DRIFT RESPONSES OF STREAM INVERTEBRATES TO A GLYPHOSATE APPLICATION

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A preliminary report on studies carried out in the Carnation Creek watershed, Vancouver Island, in 1984.

D.P. Kreutzweiser and P.D. Kingsbury

Government of Canada
Forestry Service
Forest Pest Management Institute
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

INTRODUCTION

The Carnation Creek watershed flows into the southwest corner of Barkley Sound, near Bamfield, and includes a number of small occassionally intermittent, tributaries and side channels draining a western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), amabilis fir *(Abies amabilis* (Dougl.) Forbes), and western red cedar *(Thuja plicata* Donn) forested valley. Carnation Creek has been intensively studied for 14 years under the jurisdiction of the Fisheries Research Branch of the Pacific Biological Station, Nanaimo, B.C., with emphasis on multidisciplinary research into the effects of forest harvesting on the watershed in general and on salmonid fish populations in particular (Hartman 1982).

Most of the lower portion of the Carnation Creek valley was harvested between 1975 and 1981 and subsequently reinvaded by such species as salmonberry *(Rubus spectabilis)*, red alder *(Alnus rubra)*, salal *(Gaultheria shallon)* and huckleberry *(Vaccinium* spp.). In September 1984 an aerial application of the herbicide glyphosate (Roundup) for the purpose of conifer release was made to part of the lower valley, and a number of research activities were conducted to investigate the fate and effects of the herbicide on various components of the watershed. In cooperation with the Pacific Biological Station, the B.C. Ministry of Forests, and the Pacific Forest Research Centre of the Canadian Forestry Service, the Forest Pest Management Institute (FPMI) participated in several facets of the research projects. This report deals specifically with the efforts of the Environmental Impact Section of FPMI to measure the response of aquatic invertebrates to glyphosate contamination in the

Carnation Creek watershed. A program to determine the fate and persistence of the herbicide was jointly conducted with this project, but results from residue analyses are not yet available.

METHODS

Glyphosate was applied as Roundup (41% A.I.) at a concentration of 2.0 kg/ha in a total volume of 252 L/ha from a MICROFOIL® boom with 1.52 mm rakes, mounted on a Bell G-47 helicopter. Figure 1 illustrates the spray blocks in the entire creek valley. Spraying occurred at various times over four separate days, but only those with potential for contaminating the watershed will be discussed here.

On the evening of 6 September 1984 between 1940 and 2005 h, a small section of the valley immediately adjacent to the east edge of C Creek, a small tributary stream flowing into Carnation Creek approximately 2200 m upstream from the estuary, was treated with herbicide. Most of the remaining creek valley, including the portion on the west side of C Creek, was sprayed between 1425 and 1945 on 14 September. The main channel of Carnation Creek and C Creek were allowed a 10 m no-spray buffer, while small tributary streams, designated 750 and 1600, were intentionally oversprayed.

Three invertebrate drift sample sites were selected. The main channel of Carnation Creek was sampled approximately 30 m below B-Weir, downstream of most treated portions of the valley, while two small tributaries, C Creek and 1600 sidechannel, were sampled 10 m upstream from their confluence with the main stream (Figure 1). The drift site below

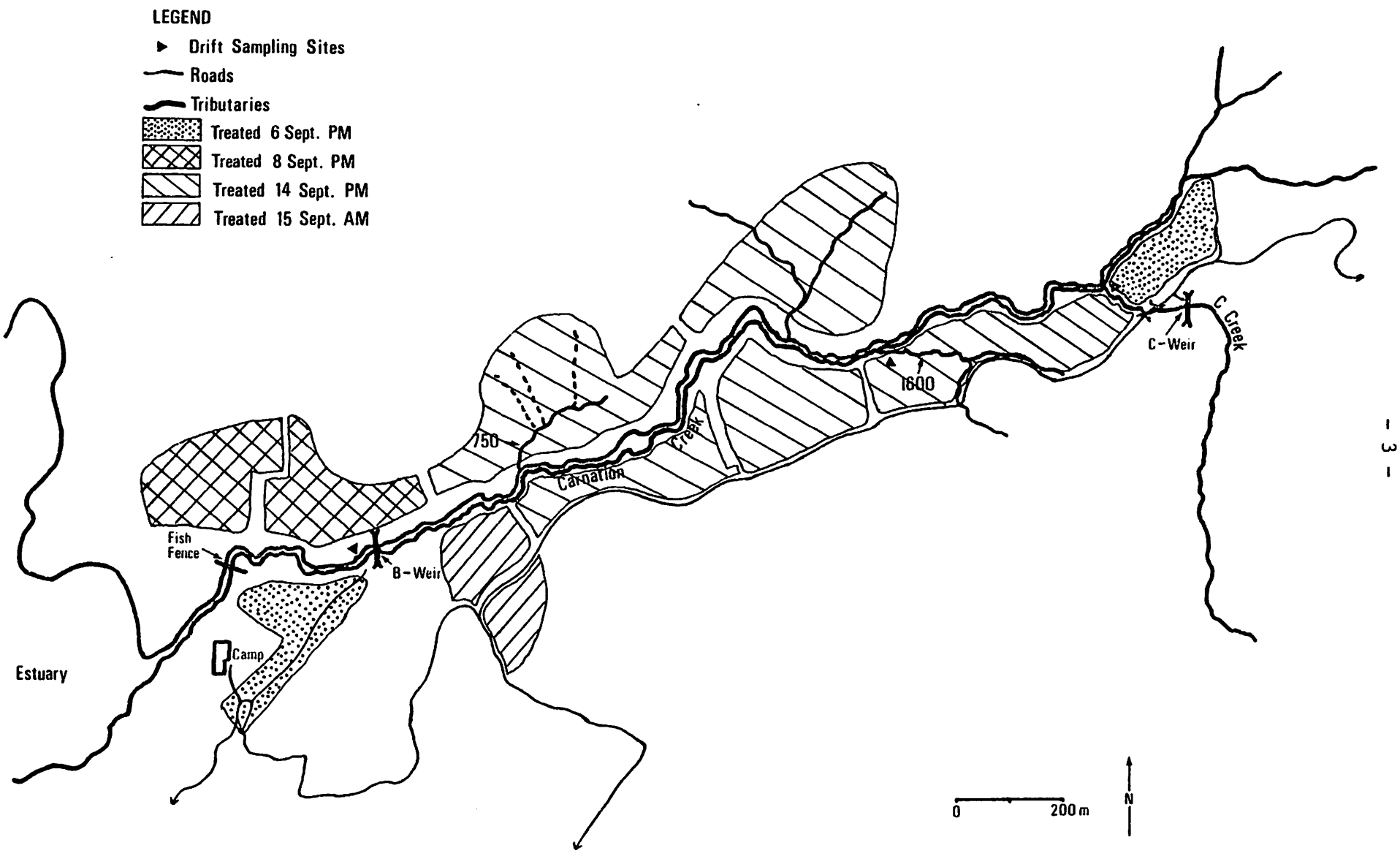

Figure 1. Glyphosate treatment blocks and drift net sampling sites in the Carnation Creek Watershed, September 1984

B-weir was typical of most of lower Carnation Creek, with a section of riffle approximately 4 m wide comprising scoured gravel with small amounts of sand and silt. Water levels in C Creek flucuated drastically throughout the sampling period such that the drift site varied from 0.5 m wide with almost no flow to 2 m wide with a moderate to fast current. The bottom type at the sampling site and through most of the section bordering the spray blocks primarily consisted of small rubble and gravel with patches of sand and silt in quieter areas. Although shoreline vegetation was dense in certain sections, C Creek contained relatively little organic debris. The 1600 tributary drained a swampy portion of the valley south of the main channel with a number of small pools and sections of moderate flow in constricted areas. In contrast to the other two sampling sites, this tributary contained a large amount of organic debris with a bottom type mostly consisting of silt, detritus, sand and small sections of fine gravel. The drift sampling site in 1600 was approximately 0.5 m wide with a flow rate that varied much less than the main channel or C Creek.

Specific drift net locations were established at each site such that each drift sample was taken at the same spot for the duration of the sampling period. The nets, measuring 0.47 x 0.32 m with a 363 μ mesh collection bag, were positioned in the streams to collect drifting organisms from a column of water for a predetermined length of time. The nets were placed such that a water column was sampled from the surface to the stream bottom where possible, and from the surface to the net bottom when water levels exceeded the height of the net opening.

Current velocity (measured with a Teledyne Gurley No. 625 Pygmy current meter) and depth of the water at the net opening were recorded with each sample taken. All invertebrates collected were sorted from the net contents, preserved in 70% methanol, and subsequently counted, identified and quantified as organisms per 10 cubic metres of water.

Drift samples were taken at hourly intervals during sunset and sunrise periods of collection dates, corresponding to the times when stream invertebrate drift normally peaks and declines. Additional hourly samples were collected immediately following the applications of herbicide.

RESULTS AND DISCUSSION

The occurrence of terrestrial invertebrates in drift collections from the three sampling sites did not indicate a glyphosate induced knockdown of flying or arboreal arthropods into the streams. Increases in the number of drifting terrestrial invertebrates recorded on the evenings of the herbicide applications (Table 1) were not significantly different (ANOVA $p > 0.05$) from pre-spray drifts collected under similar conditions, and were no higher than would be expected from the disturbance of stream bank foliage caused by the turbulence of the helicopter wake. Appendix Tables A-1 to A-3 list the taxanomic groups and numbers of terrestrial arthropods collected.

Drift densities of most aquatic invertebrates did not increase in response to the applications of herbicide. The pattern of drifting

invertebrates, illustrated in Figures 2 and 3, was not substantially altered in any of the three sites during the several day sampling period. High water conditions at both the beginning (from heavy rains on 4 September) and end (from heavy rains on evening of 15 September) of the sampling period accounted for most of the variations in total drift density.

Table 1. Peak drift (no. per 10 m^3) of terrestrial invertebrates collected in Carnation Creek.

	C Creek*	1600 Trib**	B-Weir
5 Sept. PM	8.78	5.36	0.59
6 Sept. AM	15.71	8.69	1.36
6 Sept. PM	9.76	3.57	1.39
7 Sept. AM	1.23	1.87	0.82
11 Sept. PM	3.65	4.51	0.97
12 Sept. PM	4.51	3.76	1.08
13 Sept. AM	6.25	2.65	2.17
14 Sept. PM	13.04	4.65	3.43
15 Sept. AM	1.46	4.38	0.52
15 Sept. PM	22.37	2.26	7.92

*east periphery sprayed at 1940 to 2000 h on 6 September and west periphery sprayed at 1515 to 1535 h on 14 September 1984.
**oversprayed at 1425 to 1510 h on 14 September 1984.

Since many of the organisms in the drift samples were collected in extremely low numbers (Appendix Table A1-A3 contain the actual collection data), the more frequently collected ones were selected from each site and are listed, with their relative drift levels, in Table 2. These peak drift values for the various taxa provide an indication of the flucuations in drift density that did occur for certain organisms. Some groups, such as *Baetis* sp. in B-Weir and *Capnia* sp. in C Creek, demonstrated an increase in drift after a glyphosate application, but

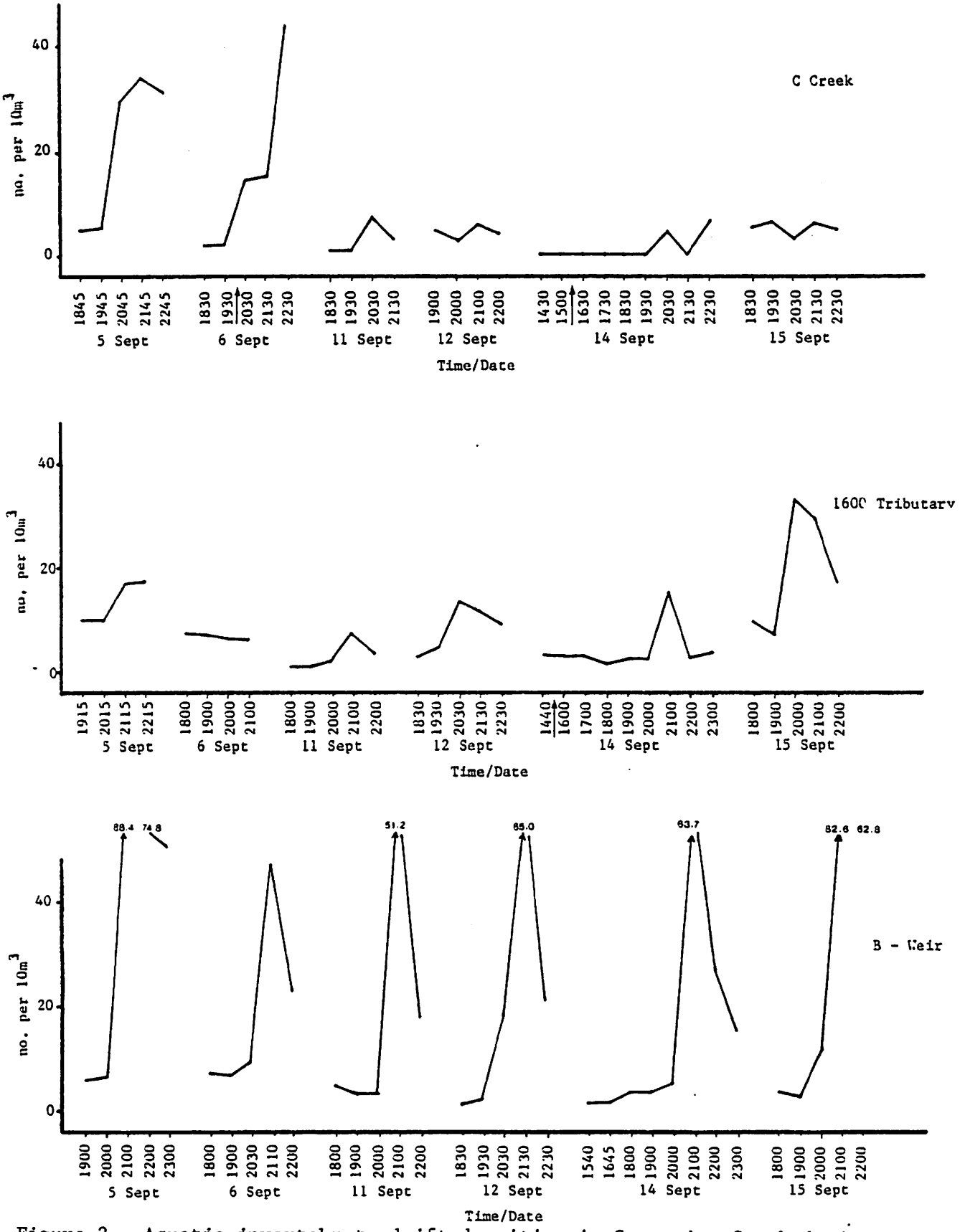

Figure 2. Aquatic invertebrate drift densities in Carnation Creek during evening sampling hours. Arrows indicate time of glyphosate applications.

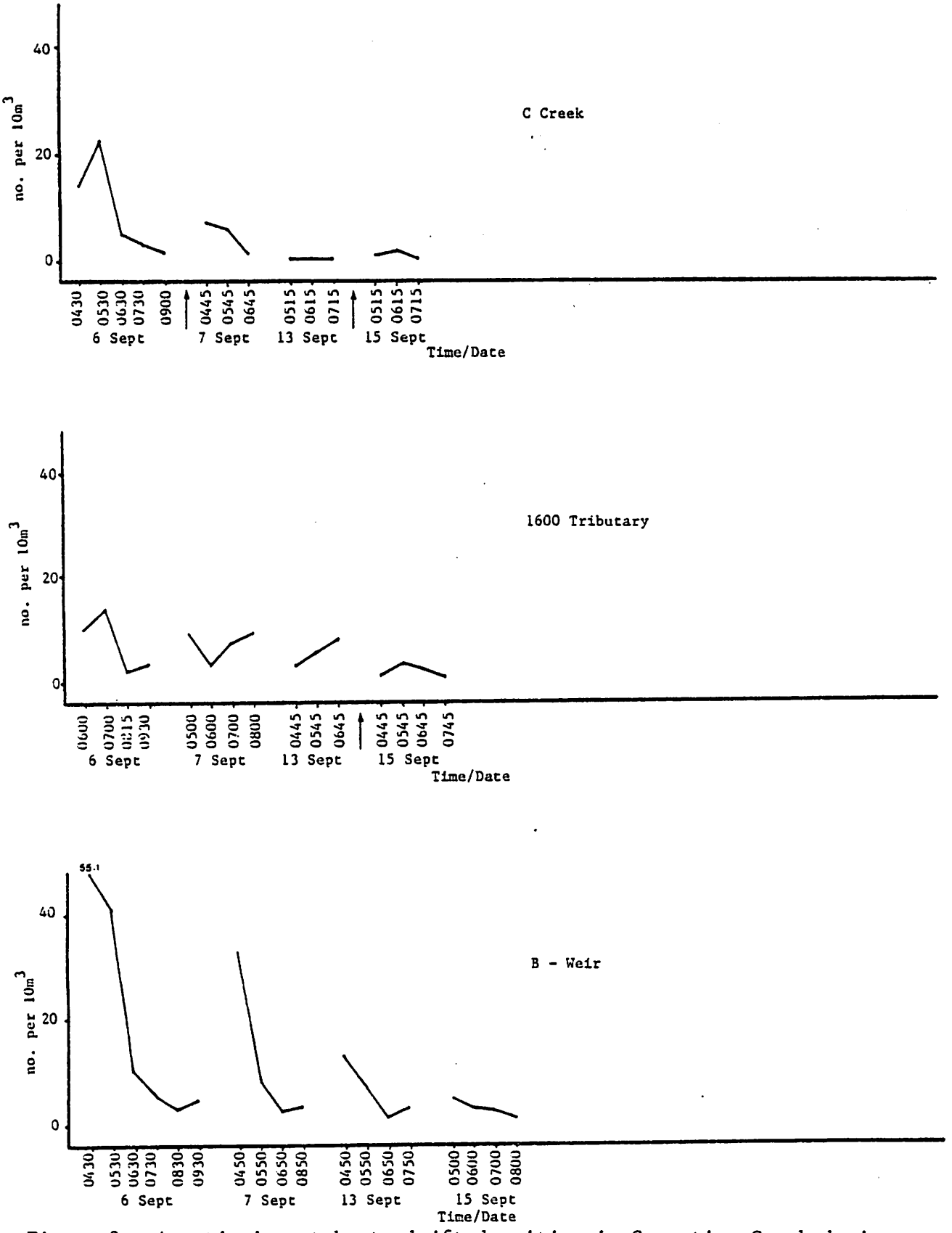

Figure 3. Aquatic invertebrate drift densities in Carnation Creek during morning sampling hours. Arrows indicate time of glyphosate applications.

Table 2. Peak drift (no. per 10 m^3) of aquatic invertebrates collected in Carnation Creek.

	5 Sept. PM	6 Sept. AM	6 Sept. PM	7 Sept. AM	11 Sept. PM	12 Sept. PM	13 Sept. AM	14 Sept. PM	15 Sept. AM	15 Sept. PM
C Creek*										
Baetis sp.	15.54	11.43	12.19	2.47	2.92	0.44	0	2.17	0	0
Paraleptophlebia sp.	2.03	1.43	21.95	1.23	1.46	0	0	2.17	0	0.94
Amphinemeura sp.	4.05	4.28	2.44	1.23	0.73	0.44	0	0	0	0.38
Capnia sp.	1.35	4.28	4.88	0	0.73	0.82	0	4.35	0	0.21
Limnephilidae (early instar)	2.70	1.43	0	2.47	0	1.32	0	0	0	1.88
1600 Tributary**										
Paraleptophlebia sp.	0.89	0	0.93	0	0.75	0.75	0	0.78	0	7.41
Amphinemeura sp.	0.89	0.87	2.04	0	0.75	0	0	0.78	0	0.96
Limnephilidae (early instar)	8.16	10.43	6.12	7.48	3.04	3.01	2.65	1.55	0.88	4.78
Chironomidae	7.14	1.74	1.02	2.80	3.06	3.01	1.32	1.55	0.88	3.33
Gammarus sp.	7.14	6.09	2.68	4.67	3.76	7.50	3.97	12.40	3.01	18.18
B-Weir										
Baetis sp.	19.38	24.21	21.45	16.93	35.35	38.48	4.34	42.64	3.60	29.43
Paraleptophlebia sp.	3.60	4.41	0.99	1.61	1.39	1.90	0	0.49	0.26	15.47
Alloperla sp.	1.48	1.92	0.46	0.54	1.86	2.71	0.14	3.43	0	1.96
Amphinemeura sp.	3.82	1.13	1.65	1.34	0.23	1.44	0	0.49	0	1.96
Capnia sp.	5.21	2.04	3.63	2.96	7.44	8.13	1.36	11.76	0.26	6.41
Lepidostoma sp.	43.76	12.67	8.58	1.88	0.48	8.40	1.63	0.98	0.26	19.61
Limnephilidae (early instar)	2.64	2.29	1.39	0.82	0.70	1.36	2.17	0.49	0.26	5.39
Chironomidae	6.53	2.49	4.17	2.42	1.39	6.14	1.36	2.45	0.52	7.84
Dixidae	1.38	1.36	0.46	0.81	0	0.54	0.27	0.49	0	6.37
Simuliidae	1.17	1.13	3.63	1.08	0.93	0.36	0.54	0.98	0.26	0.30

*east periphery sprayed at 1940 h to 200 h on 6 September and west periphery sprayed at 1515 to 1535 h on 14 September 1984
**oversprayed at 1425 h to 1510 h on 14 September 1984.

only to a level comparable to previous pre-spray evening drifts. Several taxa, including *Lepidostoma* sp. in B-Weir and early instar limnephilid caddisflies in 1600 Tributary, showed an increase in drift density at the end of the sampling period that corresponded to heavy rainfall and an approximately ten-fold increase in stream discharge. Since elevated drift levels of these same groups had previously been encountered in high water conditions at the beginning of the sampling period, the post-spray drift increases were more likely a result of the sharp increase in discharge than contamination by the herbicide.

Although the drift patterns of most invertebrates were apparently unaffected by the glyphosate applications, the drift levels of two particular groups provide some indication of a herbicide induced disturbance. *Gammarus* sp. in 1600 Tributary drifted in numbers approximately twice as high on the evening of the overspray as had been collected in pre-spray evening drifts (Table 2). This amphipod is a frequent stream drift component but is not particularily susceptable to glyphosate. In a toxicity test of aquatic organisms including four invertebrates and four species of fish, *Gammarus* sp. was found to be the least sensitive by far to Roundup contamination with a 48-h EC_{50} of 43 mg/L (Folmar *et al.* 1979). Although the magnitude of the drift increase was little more than measurable ($p > 0.05$) and the duration was less than two hours, the peak drift value from the evening of the application does represent a disruption of the previously established evening drift pattern and may indicate a slight disturbance of *Gammarus* by glyphosate contamination in 1600 Tributary. In view of the physical characteristics of this

tributary and the low water flow on the evening of 14 September, conditions under which an elevated drift rate of *Gammarus* would not be expected, this increase may be of greater significance than is normally attributed to one of this magnitude.

Immediately following the herbicide treatment to the eastern periphery of C Creek on 6 September, samples from the tributary contained a distinct increase in the number of drifting *Paraleptophlebia* sp. The peak number of these mayflies on the evening of the application adjacent to C Creek was not significantly different from the previous evening ($p > 0.05$), but as illustrated in Figure 4, the drift of *Paraleptophlebia* attained a level considerably higher (approximately 10 X the pre-spray peak) than at any other time in C Creek.

A similar increase in these mayflies in C Creek did not occur on the evening of the overspray of 1600 Tributary even though the edge of that spray block approached the western periphery of C Creek. A ten metre buffer on both sides of C Creek was observed for both applications adjacent to the creek, but recorded field observations suggested that the helicopter flew closer to the creek on the evening of 6 September than during the 1600 overspray on 14 September. During the first application adjacent to C Creek, the aircraft flew a spray pattern roughly parallel to the stream and given the circuitous nature of the creek, the opportunity for contaminating the water was greater than when the flight pattern approached the creek at right angles during the overspray of 1600. The increased opportunity for contamination of the stream during the first peripheral application may account for the apparent difference in drift response of *Paraleptophlebia* sp. in C Creek.

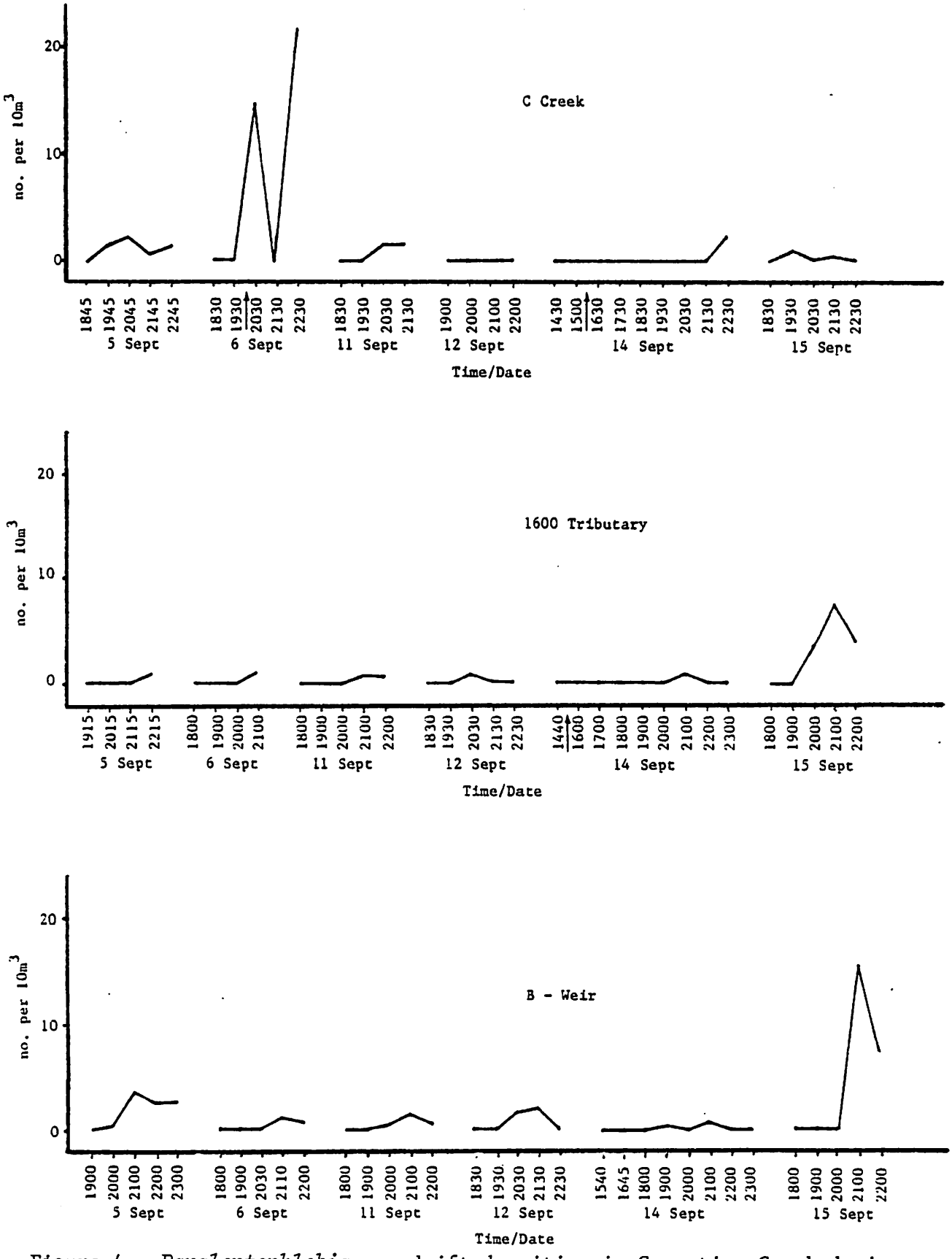

Figure 4. *Paraleptophlebia* sp. drift densities in Carnation Creek during evening sampling hours. Arrows indicate time of glyphosate applications.

This particular mayfly again demonstrated an increased drift in 1600 Tributary and B-Weir on the evening following the overspray of 1600 (Figure 4). The increases were small (less than 9X the pre-spray peak) and may simply be a response to the increase in stream discharge resulting from heavy rainfall during the evening sampling period. However, as illustrated in Figure 4, elevated drift levels of *Paraleptophlebia* sp. at these two sites were not previously associated with the high water conditions at the beginning of the sampling period. The post-spray drift increase, following the rain storm, may indicate a disturbance of this particular mayfly induced by glyphosate contamination from runoff. Morris *et al.* (1983) reviewed several glyphosate transport studies and found that in each case 99% of the total herbicide runoff into a watershed occurred in the first storm event after treatment. The small magnitude of the drift increase and the obvious influence of the increasing water levels in the present study preclude a definite conclusion of an impact on *Paraleptophlebia* mayflies in 1600 Tributary and the main channel.

SUMMARY

The application of glyphosate to or adjacent to small tributaries of Carnation Creek did not result in undue disturbance of stream invertebrates. The drift response of two particular organisms, *Gammarus* sp. and *Paraleptophlebia* sp., suggests a slight and ephemeral effect of the herbicide in and downstream of the treatment areas. None of the post-spray drift levels were significantly higher than pre-spray densities ($p > 0.05$) but a measurable alteration in the drift patterns of these two genera, especially of *Paraleptophlebia*, was demonstrated.

The lack of significant difference in drift levels does not entirely negate an indication of impact since the dynamics of natural stream drift do not readily comply with a statistical approach. The measurement of significant difference is probably inappropriate because of the variation in factors not included in the statistics, such as stream flow, light intensity, and insect morphology, that greatly influence stream invertebrate drift. An interpretation of relative drift levels must include a consideration of these integral parameters and cannot simply incorporate a test of significance amongst temporally replicated samples.

The apparent effects of the glyphosate applications on *Paraleptophlebia* mayflies suggest a particular susceptibility of this genus to the herbicide. If the drift response in C Creek was attributable to the herbicide treatment, the impact was limited to *Paraleptophlebia* since none of the other groups demonstrated a similar increase. The magnitude of the disturbance was not great enough to ecologically impact on the organism in terms of density or distribution in benthos, but may have provided evidence of a particular mayfly useful as an indicator of glysphosate effects on aquatic insects. Further investigation of the toxicity of glyphosate to *Paraleptophlebia* sp. would be appropriate.

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Appendix

Drift net catches in the Carnation Creek watershed 5 to 15 Sept. 1984

Table A-1. Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from C Creek tributary of Carnation Creek, 5 to 15 September 1984.

Date	5 Sept					6 Sept										7 Sept			10 Sept	11 Sept				
Time (PDT)	1845	1945	2045	2145	2245	0430	0530	0630	0730	0900	1830	1930	2030	2130	2230	0445	0545	0645	1100	1210	1830	1930	2030	2130
Ephemeroptera																								
Amelotus sp.					0.68																			
Baetis sp.			3.38	12.16	15.54	5.71	11.43							6.52	12.19	2.47	1.23						2.92	1.46
Cinygmula sp.			2.70			1.42																		
Ephemerella sp.															2.44									
Paraleptophlebia sp.		1.35	2.03	0.68	1.35			1.43					14.60		21.95	1.23	1.23						1.46	1.46
Rithrogena sp.				3.38	2.03	1.42																	0.73	
Serratella sp.				0.68												2.47								
Plecoptera																								
Alloperla sp.			8.11	6.08	3.38	1.42	1.43							2.17									0.73	
Amphinemoura sp.		0.68	4.05	3.38	4.05		4.28							2.17	2.44		1.23						0.73	
Capnia sp.		0.68	1.35	0.68	0.68	4.28	1.43							4.35	4.88								0.73	
Leuctra sp.			3.38	0.68			1.43																	
Trichoptera																								
Hydatophylax sp.																								
Lepidostoma sp.																								
Limnephilidae (early instar)	1.35	2.70	0.68	1.35	1.35		1.43									1.23	2.47	1.23						
Polycentropus sp.				0.68																				
Rhyacophila sp.	0.68																							
Coleoptera larvae	1.35		2.03	0.68																				
Diptera																								
Athericidae larvae																								
Chironomidae larvae	1.35		1.35	2.03	2.03				1.43	1.59											0.73	0.73		0.73
Dixidae larvae							1.43																	
Tipulidae larvae				0.68																				
Gastropoda																								
Hydracarina				0.68				2.86	1.43		2.17	2.17								1.46				
Nematomorpha																				0.73				
Total	4.73	5.41	29.05	33.78	31.08	14.28	22.86	4.28	2.86	1.59	2.17	2.17	14.6	15.22	43.90	7.41	6.17	1.23	0.00	2.19	0.73	0.73	7.30	3.65
Terrestrial																								
Aranelda	2.03				1.35																			
Chilopoda														2.17										
Coleoptera adults																								
Collembola	2.70	2.70	4.05	4.73	6.08	8.57	2.86	1.43	2.86	3.17										0.73			0.73	2.19
Diptera		1.35	2.03					4.28		1.59	2.17		7.32		4.88		1.23	1.23	1.59	0.73				1.46
Ephemeroptera																								
Homoptera				0.68	1.35	5.71								2.17					1.59	1.46				
Hymenoptera	1.35																				1.46			
Lepidoptera larvae						1.42							2.44						1.59					
Pseudoscorpionidae																								
Thysanoptera																								
Trichoptera																								
Total	6.08	3.38	6.08	5.41	8.78	15.71	2.86	5.71	2.86	4.76	2.17	0.00	9.76	4.35	4.88	0.00	1.23	1.23	4.76	2.92	1.46	0.00	0.73	3.65

(cont'd)

Table A-1 (cont'd). Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from C Creek tributary of Carnation Creek, 5 to 15 September 1984.

Date	12 Sept				13 Sept			14 Sept										15 Sept							
Time (PDT)	1900	2000	2100	2200	0515	0615	0715	1140	1430	1500	1630	1730	1830	1930	2030	2130	2230	0515	0615	0715	1830	1930	2030	2130	2230
Ephemeroptera																									
Ameletus sp.																									
Baetis sp.				0.44													2.17								
Cinygmula sp.																									
Ephemerella sp.																									
Paraleptophlebia sp.																	2.17					0.94		0.38	
Rithrogena sp.																									
Serratella sp.																									
Plecoptera																									
Alloperla sp.			2.05																0.73						
Amphinemura sp.				0.44																				0.38	
Capnia sp.			0.82	0.44											4.35								0.21		
Leuctra sp.																									
Trichoptera																									
Hydatophylax sp.		0.44																					0.21		
Lepidostoma sp.		0.44		0.44																			0.43		
Limnephilidae (early instar)	0.82	0.88		1.32																	1.32	1.88	0.21	0.77	0.61
Polycentropus sp.																									
Rhyacophila sp.																		0.73							
Coleoptera larvae	0.41																						0.21		
Diptera																									
Athericidae larvae																					1.32				
Chironomidae larvae	1.23	0.44	0.82																		2.63	2.82	1.07	2.69	3.35
Dixidae larvae	0.41	0.88																				0.47	0.21	0.38	0.30
Tipulidae larvae			1.23	0.88																			0.64	0.38	
Gastropoda																								0.38	
Hydracarina	1.23		0.82														2.17								
Nematomorpha								0.59											0.73						
Total	4.10	3.07	5.74	3.95	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	4.35	0.00	6.52	0.73	1.46	0.00	5.26	6.10	3.22	5.38	4.27
Terrestrial																									
Aranelda						0.62					1.59					2.17									0.30
Chilopoda																									
Coleoptera adults												1.96				2.17									
Collembola	4.10	0.88	1.23	0.44	1.75	1.25	1.88		1.59				4.35	4.35		4.35	2.17				18.42	4.69	3.43	9.61	2.13
Diptera			0.41		0.58		1.25	2.96		3.17	3.17							0.73			3.95	1.88	0.21	0.77	0.30
Ephemeroptera																									
Homoptera			0.82	0.88	0.58		0.62	1.18	1.59	3.17		5.92			2.17	4.35	2.17	0.73				0.47	0.43	1.92	
Hymenoptera							2.50	1.18					4.35	4.35									0.21		
Lepidoptera larvae	0.41																								
Pseudoscorpionidae																								0.77	
Thysanoptera											1.59														
Trichoptera											1.59														
Total	4.51	0.88	2.46	1.32	2.92	1.88	6.25	5.32	3.17	6.35	7.94	5.88	8.70	8.70	2.17	13.04	4.35	1.46	0.00	0.00	22.37	7.04	4.29	13.08	2.74

Table A-2. Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from 1600 Tributary of Carnation Creek, 5 to 15 September 1984.

Date	5 Sept				6 Sept								7 Sept				10 Sept	11 Sept					
Time (PDT)	1915	2015	2115	2215	0600	0700	0815	0930	1800	1900	2000	2100	0500	0600	0700	0800	1130	1230	1800	1900	2000	2100	2200
Ephemeroptera																							
Baetis sp.																							
Paraleptophlebia sp.				0.89								0.89	0.93									0.75	0.75
Plecoptera																							
Alloperla sp.	1.02																						
Amphinemura sp.		0.89			0.87				2.04										0.75		0.75		
Capnia sp.												0.89										0.75	
Hemiptera-Gerridae									1.02														
Trichoptera																							
Lepidostoma sp.						0.87																	
Limnephilidae (early instar)	8.16	2.68	3.57	1.78	1.74	10.43	1.51	2.27	2.04	6.12			0.93	0.93	3.74	7.48	2.61	2.04		0.75	0.75		
Polycentropus sp.																							
Coleoptera adults																							
larvae						0.87																0.75	
Diptera																							
Chironomidae larvae	1.02	2.68	6.25	7.14	0.87	1.74	0.76	0.76	1.02			0.89	1.87	0.93	2.80		0.87	3.06				0.75	0.75
pupae					0.87						4.46				0.93								
Dixidae larvae				1.78								0.89					0.87	1.02					
Simuliidae larvae																							
Gammarus sp.		3.57	7.14	7.14	6.09				1.02	1.02	0.89	2.68	4.67	1.87							0.75	3.76	2.26
Hydracarina								0.76								1.87		1.02	0.75				
Gastropoda											0.89												
Nematomorpha																							
Total	10.20	9.82	16.96	18.75	10.43	13.91	2.27	3.79	7.14	7.14	6.25	6.25	8.41	3.74	7.48	9.34	4.35	7.14	1.50	0.75	2.26	6.77	3.76
Terrestrial																							
Aranelda						0.87																	
Coleoptera adults																							
Collembola	5.10	1.78	0.89	1.78	3.48	7.83	2.27	0.76				0.89				1.87	4.35	1.02	1.50	2.26	3.01		
Diptera		1.78	3.57					0.76	1.02	2.04	1.78	2.68									1.50		
Ephemeroptera																							
Homoptera		1.78		1.78	0.87			0.76									0.87	2.04	0.75				
Hymenoptera																							
Thysanoptera									1.02													0.75	
Total	5.10	5.36	4.46	3.57	4.35	8.69	2.27	2.27	2.04	2.04	1.78	3.57	0.00	0.00	0.00	1.87	5.22	3.06	2.26	2.26	4.51	0.75	0.00

(cont'd)

Table A-2 (cont'd). Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from 1600 Tributary of Carnation Creek, 5 to 15 September 1984.

Date	12 Sept					13 Sept			14 Sept										15 Sept								
Time (PDT)	1830	1930	2030	2130	2230	0445	0545	0645	1150	1440	1600	1700	1800	1900	2000	2100	2200	2300	0445	0545	0645	0745	1800	1900	2000	2100	2200
Ephemeroptera																											
Baetis sp.																							0.78				
Paraleptophlebia sp.			0.75													0.78									3.34	7.41	3.87
Plecoptera																											
Alloperla sp.																											
Amphinemoura sp.														0.78											0.96		
Capnia sp.								0.66																			
Hemiptera-Gerridae										0.78																	
Trichoptera																											
Lepidostoma sp.																											
Limnephilidae (early instar)	1.50	3.01	2.26	2.26	0.75		1.32	2.65	1.55	0.78	1.55	1.55		0.78	0.78	0.78					0.88		3.88	0.66	4.78	0.74	
Polycentropus sp.							0.66																				
Coleoptera adults											0.78																
larvae					0.75																				0.96		
Diptera																											
Chironomidae larvae	0.75	0.75	2.26	3.01	2.26	0.66	1.32	0.66				1.55	0.78			0.78	0.66		0.88		0.88		1.55	1.32	1.43	3.33	1.61
pupae		0.75	0.75																								0.64
Dixidae larvae				1.50	0.75	0.66							0.78			0.78							1.55	1.32	3.34	1.48	1.93
Simuliidae larvae																										0.37	
Gammarus sp.	0.75		7.50	4.51	3.76	1.99	1.32	3.97	3.88	0.78					1.55	12.40	2.65	3.88		3.01			1.55	3.97	18.18	15.56	8.39
Hydracarina										0.78	0.78			0.78											0.48		
Gastropoda																											
Nematomorpha					0.75																	0.88					
Total	3.01	4.51	13.53	11.28	9.02	3.51	4.64	7.95	5.43	3.10	3.10	3.10	1.55	2.32	2.32	15.50	3.31	3.88	0.88	3.01	1.75	0.88	9.30	7.28	33.49	28.89	16.45
Terrestrial																											
Aranelda	0.75	0.75					0.66																				
Coleoptera adults																											
Collembola	1.50	1.50	0.75	0.75			0.66		0.78			2.32	2.32					0.77			1.75	4.38		0.66	0.48		
Diptera	0.75		2.26	2.26		0.66	1.32			0.78						0.78	0.66	2.32	1.75						0.48		0.97
Ephemeroptera														0.78													
Homoptera	0.75					1.32			0.78	0.78		0.78			0.78			1.55	2.63	0.75			1.55	0.66			0.97
Hymenoptera										2.32	0.78																
Thysanoptera														0.78													0.32
Total	3.76	2.26	3.01	5.01	0.00	1.99	2.65	0.00	1.55	3.88	0.78	3.10	2.32	1.55	0.78	0.78	0.66	4.65	4.38	0.75	1.75	4.38	1.55	1.32	0.96	0.00	2.26

Table A-3. Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from below B-Weir in Carnation Creek, 5 to 15 September 1984.

Date	5 Sept						6 Sept											7 Sept				10 Sept	11 Sept				
Time (PDT)	1730	1900	2000	2100	2200	2300	0430	0550	0630	0730	0830	0930	1800	1900	2030	2110	2200	0450	0550	0650	0850	1030	1400	1800	1900	2000	2100	2200
Ephemeroptera																0.33		1.61	0.38								0.93	
Ameletus sp.				1.39	0.64	0.88	2.04	0.68																				
Baetis sp.	0.22	0.39	0.23	19.38	11.59	9.25	24.21	11.42	1.81	0.56	0.56	0.55	0.46	1.39	2.78	21.45	9.26	16.93	5.00	1.34	0.55	0.41	0.85	0.46	0.46	0.46	35.35	12.62
Cinygmula sp.										0.11								0.27									0.46	
Drunella sp.							0.11																					
Paraleptophlebia sp.			0.07	3.60	2.34	2.53	4.41	1.36	0.11							0.99	0.46	1.61			0.27					0.46	1.39	0.48
Rithrogena sp.										0.11																		
Plecoptera																											1.86	0.48
Alloperla sp.		0.08	0.07		1.48	1.10	1.92	0.34								0.33	0.46	0.54	0.38									
Amphinemura sp.		0.08	0.07	3.82	3.51	0.99	1.13	0.79								1.65	0.46	1.34	0.38					0.25				
Archynopteryx sp.							0.11																					
Capnia sp.				5.14	5.21	1.98	1.02	2.04	0.34	0.11		0.11		0.46		3.63	0.93	2.96									7.44	0.48
Leuctra sp.				0.22	0.11	0.11		0.11							0.46	0.33											0.46	
Megaloptera-Sialis sp.								0.11																				
Trichoptera																												
Amphicosmoecus sp.						0.22																						
Apatania sp.				0.22						0.11																		
Dolophilodes sp.					0.74	0.11			0.11							0.33												0.48
Ecclisomyia sp.			0.07																				0.21					
Hydatophylax sp.	0.07		0.07				0.11			0.11		0.22	0.46															
Hydropsyche sp.				0.07	0.11	0.22		0.11								0.99		0.27										
Lepidostoma sp.		0.39	0.60	43.76	40.64	26.21	12.67	16.63	4.98	2.15	0.56	0.22	0.92	0.46	0.46	8.58	4.17	1.88	0.38		0.27	0.21					0.46	0.48
Limnephilidae (early instar)	2.39	2.42	2.64	0.37	0.42	0.11	1.13	2.04	0.56	0.79	0.79	2.29	0.92	0.46	1.39	0.99	0.93	0.54		0.54	0.82	0.52	0.21	0.70	0.23			0.48
Ochrotrichia sp.							0.11																					
Onocosmoecus sp.		0.08																										
Polycentropus sp.		0.08	0.07	0.15			0.11									0.33												
Psychoglypha sp.																												
Rhyacophila sp.					0.11		0.11																					
Coleoptera larvae	0.07	0.08		0.07			0.23																					
adults	0.45			0.15	0.23	0.11						0.11																
Diptera																												
Chironomidae larvae	0.15	0.23	0.30	6.53	4.89	3.41	2.49	2.37	1.70	0.90	0.68	0.22	0.46	0.92	0.92	1.98	4.17	2.42	0.38	0.27	0.55	0.21	0.21	0.23	0.23	0.46	1.39	0.48
pupae		0.08	0.07	0.67	0.23		0.45	0.34					0.46		0.92	0.33	0.46											0.97
Dixidae larvae	0.15		0.14	1.10	1.38	0.99	1.36	1.02		0.11				0.46	0.46			0.81										
Muleidae larvae					0.11																							
Simuliidae larvae	0.07	0.23	0.07	1.17	0.53	0.55	1.02	1.13	0.34		0.11	0.11				3.63	1.39	1.08	0.38			0.10				0.46	0.93	0.48
Tipulidae larvae				0.37	0.11	0.22	0.23																					
Hydracarina	1.64	0.78	1.28	0.15	0.42	0.33	0.11	0.34	0.79	0.45	0.79	0.76	3.24	1.39	1.85	0.99	0.46	0.54	0.76	0.54	0.82	0.31	0.21	2.56	2.09	1.39	0.46	0.48
Nematomorpha																0.33												
Total	5.23	4.92	5.81	88.40	74.79	49.34	55.09	40.84	10.75	5.54	3.51	4.59	6.94	5.56	9.72	47.19	23.15	32.79	8.07	2.69	3.30	1.76	1.69	4.19	3.02	3.25	51.16	17.96
Terrestrial																												
Araneida				0.15				0.11						0.46								0.10						
Chilopoda						0.11																						
Coleoptera	0.07					0.11		0.11													0.27							
Collembola	0.07	0.08	0.07		0.11	0.11		0.45			0.11	0.11									0.55	0.10	0.21		0.23			0.48
Diptera	0.07		0.14	0.37			0.45	0.34	0.23		0.23		0.46	0.46	0.92			0.27						0.46				
Ephemeroptera		0.31			0.11											0.33												
Hemiptera	0.07		0.07																									
Homoptera	0.07	0.16	0.07				0.34	0.34	0.11																			
Hymenoptera	0.07			0.07	0.11		0.11					0.22										0.10			0.46			0.48
Lepidoptera larvae																										0.46		
Plecoptera															0.46										0.23			
Trichoptera																												
Total	0.44	0.55	0.38	0.59	0.32	0.33	0.90	1.36	0.34	0.00	0.34	0.34	0.46	0.92	1.39	0.33	0.00	0.27	0.00	0.00	0.82	0.31	0.21	0.46	0.93	0.46	0.00	0.97

(cont'd)

Table A-3 (cont'd). Aquatic and terrestrial invertebrates (no. per 10 m^3) collected in drift samples from below B-Weir in Carnation Creek, 5 to 15 September 1984.

Date	12 Sept						13 Sept					14 Sept									15 Sept								
Time (PDT)	1350	1830	1930	2030	2130	2230	0450	0550	0650	0750	1440	1250	1540	1645	1800	1900	2000	2100	2200	2300	0500	0600	0700	0800	1800	1900	2000	2100	2200
Ephemeroptera																													
Ameletus sp.		0.22		0.54	0.27												0.49	0.49										0.75	
Baetis sp.	0.13	0.22	0.22	5.15	38.48	3.97	4.34	2.17	0.32	1.11	0.56	0.64	0.64	0.64	0.43	0.43	1.47	42.64	20.10	10.29	3.60	1.55	0.26		0.66	0.16	7.46	29.43	9.31
Cinygmula sp.																										0.16	0.30	0.38	
Drunella sp.					0.27																								
Paraleptophlebia sp.				1.62	1.90											0.21		0.49				0.26						15.47	7.35
Rithrogena sp.																													
Plecoptera																													
Alloperla sp.				0.27	2.71	0.36	0.27			0.14								3.43	1.96							0.16		0.75	1.96
Amphinemura sp.	0.13			0.54	0.27	1.44												0.49										0.75	1.96
Archynopteryx sp.																													
Capnia sp.				2.71	8.13	2.17	1.36	0.54		0.14					0.21			11.76	1.96	0.98			0.26				0.30	6.41	2.45
Leuctra sp.						0.36																							
Megaloptera-Sialis sp.				0.27																									
Trichoptera																													
Amphicosmoecus sp.																													
Apatania sp.																													
Dolophilodes sp.						0.36																							
Ecclisomyia sp.																													
Hydatophylax sp.		0.22		0.27																									
Hydropsyche sp.																		0.49				0.26							
Lepidostoma sp.	0.25			2.17	8.40	4.69	1.63	1.36	0.32							0.21	0.49	0.98	0.49	0.49				0.26			0.89	11.32	19.61
Limnephilidae (early instar)	1.01	1.08	0.87	0.81	1.36	0.36	2.17	0.54		0.70	0.28	0.64			0.43				0.49			0.26		0.26	2.49	1.44	0.89	4.91	5.39
Uchrotrichia sp.							0.27																						
Onocosmoecus sp.																													
Polycentropus sp.					0.27																						0.30		
Psychoglypha sp.																													0.49
Rhyacophila sp.																												0.37	
Coleoptera larvae																													
adults													0.21														0.30	0.75	
Diptera																													
Chironomidae larvae			0.43	2.98	2.17	6.14	1.36	1.08	0.97	0.56	0.14	0.21	0.21			0.21	1.96	1.96	0.98	2.45	0.26	0.26	0.52	0.26	0.66	0.16	1.19	4.91	7.84
pupae					0.27	0.36	0.54	0.27																		0.16		0.37	
Dixidae larvae				0.54	0.27	0.36	0.27								0.21				0.49	0.49								5.28	6.37
Heleidae larvae																													
Simuliidae larvae				0.27		0.36	0.54	0.27										0.98			0.26	0.26	0.26				0.30		
Tipulidae larvae					0.27														0.49									0.75	
Hydracarina	0.38	0.22	0.87			0.36		0.54		0.70	1.11	1.92	0.21	0.85	1.71	1.92	0.49				0.26		0.77	0.52		0.33			
Nematomorpha													0.21																
Total	1.90	1.95	2.39	18.16	65.04	21.30	12.74	6.78	1.62	3.34	2.09	3.41	1.49	1.49	2.98	2.98	4.90	63.72	26.96	14.71	4.38	2.84	2.06	1.29	3.83	2.56	11.94	82.64	62.74
Terrestrial																													
Aranelda	0.13																											0.75	
Chilopoda																													
Coleoptera											0.14	0.21								0.49					0.33				
Collembola	0.13									0.14																2.88	0.89	0.75	
Diptera			0.22		0.81		1.90		0.65		0.28		1.07		0.64	0.21	0.49				0.52	0.26	0.26	0.26	0.17	0.48	0.60	1.13	1.47
Ephemeroptera														0.21	0.21														
Hemiptera																													
Homoptera	0.25		0.22			0.36	0.27				0.28		0.21				1.96								0.17			1.89	0.98
Hymenoptera	0.13				0.27						0.14	0.21	0.21	0.43	1.07	0.21	0.98									0.48	1.49	3.02	0.98
Lepidoptera larvae										0.14																		0.37	
Plecoptera																													
Trichoptera				0.27																									
Total	0.65	0.00	0.43	0.27	1.08	0.36	2.17	0.00	0.65	0.28	0.84	0.43	1.49	0.64	1.92	0.43	3.43	0.00	0.00	0.49	0.52	0.26	0.26	0.26	0.66	3.85	2.98	7.92	3.43