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Impacts of "Altosid" Juvenile Hormone on Non-Target Organisms in an Aquatic Environment of Interior British Columbia

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Pacific Region

IMPACTS OF "ALTOSID" JUVENILE HORMONE ON NON-TARGET ORGANISMS IN AN AQUATIC ENVIRONMENT OF INTERIOR BRITISH COLUMBIA

by

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ABSTRACT

A short-term quantitative study investigated the impact of Altosid, a juvenile hormone analogue insecticide, on non-target aquatic and terrestrial invertebrates. The study was conducted near Revelstoke, British Columbia, in a beaver pond and a section of Little Fish Creek over two periods totalling 16 days, before and after hormone treatment. Changes in fauna population pre- and post-hormone application are discussed relative to the mode-of-action of the insecticide. Some reduction in emergence and moulting of organisms after hormone treatment was indicated although there was no evidence of harmful effects of Altosid. Changes in invertebrate population were attributed to a combination of Altosid effect and natural population fluctuations.

RESUME

Une étude quantitative d'une courte durée avait pour objet les effets de l'Altosid, insecticide qui est l'analogue d'un jeune hormone, sur les invertébrés aquatiques et terrestres non visés. L'étude, effectuée près de Revelstoke (Colombie-Britannique) dans un étang de castors et dans une partie du ruisseau Little Fish, se fit en deux temps, avant et après l'application des hormones, et dura 16 jours. Ce travail étudie, relativement à l'action de l'insecticide, les changements qui s'opèrent dans la population de la faune avant et après l'application des hormones. Bien que l'on ait constaté une diminution dans le nombre et la mue des organismes après l'application des hormones, on n'a pu trouver aucune preuve que l'Altosid avait eu des effets nocifs. On a attribué les changements du nombre des invertébrés aux effets combinés de l'Altosid et des fluctuations quantitatives naturelles.

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CONCLUSIONS

This study indicates that Altosid Juvenile Hormone has minimal short-term impact on non-target aquatic and terrestrial invertebrates. Conclusions from this study are limited because the brief monitoring interval only enabled observation of insects emerging during the period of study.

It is recommended that future investigation be conducted over a longer period of time, preferably up to one year, to determine the long-term direct and subtle effects of Altosid on invertebrates having life cycles stretching beyond the period of this study.

1 INTRODUCTION

Infestation of the Western Hemlock Looper (Lambdina fiscellaria lugubrosa Helst) in the Nelson Forest District of British Columbia has recently become an increasing problem. During the past few years, local populations of this lepidopterous leaf defoliator have developed to epidemic proportions in several areas, particularly in the mature and overmature hemlock-cedar forests along the Columbia River and its tributaries from Shelter Bay to north of Mica Creek.

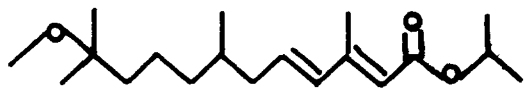
This moth appears from late September through October and deposits eggs on moss, lichens, and bark scales on the bole and limbs of trees. The eggs hatch in late spring and the larvae commence feeding soon after hatching on the newly opened buds of trees. Older larvae are extremely wasteful feeders, usually eating only a small portion of a needle and then moving on to another. For this reason this pest causes considerably more damage than other types of defoliators. Outbreaks of the Western Hemlock Looper develop rapidly and reach tree-killing proportions quickly. Tree mortality often occurs after the first year of attack, and, in the absence of control action, may continue for four years before the outbreak collapses, destroying millions of board feet of high-value timber.

In July, 1974, an experiment was initiated by the Canadian Forestry Service to study the effectiveness of Altosid juvenile hormone for the control of the Western Hemlock Looper. An area of crown land approximately 70 acres in size, 40 km south of Revelstoke and adjacent to Highway 23 along the Columbia River Valley, was selected and aerially treated with Altosid Juvenile Hormone.

The Environmental Protection Service investigated the impact of Altosid on non-target organisms. *In situ* field studies of the effects of this hormone insecticide on aquatic and terrestrial invertebrates, particularly to fish food organisms such as immature insects of different families are completely lacking. In this study, attention is focussed on the aquatic Diptera and terrestrial Hemiptera and Homoptera because of the selective potency of Altosid to these organisms. Emphasis is placed on the detection of changes relating to the moulting of juvenile insects and adult emergence rather than assessing larval and pupal morphological abnormalities which are difficult and tedious to detect.

2 LITERATURE REVIEW

Altosid, also known as Entocon™, Methoprene, and Zoecon ZR-515, belongs to the new class of synthetic pesticide called the insect growth regulator (IGR). It is a juvenile hormone analogue, synthesized from 2,4 - dienoic esters, and has the following structural formula (Dunham *et al*, 1975):



(Isopropyl (2E, 4E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienoate)

Altosid is very susceptible to microbial and photolytic degradation under environmental conditions (Schooley *et al*, 1975; Swern, 1970) and (Figures 1 and 2).

Under field conditions, technical and emulsion concentration formulations of ZR-515 have a half-life of approximately two hours, but residues of a "slow release" formulation can be detected in water up to 24 hours post application (Pawson *et al*, 1972; Schaefer & Dupras, 1973). When used at the rate of 1 lb active ingredient per acre (a.i./A) on alfalfa, Altosid had a half-life of 2 - 3 days (Quistad *et al*, 1974; Zoecon Corp., 1973).

Altosid, in very low concentrations, disrupts the hormonal balance of developing insects and interferes with physiological processes such as metamorphosis and dipause (Robbins, 1972; Schneiderman, 1972, Staal, 1975). It prevents the emergence of adults from pupae in contrast to direct toxic effects of conventional insecticides. The effects may be expressed by the occurrence of larval-pupal or pupal-adult intermediates, defective reproductive organs, or abnormal embryogenesis (Henrick *et al*, 1973). Insects belonging to the Order Diptera (flies) have been found to be extremely sensitive to the external application of Altosid during the pupal stages of their life cycle (Wright and Bowman, 1973; Staal, 1975). Although this hormone was originally developed for

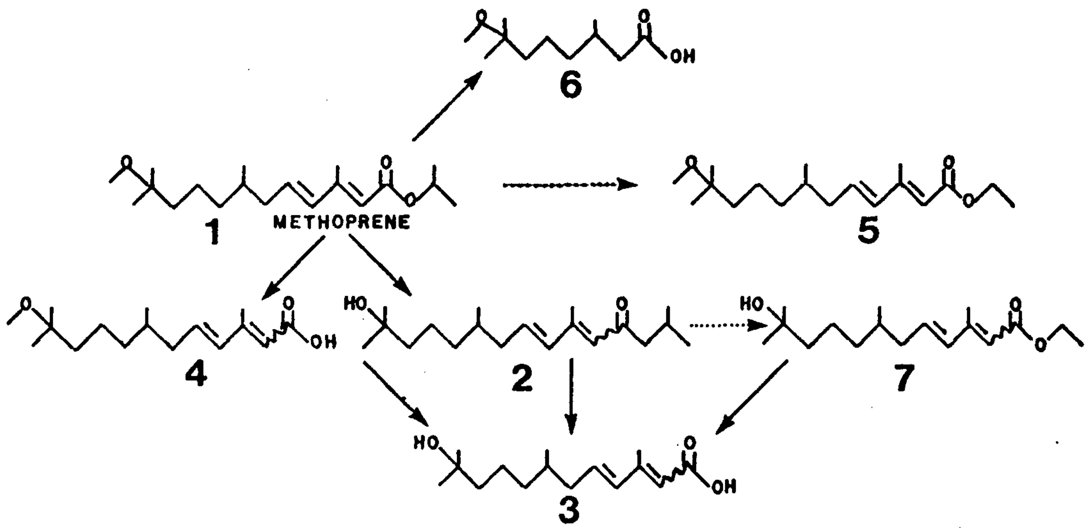


FIGURE 1. The metabolism of methoprene by aquatic microorganisms. A wavy line in structural formulas indicates an isomeric mixture about the 2-ene bond. Ethyl esters 5 and 7 are artifacts arising from transesterification (indicated by dotted arrow), Schooley *et al*, 1975.

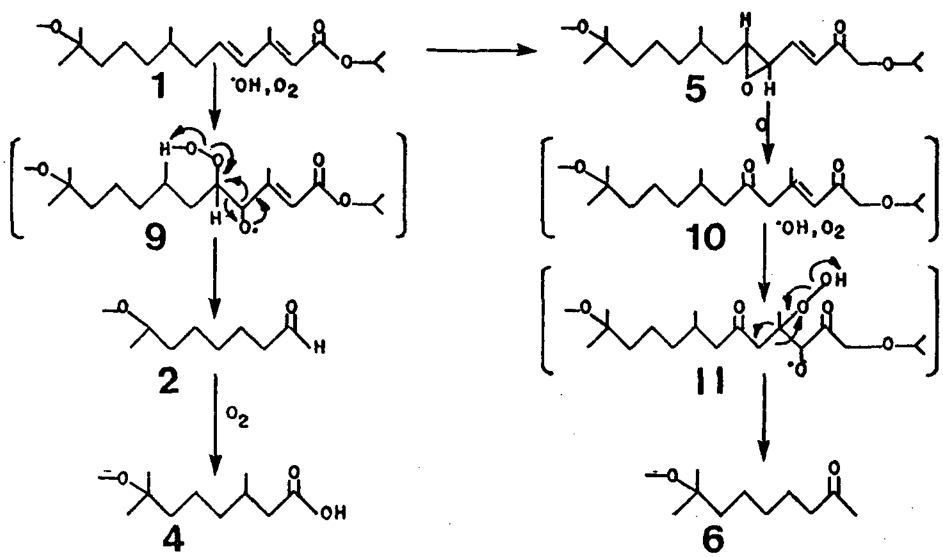


FIGURE 2. Possible mechanism for formation of photoproducts (*cf.* Swern, 1970).

the control of mosquitoes (Diptera), it has recently been shown to be effective against several insects of different orders (Menn and Beroza, 1972; Cumming and McKague, 1973; Ressig and Kamm, 1974; Westigard, 1974; and Staal, 1975).

Little work has been conducted to investigate the impact of Altosid on non-target organisms. One simulated field study showed that dosages used for mosquito larvae control produced no adverse effect on zooplankton and aquatic insecta, although Dipterean such as Chironomidae, Ephydridae, and Psychodidae demonstrated reduced emergence (Miura and Takahashi, 1973, 1974). Another work, however, reported that this compound induced mortality in the early and late instars of mayfly (Callibaetis pacificus) Seeman, and also reduced 84 percent of the predator (larval dytiscid beetle, Laccophilus sp) biomass during one season (Norland and Mulla, 1975).

Altosid has been claimed to be relatively non-toxic to birds, fish, and mammals (Zoecon Corp., 1973). The oral and subacute LD_{50} for Mallard duck and Bobwhite quail are greater than 10,000 ppm. Bluegill, trout and catfish, and largemouth bass have LC_{50} values of 4.62, 3.30, and >100 ppm, respectively. The oral and dermal LD_{50} for rat and rabbit are 34,600 mg/kg and 3,500 mg/kg, respectively.

Recent studies indicate that insects can develop resistance to Altosid (Schneiderman, 1972; Vinson and Plapp, Jr., 1974). One report stated that a strain of Musca domestica L. exhibited cross resistance to Altosid (Cerf and Georghiou, 1974).

3 MATERIALS AND METHODS

3.1 Experimental Design

The experiment was conducted in an area approximately 40 km south of Revelstoke, British Columbia, on the west side of the Columbia River Valley, adjacent to Highway 23 (Figure 3). Two separate plots totalling 28.4 ha and located in a Douglas fir and hemlock-cedar forest were treated with the insect growth regulator, Altosid.

Two beaver ponds were selected for the study (Figure 3). The size of the treated and control ponds was approximately 2.5 ha and 1.2 ha, respectively. Both ponds were surrounded by swamp consisting of graminaceous grasses, sedges, alder, salmonberry, blueberry, log and forest debris with hemlock-cedar forest at the perimeter. They were approximately 1.6 km apart. Both were fed by small creeks and surface runoff, and their substrates consisted entirely of mud.

A section of Little Fish Creek was also monitored. The treated part was approximately 300 m in length (Figure 3). A control station was located upstream, about 60 m outside the boundary of the plot. Streambank vegetation consisted of deciduous regrowths, willow, pine, salmonberry, blueberry, alder, sedges, graminaceous grasses and log debris. Boulders, course and fine gravel, were the predominant bottom-stream substrate. Smooth flow with riffles and pools characterized the upstream control station, while rapid flow with fewer riffles formed the main features downstream inside the treated plot.

3.2 Insecticide Application

The Altosid insect growth regulator was formulated as an emulsifiable concentrate. The active ingredient was Isopropyl (2E,4E) -11-methoxy - 3,7,11 - trimethyl -2,4 - dodecadienoate (65% by volume) and inert material (35% by volume). Besides Altosid, the spray emulsion contained Rhodomine B dye (0.1% by volume). The hormone was applied with a Cessna Agwagen aircraft at the rate of 142 mls a.i./ha(1.95 fl oz (U.S.) a.i./A) between 2000 and 2100 hours on July 30, 1974. Application details are tabulated in Appendix I.

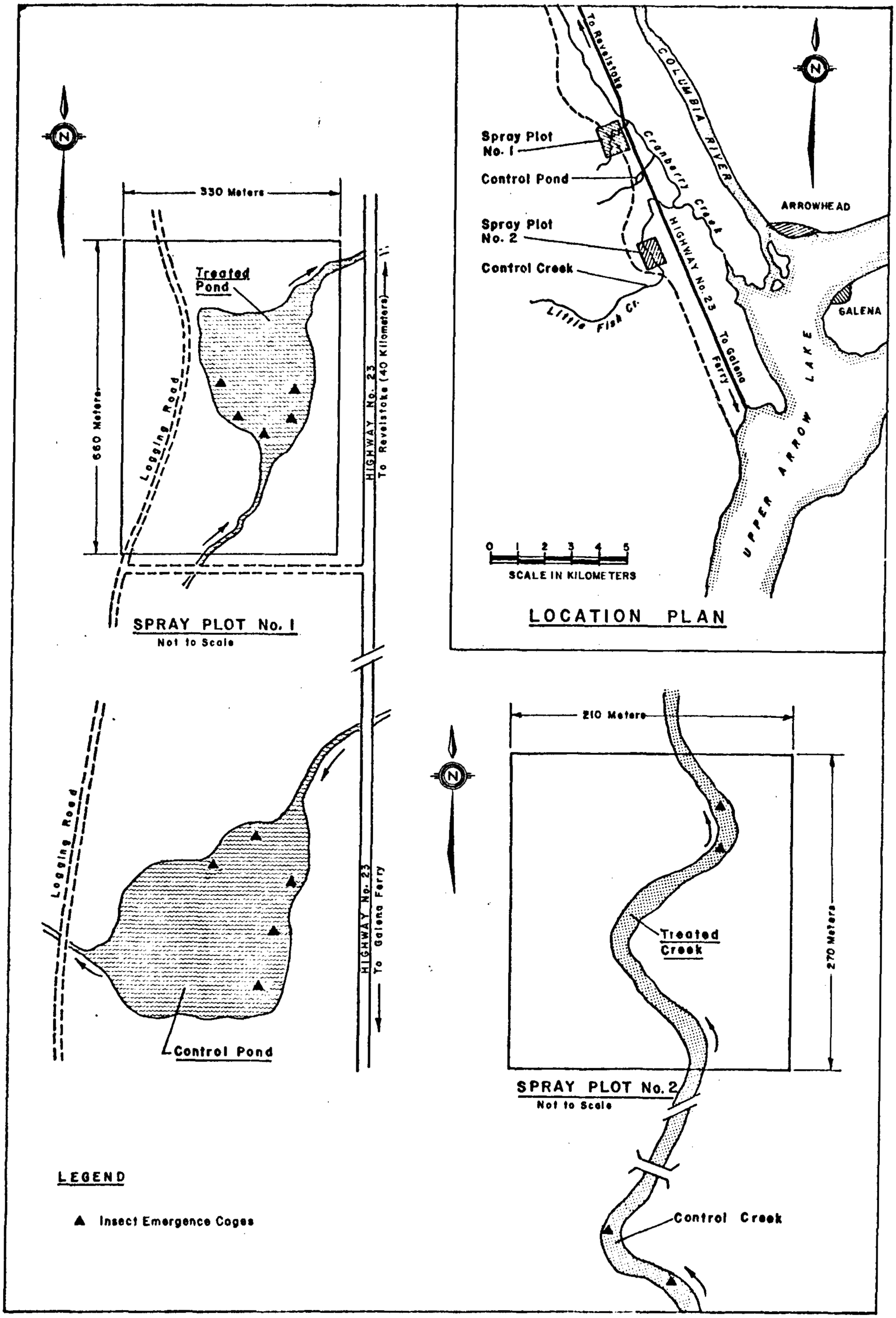


FIGURE 3 LOCATION OF SPRAY PLOTS

3.3 Observations and Sampling

Water chemistry determinations, temperature measurements, and biological sampling were conducted during the following periods:

1. Pre-treatment (6 days): July 25 - 30, 1974;
2. Post-treatment I (6 days): July 31 - August 6, 1974;
3. Post-treatment II (4 days): August 27 - 30, 1974.

3.3.1 Water Chemistry and Physical Studies. Air and water temperatures were recorded with a centigrade thermometer three times daily. Dissolved oxygen (DO), pH, and stream discharges were measured twice weekly at the two creek study sites. Appropriate Hach Kits were employed to determine the pH and DO. Water samples were also taken twice a week, and were frozen and submitted to Environment Canada Chemistry Laboratory at Cypress Creek, West Vancouver, for analyses. A Hach 1860 A Turbidimeter was used for the turbidity measurements, and a Jarrell Ash 810 atomic absorption spectrophotometer was used to determine total water hardness determination.

The stream velocity was measured with a Gurley mechanical current meter (PH-1). Readings of stream current were taken at 1.2 meter intervals across a representative transect at each creek station. The discharge of water was calculated from Embody's formula for volume of flow in water (Welch, 1948).

3.3.2 Biological Sampling. Representative invertebrate samples were obtained by the following methods: (a) emergence cages, (b) sweep nets, (c) surber samplers, and (d) drift nets.

Emergence cages: The emergence cages were designed to trap newly emerged adult aquatic insects. The pyrimidal cages were made of plexiglass with aluminium supporting frames and enclosed a water surface area of 0.2 m^2 (Figures 4 and 5). Five cages were placed approximately 60-80 m apart around the periphery of each pond where the depth of water was between 0.5 - 0.6 m. At each creek station, two cages were placed in riffles between 0.15 - 0.20 m deep. The edge of all

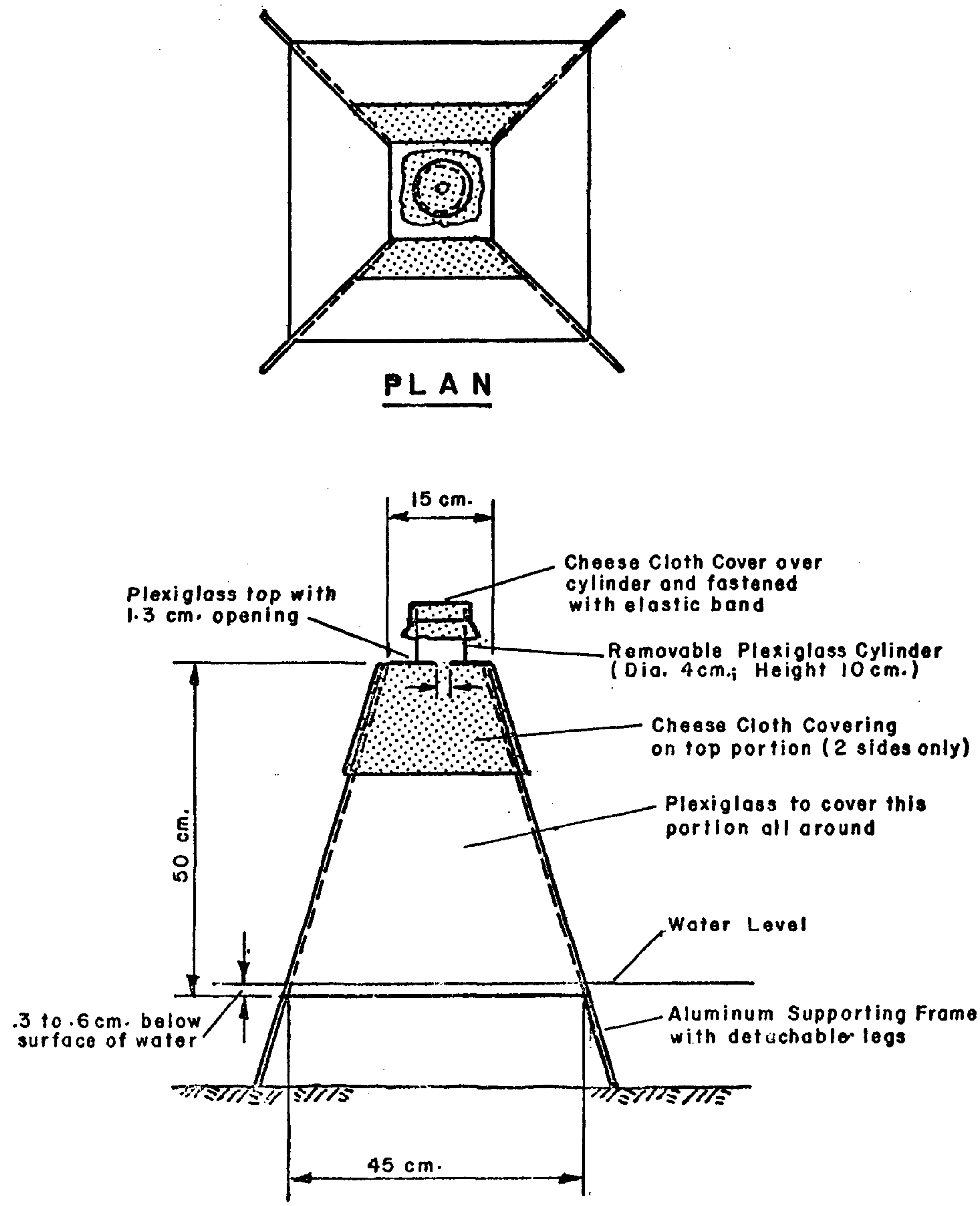


FIGURE 4 DIAGRAM OF AN EMERGENCE CAGE

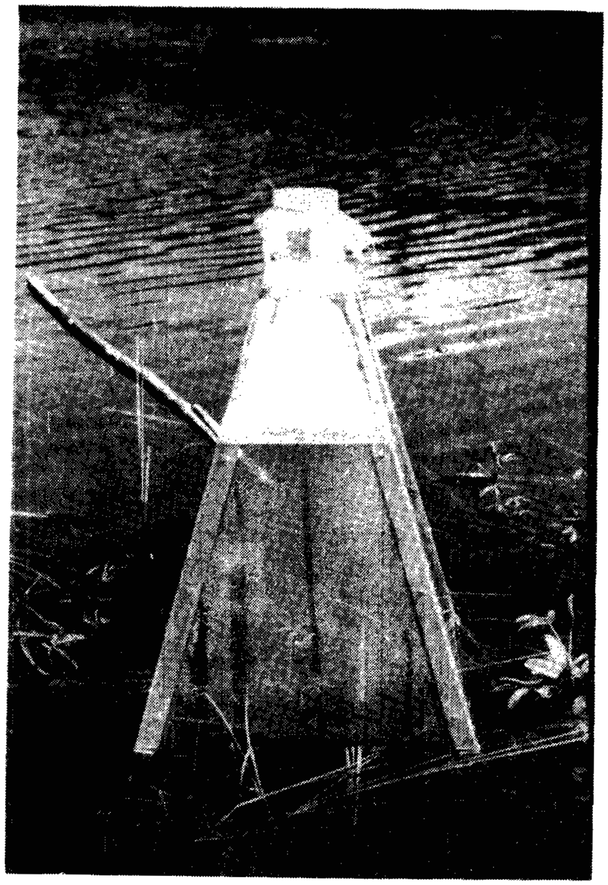


FIGURE 5 INSECT EMERGENCE CAGE

cages was set about 0.3 - 0.6 cm below water surface to prevent insect escape. Newly-emerged adult aquatic insects were trapped in a removable plexiglass cylinder on top of each cage. The insects were immobilized with 70 percent alcohol and collected in labelled bottles every day between 1000 - 1100 hours.

Sweep nets: Sweep nets (36 cm diameter, 0.1 cm mesh) were used for the collection of pond invertebrates and semi-terrestrial arthropods in marginal areas near the ponds. Aquatic organisms were sampled on submerged grasses and sedges by taking fifty random dips along the pond edges. All vegetative debris was carefully removed to reduce the bulk of each sample. Samples were taken twice before and after treatment and again one month after the spray (post-treatment II). Semi-terrestrial arthropods were sampled from emergent vegetation around the ponds by taking 100 sweeps along two randomly-selected 25 m transects. Samples were taken every day between 1100 - 1200 hours during the period of study.

Surber samplers: Surber samplers (0.1 m^2 total area) were used for the collection of stream-bottom invertebrates. Riffle sections were sampled in workable depths where the substrate consisted of medium-size boulders mixed with large gravel and coarse sand. Each sample was collected slightly upstream from the previous one and downstream from the drift nets. The contents of each net were emptied into a 297 micron sieve, washed to remove large debris and rocks, and preserved in 70 percent alcohol. Five surber samples were taken and retained in separate bottles at each site during each sampling period. Sampling was conducted twice before and after spraying, and also one month after treatment to monitor delayed effects.

Drift nets: Drift nets (0.1 m^2 in area, 0.1 cm mesh) were used to sample invertebrate drift. The downstream station, within the spray plot, were monitored for insecticide effects while the upstream station served as a control. The control was located outside the spray plot (Figure 3). Two sampling regimes were used during the study periods: (1) 24-hour continuous drift, and (2) 0.25-hour drift taken at intervals of 7-8 hours. The sampling area of the 24-hour net was reduced to 0.01 m^2 by an aluminium front plate needed to prevent excessive collection of detritus. Two 24-hr and two 0.25-hr nets were used at each creek site. Periodic drift (0.25-hr net) was taken three times daily between the hours of 0630-0715, 1330-1415, and 2030-2115. The contents from the drift nets of each sampling time were pooled.

All biological samples were preserved in 70% ethanol in labelled bottles and retained for examination, identification, and enumeration in the laboratory.

3.4 Sample and Data Analyses

Invertebrate samples were counted and identified using the following keys: Borror and DeLong (1970), Pennak (1953), and Usinger (1968).

Diversity ($\bar{d}$) and evenness (E) indices were used to quantify the impact of Altosid on aquatic and terrestrial invertebrates. The expressions adapted for the calculations were the expanded formulae of Wilhm and Dorris (1968) and Pielou (1967) as described in Wilson and Wan (1975). Values of ($\bar{d}$) and (E) for invertebrates were calculated for the treated pond and creek and their control counterparts using sampling period and mean number of organisms/taxa/day as variables. Values were computed to the family level.

A Hewlett Packard computor Model 9830A (with automatic plotter) was employed to perform all calculations.

4 RESULTS

4.1 Water Chemistry and Physical Parameters

Appendix II summarizes the values of dissolved oxygen (DO), pH, Ca++, Mg++, hardness, and turbidity of Little Fish Creek and the study ponds. The creek water was less turbid than the ponds, and had higher values of Ca++ and total $CaCO_3$, with a neutral to slightly alkaline pH varying from 6.9 to 7.3. Pond water had very low values of Ca++ and total $CaCO_3$, and was slightly acidic with a pH ranging from 6.1 to 6.5. The dissolved oxygen of both the creek and ponds remained fairly constant at 11 - 12 ppm during the period of study. Slight drop in DO and pH, however, was observed in the Altosid-treated pond shortly after spraying. DO and pH dropped to 8 and 5.9 ppm, respectively, soon after treatment. Both values returned to normal 12 - 24 hours later.

Daily air and water temperatures of the study areas are shown in Figure 6. Greater changes of daily air temperatures occurred at the creek stations and control pond with an average of 15.3^{o}C in the morning (0730 hrs) and 30.8^{o}C in the afternoon (1200-1300 hrs). The range of temperature change at the treated pond was smaller, averaging 23^{o}C and 28.5^{o}C in the morning (0700 hrs) and afternoon (1230 hrs), respectively. Mean water temperatures of Little Fish Creek and control pond averaged 12.6^{o}C in the morning and 16.7^{o}C in the afternoon. At the treated pond the water temperature remained high with a mean of 23.5^{o}C in the morning and 23.8^{o}C in the afternoon indicating little or no fluctuation.

Both the average water depth and stream discharge decreased during the sampling period. Between July 26 and August 4, discharge dropped from 0.35 m^3/sec to 0.21 m^3/sec, a 40 percent reduction at both stations. The mean water depth fell from 0.22 m to 0.18 m at the control station and from 0.25 m to 0.17 m in the treated area.

4.2 Biological Observations

Invertebrates obtained from the different methods of sampling represented the major orders of aquatic, semi-aquatic, and terrestrial

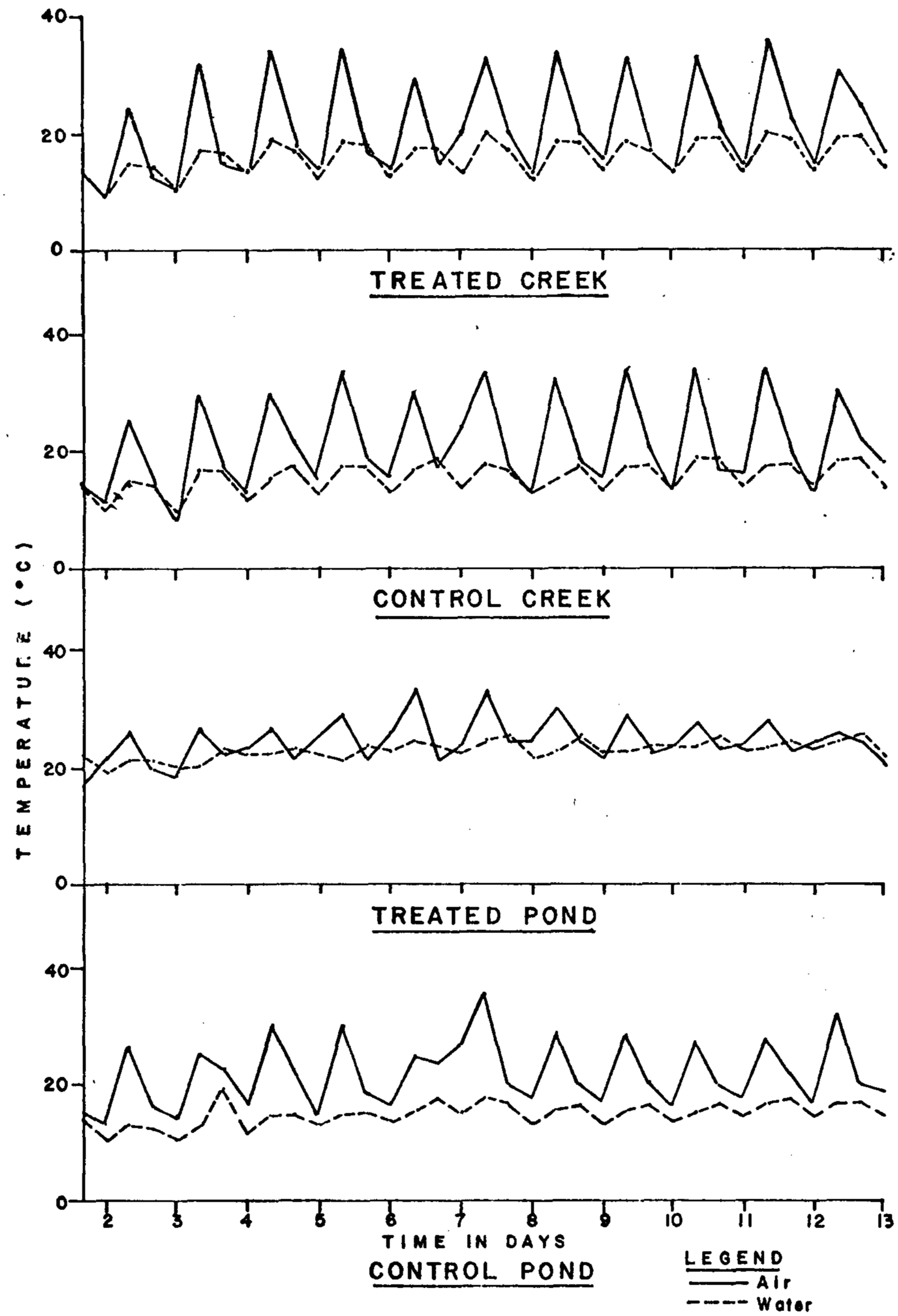


FIGURE 6 VARIATION OF DAILY AIR AND WATER TEMPERATURES

insects, mites, and other arthropods (Appendix III). Arthropods from emergence cages were exclusively adults while those collected from surber samplers were all immature stages. Samples caught by net sweeping contained a mixture of adult and immature stages. The 24-hour drift net samples consisted of adults, immature stages, and their exuviae. However, the 0.25-hour periodic drift net samples were almost entirely exuviae.

4.2.1 Effects of Altosid on Pond Insects. The daily emergence of total insects in the control and Altosid-treated ponds is illustrated in Figure 7.

4.2.1.1 Emergence of insects. The histogram (Figure 7) shows that there were no significant changes (Duncan's multiple range test, P = 0.05) in the mean emergence rate in the control pond during the study periods. In the Altosid treated pond, however, large variations in emergence were indicated. Greater emergence of insects was observed during pre-spray and post-spray II than occurred during post-spray I. Significantly lower rates of insect emergence (Duncan's multiple range test, P = 0.05) were recorded during pre-spray and post-spray I, particularly two days before Altosid treatment and at day 6 and 31 following treatment.

Table 1 presents the different families of Diptera caught and their rate and change of emergence from control pond. The flies accounted for more than 90 percent of the arthropods caught, and were represented by seventeen families, eight of which, notably Anthomyiidae, Ceratopogomidae, Chaoboridae, Empididae, Muscidae, Scatopsidae, Simulidae, and Tendipedidae, dominated the total number. A significant increase (P = 0.10, n = 11) and decrease (P = 0.05, n = 8) in the mean rate of emergence of total insect numbers was obtained during post-spray I and II, respectively (Table 2). The change during period I was primarily due to a significant increase in emergence of Muscidae (P = 0.05, n = 12). The decrease during period II was because of two factors: (a) a significant decrease in rate of emergence of Certopogonidae (P = 0.10, n = 9) and Tendipedidae (P = 0.05, n = 9), and (b) the absence of some families such as Chaoboridae, Empididae, and Simulidae.

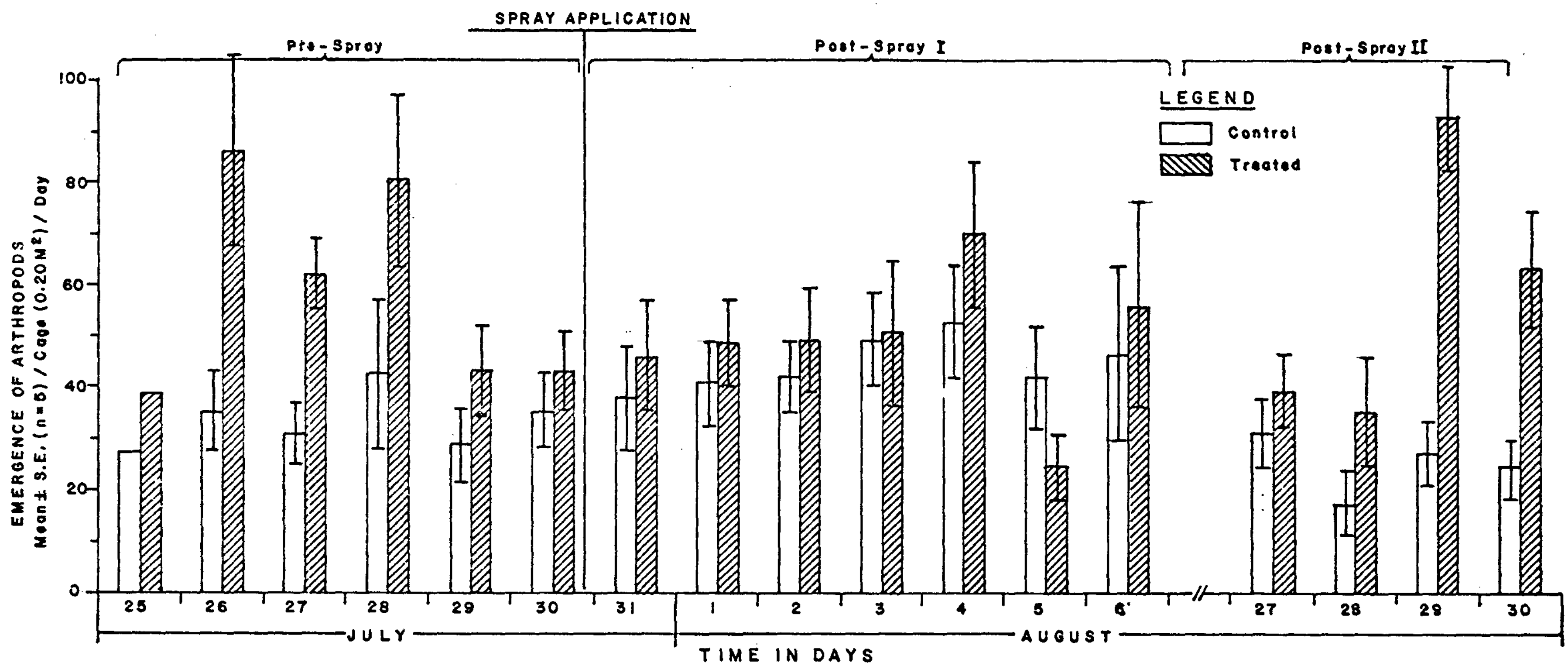


FIGURE 7 RATE OF EMERGENCE OF ARTHROPODS IN CONTROL AND ALTOSID-TREATED PONDS

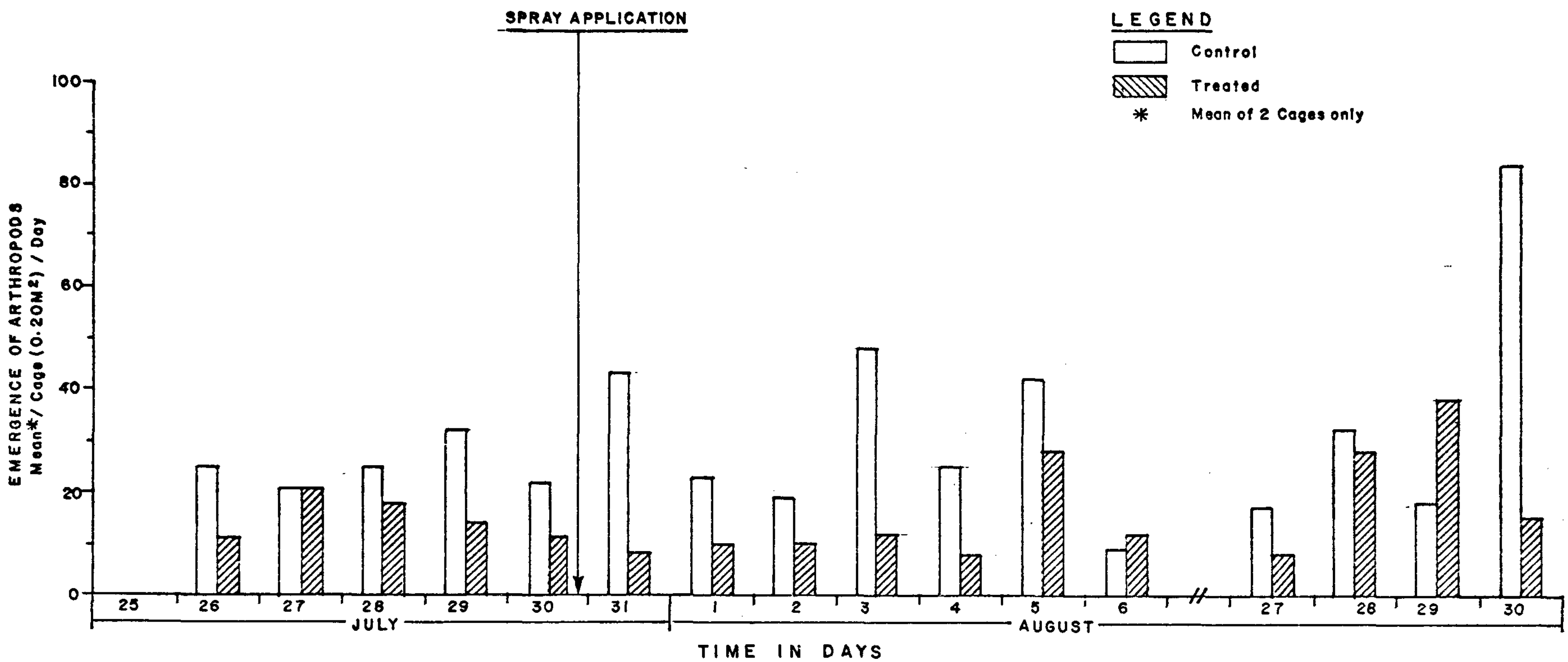


FIGURE 8 RATE OF EMERGENCE OF ARTHROPODS IN CONTROL AND ALTOSID-TREATED CREEK STATIONS

TABLE 1 CHANGES IN RATE OF EMERGENCE OF INSECTA FROM CAGES IN CONTROL POND

Insecta	Rate of Emergence*			Change I	Change II
	Pre-spray[a]	Post-spray I[b]	Post-spray II[c]		
O. DIPTERA					
F. Anthomyiidae	3.8	4.6	6	1.2	1.6
F. Cecidomyiidae	0	0.7	0	-	-
F. Ceratopogonidae	20.5	33.0	4.6	1.6	0.2
F. Chaoboridae	4.9	0.4	0	0.1	-
F. Culicidae	1.3	1.4	1.7	1.1	1.2
F. Dixidae	0.9	0.6	0	0.7	-
F. Dolichopodidae	0	0.9	0.3	-	-
F. Empididae	26.0	8.6	0	0.3	-
F. Muscidae	17.5	55.9	52.3	3.2	3.0
F. Mycetophilidae	0	1.4	0	-	-
F. Phoridae	1.3	0.7	0.3	0.5	0.2
F. Psychodidae	3.3	2.7	0.3	0.8	0.1
F. Scatopsidae	7.1	5.7	1.4	0.8	0.2
F. Simulidae	6.7	1.7	0	0.3	-
F. Tabanidae	0	0.1	0	-	-
F. Tendipedidae	79.6	84.9	44.6	1.1	0.6
F. Tipulidae	0.5	0.4	0	0.8	-
O. HYMENOPTERA					
F. Ichneumonidae	1.1	1.0	0.6	0.9	0.5
O. LEPIDOPTERA					
F. Pyralidae	0.7	6.1	0.3	8.7	0.4

* = Number of Diptera per m^2 per day

Change I = $\frac{\text{Rate of emergence of post-spray I}}{\text{Rate of emergence of pre-spray}}$

Change II = $\frac{\text{Rate of emergence of post-spray II}}{\text{Rate of emergence of pre-spray}}$

>1 = increase; <1 = decrease

a, b, c = 5, 7 and 3 days, respectively

TABLE 2 CHANGES IN TOTAL ARTHROPOD NUMBERS DURING DIFFERENT SAMPLING PERIODS

Method of Sampling	Location	Sampling Period			Change I[a]	Change II[a]
		Pre-spray[b] (Mean±S.E.)	Post-spray I[c] (Mean±S.E.)	Post-spray II[d] (Mean±S.E.)		
Emergence cages*	Control pond	182±20	225±11	119±15	1.2	0.7
	Altosid pond	320±41	249±28	329±76	0.8	1.0
	Control ck. station	47±4	59±12	81±41	1.2	1.7
	Altosid ck. station	29±5	25±6	48±18	0.9	1.6
Net-sweeping+	Control pond	1103±26	1021±19	604±32	0.9	0.6
	Altosid pond	825±28	1092±36	671±44	1.3	0.8
Surber samplers*	Control ck. station	120±5	142±5	152±12	1.2	1.3
	Altosid ck. station	137±7	174±8	301±16	1.3	2.2
Drift nets[e] (24-hr)	Control ck. station (L)	605±180	432±56	-	0.7	-
	(Ex)	771±110	1942±271	-	2.5	-
	Altosid ck. station (L)	208±55	174±20	-	0.8	-
	(Ex)	1590±205	1756±212	-	1.1	-

* Number of arthropods per m^2 per day

\+ Number of arthropods per 100 sweeps per day

a See Table 1 for meaning

b,c,d, (N = 5,7,3, respectively)

e Number per 0.02 m^2 sampling area; L = Live; Ex = Exuviae

In the Altosid-treated pond (Table 3) only 13 families of Diptera were caught. The dominant groups which accounted for 90 percent of the invertebrates were Ceratopogonidae, Chaoboridae, Muscidae, and Tendipedidae. Although a significant decrease (P = 0.20, n = 12) in mean rate of daily emergence of total arthropods was recorded during post-spray I, a regain in rate of emergence to pre-spray level was achieved during post-spray II. The change in rate of emergence during the period following Altosid treatment was related to significant decreases of seven groups of insects: Anthomyiidae (P = 0.05, n = 12), Chaoboridae (P = 0.01, n = 12), Certatopogonidae (P = 0.02, n = 12), Empididae (P = 0.10, n = 12), Braconidae (P = 0.01, n = 12), Ichneumonidae (P = 0.10, n = 12), and Pyralidae (P = 0.02, n = 12).

4.2.1.2 Net-sweeping insects. The different groups of arthropods collected by net-sweeping and their change in numbers during post-spray I and II are presented in Appendix V and VI. No significant change was noted at both ponds following Altosid application. However, in the control pond, the total mean numbers collected during post-spray II were significantly less (P = 0.05, n = 9) than pre-spray numbers (Table 2). This was due to a decrease in numbers of Hemiptera even though a large increase of Thysanoptera occurred.

The major orders of aquatic arthropods collected by net-sweeping pond water are presented in Appendix VII. In both the control and Altosid-treated ponds a drop in total numbers of arthopods occurred during post-spray period I. During post-spray period II, however, the arthropod population increased by 2.6 times in the control pond, while there was no change in the treated pond. The increase in the control pond was attributed to large increases of aquatic Ephemeroptera, Odonata, Diptera, and Coleoptera. This increase did not occur in the Altosid-treated pond.

TABLE 3 CHANGES IN RATE OF EMERGENCE OF INSECTA FROM CAGES IN ALTOSID-TREATED POND

Insecta	Rate of Emergence*			Change I	Change II
	Pre-spray[a]	Post-spray I[b]	Post-spray II[c]		
O. DIPTERA					
F. Anthomyiidae	0.4	0	0.3	-	0.8
F. Ceratopogonidae	4.7	1.0	4.0	0.2	0.9
F. Chaoboridae	11.6	0.3	0	<0.1	-
F. Culicidae	0	0	2.0	-	-
F. Dolichopodidae	0	0.3	0	-	-
F. Empididae	1.5	0.3	0.3	0.2	0.2
F. Muscidae	7.5	6.7	13.4	0.9	1.8
F. Phoridae	0.4	0.1	0.3	0.3	0.8
F. Psychodidae	0.2	0	0	-	-
F. Scatopsidae	1.1	0.4	1.1	0.4	1.0
F. Simulidae	0.4	0	0	-	-
F. Tendipedidae	262.4	219.6	270.3	0.8	1.0
F. Tipulidae	0.2	0.1	0	0.5	-
O. HYMENOPTERA					
F. Braconidae	2.5	0.3	0.6	0.1	0.2
F. Ichneumonidae	7.1	2.7	5.4	0.4	0.8
O. LEPIDOPTERA					
F. Pyralidae	12.0	3.9	0.3	0.3	<0.1

* = Number of insects per m^2 per day

Change I, II - See Table 1

>1 = increase; <1 = decrease

a, b, c = 5, 7, and 3 days, respectively

4.2.2 Effects of Altosid on Creek Insects. The daily emergence of total insects in the control and Altosid-treated creek station is illustrated in Figure 8.

4.2.2.1 Emergence of insects. The histograms illustrated in Figure 8 indicate changes in emergence of total insect numbers at the control station. The peaks occurring every two to three days appeared to coincide with the emergence of Diptera Ceratopogonidae and Tendipedidae (Appendix IV). These peaks did not appear at the Altosid-treated station, where a steady rate of emergence was indicated throughout the period of study.

No change in rate of emergence of total arthropods was observed at the control and Altosid-treated creek stations during the periods of study (Table 2).

4.2.2.2 Drift organisms. Figures 9 and 10 illustrate the drift patterns of the 3 x 0.25-hour and 24-hour samples from the creek stations. In the 0.25-hour drift, no changes in drift patterns were observed. The peak drift occurred during afternoons. In the 24-hour drift the number of exuviae collected at days 9 and 10 (i.e., 1 and 2 days post-application) appeared to be less than the control station. These changes were not observed in the live samples.

The different kinds of invertebrates and their exuviae collected from the 24-hour drift are presented in Appendix VIII. The dominant groups from control and treated stations were Diptera, Ephemeroptera, and Trichoptera. Generally, the exuviae were far more numerous than live organisms. No large changes of live organisms occurred at either station after spray application. The exuviae from the control station increased significantly ($P = 0.01$, $n = 12$) by a factor of 2.5 (Table 2), even though there was no change in the Altosid station. The increase at the control station was attributed to large increases in exuviae collected from Baetidae, Simulidae, and Tendipedidae which could be an indication of active moulting of these invertebrates. In the hormone-treated station, no such increase was observed.

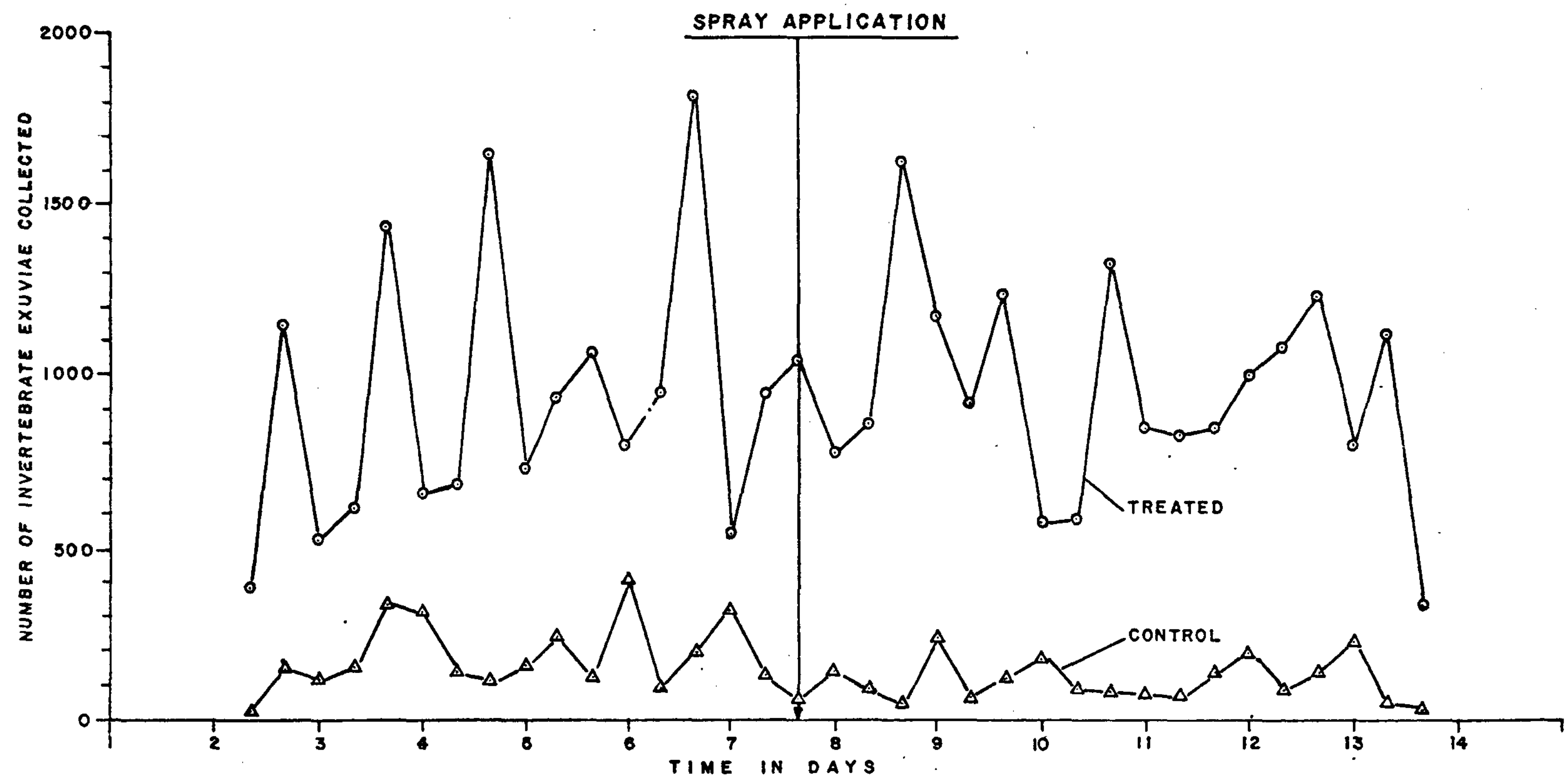


FIGURE 9 DRIFT OF INVERTEBRATE EXUVIAE IN LITTLE FISH CREEK (15-MINUTE SAMPLE)

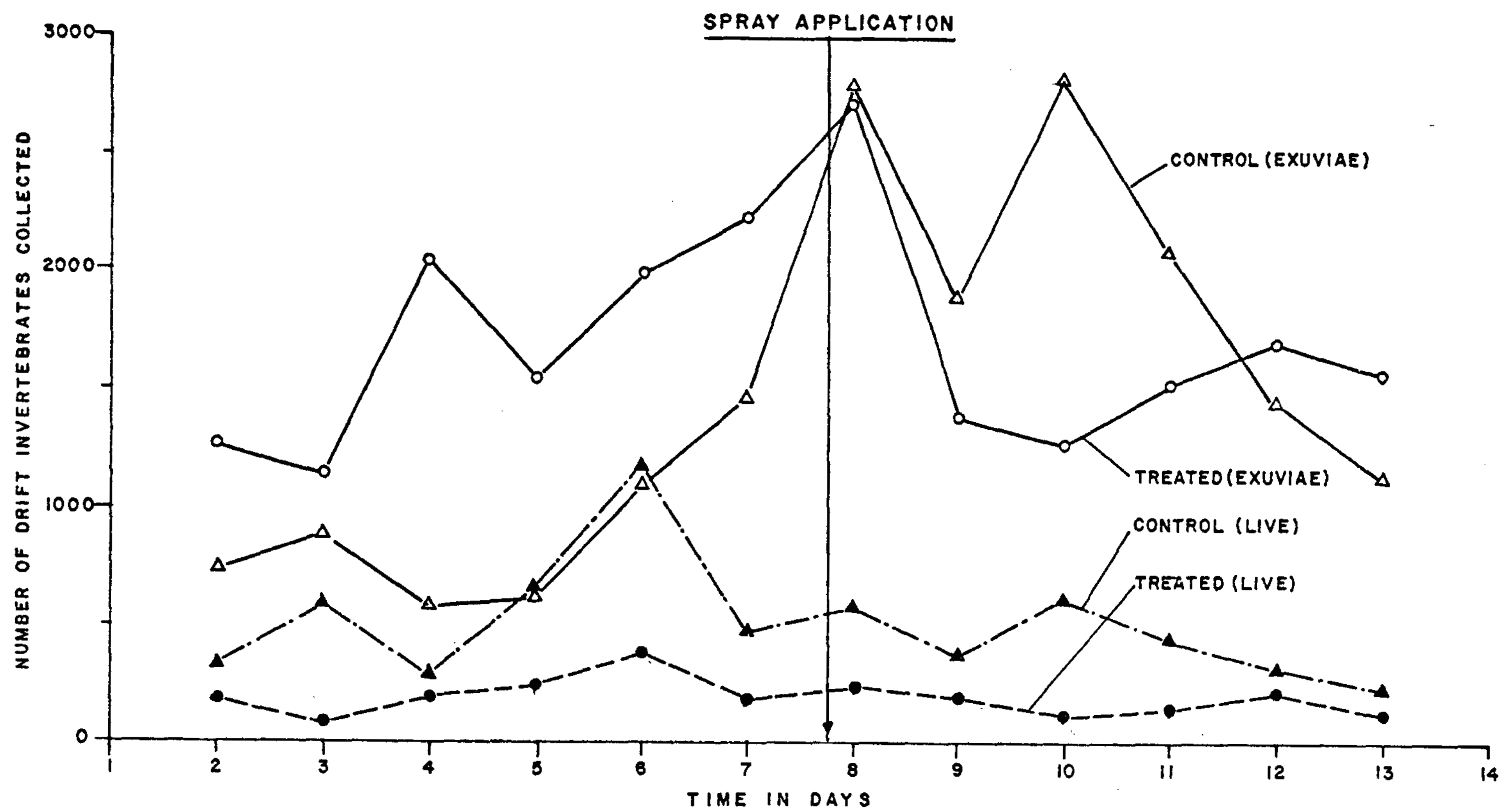


FIGURE 10 DRIFT OF INVERTEBRATES AND THEIR EXUVIAE IN LITTLE FISH CREEK (24- HOUR SAMPLE)

4.2.2.3 Benthic invertebrates. Appendices IX and X present the different types of bottom invertebrates collected by Surber sampling. At the control and Altosid stations the number of invertebrates remained essentially unchanged during post-spray I and II (Table 2). Approximately twice as many organisms were collected in the Altosid-treated area during post-spray II. The increase contained large numbers of Diptera (Simulidae), Ephemeroptera (Baetidae), Plecoptera (Perlidae and Perloididae) and Trichoptera (Psychomyidae and Rhyacophilidae).

4.2.3 Diversity of Invertebrate Communities. The diversity ($\bar{d}$) and evenness (E) values of invertebrate communities from the ponds and creeks are presented in Appendix XI. Generally, there was more variation in ($\bar{d}$) and (E) in the ponds than in the creek stations. Both values increased with time in the control pond, with the exception of emergence in post-spray II where a significant drop ($P = 0.05$, $n = 9$) was recorded. Although a significantly ($P = 0.20$, $n = 12$) lower ($\bar{d}$) was obtained from the emergence in the Altosid-treated pond during post-spray I, both ($\bar{d}$) and (E) from the other sampling methods remained essentially unchanged. A similar situation was evident in both values from different sampling procedures in the creek stations. However, a significantly ($P = 0.02$, $n = 9$) lower ($\bar{d}$) was indicated from emergence in the Altosid-treated creek station during post-spray II.

5 DISCUSSION

Several groups of hemimetabolous (incomplete metamorphosis) and holometabolous (complete metamorphosis) insects dominated the pond and creek water habitats, namely: Diptera, Ephemeroptera, Lepidoptera, Plecoptera, and Trichoptera. Hemiptera and Hemoptera were among some of the major semi-terrestrial insects. All these groups were collected during the period of study at both the control and treated sites. The majority of the insects were univoltine. Several families of aquatic Diptera (Simulidae and Tendipedidae) and terrestrial Homoptera (Aphididae and Cicadellidae) exhibiting either bi-voltine or multi-voltine life histories were also present.

Many environmental factors influence the development and emergence of insects. Temperature, day length, availability of food, and dissolved substances such as oxygen and minerals could induce or arrest the growth of insects (Bursell, 1964; Hynes, 1970; Wigglesworth, 1965). These conditions remained essentially constant during the period of study at Revelstoke. The weather at the study sites was hot and humid, typical of inland mid-summer conditions. Both air and water temperatures remained uniform, exhibiting duirnal fluctuations, although the water temperature of the treated pond was relatively higher than the control. No drastic changes were recorded in the pH, DO, hardness, and turbidity of water, except a slight drop in pH and DO at the Altosid pond shortly after hormone application. This persisted for approximately 12 hours. Interruption of insect development attributable to changes of environmental conditions would therefore be unlikely.

The development of immature insects to adult form depends on a delicate endocrine balance (Bursell,1964; Wigglesworth, 1964, 1965). Contact with externally-introduced juvenile hormone can upset this sensitive balance in young insects and induce changes in development. Both target and non-target insects may be affected if hormone contact was made. Response of insects to this exogenous hormone may be expressed by the following phenomena: (a) change in rate of emergence, (b) cessation of ecdysis, and (c) development of abnormal morphological features in immature stages (Staal, 1975).

Changes in rates of insect emergence which could be related to exogenous hormone application occurred at the Altosid-treated pond. Several insects exhibited lower rates of emergence following hormone treatment. The change for Ceratopogonidae, Chaoboridae, Ichneumonidae, Muscidae, and Pyralidae from Altosid pond was respectively 8, 3, 2, 4, and 29 times smaller than the control during post-spray I (Appendix XII). Some recovery in emergence appeared to have been achieved during post-spray II for Ceratopogonidae, Muscidae, and Ichneumonidae, but not in Pyralidae, which remained more than 20 times less than the control. Pyralids are insects belonging to the same Order as the Western Hemlock Looper.

The data also indicated that insect emergence of the control pond was at a steady rate. In the Altosid pond, however, this was not observed. The rate of emergence was interrupted 2 days before, and 6 and 31 days after, hormone application. A significant drop in total insect emergence was recorded during those 3 days (Figure 7). The drop which occurred 2 days before and 31 days after Altosid treatment may have been fluctuation. The sharp decrease in emergence at day 6 following application, however, could be either caused by Altosid, natural fluctuations, or a combined effect of the hormone and natural fluctuations in emergence.

In the control pond, the numph/adult ratio of hemimetabolous insects decreased with time (Appendix XIII). This demonstrated that as the mid-summer conditions progressed more and more of the nymphs were transformed to adults. At the Altosid pond this pattern, which should be comparable for the same insects, was not observed. In fact, the ratio remained either unchanged (Cicadellidae and Delphacidae) or increased (Largidae), demonstrating that there could have been arrestment in their transformation to the adult stage. Egg eclosion of Delphacidae was indicated by the high nymph/adult ratio at the control pond during post-spray II. At the treated pond a low ratio was observed for this insect during the same period, demonstrating that Altosid may have prevented egg eclosion. The diversity index increase with time in the control pond indicated addition of new insect groups either from egg-hatching or migration from the surrounding forest area. In the Altosid pond, the indices dropped or remained static following hormone treatment, indicating that fewer or no new insect groups were added.

At the Altosid-treated station in Little Fish Creek, the number of invertebrate exuviae collected by drift nets one week after hormone treatment was 2.5 times less ($P = 0.01$) than that of the control station. Twice as many benthic invertebrates ($P = 0.01$) were found via Surber sampling one month following hormone application. These observations suggest that Altosid could have reduced the moulting activity of the benthic organisms and consequently fewer adults emerged. However, it is difficult to attribute these changes directly to Altosid without further studies. Extrinsic factors such as stream discharge, distribution of exuviae in the discharge, physical features of the stream, and location of drift nets could also influence the numbers of exuviae. Moreover, the benthic invertebrate population one month post hormone treatment may have been either the surviving resident population or new migrants from upstream. The physical characteristics of stream substrates, which change constantly, also influence the distribution of benthic invertebrates. There was no change in the diversity indices of both control and Altosid creek stations. This demonstrated that the number of insect groups remained basically the same as pretreatment.

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APPENDICES

APPENDIX I APPLICATION DETAILS

Weather - clear evening, some sun
Air temperature - $22^{0}C$ (mean)
Wind velocity - 0 to 3 mph

Aircraft Specifications:

(a) aircraft: Cessna Agwagen
(b) flight speed: 110 mph
(c) nozzle type: #40, 8010 "Tee-Jet"
(d) boom pressure: 52 p.s.i.
(e) volume carried: 150 gals of water solution (225 fl oz Altosid and 19.5 fl oz Rhodomine B)
(f) no. of gal/acre delivered: 2 U.S. gal/acre
(g) height above trees: 100 ft
(h) no. of swaths (pond): eleven (100 ft wide)
(creek): seven (100 ft wide)
(i) length and width of swaths (pond): 100 x 2200
(creek): 100 x 900
(j) rate per acre (theoretical): 3 oz a.i./acre

Plot Details:

(a) dimensions of pond plot: 2200' x 1100'
creek plot: 900' x 700'
(b) total area of pond plot: 55 acres
creek plot: 14.5 acres

APPENDIX II WATER CHEMISTRY OF LITTLE FISH CREEK AND PONDS

Date (1974)	DO (ppm)	pH	Ca++ (ppm)	Mg++ (ppm)	Total Hardness mg/litre $CaCO_3$	Turbidity (F.T.O.)
Little Fish Creek (Control Station)						
July 25	12	6.9	4.7	0.76	15.00	1.2
July 28	12	7.0	5.8	1.20	20.00	1.0
July 31	12	7.0	4.5	1.90	19.00	0.9
Aug. 4	11	7.0	2.9	0.80	10.00	0.6
Little Fish Creek (Treated Station)						
July 25	12	7.2	4.2	1.10	15.00	1.2
July 28	12	7.2	5.2	1.20	18.00	0.8
July 31	12	7.2	6.9	1.40	23.00	0.6
Aug. 4	11	7.3	3.9	0.83	13.00	0.8
Control Pond						
July 25	11	6.4	1.1	0.61	2.00	0.32
July 28	12	6.3	1.4	1.30	0.80	8.60
July 31	11	6.5	1.4	6.80	31.00	0.72
Aug. 4	11	6.2	2.1	9.52	0.70	44.00
Treated Pond						
July 25	12	6.2	0.88	0.43	1.30	3.90
July 28	11	6.2	0.69	0.67	0.80	4.50
July 31 (a)	10	6.1	0.89	0.61	1.30	4.70
(b)	12	6.2	-	-	-	-
Aug. 4	11	6.3	0.60	0.30	0.90	2.70

(a) and (b) = 12 and 24 hours post-treatment, respectively

APPENDIX III FAMILIES OF ARTHROPODS CAUGHT IN EMERGENCE CAGES

Arthropoda	Ponds		Little Fish Creek	
	Control	Altosid-Treated	Control Station	Altosid-Treated Station
O. ACARI				
F. Acaridae	+	+	+	+
O. COLLEMBOLA				
F. Sminthuridae	+	-	-	-
O. COLEOPTERA				
F. Amphizoidae	+	+	-	-
F. Coccinelidae	+	-	-	-
F. Curculionidae	+	-	+	-
F. Staphylinidae	-	-	+	-
O. DIPTERA				
F. Anthomyiidae	+	+	+	-
F. Ceratopogonidae	+	+	+	+
F. Cecidomyiidae	+	-	+	+
F. Chaoboridae	+	+	-	+
F. Culicidae	+	+	+	+
F. Dixidae	+	-	+	-
F. Dolichopodidae	+	+	+	-
F. Empididae	+	+	-	+
F. Muscidae	+	+	+	+
F. Mycetophilidae	+	-	+	+
F. Phoridae	+	+	+	+
F. Pipunculidae	-	-	+	-
F. Psychodidae	+	+	+	+
F. Scatopsidae	+	+	+	+
F. Simulidae	+	+	+	-
F. Tabanidae	+	-	-	-
F. Tendipedidae	+	+	+	+
F. Tipulidae	+	+	-	+
O. EPHEMEROPTERA				
F. Ephemeridae	-	+	-	-
F. Heptageniidae	-	-	+	+
O. HEMIPTERA				
F. Macroveliidae	+	-	-	-
O. HOMOPTERA				
F. Aphididae	+	+	+	-
F. Cicadelidae	+	+	+	-
O. HYMENOPTERA				
F. Braconidae	+	+	-	-
F. Ichneumonidae	+	+	-	+
F. Scelionidae	-	-	+	-
F. Trichogrammatidae	+	+	-	-
O. LEPIDOPTERA				
F. Pyralidae	+	+	+	+
O. ODONATA				
F. Coenagrionidae	-	+	-	-
O. TRICHOPTERA				
F. Limnephilidae	+	+	-	-
F. Phryganeidae	+	+	-	-
F. Psychomyiidae	+	+	-	-
F. Rhyacophilidae	-	-	+	+
O. THYSANOPTERA				
F. Phlaeopthripidae	-	+	-	-
F. Thripidae	-	-	+	-
No. of Families present	32	27	24	17

\+ present

\- absent, or not caught

APPENDIX IV DAILY EMERGENCE OF CERATOPOGONIDAE AND TENDIPEDIDAE OF ORDER DIPTERA

Date	Control Creek*		Altosid-Treated Creek*	
	Ceratopogonidae	Tendipedidae	Ceratopogonidae	Tendipedidae
July 26	16	24	3	11
July 27	16	14	8	30
July 28	35	9	6	25
July 29	<u>49</u>	9	14	10
July 30	29	7	6	11
July 31	<u>55</u>	<u>13</u>	8	4
August 1	26	7	5	10
August 2	20	9	5	10
August 3	<u>53</u>	3	12	4
August 4	38	0	7	5
August 5	<u>55</u>	<u>14</u>	30	20
August 6	3	3	10	4
August 27	0	17	0	3
August 28	6	36	3	47
August 29	5	18	2	70
August 30	2	<u>157</u>	1	28

* Total of 2 cages

Numbers underlined account for the peaks in Figure 9.

APPENDIX V CHANGES IN NET-SWEEP ARTHROPOD POPULATIONS IN MARGINAL AREAS OF CONTROL POND

Arthropoda	Mean Numbers Collected ($\bar{x}$/100 sweeps/day) Pre-Spray	Post-Spray I	Post-Spray II	Change I+	Change II+
ACARI	0.8	0.2	0.7	0.3	0.9
ARANEIDA	23.7	31.2	22.3	1.3	0.9
COLEOPTERA (A)	14.5	9.3	17.3	0.6	1.2
(L)	4.3	15.3	4.0	3.6	0.9
COLLEMBOLA	0.2	0.3	0.3	1.5	1.5
DIPTERA	130.5	171.0	101.0	1.3	0.8
GASTROPODA	0.8	1.0	1.3	1.3	1.6
HEMIPTERA (TOTAL)	739.7	612.8	152.7	0.8	0.2
F. Largidae (A)	27.2	47.3	85.3	1.7	3.1
(N)	641.0	512.7	45.3	0.8	0.1
F. Miridae (A)	14.0	6.7	5.7	0.5	0.4
(N)	52.3	10.0	5.0	0.2	0.1
F. Pentatomidae (A)	0.5	0.7	0	1.4	-
(N)	2.8	1.0	4.2	0.4	1.5
F. Pyrrhocoridae (A)	1.3	4.3	6.0	3.3	4.6
(N)	0	29.5	0	-	-
F. Reduviidae (A)	0.3	0.2	0.7	0.7	2.3
F. Saldidae (A)	0.2	0.3	0.3	1.5	1.5
HOMOPTERA (TOTAL)	144.8	143.3	170.7	1.0	1.2
F. Aphididae (A)	47.0	22.3	5.7	0.5	0.1
(N)	36.7	5.3	0	0.1	-
F. Cicadellidae (A)	31.5	64.8	86.3	2.0	2.7
(N)	21.2	42.2	52.0	2.0	2.5
F. Cercopidae (A)	0.5	0.5	0.3	1.0	0.6
F. Delphacidae (A)	3.2	2.2	1.7	0.7	0.5
(N)	2.5	5.0	24.3	2.0	9.7
F. Psyllidae (A)	1.8	1.0	0.3	0.6	0.2
(N)	0.3	0	0	-	-
HYMENOPTERA	37.0	26.7	17.3	0.7	0.5
LEPIDOPTERA (A)	1.3	3.7	1.0	2.9	0.8
(C)	1.7	0.7	2.3	0.4	1.4
ODONATA	0.5	0.2	0	0.4	-
ORTHOPTERA	0	0.2	0.3	-	-
PSOCOPTERA	0.2	4.3	0.3	21.5	1.5
THYSANOPTERA	2.5	0.5	111.7	0.2	44.7
TRICHOPTERA	0.2	0	1.0	-	5.0

+ - See Table 1 for meaning

A - Adults
C - Caterpillars
L - Larvae
N - Nymphs

APPENDIX VI CHANGES IN NET-SWEEP ARTHROPOD POPULATIONS IN MARGINAL AREAS OF ALTOSID-TREATED POND

Arthropoda	Mean Numbers Collected ($\bar{x}$/100 sweeps/day) Pre-Spray	Post-Spray I	Post-Spray II	Change I+	Change II+
ACARI	1.0	1.0	0.3	1.0	0.3
ARANEIDA	12.3	27.7	21.7	2.3	1.8
COLEOPTERA (A)	12.0	9.5	6.3	0.8	0.5
(L)	5.3	14.7	5.0	2.8	0.9
COLLEMBOLA	0.8	4.7	4.3	5.9	5.4
DIPTERA	229.2	117.5	108.0	0.5	0.5
GASTROPODA	0	0.3	0.3	-	-
HEMIPTERA (TOTAL)	258.3	401.8	148.3	1.6	0.6
F. Largidae (A)	10.7	7.2	37.3	0.7	3.5
(N)	111.2	270.5	79.0	2.4	0.7
F. Miridae (A)	76.5	48.8	11.7	0.6	0.2
(N)	57.3	29.3	1.2	0.5	<0.2
F. Pentatomidae (A)	0	0.2	0.7	-	-
(N)	0.3	3.5	0.3	11.7	1.0
F. Pyrrhocoridae (A)	1.7	0.8	8.7	0.5	5.1
(N)	0	0.5	4.3	-	-
F. Reduviidae (A)	0.3	0.8	0.3	2.7	1.0
F. Saldidae (A)	0.3	0	1.3	-	4.3
HOMOPTERA (TOTAL)	239.0	279.0	339.7	1.2	1.4
F. Aphididae (A)	81.3	19.3	83.3	0.2	1.0
(N)	1.2	0	0	-	-
F. Cicadellidae (A)	96.7	207.5	278.0	2.1	1.8
(N)	50.2	34.5	63.7	0.7	1.3
F. Cercopidae (A)	4.2	11.5	2.0	2.7	0.5
(N)	0.7	0.2	0	0.3	-
F. Delphacidae (A)	2.8	4.5	4.7	1.6	1.9
(N)	1.5	0.8	3.7	0.5	2.5
F. Membracidae (A)	0	0	3.3	-	-
F. Psyllidae (A)	0.5	0.7	1.0	1.4	2.0
HYMENOPTERA	28.5	22.3	16.3	0.8	0.6
LEPIDOPTERA (A)	3.3	3.3	1.3	1.0	0.4
(C)	1.3	3.7	3.7	2.9	2.9
ODONATA	3.7	4.2	2.0	1.1	0.5
ORTHOPTERA	0.2	0.2	0.3	1.0	1.5
PSOCOPTERA	25.3	199.0	10.0	7.9	0.4
THYSANOPTERA	4.2	2.7	3.3	0.6	0.8
TRICHOPTERA	0.7	0.2	0.7	0.7	1.0

\+ - See Table 1 for meaning

A,C,L,N - See Appendix IV for meaning

APPENDIX VII CHANGES OF AQUATIC ARTHROPOD NUMBERS IN CONTROL POND AND IN POND TREATED WITH ALTOSID

Arthropoda	Numbers Collected(x/100 sweeps/day) Pre-Spray	Post-Spray I	Post-Spray II	Change I+	Change II+
Control Pond					
ARANEIDA	2.0	3.5	1.0	1.8	0.5
COLEOPTERA	3.0	4.5	13.0	1.5	4.3
DIPTERA	7.5	6.0	51.0	0.8	6.8
EPHEMEROPTERA	5.0	3.0	61.0	0.6	12.2
GASTROPODA	36.5	9.0	13.0	0.3	0.4
HEMIPTERA	5.0	6.0	11.0	1.2	2.2
HIRUDINEA	0	0.5	0	-	-
HYMENOPTERA	0.5	1.5	1.0	1.0	2.0
LEPIDOPTERA	0	1.5	0	-	-
ODONATA	7.0	4.5	74.0	0.6	10.6
PELECYPODA	0	2.0	2.0	-	-
PLECOPTERA	0	0	1.0	-	-
TRICHOPTERA	31.0	25.0	23.0	0.8	0.7
TOTAL	98.0	67.0	251.0	0.7	2.6
Treated Pond					
ARANEIDA	1.0	2.0	0	2.0	-
COLEOPTERA	7.0	3.5	2.0	0.5	0.3
DIPTERA	19.5	10.0	1.0	0.5	0.1
EPHEMEROPTERA	1.5	1.0	0	0.7	-
GASTROPODA	0	1.0	0	-	-
HEMIPTERA	33.0	31.5	23.0	1.0	0.7
HIRUDINEA	0.5	0.5	3.0	1.0	6.0
HYMENOPTERA	0	0.5	1.0	-	-
LEPIDOPTERA	0	0.5	1.0	-	-
ODONATA	13.0	11.5	29.0	0.9	2.2
PELECYPODA	1.0	0.5	4.0	0.5	4.0
PLECOPTERA	1.0	0	0	-	-
TRICHOPTERA	13.0	3.5	3.0	0.3	0.2
TOTAL	90.5	66.0	67.0	0.7	0.7

\+ - See Table 1 for meaning

APPENDIX VIII CHANGES OF DRIFT INVERTEBRATES IN LITTLE FISH CREEK - 24 HR DRIFT

Invertebrates	Number Collected(x/day)		
	Pre-spray *	Post-spray *	Change +
Control Station			
Baetidae (EX)	334.7	1097.3	3.3
(L)	280.0	104.0	0.4
Ceratopogonidae (L)	21.3	36.0	1.7
Daphinidae (L)	64.0	60.0	0.9
Heptageniidae (EX	9.3	8.0	0.9
Limnephilidae (L)	1.2	1.7	1.4
Perloididae (EX)	5.3	5.3	1.0
Psychomyiidae (EX)	12.0	17.3	1.4
(L)	10.7	2.7	0.3
Simulidae (EX)	25.3	26[illegible].7	10.4
(L)	28.0	22.7	0.8
Terdipedidae (EX)	482.7	609.3	1.3
(L)	146.7	166.7	1.1
TOTAL * (EX)	885.3	2022.7	2.3
(L)	584.2	424.3	0.7
Altosid Station			
Baetidae (EX)	704.0	802.7	1.1
(L)	68.0	57.3	0.8
Ceratopogonidae (L)	16.0	26.7	1.7
Heptageniidae (EX)	112.0	42.7	0.4
Pertidae (EX	4.8	4.6	1.0
Perloididae (EX)	13.3	17.3	1.3
Psychomyiidae (EX)	133.3	85.3	0.6
Simulidae (EX)	110.7	278.7	2.5
(L)	2.7	10.7	4.0
Tendipedidae (EX)	610.7	425.3	0.7
(L)	84.0	70.7	0.8
TOTAL * (EX)	1693.3	1681.3	1.0
(L)	203.3	172.3	0.9

*, + - See Table 1 for meaning
EX - Exuviae
L - Live

APPENDIX IX CHANGES OF BOTTOM INVERTEBRATES IN LITTLE FISH CREEK (CONTROL STATION SURBER SAMPLES)

Invertebrates	Number Collected*			Change I+	Change II+
	Pre-spray	Post-spray I	Post-spray II		
COLEOPTERA					
F. Amphizoidae	0	0.5	4.0	-	-
F. Dyhscidae	2.0	3.5	0	1.8	-
F. Elmidae	12.0	17.0	46.0	1.4	3.8
DIPTERA					
F. Ceratopogonidae	2.0	0.5	1.0	0.3	0.5
F. Dixidae	0	0.5	1.0	-	-
F. Empididae	6.5	3.0	1.0	0.5	0.2
F. Muscidae	3.5	1.0	1.0	0.3	0.3
F. Simulidae	52.0	104.0	233.0	2.0	4.5
F. Tendipedidae	230.5	187.0	156.0	0.8	0.7
EPHEMEROPTERA					
F. Baetidae	199.0	277.5	179.0	1.4	0.9
F. Heptageniidae	39.0	47.5	33	2.1	0.9
LEPIDOPTERA					
F. Pyralidae	4.0	3.0	1.0	0.8	0.3
PELECYPODA					
F. Sphaeriidae	0.5	1.0	2.0	2.0	4.0
PLECOPTERA					
F. Chloroperlidae	3.0	6.5	11.0	2.2	3.7
F. Perloididae	0	0	12.0	-	-
F. Perlidae	0	1.5	1.0	-	-
TRICHOPTERA					
F. Hydropsychidae	20.5	15.0	7	0.7	0.3
F. Leptoceridae	6.5	3.0	2	0.5	0.3
F. Limnephilidae	0	2.5	0	-	-
F. Psychomyiidae	15	26.5	61	1.8	4.1
F. Rhyacophilidae	3	8.5	10	2.8	3.3

\+ - See Table 1 for meaning

* - Number of invertebrates per m^2 per day

APPENDIX X CHANGES OF BOTTOM INVERTEBRATES IN LITTLE FISH CREEK (ALTOSID STATION SURBER SAMPLES)

Invertebrates	Number Collected*			Change I+	Change II+
	Pre-spray	Post-Spray I	Post-spray II		
COLEOPTERA					
F. Amphizoidae	0.5	4.0	7	8.0	14.0
F. Dytiscidae	0	0.5	1	-	-
F. Elmidae	33.5	29	25	0.9	0.8
DIPTERA					
F. Ceratopogonidae	10.0	157.0	42	15.7	4.2
F. Dixidae	0	0	1	-	-
F. Empididae	7.0	25.5	4	3.6	0.6
F. Muscidae	2.5	4.0	1	1.6	0.4
F. Simulidae	35.0	27.0	435	0.8	12.4
F. Tendipedidae	243.0	317.5	298	1.3	1.2
F. Tipulidae	0.5	0	3.0	-	6.0
EPHEMEROPTERA					
F. Baetidae	202.5	216.5	367.0	1.1	1.8
F. Heptageniidae	64.5	16.0	31.0	0.3	0.5
GASTROPODA					
F. Valvatidae	0.5	0.5	1.0	1.0	2.0
LEPIDOPTERA					
F. Pyralidae	1.0	1.0	1.0	1.0	1.0
PELECYPODA					
F. Sphaeriidae	0.5	0.5	0	1.0	-
PLECOPTERA					
F. Chloroperlidae	12.0	8.5	24	0.7	2.0
F. Perlidae	2.0	3.5	12	1.8	6.0
F. Perloididae	13.0	7.5	39	0.6	3.0
TRICHOPTERA					
F. Hydroptilidae	3.5	3.5	5	1.0	1.4
F. Hydropsychidae	11.5	4.5	26	0.4	2.3
F. Leptoceridae	0.5	8.5	8	17.0	16.0
F. Limnephilidae	1.5	0.5	1	0.3	0.7
F. Psychomyiidae	34.0	25.0	150	0.7	4.4
F. Rhyacophilidae	4.0	8.0	27	2.0	6.8

\+ - See Table 1 for meaning

* - Number of invertebrates per m^2 per day

APPENDIX XI DIVERSITY AND EVENNESS VALUES OF AQUATIC AND SEMI-AQUATIC INVERTEBRATES OF CREEK AND POND STATIONS

STATIONS	SAMPLING METHOD	SAMPLE SIZE/DAY	DIVERSITY INDEX (Mean ± S.E.)[a]			EVENNESS (Mean ± S.E.)[a]		
			PRE-SPRAY	POST-SPRAY I	POST-SPRAY II	PRE-SPRAY	POST-SPRAY I	POST-SPRAY II
CONTROL POND	Emg.Cages*	5x0.2 m^2	1.806 ± 0.138	1.969 ± 0.057	1.300 ± 0.149	0.665 ± 0.030	0.671 ± 0.010	0.644 ± 0.054
	Aq. net+	50 sweeps	2.261 ± 0.061	2.830 ± 0.336	2.562 ± -	0.733 ± 0.008	0.818 ± 0.098	0.771 ± -
	Ter. net+	100 sweeps	1.490 ±0.130	1.700 ± 0.054	2.299 ± 0.084	0.477 ± 0.040	0.540 ± 0.032	0.698 ± 0.067
TREATED POND	Emg.Cages*	5x0.2 m^2	1.034 ± 0.136	0.729 ± 0.114	0.842 ± 0.205	0.422 ± 0.041	0.351 ± 0.047	0.399 ± 0.060
	Aq.net+	50 sweeps	2.066 ± 0.174	2.101 ± 0.521	2.119 ± -	0.711 ± 0.027	0.692 ± 0.031	0.669 ± -
	Ter. net+	100 sweeps	2.096 ± 0.081	2.98 ± 0.047	2.070 ± 0.122	0.631 ± 0.034	0.576 ± 0.015	0.582 ± 0.068
CONTROL CREEK	Emg.Cages*	2x0.2 m^2	1.519 ± 0.199	1.595 ± 0.133	1.317 ± 0.391	0.649 ± 0.073	0.681 ± 0.058	0.622 ± 0.089
	Drift net*	3x0.25hr(Ex)	1.563 ± 0.145	1.349 ± 0.088	-	0.522 ± 0.052	0.495 ± 0.032	-
		24-hr(Ex)	1.307 ± 0.123	1.560 ± 0.059	-	0.568 ± 0.032	0.620 ± 0.056	-
		(L)	2.257 ± 0.147	2.337 ± 0.170	-	0.728 ± 0.049	0.759 ± 0.020	-
	Surber*	5x0.2 m^2	1.972 ± 0.134	2.148 ± 0.124	2.243 ± 0.146	0.626 ± 0.035	0.618 ± 0.037	0.703 ± 0.028
ALTOSID-TREATED CREEK	Emg.Cages*	2x0.2 m^2	1.466 ± 0.161	1.667 ± 0.122	0.769 ± 0.154	0.719 ± 0.053	0.808 ± 0.053	0.620 ± 0.180
	Drift net*	3x0.25hr(Ex)	1.374 ± 0.108	1.445 ± 0.052	-	0.449 ± 0.033	0.471 ± 0.018	-
		24-hr(Ex)	1.930 ± 0.039	1.935 ± 0.069	-	0.683 ± 0.024	0.663 ± 0.019	-
		(L)	2.024 ± 0.143	1.993 ± 0.159	-	0.785 ± 0.038	0.819 ± 0.042	-
	Surber*	5x0.2 m^2	2.406 ± 0.166	2.066 ± 0.223	2.549 ± 0.156	0.728 ± 0.047	0.598 ± 0.064	0.674 ± 0.039

Ex - Exuviae, L - Live
* - Total number, Family level
\+ - Total number, Order level
a - Calculated from the daily D.I. of each period of study

APPENDIX XII COMPARISON OF EMERGENCE CHANGES OF SELECTED INSECTA IN CONTROL AND ALTOSID POND

Insecta	Change I*		C/A Ratio
	Control Pond (C)	Altosid Pond (A)	
Ceratopogonidae	1.6	0.2	8.0
Chaoboridae	0.08	0.03	2.7
Ichneumonidae	0.9	0.4	2.3
Muscidae	3.2	0.9	3.6
Pyralidae	8.7	0.3	29.0

* See Table 1.

APPENDIX XIII NYMPH/ADULT RATIO OF HEMIMETABOLOUS INSECTS

Insecta	Nymph/adult Ratio		
	Pre-spray	Post-spray I	Post-spray II
CONTROL POND			
Hemiptera			
F. Largidae	23.6	10.8	0.5
F. Miridae	3.7	1.5	0.9
F. Pentatomidae	5.6	1.4	0
Homoptera			
F. Aphididae	0.8	0.3	0
F. Cicadellidae	0.7	0.7	0.6
F. Delphacidae	0.8	2.3	14.3
ALTOSID POND			
Hemiptera			
F. Largidae	10.4	37.6	2.1
F. Miridae	0.8	0.6	0.1
F. Pentatomidae	0	17.5	0.4
Homoptera			
F. Aphididae	0.1	0	0
F. Cicadellidae	0.5	0.2	0.4
F. Delphacidae	0.5	0.2	0.8