A PRELIMINARY REPORT ON THE IMPACT ON STREAM FAUNA OF HIGH DOSAGE APPLICATIONS OF RELDAN®

by

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INTRODUCTION

RELDAN® (chlorpyrifos-methyl) is a broad spectrum organophosphate insecticide which kills insects on contact, by ingestion and to a lesser extent by vapour action. Laboratory screening and simulated aerial spray trials by personnel from the Forest Pest Management Institute (FPMI) prior to 1977 indicated that this compound showed good potential as a control agent for larvae of the spruce budworm, *Choristoneura fumiferana* Clemens. Field efficacy trials on small plots treated with aerial applications of this material were first conducted by FPMI near Ste. Anne des Monts, Quebec in 1977, and again in the vicinity of Fredericton, New Brunswick in 1979.

Although RELDAN® is of low mammalian and avian toxicity, it has proven to be highly toxic to fish and certain crustaceans in laboratory bioassays (unpublished data, Dow Chemical Company). Concern over possible toxic effects in the aquatic environment resulted in the initiation of a preliminary aquatic impact study by the Environmental Impact Section of FPMI in association with the 1977 efficacy trials in Quebec. This study was carried out in the headwater portion of a small tributary stream which flowed through an efficacy plot treated with 140 grams active ingredient per hectare of RELDAN®, and the results were reported by Kingsbury (1979).

Two streams near St. Donat de Montcalm, Quebec were treated experimentally with RELDAN® and monitored for aquatic impact by the Environmental Impact Section of FPMI in 1979. An analysis of the results of these studies which were carried out in cooperation, and with support from, Dow Chemical of Canada Ltd., is presented here. Because this is only a preliminary report, some information, most notably raw data, has of necessity been omitted. Wherever possible, however, graphics have been used to illustrate and aid in the interpretation of results. In addition some topics (e.g., site selection and description, deposit assessment, sampling methods) have been touched on only briefly. These deficiencies will be remedied in a much expanded final report. Finally it should be stressed that any conclusions stated in this report are only tentative and are subject to change as more data becomes available and is reviewed.

SPRAY APPLICATION

In 1979, the Environmental Impact Section of FPMI had planned to study the effects of RELDAN® when applied to streams at dosage rates similar to those being considered for spruce budworm control. Two streams in Montcalm County, Quebec, were selected for treatment. One (Ruisseau Chertsey) was to receive a double application of 70 grams active ingredient per hectare, and the other (Ruisseau Wexford) a double application of 140 grams active ingredient per hectare (Figure 1). A small unnamed stream which crosses Highway 18 approximately 5.5 kilometers south of St. Donat de Montcalm was to be used as an untreated control.

The first application commenced at 0600 at Ruisseau Chertsey and at 0630 at Ruisseau Wexford on the morning of 28 June 1979. Application was by Cessna 185 aircraft equipped with an AU 3000 Micronair® spray emission system calibrated to deliver the formulations at a rate of 1.46 litres per hectare. A single swath approximately 60 meters in width was flown up each study stream beginning immediately downstream from the sampling station and terminating approximately 4.0-4.5 kilometers upstream. Meteorological measurements taken at the St. Donat de Montcalm airport at the time of the spray applications are presented in Table 1.

Application problems at the time of the first spray resulted in severe overdosing of both treatment streams, and the second applications had to be cancelled. Calculations later revealed that Ruisseau Chertsey had been treated at a dosage rate of 725 grams active ingredient per hectare, and Ruisseau Wexford at a dosage rate of 858 grams active ingredient per hectare (approximately 10.4 and 6.1 times the planned dosage rates respectively). The composition of the spray mixtures were as follows:

Ruisseau Chertsey	98% RELDAN® (XRC-0057)[1] 2% automate "B" red dye[2]
Ruisseau Wexford	98% RELDAN® (XRC-0058)[1] 2% automate "B" red dye[2]

SAMPLING METHODS

Methods used for deposit assessment, stream chemistry and biological sampling were similar to those described by Kingsbury et al. (1979). Stream searches were conducted daily for three days following the insecticide applications to observe and collect dead or distressed aquatic organisms.

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[1]Dow Chemical of Canada Ltd., Sarnia, Ontario.

[2]Morton Williams Ltd., Ajax, Ontario.

FIG. 1 DIAGRAM OF EXPERIMENTAL BLOCK

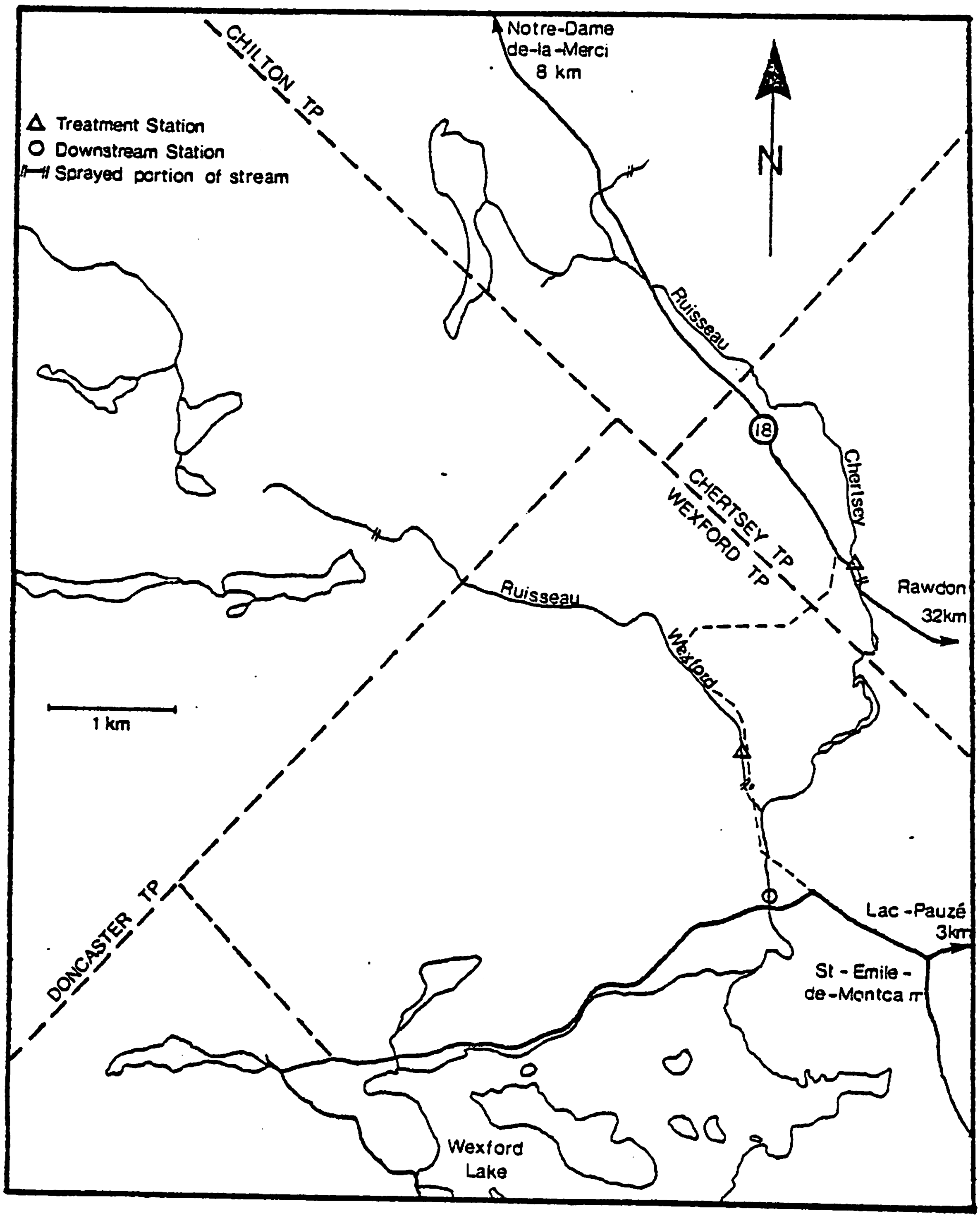


Table 1
Weather conditions at the St. Donat-de-Montcalm airport at the time of the 28 June 1979 RELDAN® treatments

Time	Temperature (°C)	Relative Humidity (%)	Wind Speed (kph)	Wind Direction (°Magnetic)	Cloud Cover	Comments
0530	10.25	100	0.0 - 1.5	180		foggy
0610	10.50	100	0.0 - 1.5	180		foggy
0650	12.70	98	0.0 - 3.5	180		foggy
0715	13.30	95	3.5 - 5.0	180	7/10	foggy patches

RESULTS

Deposit

Deposit measurements for the two RELDAN® applications are summarized in Table 2. In terms of volume of spray products deposited, the two treatments were quite similar. Differences in mean drop density, however, would seem to indicate that a comparatively larger number of small diameter droplets were deposited at the Ruisseau Wexford sampling station than at the Ruisseau Chertsey sampling station. As expected, deposit on midstream samplers was heavier than on stream bank samplers at both treatment stations due to the effects of screening by overhanging vegetation. The higher deposit recorded on stream bank samplers at Ruisseau Wexford as compared to Ruisseau Chertsey may have resulted from differences in the thickness of stream bank cover at the two stations. Deposit measured at the downstream station was negligible.

Water Chemistry

The water quality parameters for each aquatic sampling station are summarized in Table 3.

Terrestrial knockdown

Knockdown of terrestrial invertebrates into buckets on spray day was approximately 8 and 19 times the pre-spray averages respectively at Ruisseau Chertsey and Ruisseau Wexford (Figure 2). Knockdown was primarily of flying diptera (45.3% of the total knockdown at Ruisseau Chertsey and 49.0% at Ruisseau Wexford) with lesser numbers of coleoptera (10.1% at Ruisseau Chertsey and 6.2% at Ruisseau Wexford), hymenoptera (7.0% at Ruisseau Chertsey and 7.6% at Ruisseau Wexford) and other invertebrates (Figure 3). Collembola were a particularly important component of the spray day collections at Ruisseau Wexford (23.5% of the total knockdown) as were hemiptera and ephemeroptera at Ruisseau Chertsey (11.0% and 9.4% of the total respectively). By the day after application knockdown was very nearly back to normal except for diptera which were still showing up in unusual numbers at both treatment stations up to two days after application. No significant increases in knockdown were noted at the control station around the time of the insecticide applications (Figures 2 and 3).

Large numbers of terrestrial invertebrates were collected in drift net sets at Ruisseau Chertsey and Ruisseau Wexford following the insecticide applications (Figure 4). Numbers did not peak until at least 2 hours after application at both treatment stations (peak levels of 116.7 and 154.2

Table 2
Deposit assessment summary
for the 28 June 1979 RELDAN® treatments
Montcalm County, Quebec

	Number of Deposit Samplers	Mean Drop Density (Drops/cm^2)	Mean Volume Deposited (1/ha)	Mean Percent of Emitted Volume Recovered
Ruisseau Chertsey				
Mid-stream samplers	7	19.06	0.250	17.12
Stream bank samplers	7	12.09	0.070	4.79
Ruisseau Wexford				
Mid-stream samplers	5	41.13	0.232	15.89
Stream bank samplers	5	15.41	0.126	8.63
Ruisseau Wexford Downstream	5	0.10	0.002	0.14

* spray emission rate of 1.46 1/ha (20 fl. oz/acre)

Table 3
Water quality parameters in study streams
Montcalm County, Quebec
16 June - 30 August 1979

	Date	Temperature (°C)	Dissolved Oxygen (mg/l)	pH	Alkalinity (gpg)	Hardness (gpg)
Untreated Control	16.6.79	19.0	9	6.5	2	2
	3.7.79	17.0	9	7.0	1	2
	9.7.79	17.0	8	7.0	2	2
	28.8.79	18.0	8	7.0	1	3
Ruisseau Chertsey	16.6.79	18.0	9	6.5	1	3
	4.7.79	--	9	6.5	1	3
	8.7.79	16.0	9	7.0	1	2
	30.8.79	17.5	7	6.5	1	3
Ruisseau Wexford	16.6.79	17.0	8	7.0	2	2
	4.7.79	--	8	7.0	1	2
	8.7.79	16.0	9	7.0	2	1
	30.8.79	16.0	8	7.0	1	2
Ruisseau Wexford Downstream	17.6.79	21.0	8	6.5	2	3
	4.7.79	--	9	6.5	1	3
	8.7.79	17.5	9	7.0	1	3
	30.8.79	17.0	8	7.0	1	3

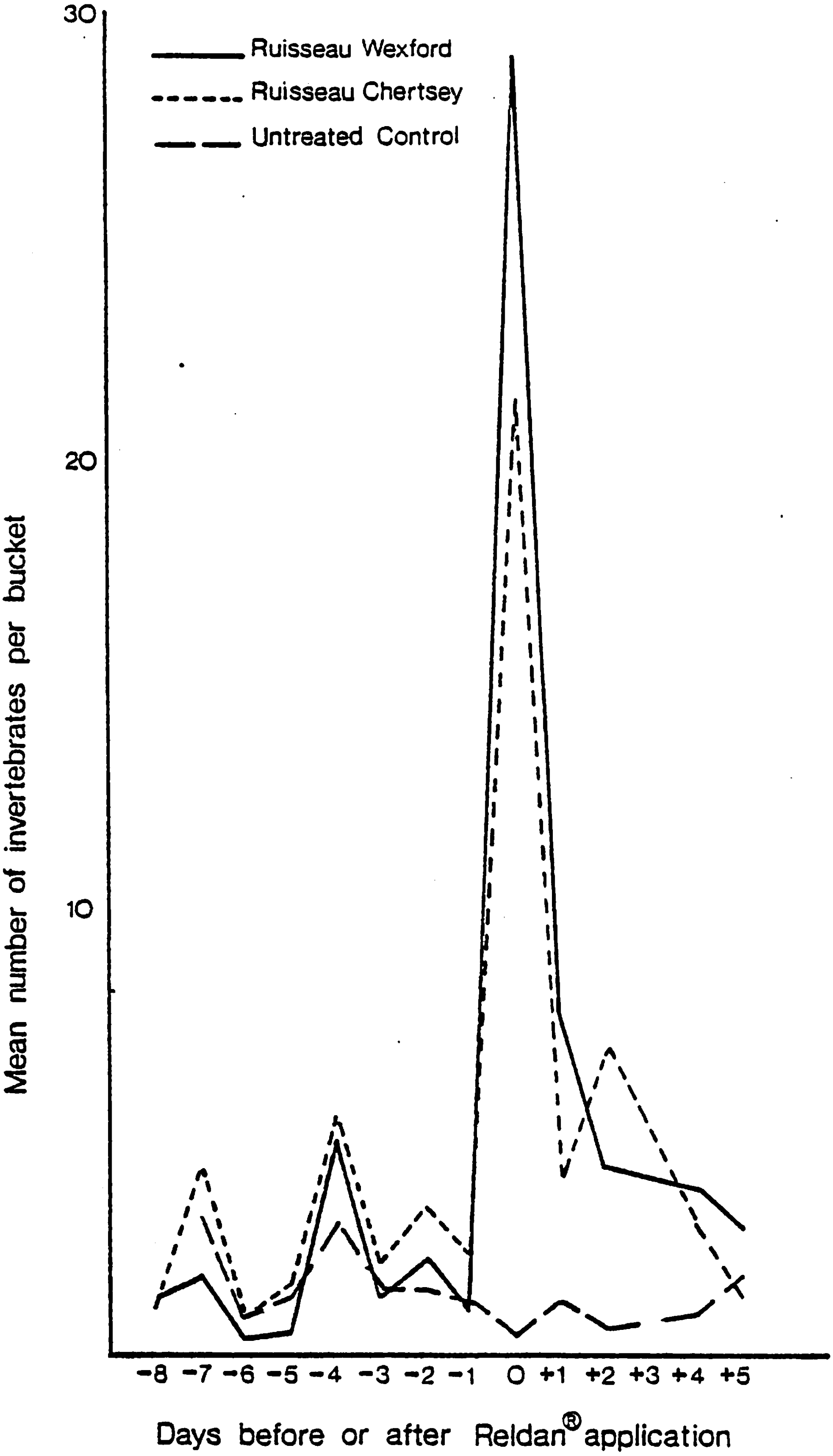
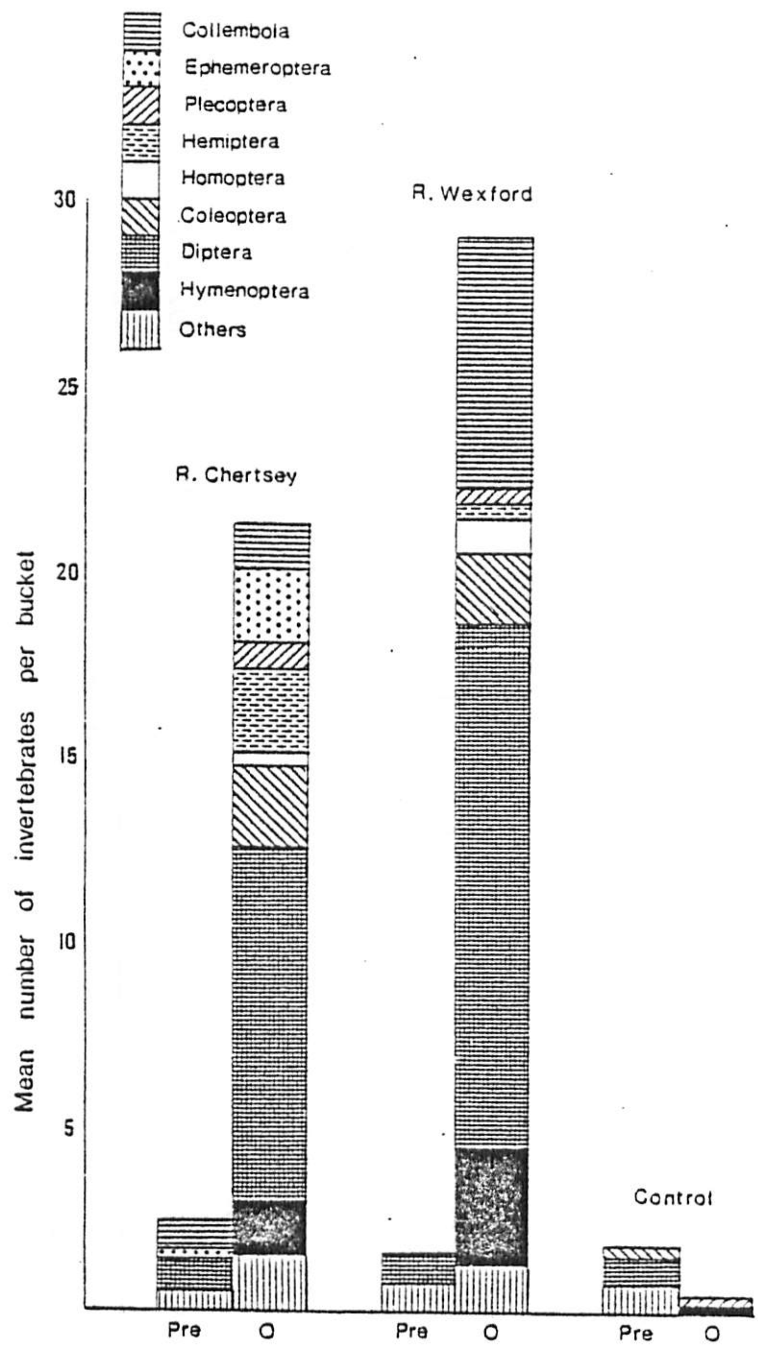


Figure 2. Terrestrial organisms collected from buckets along R. Chertsey and R. Wexford treatment streams and the untreated control stream



Pre – average over 8 pre-spray samples at R.Chertsey and R.Wexford; 7 pre-spray samples at Control

O – spray day samples

Figure 3. Comparison of terrestrial invertebrates collected from buckets prior to and on the day of the RELDAN® applications

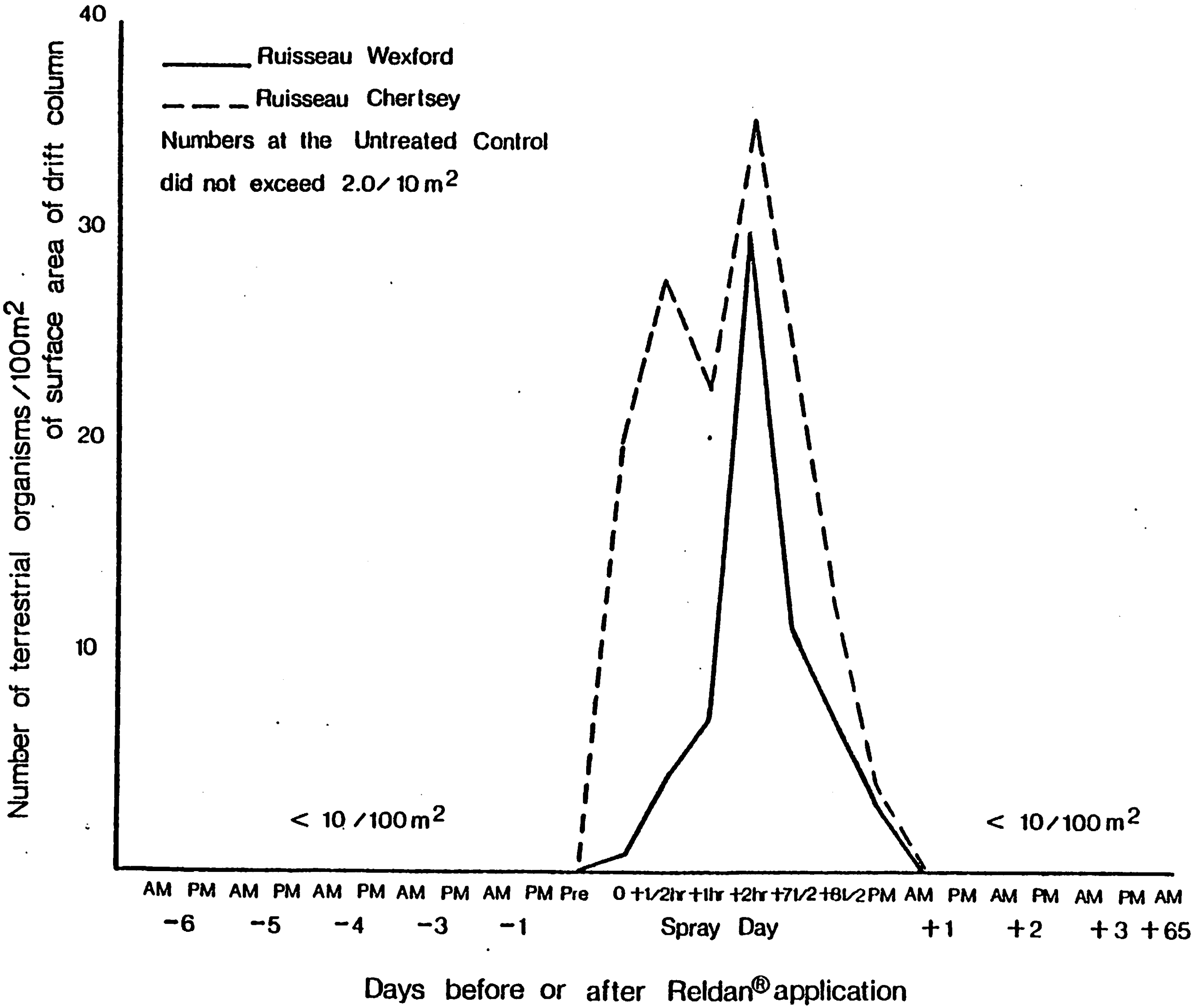


Figure 4. Terrestrial organisms caught in drift net sets at R. Chertsey and R. Wexford treatment stations

times the pre-spray averages at Ruisseau Chertsey and Ruisseau Wexford respectively). Numbers were declining 8 1/2 hours after application at Ruisseau Chertsey and 7 1/2 hours after application at Ruisseau Wexford, and by the next morning were back to normal at both stations. Flying diptera were the most important component of the spray day drifts at both stations, but homoptera were also collected in large numbers at Ruisseau Wexford, as were hemiptera at Ruisseau Chertsey. No significant increases in terrestrial invertebrate drift were noted on spray day at either the downstream station or the untreated control station.

Aquatic invertebrate drift

Substantial increases in aquatic invertebrate drift were recorded at both treatment stations following insecticide applications (Figure 5). At Ruisseau Chertsey numbers peaked within 1/2 hour of application at a level approximately 2300 times the pre-spray average. At Ruisseau Wexford numbers peaked within 2 hours but at a somewhat lower level (approximately 1400 times the pre-spray average). By 8 1/2 hours after application the number of drifting aquatic invertebrates at Ruisseau Chertsey had dropped considerably (< 70 times the pre-spray average) and by 38 hours was below the pre-spray average. A somewhat more prolonged effect was noted at Ruisseau Wexford where drift was still fairly heavy 7 1/2 hours after application (approximately 260 times the pre-spray average) and increased drifting was evident even up to 51 1/2 hours after application (approximately 7 times the pre-spray average). At the downstream station small increases were noted in the first two 12 hour post-spray drift samples (5.6 and 4.8 times the pre-spray average respectively).

Baetid mayfly nymphs (Ephemeroptera: Baetidae) were by far the most heavily represented group of aquatic invertebrates in post-spray drift samples at both treatment stations, but large numbers of heptagenid mayfly nymphs, (Ephemeroptera: Heptageniidae) stonefly nymphs (Plecoptera), chironomid larvae (Diptera: Chironomidae), blackfly larvae (Diptera: Simuliidae), caddisfly larvae (Trichoptera) and collembola were also collected (Figures 6 and 7). Aquatic coleoptera, hemiptera, hydracarina and other aquatic diptera larvae were collected in smaller numbers. At the downstream station baetid mayfly nymph and chironomid larvae were the most abundant groups collected in the first two post-spray drift samples.

Small increases in drift were also noted at both treatment stations and at the control station 3 days after application. These increases correspond to heavy rainfall and increased stream discharges on this date.

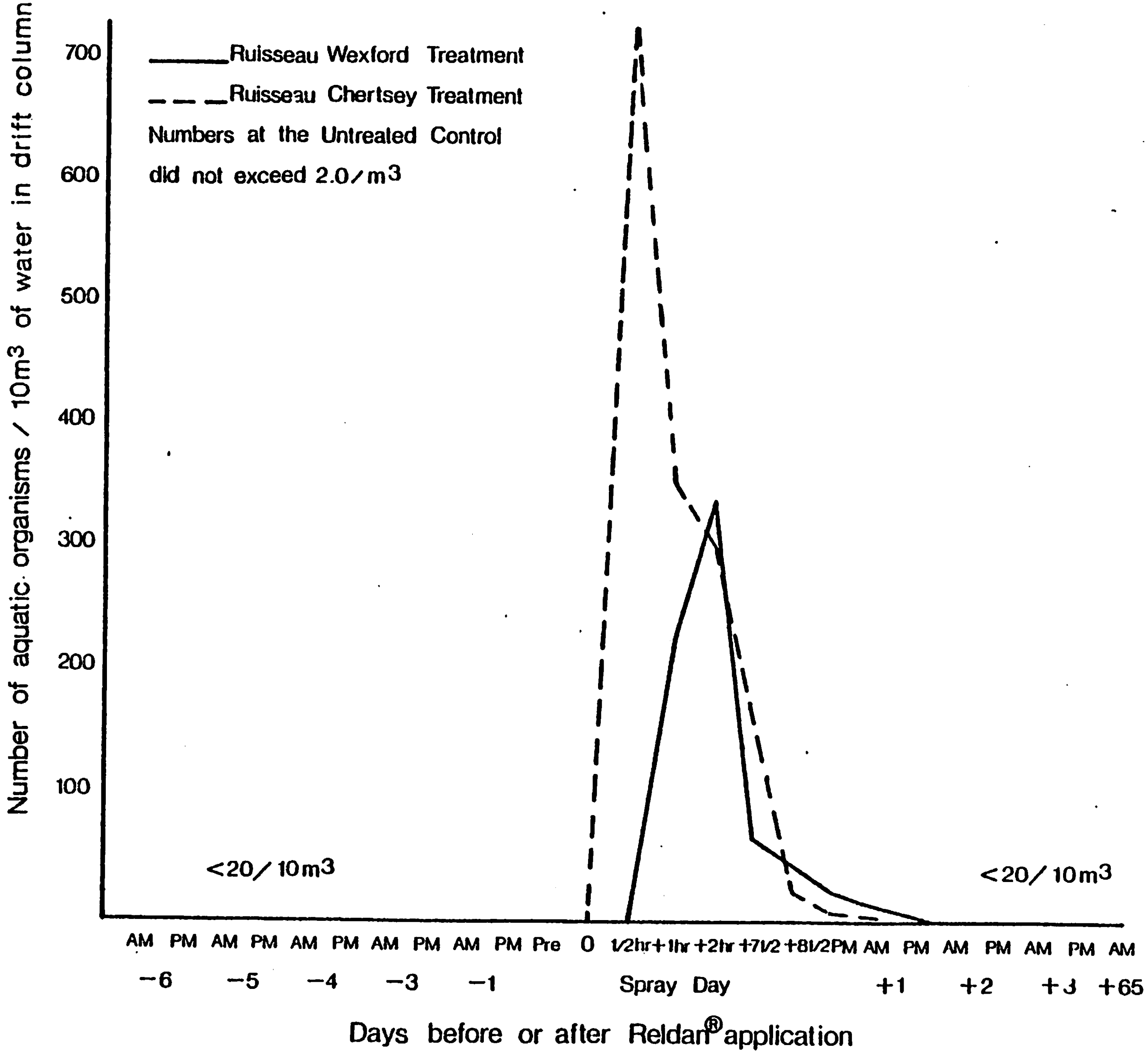


Figure 5. Aquatic organisms caught in drift net sets at R. Chertsey and R. Wexford treatment stations

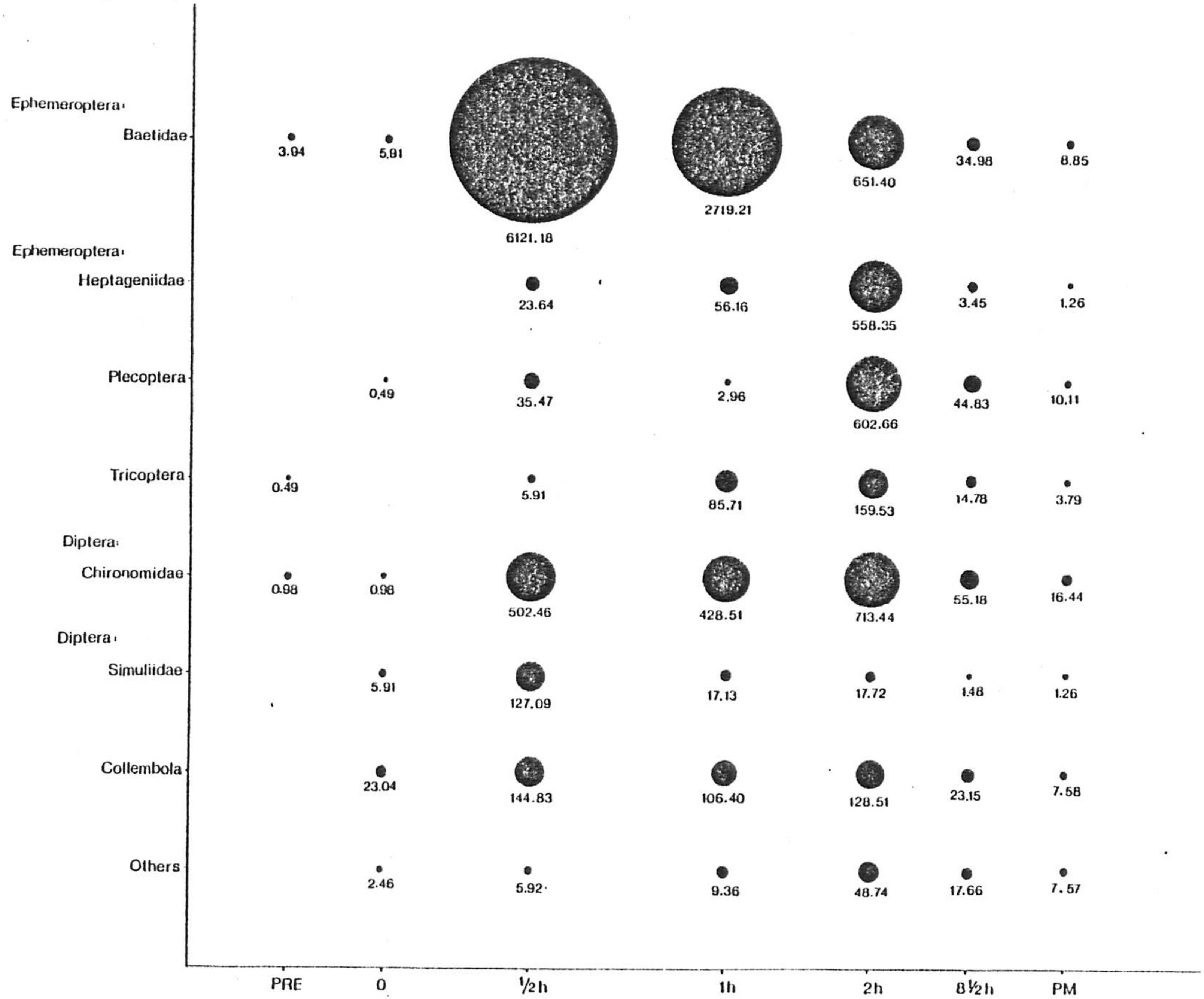


Figure 6. Aquatic organisms caught in spray day drift net sets at R. Chertsey treatment station (expressed as number of organisms/10 m^3 of water passing through the drift net)

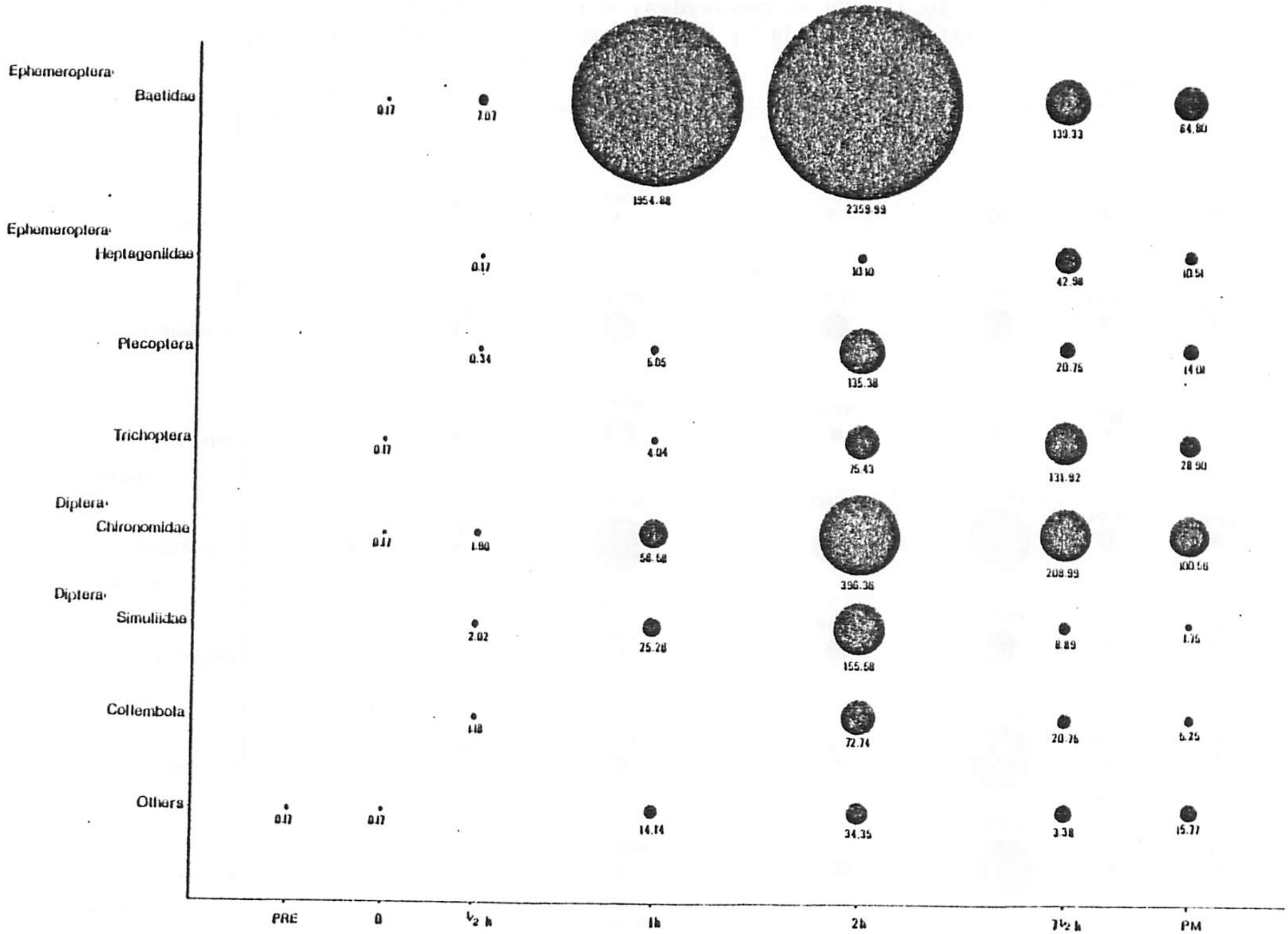


Figure 7. Aquatic organisms caught in spray day drift net sets at R. Wexford treatment station (expressed as number of organisms/10 m^3 of water passing through the drift net)

Bottom fauna

Benthic invertebrates were significantly reduced in numbers at the Ruisseau Chertsey (by 88.9% in Surbers and 98.6% on rocks) and Ruisseau Wexford (by 66.7% in Surbers and 95.9% on rocks) treatment stations, and at the downstream station (by 83.8% in Surbers and 98.0% on rocks), in the first post-spray bottom fauna sample taken 6 days after the two RELDAN® applications (Figures 8, 9, 10 and 11). Numbers of benthic invertebrates at the control station were also reduced at this time, but not by as much (by 14.3% in Surbers and 40.3% on rocks).

Due to their relatively large numbers in pre-spray samples heptagenid mayfly nymphs, baetid mayfly nymphs and chironomid larvae were the groups in which reductions were most evident. Numbers of chironomid larvae were greatly reduced in Surber samples (by 81.5% at Ruisseau Chertsey, 100% at Ruisseau Wexford and 98% at the downstream station) and completely eliminated from rocks at the two treatment stations and the downstream station. Numbers were also reduced at the control station however (by 52% in Surbers and 90% on rocks), indicating that adult emergence may have been at least partially responsible for the reductions observed.

Heptagenid mayfly nymphs were essentially eliminated from the first post-spray bottom fauna samples at both Ruisseau Chertsey and Ruisseau Wexford (100% reduction on rocks and in Surbers at Ruisseau Wexford; 100% reduction on rocks and 95.6% reduction in Surbers at Ruisseau Chertsey). Baetid mayfly nymphs disappeared from rocks and Surbers at Ruisseau Chertsey following the spray, and were almost eliminated from rocks at Ruisseau Wexford, but were only reduced by 30.8% in Surbers at Ruisseau Wexford. At the downstream station heptagenid and baetid mayfly nymph populations were reduced by 92.6% and 100% respectively on rocks, but by only 85.6% and 75% in Surbers. At the control station, numbers of baetid mayfly nymphs were slightly reduced in the first post-spray sample (by 33.3% on rocks and 26.3% in Surbers) but numbers of heptagenid mayfly nymphs remained essentially unchanged.

In addition to reductions in total numbers of organisms, significant reductions in diversity were also observed at both treatment stations and the downstream station following the RELDAN® applications. Individuals from 15 taxonomic groups were collected in the immediate pre-spray bottom fauna sample at Ruisseau Chertsey as opposed to only 6 groups in the first post-spray sample; 8 in the pre-spray and 5 in the post-spray at Ruisseau Wexford; and 18 in the pre-spray and 12 in the post-spray at the downstream station. At the control station 8 groups were represented in the pre-spray sample and 6 in the first post-spray sample.

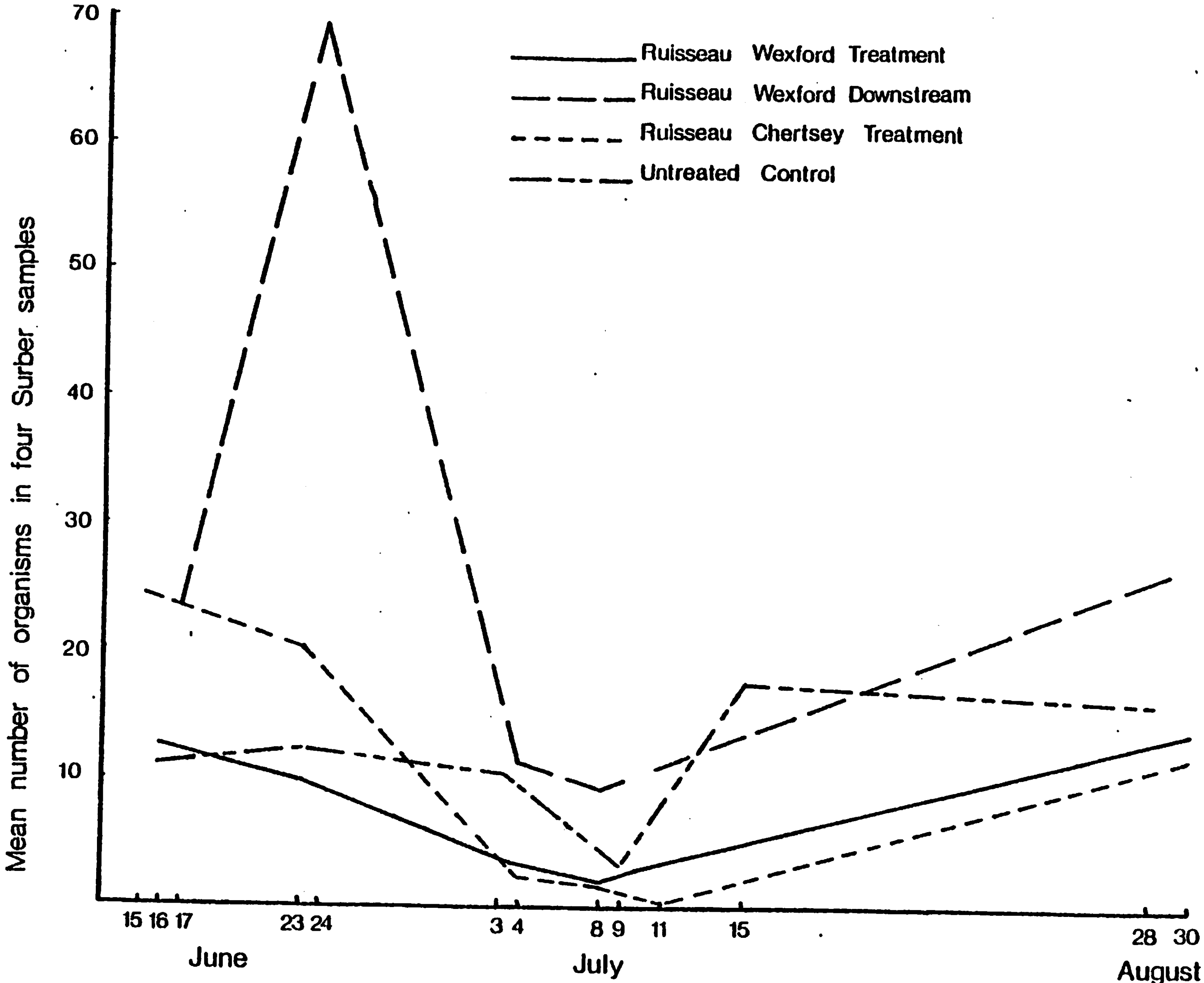


Figure 8. Aquatic organisms collected in Surber samples from R. Wexford, R. Wexford Downstream, R. Chertsey and the Untreated Control Stream

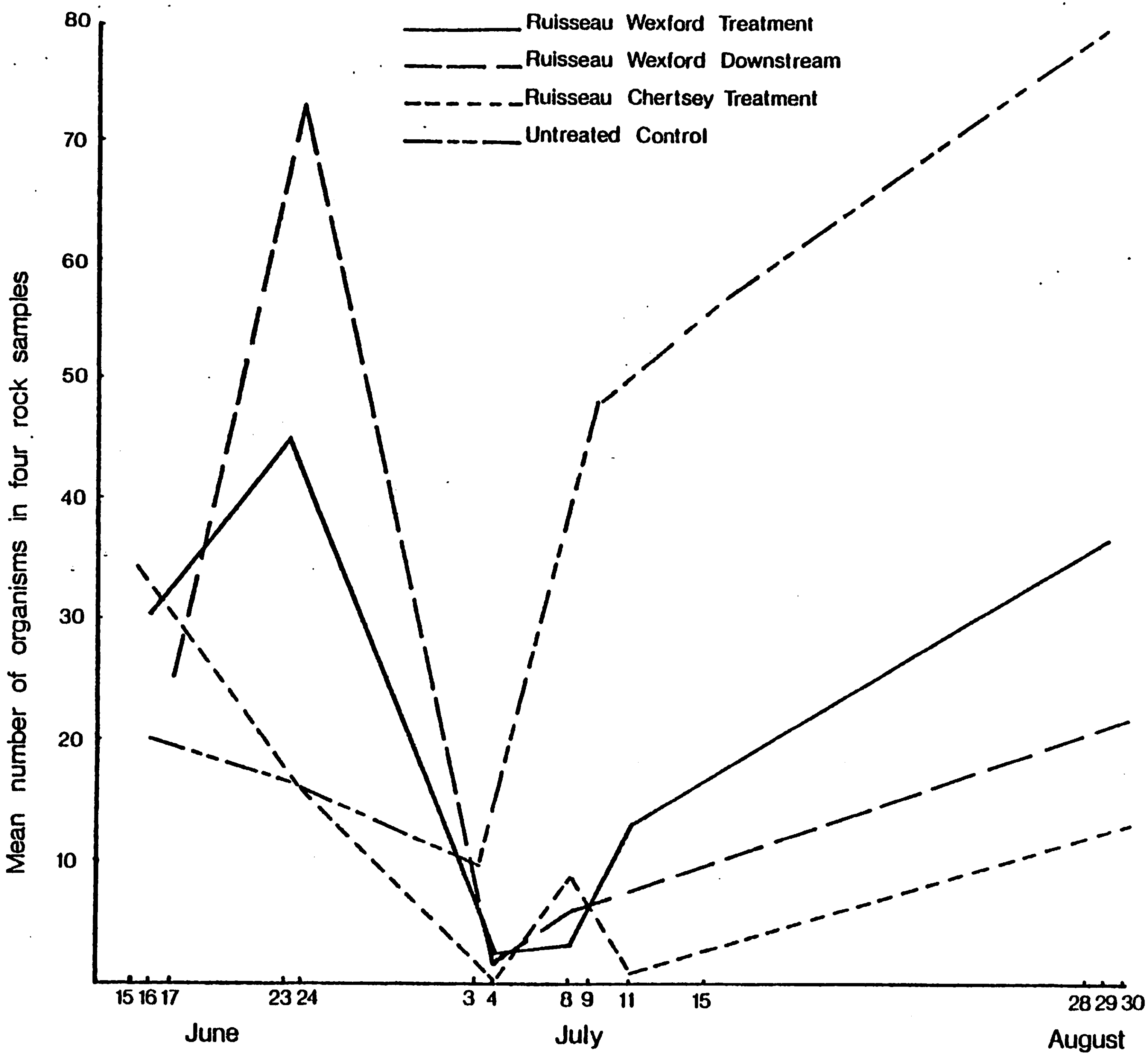


Figure 9. Aquatic organisms collected in rock samples from R. Wexford, R. Wexford Downstream, R. Chertsey and the Untreated Control Stream

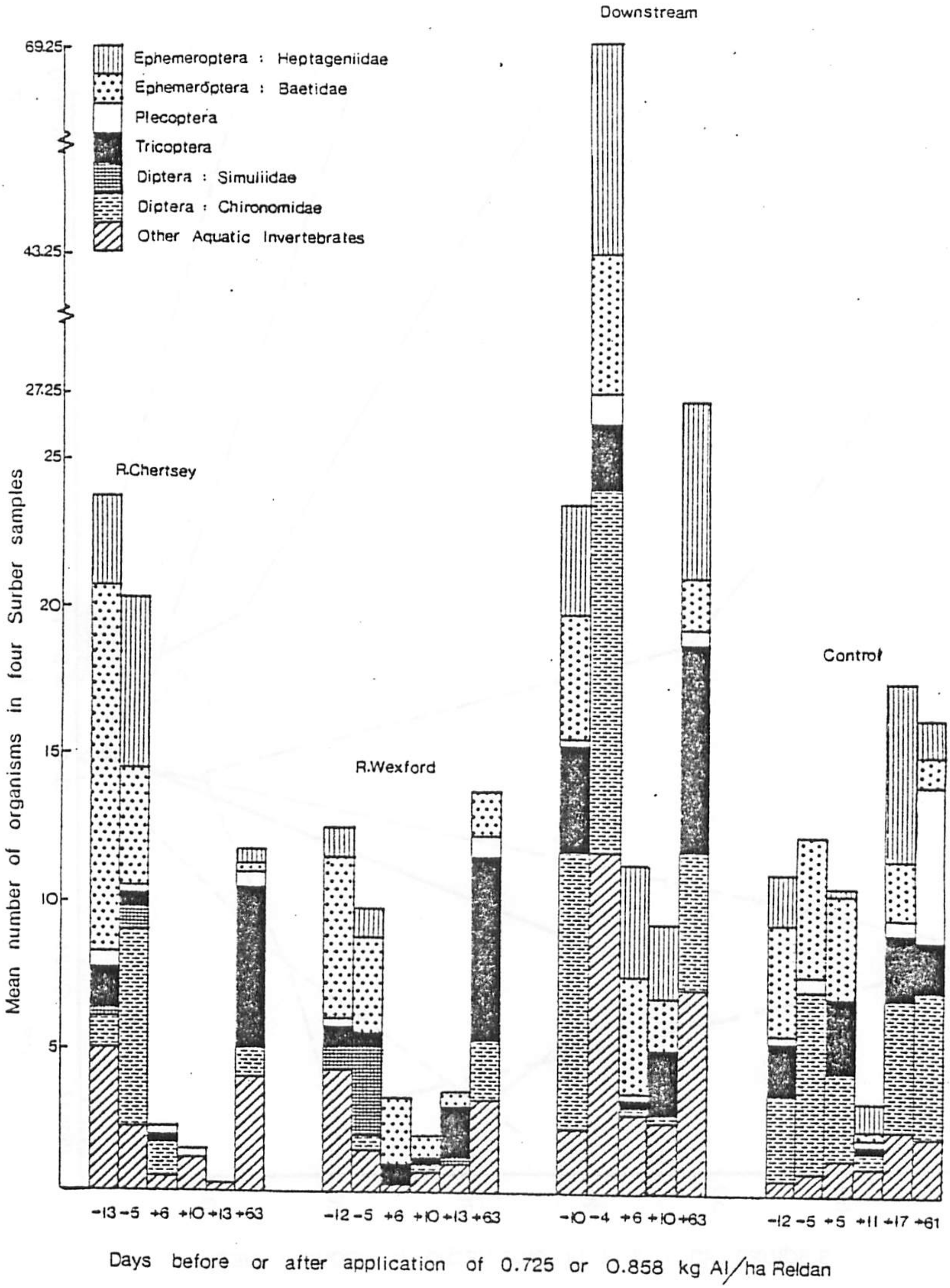


Figure 10. Changes in abundance of selected groups of aquatic invertebrates from Surber samples

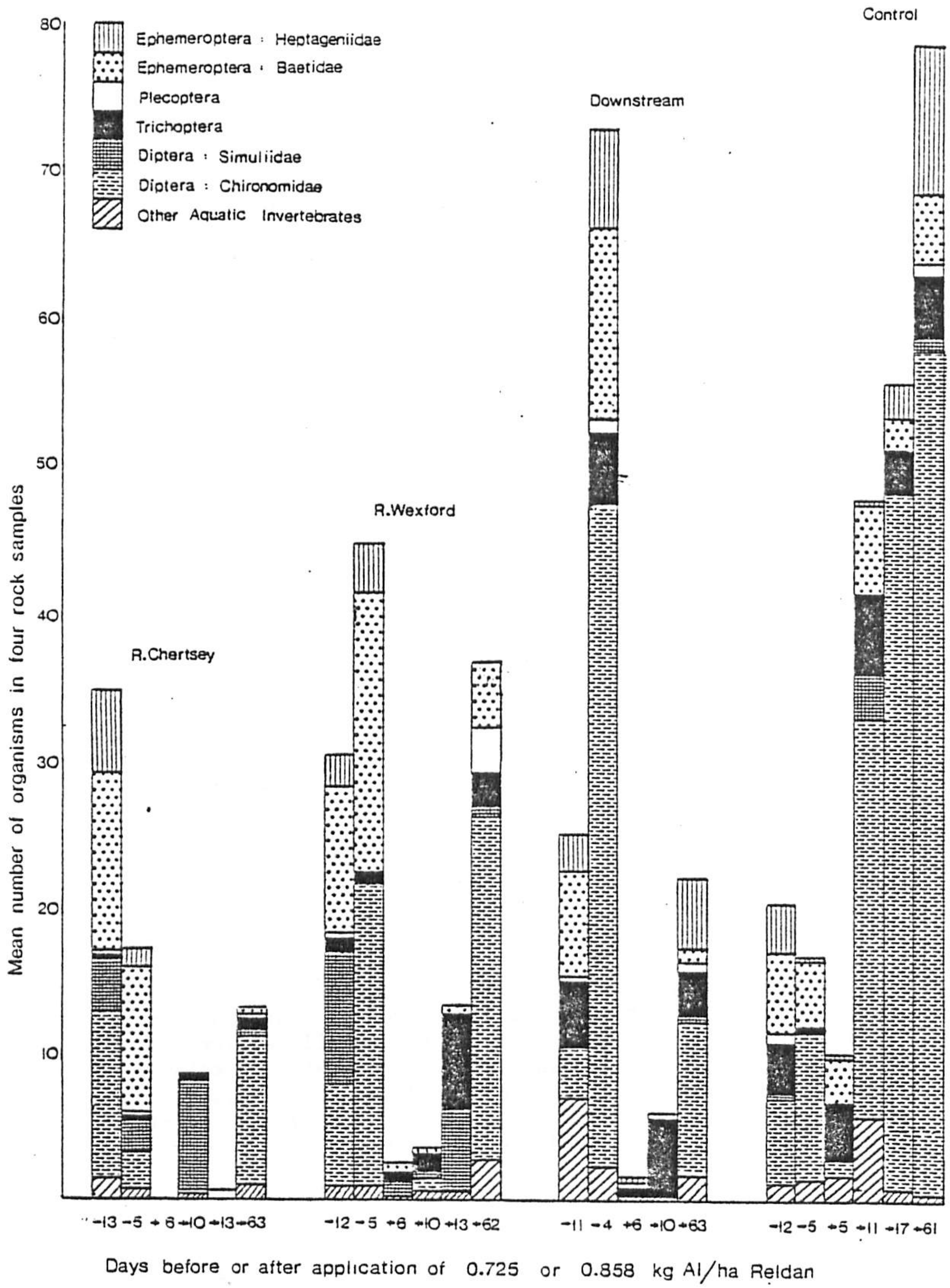


Figure 11. Changes in abundance of selected groups of aquatic invertebrates from rock samples

Bottom fauna populations remained at a low level of abundance and diversity through the +13 day post-spray samples at Ruisseau Chertsey and Ruisseau Wexford, and the +10 day post-spray sample at the downstream station. By the time of the 2 month post-spray sample, there was partial recovery of chironomid larvae populations at Ruisseau Chertsey, but numbers of baetid mayfly nymphs were still very low (< 10% of the number in the immediate pre-spray Surber and rock samples). At Ruisseau Wexford chironomid larvae and baetid mayfly nymph populations had both recovered to close to their pre-spray levels by the time of the 2 month post-spray sample. Heptagenid mayfly nymphs were still very uncommon at this time, however, at both Ruisseau Chertsey and Ruisseau Wexford; two were collected at Ruisseau Chertsey and none at Ruisseau Wexford as opposed to 28 at Ruisseau Chertsey and 17 at Ruisseau Wexford in the immediate pre-spray sample. At the downstream station populations of heptagenid mayfly nymphs, baetid mayfly nymphs and chironomid larvae had all partially recovered by the time of the 2 month post-spray sample with a corresponding increase in diversity of aquatic fauna at this time.

Stream Searches

Large numbers of dead and distressed stonefly nymphs (Plecoptera: Perlidae) were observed in Ruisseau Chertsey following the 28 June insecticide application. In addition, a total of 25 dead crayfish (Decapoda: Astacidae), 14 dead brook sticklebacks, *Culaea inconstans* Kirtland, one dead creek chub, *Semotilus atromaculatus* Mitchill, and one dead common shiner, *Notropis cornutus* Mitchill, were collected in post-spray searches of approximately 300 meters of stream bottom. Only three living crayfish were recorded during these searches, but very large numbers of apparently unaffected individuals of all three fish species were seen.

At Ruisseau Wexford no living and only one dead crayfish were recorded in post-spray stream searches. Large numbers of dead caddisfly larvae (Trichoptera: Limnephilidae) were found on the bottom of a small impoundment approximately one kilometer upstream from the drift station. No dead or distressed brook trout, *Salvelinus fontenalis* Mitchill, the only fish species present in Ruisseau Wexford, were observed.

Fish diets

Detailed changes in brook trout, common shiner, and creek chub diets are summarized graphically in the accompanying figures, (Figures 12, 13, 14 and 15*) and only general trends will be described here.

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*see Appendix for explanation of codes.

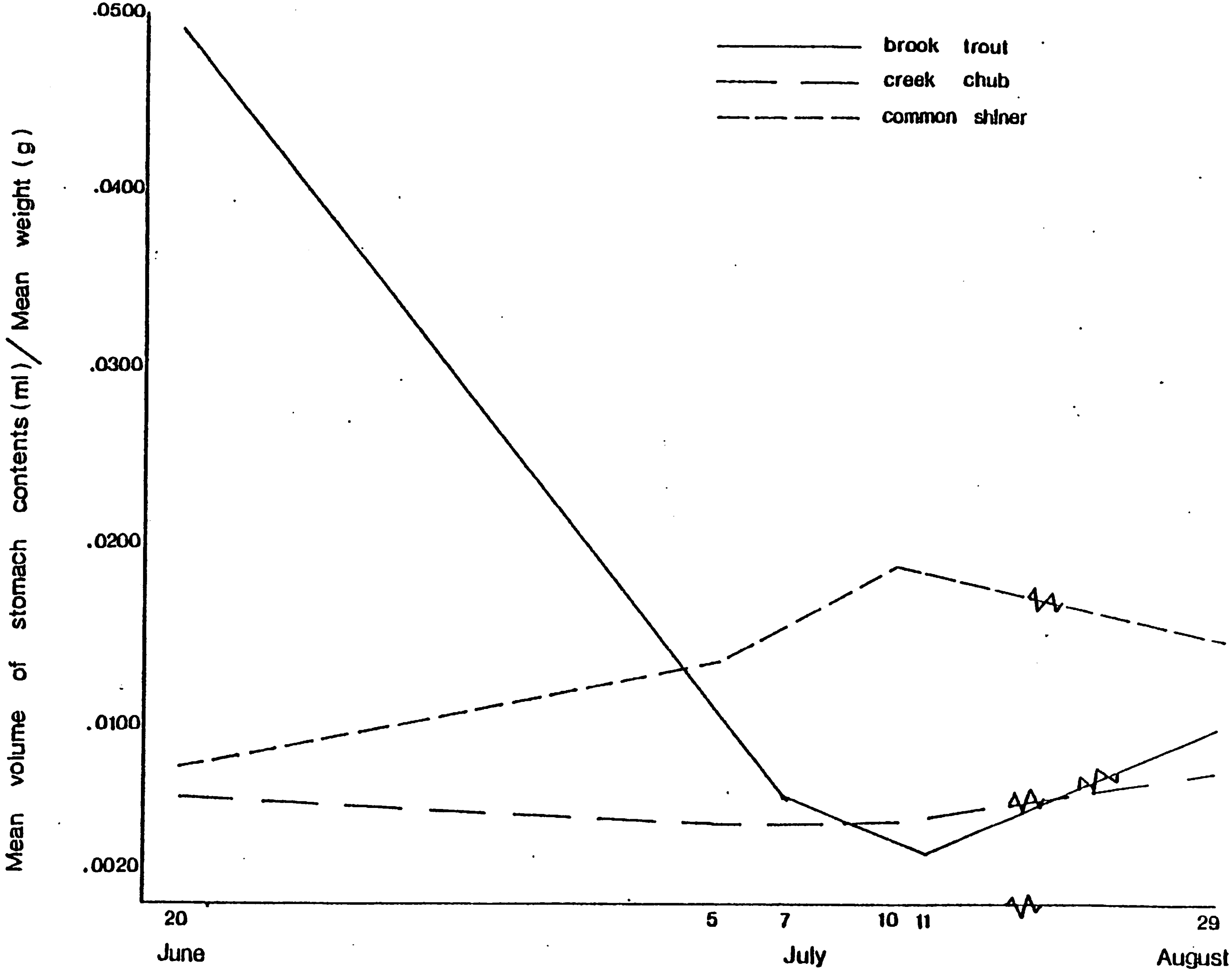

Figure 12. Quantity of food ingested by fish sampled for stomach content analysis from R. Wexford and R. Chertsey

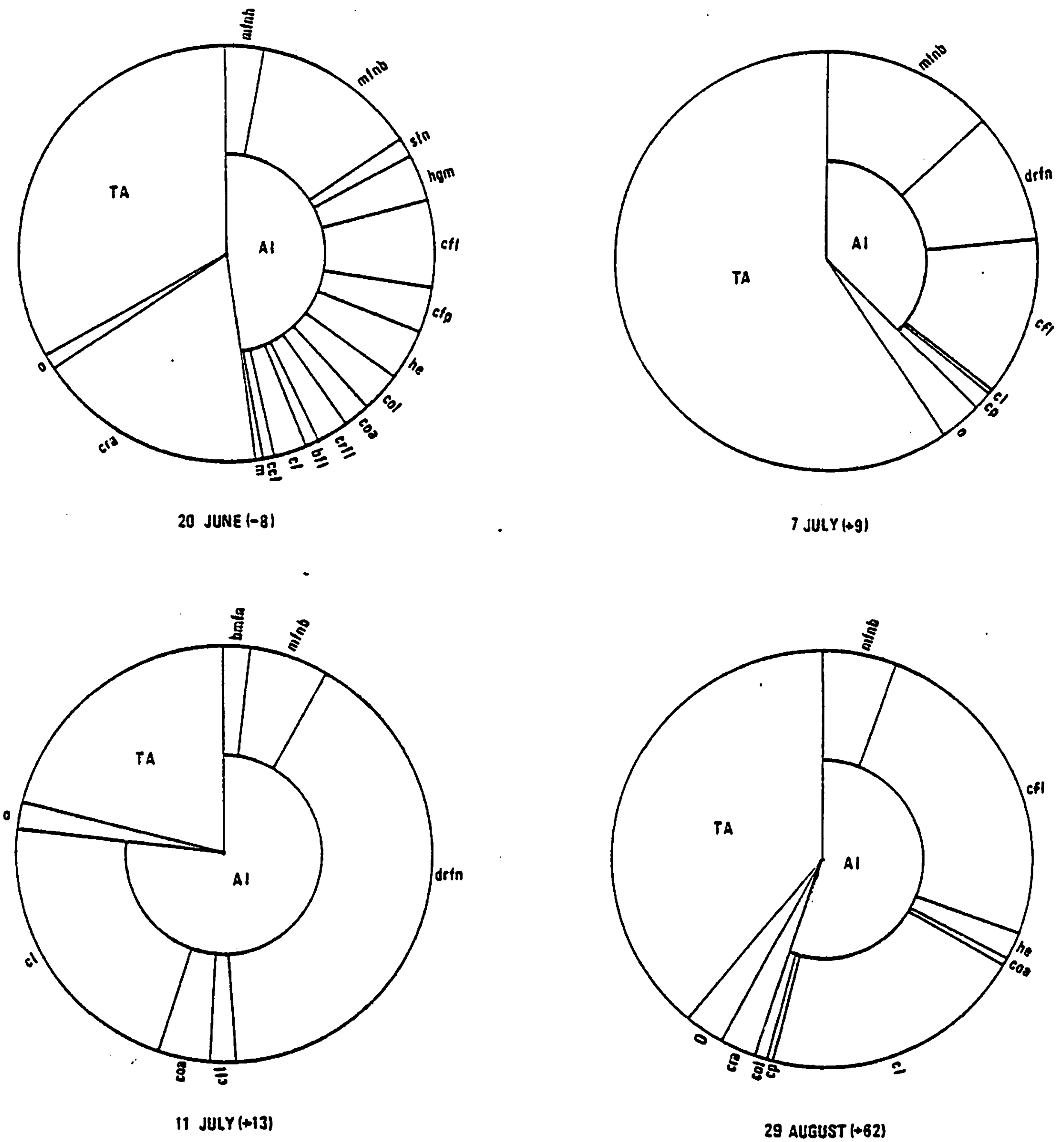

Figure 13. Dietary changes in brook trout sampled from R. Wexford

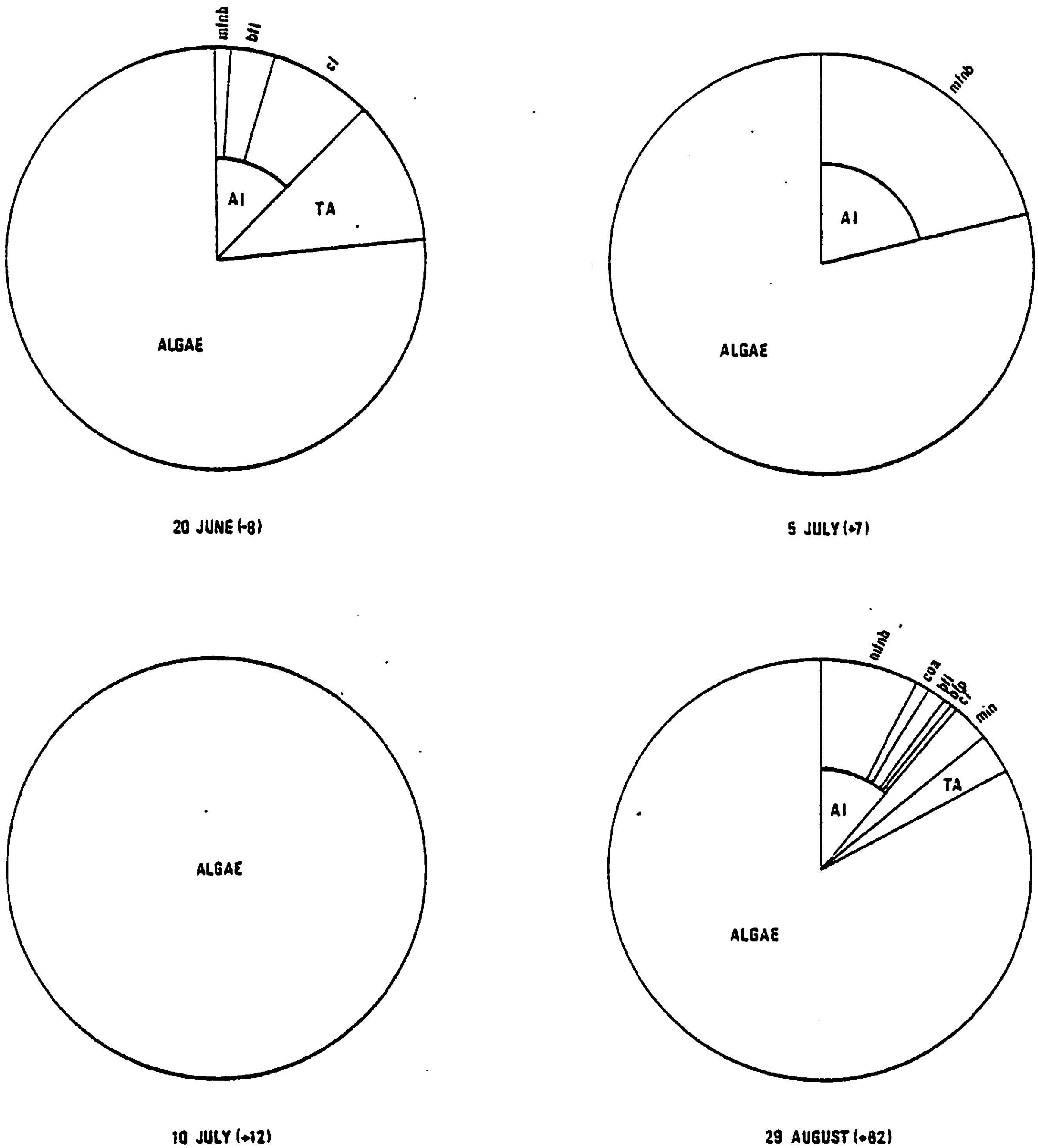

Figure 14. Dietary changes in common shiners sampled from R. Chertsey

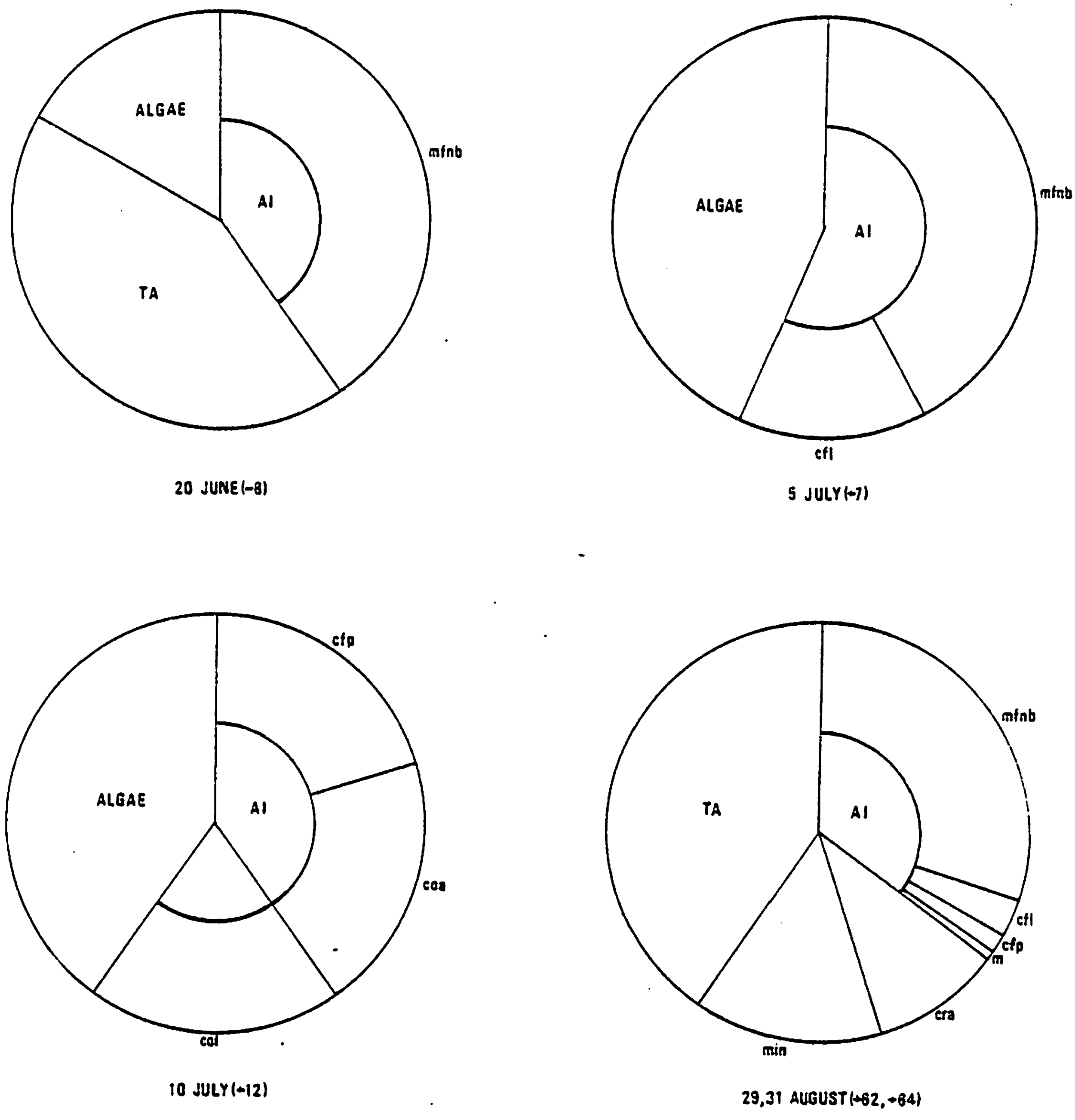

Figure 15. Dietary changes in creek chubs sampled from R. Chertsey

A substantial reduction in the quantity of food ingested by brook trout, as indicated by the ratio of mean volume of stomach contents (ml)/mean weight of fish (g), was noted following the insecticide application at Ruisseau Wexford (Figure 12), a trend which was still evident up to the 2 month post-spray sample. No similar trend was noted for either common shiners or creek chubs from Ruisseau Chertsey.

Significant changes in the composition of brook trout diets were also observed (Figure 13). An increase in the importance of terrestrial invertebrates in the diet, particularly homoptera and diptera, was noted in the 9 day post-spray sample. Although aquatic insects generally decreased in importance in the 9 day post-spray sample, dragonfly nymphs (Odonata) and caddisfly larvae both increased in importance as a food source at this time. In addition, pre-spray stomachs contained a greater diversity of aquatic insect species than did post-spray stomachs. Crayfish, which were eaten only occassionally in the pre-spray sample, but which still contributed considerably to the volume of the stomach contents of brook trout at this time, disappeared from the first post-spray sample altogether. By the time of the 13 day post-spray sample, terrestrial invertebrates had decreased in importance to below the pre-spray level, while dragonfly nymphs and chironomid larvae had both greatly increased in importance. It should be noted here that in the pre-spray sample 9 different terrestrial invertebrate orders were represented in brook trout stomachs, but by 13 days after application only 2 orders were found. Terrestrial invertebrates (from 8 different orders) were once again a very important dietary item in the 2 month post-spray sample, as were chironomid larvae and caddisfly larvae. Diversity of the diet in terms of aquatic insects, however, was still quite low at this time.

Algae was the most important single food source for common shiners at Ruisseau Chertsey (making up greater than 75% of the volume of stomach contents in all samples) throughout the study period (Figure 14). Terrestrial invertebrates, blackfly larvae and chironomid larvae all disappeared from the diet of common shiners 9 days after the RELDAN® application, and were replaced by baetid mayfly nymphs. Four days later fish were feeding exclusively on algae. By the time of the 2 month post-spray sample, however, fish were feeding on a variety of aquatic insects, terrestrial invertebrates and minnows, in addition to algae.

Terrestrial invertebrates disappeared from creek chub diets following the RELDAN® application at Ruisseau Chertsey (Figure 15). There was a corresponding increase in the amount of algae eaten, and addition of caddisfly larvae to the diet, at this time (7 day post-spray sample). Baetid mayfly nymphs were taken in approximately equal amounts in the pre- and post-spray samples. Five days later baetid mayfly nymphs and caddisfly larvae disappeared from creek chub stomachs and were replaced by caddisfly pupae, aquatic coleoptera and collembola. By the time of the 2 month post-spray sample algae was no longer present in the diet and creek chubs were feeding on a variety of aquatic insects, crayfish, minnows and terrestrial invertebrates.

SUMMARY AND CONCLUSIONS

RELDAN® had a number of significant environmental effects when aerially applied at dosage rates of 725 and 858 grams active ingredient per hectare to two streams in Quebec in 1979:

1) RELDAN® had a significant insecticidal effect on terrestrial invertebrates in general and flying diptera in particular. The effects of the applications were confined to spray day for most invertebrate groups, but were still evident among diptera up to two days after application.

2) Substantial reductions in total numbers and diversity of aquatic invertebrates were documented in both study streams following RELDAN® applications. Population reductions were most evident among heptagenid and baetid mayfly nymphs and chironomid larvae, but stonefly nymphs, caddisfly larvae and several other invertebrate groups were also affected. Partial recovery was evident at all three study stations two months after application.

3) Mortality of brook sticklebacks, creek chubs, and common shiners was documented in the 725 grams/hectare treatment stream, but not at a level considered to be significant in terms of total fish populations. Some mortality of crayfish was also noted. No incidence of fish mortality (brook trout were the only fish species present) was recorded in the 858 grams/hectare treatment stream.

4) From the numbers of dead and distressed fish collected in post-spray stream searches, it would appear that RELDAN® is more toxic to brook sticklebacks than it is to brook trout, creek chubs and common shiners. Acute toxicity tests conducted recently at the FPMI laboratory in Sault Ste. Marie, which tend to confirm this observation with respect to brook trout and brook sticklebacks, will be presented in a later report.

5) Significant changes in the composition of brook trout, creek chub and common shiner diets were evident following RELDAN® applications. A reduction in the quantity of food ingested by brook trout was also observed. Unfortunately there is no comparable control data to confirm whether these changes were spray related or not.

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Kingsbury, P.D. 1979. Preliminary field assessment of the effects of chlorpyrifos-methyl on stream fauna. Unpublished report to Dow Chemical of Canada Ltd., Sarnia, Ontario.

Kingsbury, P.D., S.B. Holmes and R.L. Millikin. 1980. Environmental effects of a double application of azamethiphos on selected terrestrial and aquatic organisms. Information Report FPM-X-33, Forest Pest Management Institute, Sault Ste. Marie, Ontario.

APPENDIX

Explanation of codes used in Figures 13, 14 and 15

TA	terrestrial arthropods
AI	aquatic insects
col	Collembola
bmfn	burrowing mayfly nymphs (Ephemeroptera: Ephemeridae)
mfnh	heptagenid mayfly nymphs (Ephemeroptera: Heptageniidae)
mfnb	baetid mayfly nymphs (Ephemeroptera: Baetidae)
drfn	dragonfly nymphs (Odonata)
sfn	stonefly nymphs (Plecoptera)
he	aquatic Hemiptera
hgm	hellgramites (Megaloptera: Corydalidae)
cfl	caddisfly larvae (Trichopera)
cfp	caddisfly pupae (Trichoptera)
coa	aquatic Coleoptera
crfl	cranefly larvae (Diptera" Tipulidae)
bfl	blackfly larvae (Diptera: Simuliidae)
cl	chironomid larvae (Diptera: Chironomidae)
cp	chironomid pupae (Diptera: Chironomidae)
ccl	culicoides larvae (Diptera: Heleidae)
m	miscellaneous aquatic insects
cra	crayfish (Decapoda: Astacidae)
o	other aquatic invertebrates
min	minnows