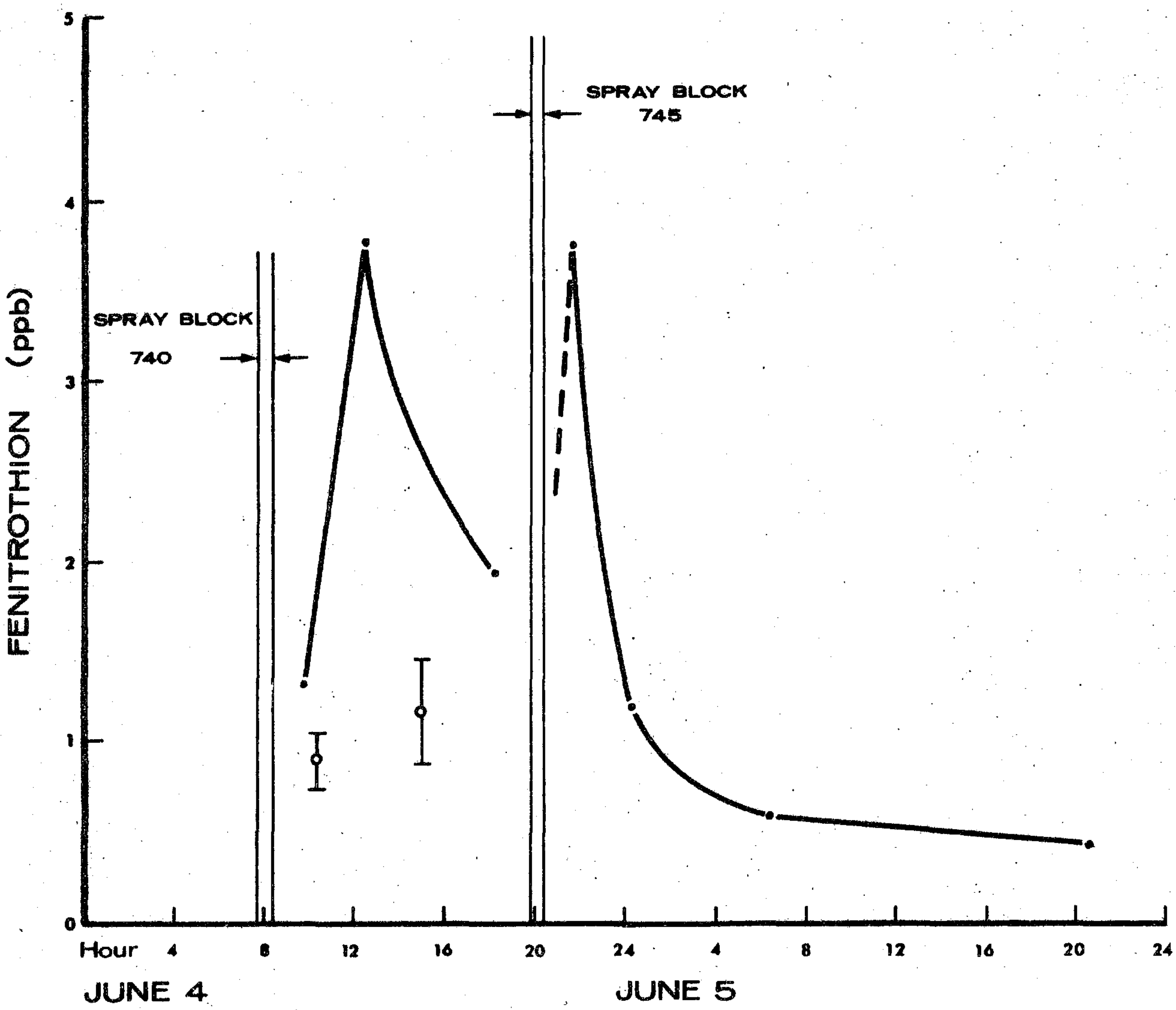

Fig. 9. Fenitrothion concentration in Narrows Mountain Brook, 4 and 5 June. Legend as for Fig. 8.