PRELIMINARY REPORT ON THE ENVIRONMENTAL IMPACT OF EXPERIMENTAL PERMETHRIN APPLICATIONS IN QUEBEC, 1980

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INTRODUCTION

Experimental applications of permethrin, a synthetic pyrethroid insecticide, were included as a part of the 1980 spruce budworm aerial spray program of the Quebec Service d'Entomologie et de Pathologie. In addition to provincial monitoring of the application effects, the Forest Pest Management Institute assessed the environmental impact and persistence of the pesticide. Additional support and analytical services were provided by Chipman Inc.

Four 400 ha blocks in Kamouraska County in the Lower St. Lawrence Region of Quebec were treated with 17.5 g AI/ha permethrin emitted in 1.46 ℓ/ha. Two single application blocks (301, 304) were treated on 6 and 7 June 1980, while two double application blocks (302, 303) received successive treatments on 7 and 17 June, and 6 and 15 June 1980, respectively.

Aquatic invertebrate populations were monitored within and below a single (St. Denis 301) and a double (Manie 303) application block (Figures 1 and 2). Aquatic invertebrates were also sampled in the single application block Manie 304 which, being located immediately upstream from block 303, in effect contributed pesticide equivalent to a third application to the lower sections of Riviere Manie. Sampling of terrestrial invertebrates and small mammals was confined to the double application block 303. Residual permethrin levels were monitored in water, sediment, and litter from and below block 303, and in water from the single application block 301. In addition to the treatment sampling areas, a temporal control was established in Riviere Manie approximately 1.5 km upstream from block 304, while a section of Riviere du Loup located approximately 7 km southeast of blocks 301 and 302 served as a spatial control.

RESULTS

Pesticide Deposit

The results of pesticide deposit obtained from the double application block (303) represent measurements taken from the initial application only, since logistical problems prevented deposit analysis of the second application. The amount of emitted formulation deposited on sample cards ranged from 2.74 to > 100% with instream and open samples receiving substantially greater deposit than shoreline and heavily canopied areas (Table 1). Although droplet densities did not exceed 10/cm^2, the mean diameters of the droplets deposited were approximately 1.5 to 2 times larger than those measured from previous experimental permethrin applications (Kingsbury and Kreutzweiser 1979, 1980).

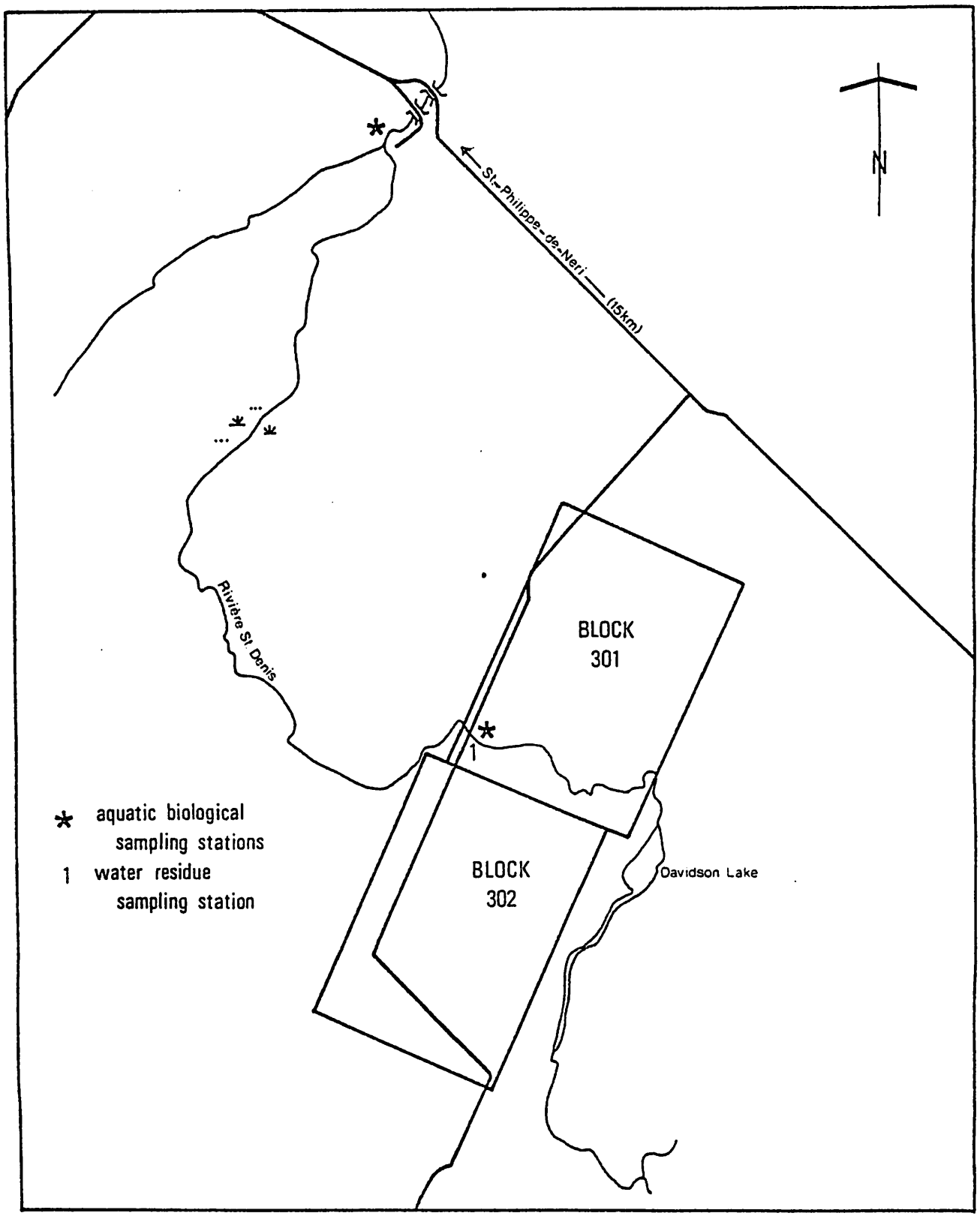


Figure 1 Permethrin application blocks on Riviere St. Denis, Kamouraska County, Quebec, 1980

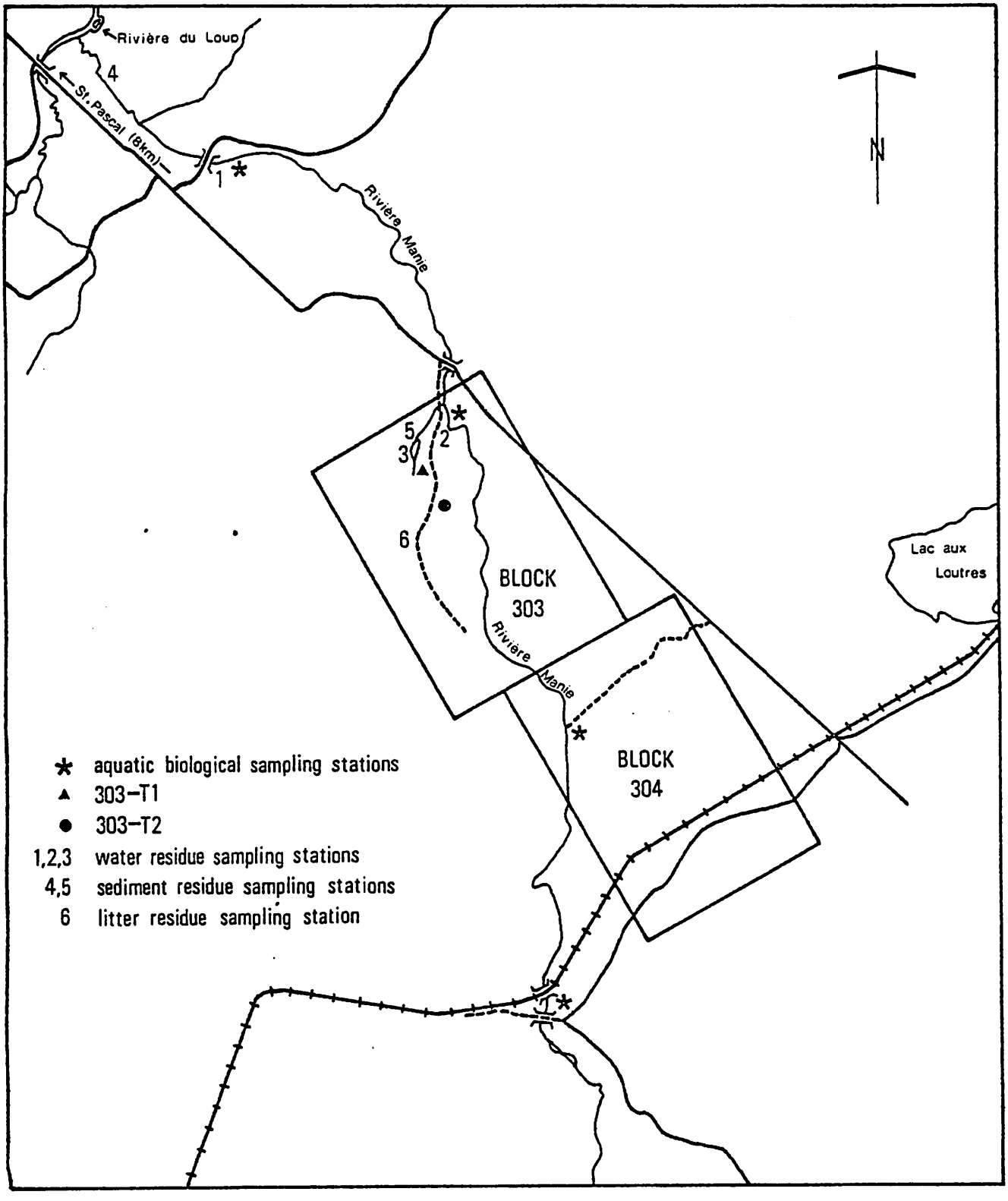


Figure 2 Permethrin application blocks on Riviere Manie, Kamouraska County, Quebec, 1980

Table 1

Deposit analysis of 17.5 g AI/ha permethrin applied at an emission rate of 1.46 ℓ/ha to treatment blocks* Kamouraska County, Quebec, 1980.

	Spot Counting Analysis		Mean Density (Drops per cm^2)	Mean Droplet Diameter Deposited (μ)
	ℓ/ha	% deposit		
Riviere Manie 304 instream	0.33 ± 0.32	22.60	2.67	138.2 ± 13.4
shoreline	0.08 ± 0.03	5.48	1.11	105.8 ± 4.9
303 instream	1.00 ± 0.24	68.49	4.21	140.0 ± 8.8
shoreline	0.73 ± 0.50	50.00	4.08	130.3 ± 15.6
Downstream instream	0.004 ± 0.002	0.27	0.18	63.2 ± 5.6
Riviere St. Denis 301 instream	2.12 ± 2.05	145.20	9.07	125.8 ± 41.8
shoreline	0.57 ± 0.16	39.04	5.13	107.2 ± 14.8
Downstream instream	0	0	-	-
Terrestrial sampling area				
303-1	0.20 ± 0.08	13.70	2.04	116.4 ± 7.3
303-2 (canopy)	0.12 ± 0.09	8.22	0.68	147.3 ± 15.4
303-2 (no canopy)	0.86 ± 0.28	58.90	3.18	161.5 ± 10.8
Sediment residue sampling area	0.64 ± 0.07	43.84	5.55	121.9 ± 2.1
Litter residue sampling area	0.04 ± 0.03	2.74	0.41	111.9 ± 15.9

*results from double application block (303) obtained from initial application only.

Pesticide Residues

Permethrin residues in water, sediment, and forest litter were measured by the chemistry section of Chipman Inc. and a small proportion of the samples collected were also analyzed by the Analytical Chemistry group at the Forest Pest Management Institute to confirm their results. The concentrations of residues determined by the two participating chemistry groups were consistently similar.

The mean values of pesticide residue calculated from several replicate samples taken at each interval have been presented in Table 2. Concentrations of residual permethrin in standing water ranged from 0.03 to 1.35 µg/ℓ and persisted at a mean level of 0.14 µg/ℓ for at least 96 hours after the initial application and at 0.06 µg/ℓ for at least 48 hours following the second application. Residue levels in the single application stream (St. Denis 301) peaked at 1.30 µg/ℓ one-half hour after the application and remained at 0.31 µg/ℓ for at least 24 hours post-spray. Samples from the double application stream (Manie 303) indicate residue levels generally ranged from 0.05 to 1.84 µg/ℓ with the exception of two anomalous samples containing 13.77 and 86.21 µg/ℓ permethrin. When tested against the three respective replicates the high concentrations of these samples are statistically improbable ($p < 0.01$) and have therefore been excluded from the calculation of mean values. Permethrin concentrations in the water persisted at mean levels of 0.15 µg/ℓ for at least 96 hours and 0.03 µg/ℓ for at least 48 hours after the first and second applications respectively. Pesticide residue levels measured at the Manie Downstream station, approximately 3 km below Manie 303, varied from 0.03 µg/ℓ to 0.91 µg/ℓ with one sample (6 hours post-second application) containing 29.38 µg/ℓ. This sample does not fall within 99 percent confidence limits ($p < 0.01$) and has been excluded from the analysis of mean concentrations. Residues persisted at a mean level of 0.03 µg/ℓ 24 hours after the initial application and at 0.04 µg/ℓ 12 hours after the second application. With the exception of the three anomalous samples mentioned above, the levels of residual pesticide were comparable to those measured in previous experimental permethrin applications, but persisted much longer (Kingsbury and Kreutzweiser 1979, 1980). Residue concentrations in water did not attain non-detectable levels in any of the areas by the end of the sampling period.

Measurements of permethrin residues in sediment collected from a pond and outflow stream in block 303 varied widely after the second application from non-detectable levels to 0.095 µg/g, but appeared to stabilize at a relatively high mean concentration of 0.012 µg/g 59 days after the applications (Table 3). Accumulation of residual permethrin in stream sediment collected from a section of Riviere Manie approximately 4.5 km downstream from block 303 was minimal. Only 2 of a total of 24 samples taken contained measurable amounts of pesticide.

The second application appeared to contribute significantly to the level of permethrin residues in forest litter in block 303 (Table 3). Mean concentration ranged from 0.001 µg/g to 0.053 µg/g but were reduced to non-detectable levels by the end of the 59 day sampling period.

Table 2

Permethrin residues (µg/ℓ) in water samples taken from treatment areas Kamouraska County, Quebec, 1980.

Sampling Regime	Manie 303	Manie Downstream	Pond 303	St. Denis 301
Number of replicate samples	5	5	2	3
Pre-spray	N.D.	-	N.D.	-
First application				
½ hr post-spray	-	-	-	1.30 ± 0.60
1½ hr	0.62 ± 0.07	0.28 ± 0.15	0.10 ± 0.00	-
6 hr	0.43 ± 0.13	0.59 ± 0.20	0.62 ± 0.01	0.64 ± 0.25
12 hr	0.13 ± 0.09	0.25 ± 0.25	0.14 ± 0.01	0.32 ± 0.04
24 hr	0.11 ± 0.11*	0.03 ± 0.02	0.13 ± 0.04	0.31 ± 0.01
96 hr	0.15 ± 0.10	-	0.14 ± 0.16	-
Second application				
1 hr post-spray	1.58 ± 0.24*	-	0.23 ± 0.10	
1½ hr	-	0.09 ± 0.06	-	
6 hr	0.24 ± 0.22	0.08 ± 0.01*	0.77 ± 0.10	
12 hr	0.15 ± 0.06	0.04 ± 0.02	0.84 ± 0.73	
24 hr	0.55 ± 0.59	-	0.12 ± 0.01	
48 hr	0.03 ± 0.03	-	0.06 ± 0.01	

" - " indicates no sample taken
N.D. - none detected
Limit of detection 0.01 µg/ℓ (ppb)
* means calculated from four replicates only - anomalous samples ($p < 0.01$) have been excluded.

Table 3

Permethrin residues (µg/g) in sediment and litter samples from treatment area Kamouraska County, Quebec, 1980.

Sampling Regime	Sediment		Litter
	Manie 303 (pond and outlet)	Manie Downstream	Block 303
Number of replicate samples	7	5	5
Pre-spray	N.D.	-	N.D.
First application			
1 day post-spray	-	-	0.001 ± 0.002
4 days	-	-	0.004 ± 0.006
Second application			
1 day post-spray	0.004 ± 0.008	-	0.030 ± 0.014
4 days	0.004 ± 0.008		0.053 ± 0.073
6 days	-	0.002 ± 0.005**	-
8 days	0.015 ± 0.035*	N.D.	0.039 ± 0.056
26 days	0.006 ± 0.009	0.012 ± 0.028**	0.016 ± 0.012
59 days	0.012 ± 0.009	N.D.	N.D.

" - " indicates no sample taken
N.D. - none detected
Limit of detection 0.003 µg/g (ppm)
* increased mean and large variance introduced by one of seven samples with value 47 times greater than the other six.
** increased mean and large variance resulted from single sample since four of five samples contained no detectable levels.

Aquatic Invertebrates

Drift data have not been analyzed to date, but recorded field observations show massive increases in the number of drifting invertebrates occurred after each application. The single block treatment resulted in a dramatic drift increase which persisted for 24 hours. No increase was evident at the station approximately 7 km below the block. The initial application to the double block produced massive drift increases within the block and at a sampling area 3 km downstream, and persisted for up to 24 hours. The second application resulted in significant but much reduced increases in drifting invertebrates that persisted for less than 4 hours in the block and for up to 12 hours downstream.

Ephemeroptera nymphs comprised the largest proportion of bottom fauna populations in all sample areas and demonstrated the most apparent indications of pesticide effects. Surber sampling in the single application block (301) showed a significant reduction (75%) in mayfly nymphs, while benthic invertebrates sampled on rocks were virtually eliminated following the application (Figures 3 and 4). No pesticide-induced changes in bottom fauna populations were evident at the station approximately 7 km below the treatment block. Mayfly nymphs in the double application block (303), were substantially reduced in benthos samples after the first spray and almost eliminated following the second application (Figures 5 and 6). At the station approximately 3 km below the double block, mayfly nymph populations were reduced by about 90% after the initial application and remained suppressed at that level for approximately 30 days after the second application. The level of mayfly nymph populations in the single application block 304 (immediately upstream from 303) did not demonstrate pesticide related fluctuations and followed a pattern similar to that of the temporal control station. The apparent lack of pesticide effects on bottom dwelling insects in block 304 concur with recorded observations and measurements of a comparatively lighter deposit (Table 1), a shorter section of stream treated, and a lower level of post-spray invertebrate drift.

Substantial numerical recovery of benthic invertebrate populations was apparent by mid-August and virtually complete by late September at all stations affected by the permethrin treatments. Complete tabulations of aquatic fauna sampled in both benthos and drift are forthcoming in a later publication.

Terrestrial Invertebrates

The permethrin applications to block 303 resulted in moderate increases in the number of arboreal and flying arthropods collected in the two terrestrial invertebrate knockdown sampling areas (Figures 7 and 8). In three of the four instances, the increases were limited to the day of application and did not persist beyond 24 hours. The number of arthropods collected in 303-T1 following the second application continued to increase 24 hours after the spray but reflected a similar occurrence in the control area and may have been the result of heavy rainfall from the previous night.

Flying insects, mainly dipterans, as well as spruce budworm, hymenopterans, beetles and spiders comprised the major portion of collected invertebrates in both the treated and control areas. The magnitude of invertebrate knockdown was

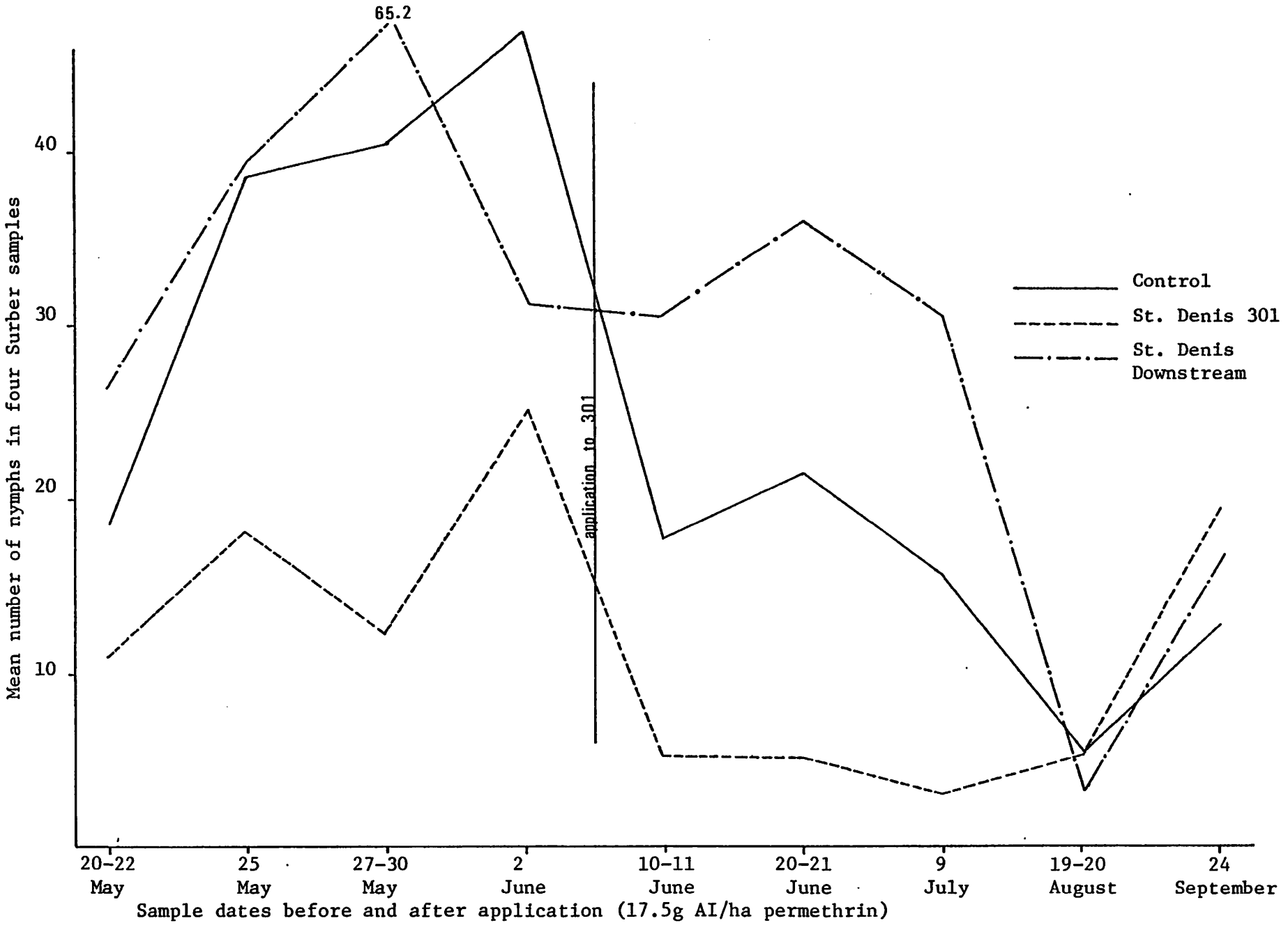


Figure 3 Mayfly nymphs collected in Surber samples taken from Riviere St. Denis and the untreated control section of Riviere du Loup, Kamouraska County, Quebec, 20 May to 24 September 1980

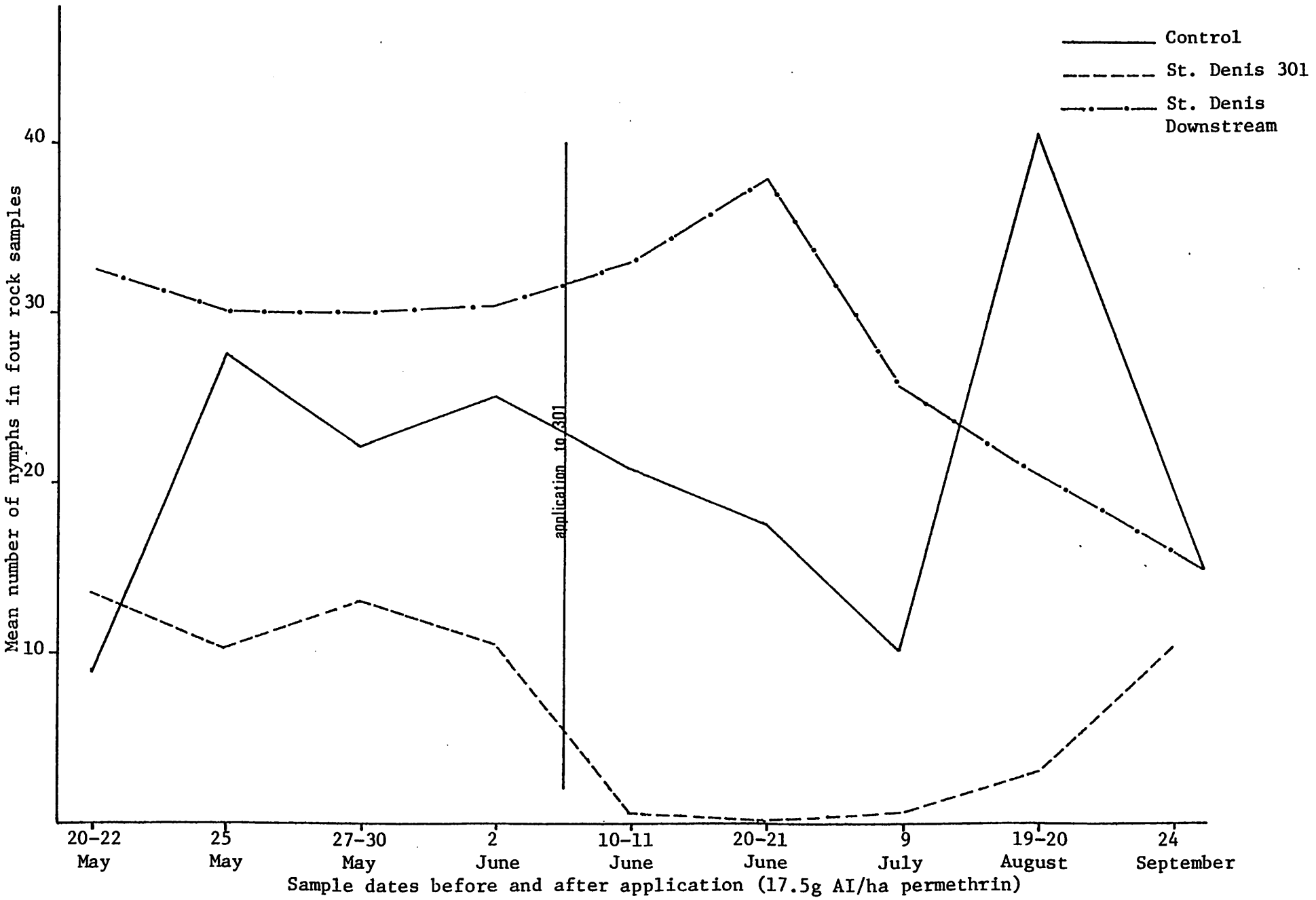


Figure 4 Mayfly nymphs collected from four rocks taken from Riviere St. Denis and the untreated control section of Riviere du Loup, Kamouraska County, Quebec, 20 May to 24 September 1980

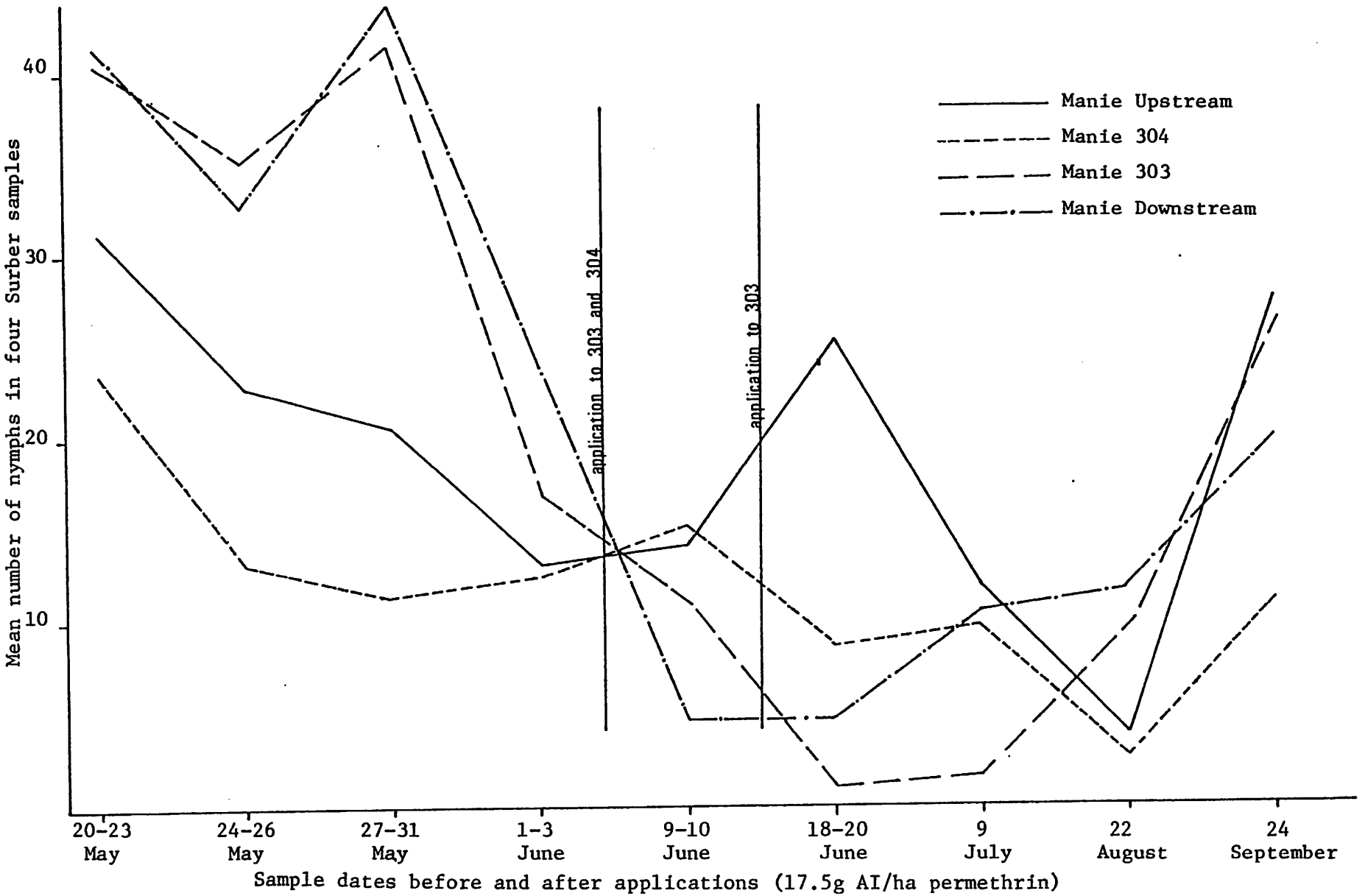


Figure 5 Mayfly nymphs collected in Surber samples from Riviere Manie, Kamouraska County, Quebec, 20 May to 24 September 1980

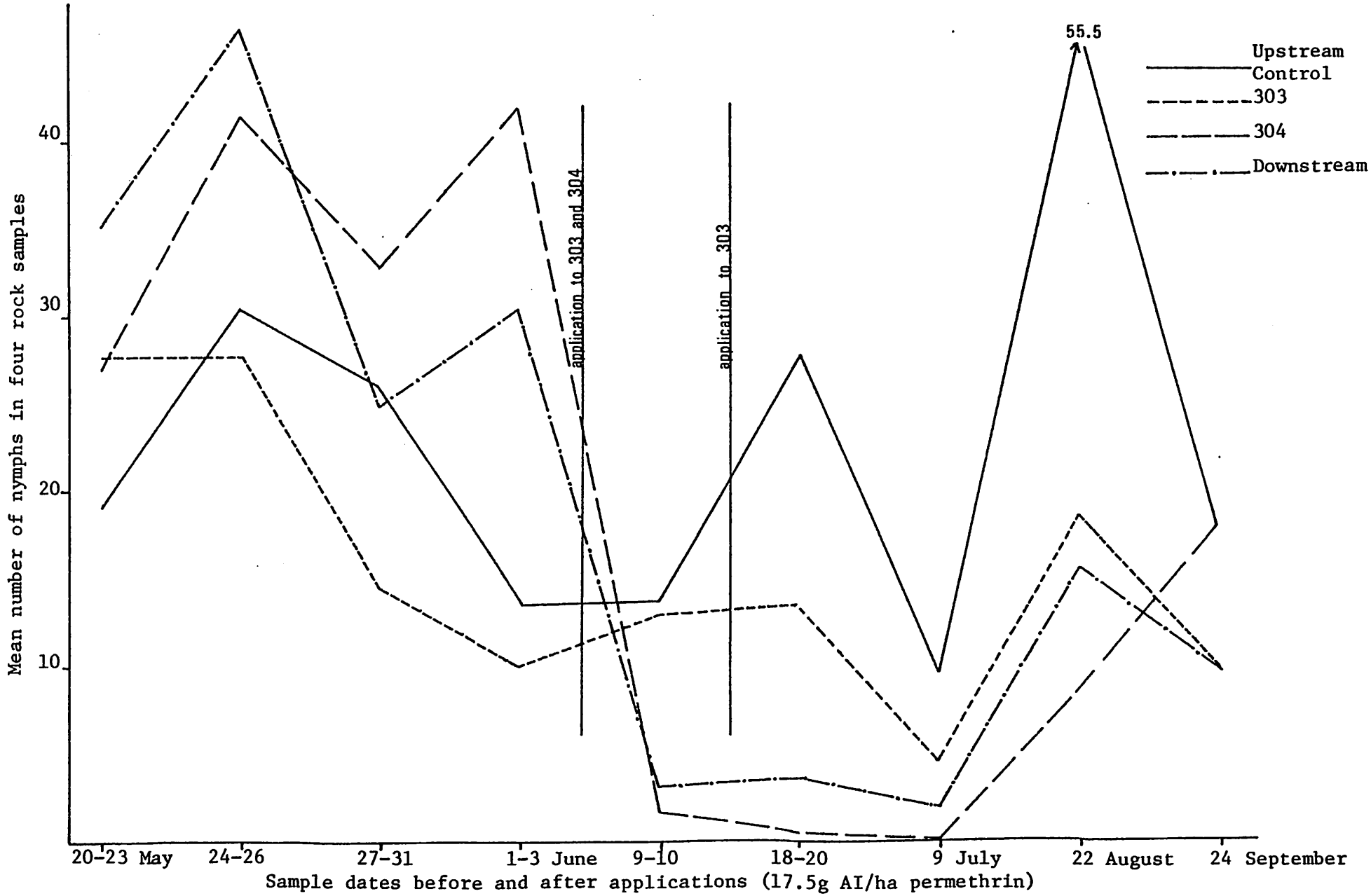
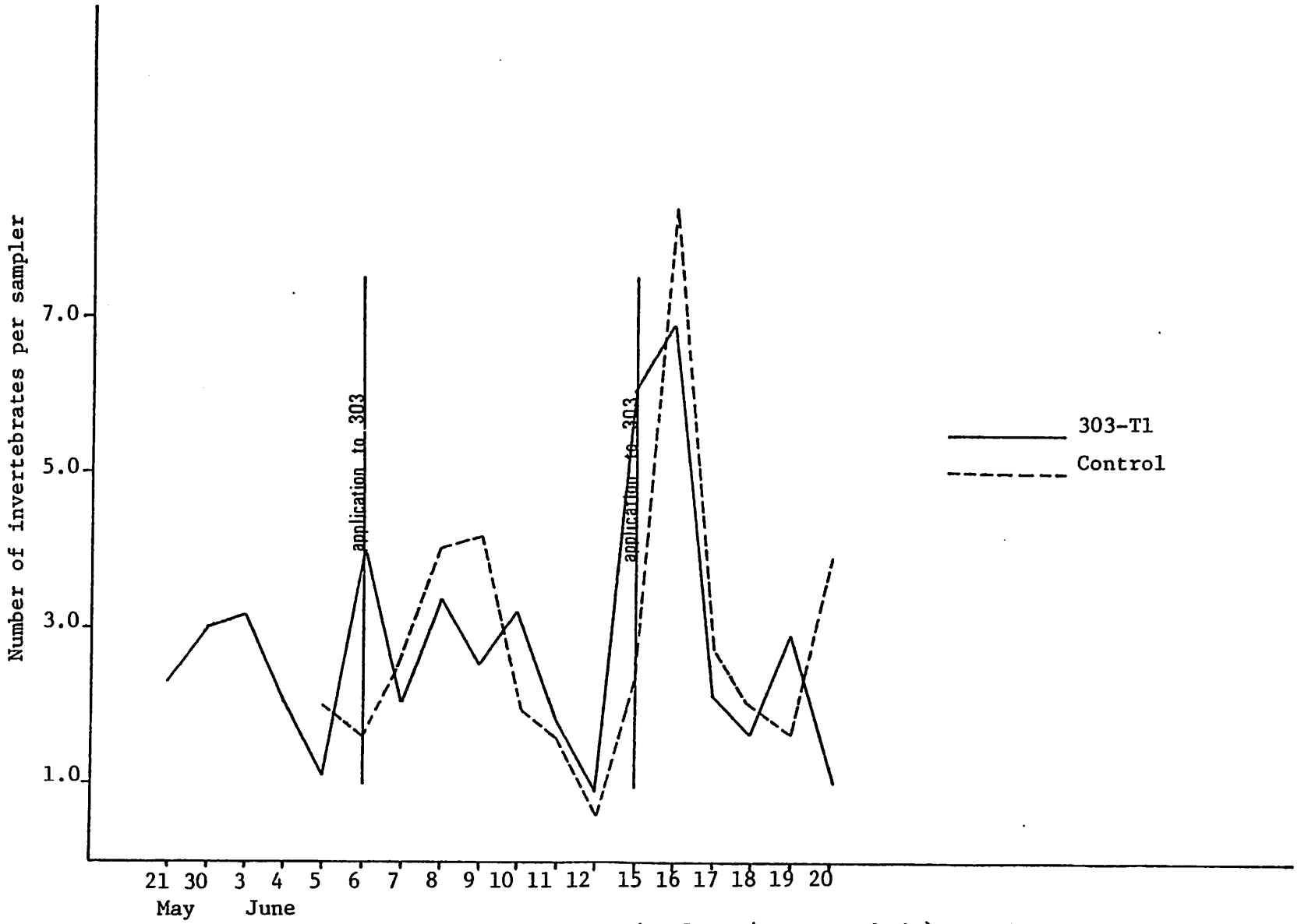


Figure 6 Mayfly nymphs collected from rocks taken from Riviere Manie, Kamouraska County, Quebec, 20 May to 24 September 1980



Sample dates before and after applications (17.5g AI/ha permethrin)

Figure 7 Terrestrial invertebrate knockdown from foliage in double application block 303, Kamouraska County, Quebec, 27 May to 20 June 1980

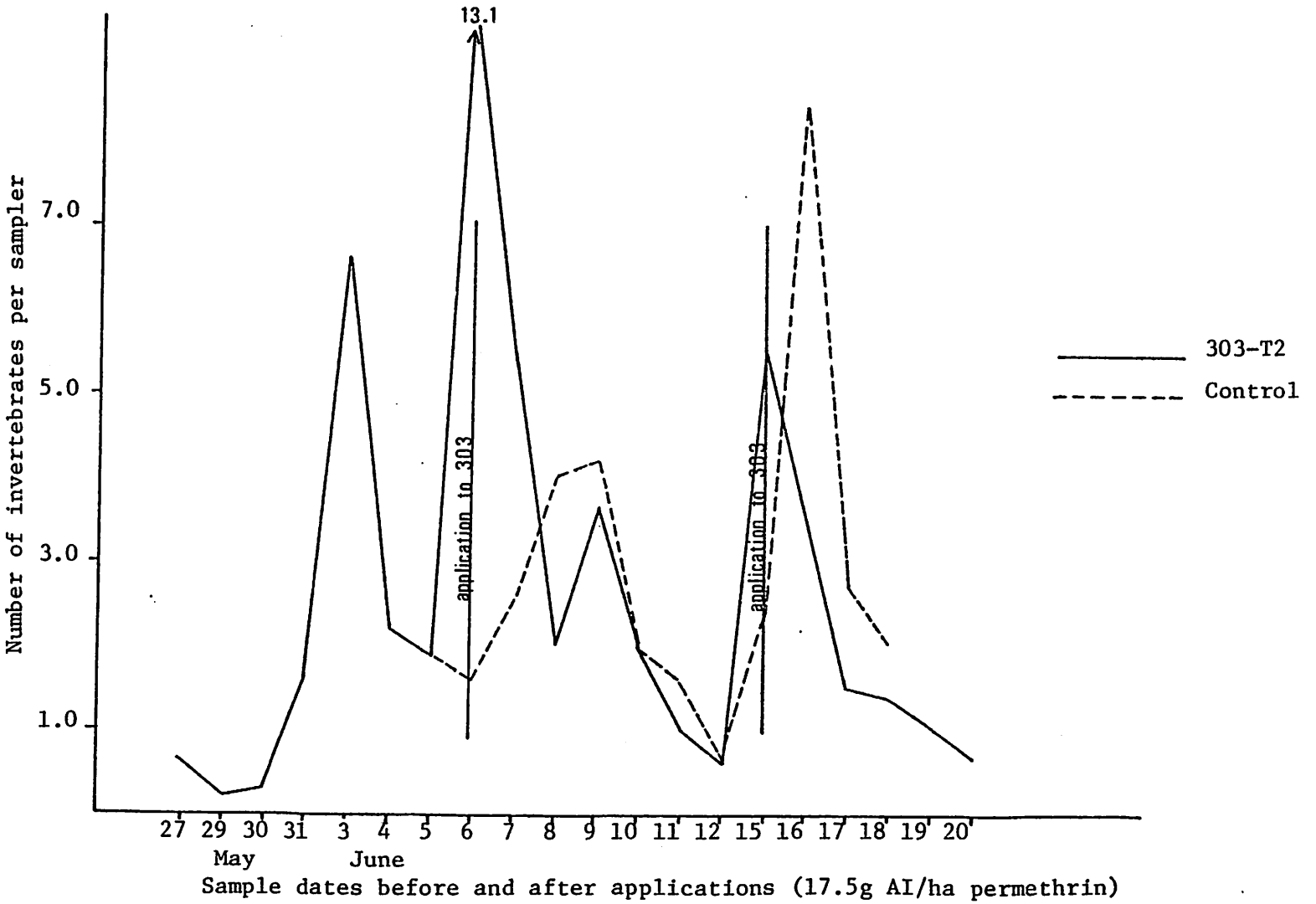


Figure 8 Terrestrial invertebrate knockdown from foliage in double application block 303, Kamouraska County, Quebec, 27 May to 20 June 1980

similar to that found in a previous semi-operational permethrin application (Kingsbury and Kreutzweiser 1980), but considerably less than the impact of a permethrin application reported by Kingsbury and McLeod (1979).

Results from pitfall trapping, used as a means of determining a level of ground dwelling invertebrate activity, are presented in Table 4. The number of arthropods collected in the traps tended to increase later in the season and generally exhibited a similar pattern in the treatment and control areas (Figure 9). The slightly decreased numbers between the end of the pre-spray and the beginning of the post-spray sampling periods in the treatment block may suggest a reduced level of activity but the extent of the decrease and the resurgence of numbers two days later in the sampling period reduce the likelihood of an indication of impact.

Small mammals

Small mammals were collected in the double application block 303 and the control area prior to and two months after the permethrin application. Although the number of captures almost doubled during the late summer post-spray sampling period, the total numbers of animals trapped during the program were quite low, with an animal per trap-night success ratio of 0.004 and 0.014 in the control area and 0.007 and 0.024 in the treatment block (Tables 5 and 6). Approximately 40% of the animals captured from both areas in August were young of the year. The similar trends in population size and age class structure on the two plots indicate the lack of effects of the permethrin treatments on the small mammal complex, but the low numbers encountered preclude definite conclusions.

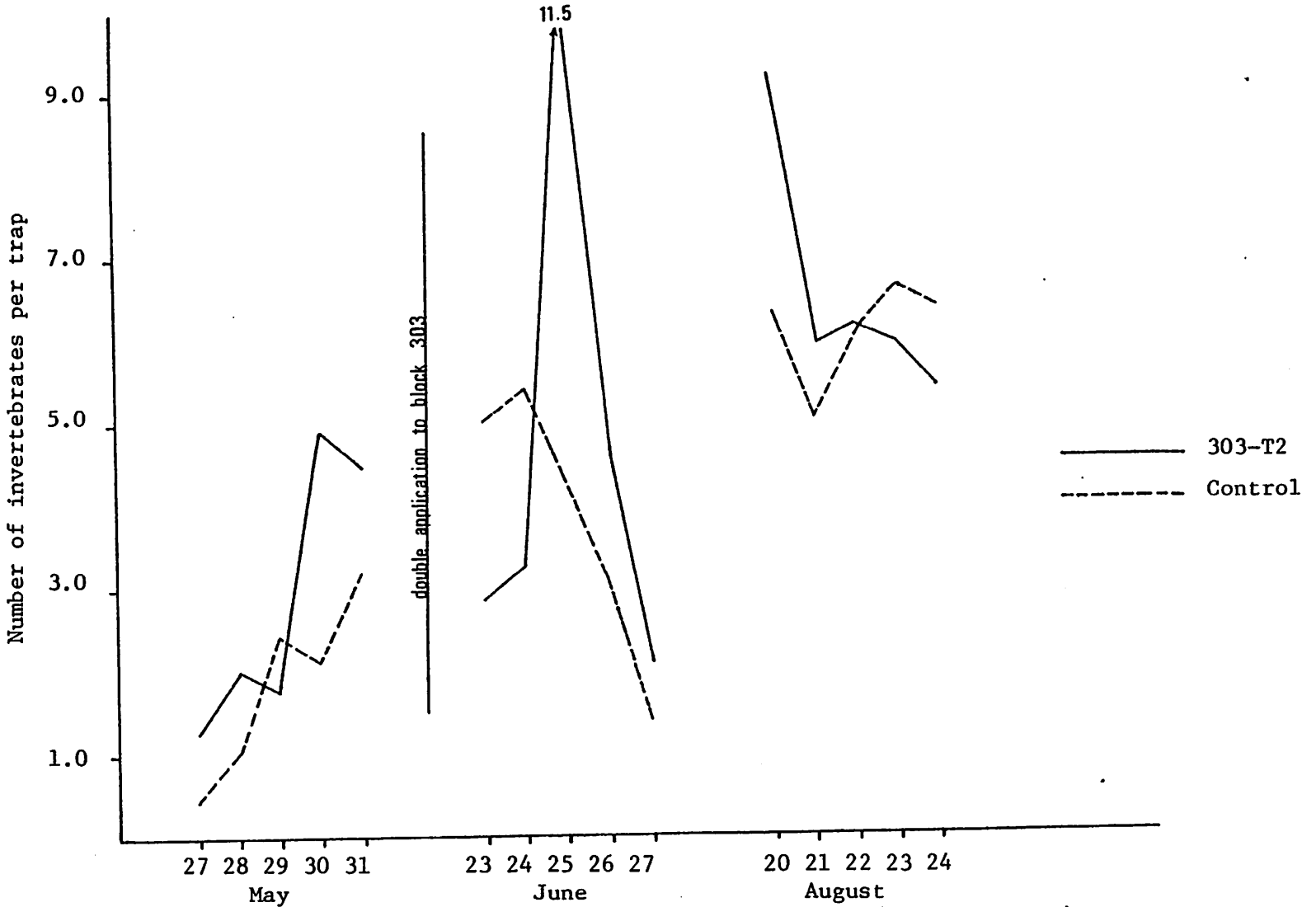
Table 4

Summary of pitfall trapping results expressed in organisms per sampler for ground dwelling invertebrates in treatment* and control areas Kamouraska County, Quebec, 27 May to 24 August 1980.

	MAY								JUNE								AUGUST							
	27	28	29	30	31	TOTAL	MEAN	S.D.**	23	24	25	26	27	TOTAL	MEAN	S.D.	20	21	22	23	24	TOTAL	MEAN	S.D.
TREATMENT BLOCK																								
Coleoptera																								
Carabidae	0.25	0.30	0.35	0.35	0.40	1.65	0.33	0.06	0.61	0.35	0.78	0.65	0.25	2.64	0.53	0.22	0.40	0.14	0.11	0.10	0.10	0.85	0.17	0.13
Curculionidae	0.05					0.05	0.01	0.02										0.14		0.05		0.19	0.04	0.06
Elateridae																								
Staphylinidae	0.01	0.15		0.10	0.10	0.36	0.07	0.06	0.44	0.10	0.33	0.15	0.13	1.15	0.23	0.15	0.60	0.14	0.33	0.55	0.65	2.27	0.45	0.21
Unidentified			0.05	0.05	0.05	0.15	0.03	0.03	0.06	0.05	0.06			0.12	0.03	0.03								
Phalangida				0.05		0.05	0.01	0.02	0.17	0.15	0.78	0.40	0.31	1.81	0.36	0.26	0.60				0.05	0.65	0.13	0.26
Acari	0.10	0.10	0.40	0.70	0.10	1.40	0.28	0.27	0.06		2.28	0.25	0.06	2.65	0.53	0.10	1.60	0.57	0.39	0.10	0.85	3.51	0.70	0.57
Araneida	0.65	1.20	0.90	3.60	2.85	9.20	1.84	1.31	1.50	2.35	5.17	1.50	0.75	11.27	2.25	1.73	2.00	1.85	1.06	1.00	0.90	6.81	1.36	0.52
Collembola	0.15	0.25		0.05	0.95	1.40	0.28	0.39	0.11	0.25	2.10	1.60	0.56	4.62	0.92	0.88	4.00	3.00	4.28	4.10	2.90	18.28	3.66	0.65
TOTALS	1.21	2.00	1.70	4.90	4.45	14.26			2.84	3.25	11.50	4.55	2.06	24.26			9.20	5.84	6.17	5.90	5.45	32.56		
CONTROL BLOCK																								
Coleoptera																								
Carabidae	0.20	0.10	0.30	0.40		1.00	0.20	0.16	0.80	0.70	0.50	0.30	0.20	2.50	0.50	0.25		0.40		0.40	0.30	1.10	0.22	0.20
Curculionidae																								
Elateridae					0.80	0.80	0.16	0.36	0.10		0.10			0.20	0.04	0.05								
Staphylinidae				0.10	0.30	0.40	0.08	0.13	1.10	1.20	0.60	0.10		3.00	0.60	0.55		0.70	0.30	0.50	0.70	2.20	0.58	0.18
Unidentified					0.10	0.10	0.02	0.05			0.10	0.30	0.10	0.50	0.10	0.12								
Phalangida			0.20			0.20	0.04	0.09	0.10	0.30	0.30	0.70	0.50	1.90	0.38	0.23	0.40	0.10	0.10	0.50	0.70	1.70	0.36	0.26
Acari			0.10	0.10	0.10	0.30	0.06	0.05									0.30	0.10	0.30	0.30		1.00	0.20	0.14
Araneida	0.20	0.70	1.80	1.40	1.80	5.90	1.18	0.71	2.70	2.80	1.60	1.60	0.50	9.20	1.84	0.94	1.20	0.40	1.70	0.60	1.00	4.90	0.98	0.51
Collembola		0.20		0.10	0.10	0.40	0.08	0.08	0.20	0.40	0.40		0.10	1.10	0.22	0.18	4.40	3.30	3.70	4.30	3.70	19.40	3.88	0.46
TOTALS	0.40	1.00	2.40	2.10	3.20	9.10			5.00	5.40	3.60	3.00	1.40	18.40			6.30	5.00	6.10	6.60	6.40	30.30		

*block 303 treated with 17.5 g AI/ha permethrin at 0455 to 0528 hrs on 6 June and again at 1430 to 1500 hrs on 15 June 1980.

**standard deviation



Sample dates before and after applications (17.5g AI/ha permethrin)

Figure 9 Terrestrial invertebrates collected from pitfall traps set in double application block 303, Kamouraska County, Quebec, 27 May to 24 August 1980

Table 5

Small mammals captured in untreated control block.
Kamouraska County, Quebec 1980.

		MALES		FEMALES				
					adult			
						Pregnant		
Date	Species	adult	sub-adult	sub-adult	not pregnant	embryo	scars	Total animals
23-31 May	*Sorex cinereus*					7	0	1
	Clethrionomys gapperi	2				4	2	3
	Napaeozapus insignis	4						4
	TOTALS	6	0	0	0	2		8
20-24 August	*Sorex cinereus*		3					3
	Blanaria brevicauda		1					1
	Clethrionomys gapperi	2	2		2			6
	Zapus hudsonius				1			1
	Napaeozapus insignis	1			2			3
	TOTALS	3	6	0	5	0		14

Table 6

Small mammals captured in double application block 303*
Kamouraska County, Quebec 1980.

		MALES		FEMALES				
					adult			
						Pregnant		
Date	Species	adult	sub-adult	sub-adult	not pregnant	embryo	scars	Total animals
23-31 May	*Sorex cinereus*	2	0	0	2	2	13	5
	Peromyscus maniculatus	3	0	0	0	9	2	5
	Clethrionomys gapperi	5	1	0	0	13	1	9
	TOTALS	10	1	0	2	6		19
20-24 August	*Sorex cinereus*	6	2	4	3		13	15
	Peromyscus maniculatus	3	1	3	1		6	8
	Clethrionomys gapperi	2	3	1		11		8
	Synaptomys cooperi	1						1
	Zapus hudsonius				1			1
	Napaeozapus insignis	1		1	1			3
	TOTALS	13	6	9	6	2		36

*block 303 treated with 17.5 g AI/ha permethrin at 0455 to 0528 hrs on 6 June and again at 1430 to 1500 hrs on 15 June 1980.

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