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Impacts of Chlorophenoxy Herbicides on a Coastal Forest Environment of British Columbia

Surveillance Report
EPS 5-PR-75-4

Pacific Region

IMPACTS
of
CHLOROPHENOXY HERBICIDES
on a
COASTAL FOREST ENVIRONMENT
of
BRITISH COLUMBIA

by

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ABSTRACT

The 1973-1974 studies demonstrated that amine and ester formulations of 2,4-D and 2,4,5-T were equally effective for roadside alder control. The minimum amount of effective chemical for summer foliar treatment was 1-2 lbs. active material per acre. Two to four weeks were required for the chlorophenoxy compounds to produce their toxic effects on alder. Leaf mortality was used for assessing alder kill.

Small quantities of chlorophenoxy residues were found in the air at a distance of 20 feet from the point of application. Although 99 per cent of the residues in the forest litter disappeared within one week following application, residues in the treated vegetation were detected after leaf excision for more than 50 weeks after treatment. There was indication that some of these residues were released to the soil. Only trace amounts of chlorophenoxy residues were detected in the ditch water 1-2 hours after spray application.

A significant reduction in population of non-target terrestrial arthropods was observed in treated plots of foliar treatment soon after spray application. No decrease in number of birds near the experimental plots was noted after herbicide application.

Chlorophenoxy amines were less toxic to fish than the ester formulations. Large amine molecules appeared to be more toxic to coho fingerlings than small molecules.

RÉSUMÉ

Les études menées en 1973-1974 ont démontré que les formules de 2,4-D et de 2,4,5-T qui contiennent des amines, et celles qui contiennent des esters, détruisent avec la même efficacité les aunes qui poussent le long des routes. Pour empêcher la croissance de ces plantes pendant l'été, il a fallu les arroser de ces produits chimiques actifs au taux minimal d'une à deux (1-2) livres l'acre. Il a fallu attendre de deux à quatre semaines avant que les composés de chlorophénoxie ne produisent leurs effets toxiques sur les aunes. On a jugé que les aunes étaient détruites lorsque leurs feuilles mouraient.

On a trouvé une faible quantité de chlorophénoxie dans l'air à une distance de 20 pieds de l'endroit où on l'avait appliqué. Bien qu'il ne restait plus qu'un pour-cent des résidus chimiques dans les détritus de bois une semain après l'application des herbicides, on pouvait encore en trouver des traces dans les plantes traitées, après l'excision des feuilles, au-delà de 50 semaines plus tard. Certains indices ont permis de croire que ces résidus se sont introduits dans le sol. Une ou deux heures après l'application des produits chimiques, on a trouvé une quantité infime de chlorophénoxie dans l'eau des fossés.

Peu après l'application des herbicides, on a remarqué une réduction importante dans la quantité d'arthropodes terrestres non visés par l'application des produits chimiques dans les endroits traités. Après l'application des herbicides, le nombre des oiseaux n'a semble-t-il pas baissé près des terrains qui ont fait l'objet de ces expériences.

Les formules de chlorophénoxie qui contenaient des amines ont eu moins d'effets toxiques sur les poissons que celles qui contenaient des esters. Les grandes molécules d'amine ont semblé plus toxiques aux saumoneaux coho que les petites.

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CONCLUSIONS

The following conclusions were drawn from the results of three experiments, and may be applicable to similar alder control programmes:

I. Amine and ester formulations of chlorophenoxy herbicides are equally effective for alder control along rights-of-way. However, the amine formulations should be used in areas where fish-sensitive water bodies are involved.

II. The minimum effective amount of chemical is 1-2 lbs. active ingredient per acre of 2,4-D; 2,4,5-T or 2,4-D + 2,4,5-T formulations, i.e., equivalent to 0.20-0.40 gal. (80 oz./gal. a.i.) in 16 gallons of water per acre; delivery rate of sprayer to be set at 1/2 pint/minute.

The amount of active ingredient of cholorophenoxy compound required to achieve adequate control depends to a large extent on the age of the alder. Generally alder between the height of 3 to 6 feet can be adequately controlled by using 1.5 lb. a.i./A, i.e., equivalent to 0.30 gal. of (80 oz./gal. active ingredient in 17 gal. of water per acre), while those between the height of 6 to 12 feet require 2.5 lb. a.i./A. i.e., equivalent to 0.50 gal. of 80 oz./gal. active ingredient in 16 gal. water per acre.

III. Leaf mortality in alder is a good indicator of tree mortality.

IV. Chlorophenoxy drifts from a truck-mounted mist blower are minimal at distances greater than 20 feet under calm morning conditions. A buffer strip of 25-30 feet should be adequate to prevent the contamination of water bodies.

V. Chlorophenoxy residues persist in the soil and alder litter for more than 1 year; the amount of residues in the litter is twice that found in the soil.

More studies should be conducted to investigate the environmental impact of chlorophenoxy compounds from excised alder leaves and their subsequent release to the soil because substantial quantities of both 2,4-D and 2,4,5-T are found in the substrate of forest floor one year following herbicide treatment.

Only trace amounts of chlorophenoxy residues appear in the water of ditches 1-2 hours after spray application.

VI. Amines of 2,4-D and 2,4-D + 2,4,5-T are approximately 1/5 as toxic to coho fingerlings than their ester counterparts. However, large, long C-chained chlorophenoxy amines are 10-15 times more toxic to coho fingerlings than small, short C-chained amines. The toxicity to fish and fish food organisms of different formulation of chlorophenoxy chemicals, particularly in relation to short and long C-chained molecules of amine and ester compounds, should be further investigated.

VII. Chlorophenoxy sprays, irrespective of doses or formulations, reduce approximately 50 per cent of the non-target terrestrial arthropod population in the spray plots shortly after treatment.

VIII. Late summer foliar treatment of roadside alder (i.e., end of August) is generally preferred in order to prevent the disruption of the breeding habitat of birds and wildlife during early summer.

1. INTRODUCTION

The use of chlorophenoxy herbicides for brush control has been the subject of much recent discussion. The main concern is their possible deleterious interactions with life processes. Several reports have been published on the teratological potential of some of these materials. As a result, there are increasing concerns over their possible effects on non-target aquatic and terrestrial organisms, including man.

In British Columbia, chlorophenoxy herbicides are employed to control undesirable vegetation in agriculture, forestry, manufacturing industries and along rights-of-way. No decrease in their use in the foreseeable future is envisioned unless there is a dramatic development of alternative and cheaper methods, or detrimental effects on non-target organisms are demonstrated and further restrictions imposed.

In 1973 the Environmental Protection Service with the cooperation of British Columbia Forest Products Limited initiated a two-year study to monitor the environmental impacts associated with the application of 2,4-D and 2,4,5-T to forest lands along rights-of-way. The principle objective of the study was to obtain field data relating to (1) the effectiveness of chlorophenoxy formulations at minimum rates of application during different seasons of the year, (2) drift problems, (3) residues and their persistence in the environment, and (4) impacts on non-target organisms such as birds, fish, terrestrial arthropods, and wildlife. The parameters listed above are important considerations for the development of sound guidelines. The monitoring results of three field applications of selected chlorophenoxy compounds are presented and discussed in this report.

2. REVIEW OF ENVIRONMENTAL IMPACTS OF CHLOROPHENOXY HERBICIDES

Chlorophenoxy compounds were first discovered by Zimmerman and Hitchcock in 1942 and their subsequent use as herbicides in 1944 began the modern era of selective chemical weed control. They are hormone-type chemicals, which must be absorbed and translocated in plant tissue to be effective. They are selective materials employed for the control of woody broadleaved weeds, especially perennials. Chlorophenoxy chemicals display optimum dosage responses; below this optimum dosage provides too little toxicant to be effective, too much provides excessive contact injury to the foliage, resulting in little translocation (Ashton and Crafts, 1973).

Little work has been carried out to investigate the significance of impacts on the environment of different formulations of chlorophenoxy compounds used in brush control. The concern is the direct and indirect contamination via drift and adverse effects on non-target organisms. The toxicity to fish depends on the formulation of the herbicide. Generally ester formulations are about 30-40 times more toxic to fish and some aquatic invertebrates than amine formulation, (Pimentel, 1971). When properly used, chlorophenoxy chemicals are reported to be relatively non-toxic to birds and mammals (Rowe and Humas, 1954; Johnson, 1971; Laning Jr., 1973).

Residues of chlorophenoxy compounds in the environment resulting from different methods of application is another area of concern. The amount of residues in the air, soil and water depends to a large extent on the chemical formulation, method and timing of application, and on physical and environmental factors (Norris et al, 1972). Recent studies demonstrated that the drift potential from ester formulations of chlorophenoxy was about 3-10 times greater than from amine formulation under similar conditions of test (Grover et al, 1972). Residues of 2,4-D and 2,4,5-T from an aerial application of 50/50 iso-octyl ester mixture were detected at distances greater than 500 feet outside spray plots with the greatest amounts occurring within 180 feet of the plot (Wilson and Wan, 1975, manuscript in preparation).

All available information indicates that some chlorophenoxy herbicides may enter streams flowing through or adjacent to areas being sprayed. The level detected in the streams, however, was very low. In 6 years of monitoring spray operations in Western Oregon, scientists have never found chlorophenoxy residues exceeding 0.1 ppm in streams (Norris et al, 1970, and Norris, 1971).

Chlorophenoxy compounds have been reported to degrade rapidly in water (Pimentel, 1971). Little or no work has been conducted to compare the rate of degradation in water of amine and ester formulation of these chemicals. Simple amines are much more soluble in water than long C-chained amines or esters. They would probably disappear more rapidly in water because of greater solubility than long C-chained amines or ester compounds under field conditions.

The forest floor is a major recipient of herbicides, whether applied from aircraft or by ground spray systems. Rapid degradation of chlorophenoxy compounds by micro-organisms in soil has been shown in several studies (Norris, 1967, 1970, 1971). Generally these studies demonstrated that 85-90% of 2,4-D would be degraded in about two weeks, but 2,4,5-T is more persistent. In one study, 2,4,5-T has been shown to persist in moist soil for more than 6 months (DeRose and Newman, 1948).

Chlorophenoxy chemicals may be used in the management of wildlife habitat for pruning off undesirable plant species (Gysel, 1967; Barrows, 1969; Bramble and Byrnes, 1972; Laning Jr., 1973).

3. MATERIALS AND METHODS

3.1 Experimental Location

The study area was located in the southwest corner of Vancouver Island near Caycuse, British Columbia. The experimental plots were located at Mile 5 and 27 from Caycuse on Nixon Creek and Nitinat River, respectively (Figure 1).

3.2 Experimental Layout and Application Method

Three seasonal sprays were conducted and their respective dates are as follows:

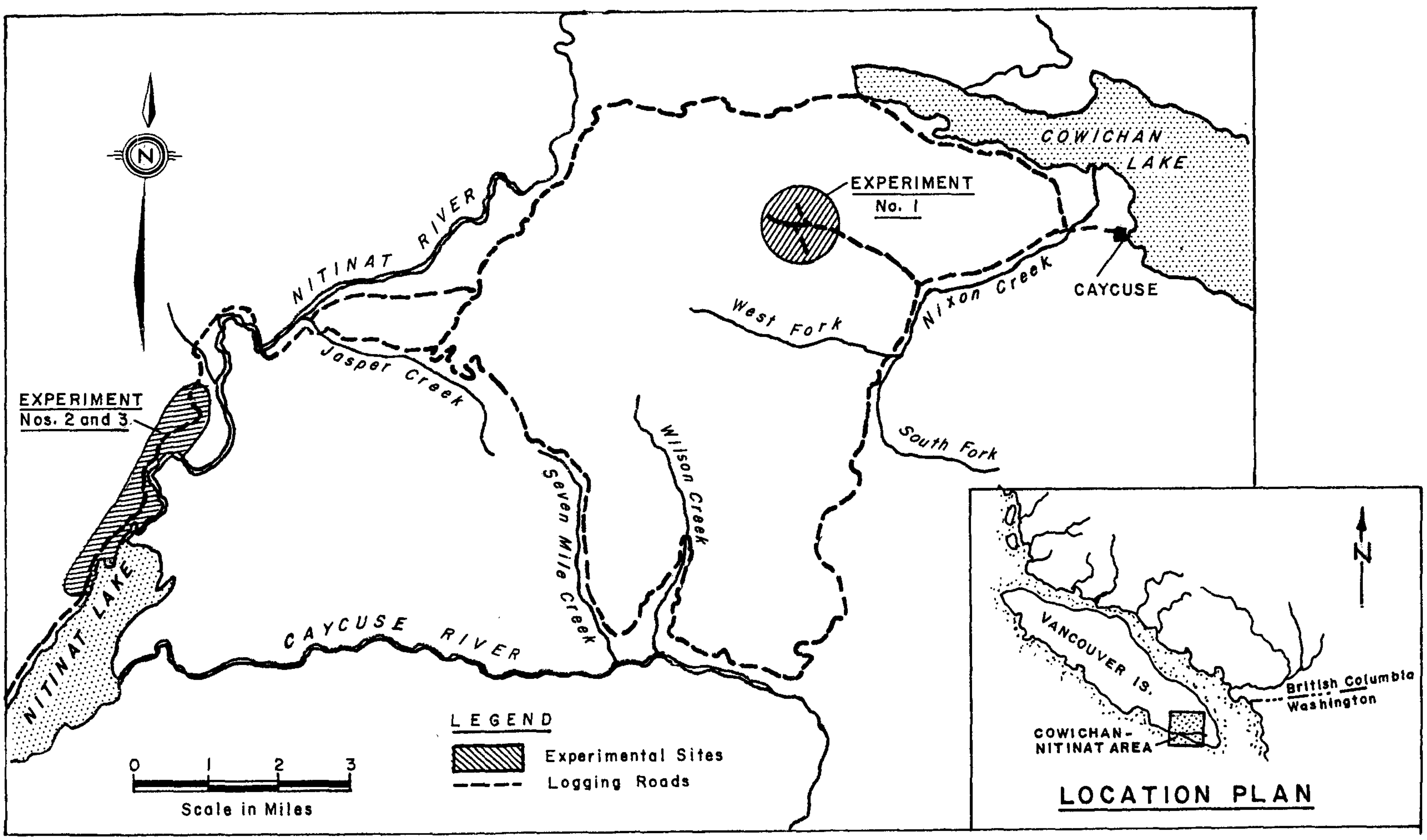


FIGURE 1 LOCATION OF EXPERIMENTAL PLOTS

(1) A late summer spray - August, 1973;
(2) A dormant spray - April, 1974; and
(3) An early summer spray - June, 1974.

Figures 2 and 3 illustrate the plot layout of the 3 experiments. All experiments were randomized. Experiment (1) had 4 treatments, each at 5 concentrations, i.e., at 0, 0.5, 1.0, 2.0, and 4.0 lbs. active ingredient per acre. Experiments (2) and (3) carried 6 treatments each, both also at 5 concentrations including one control. All experiments were replicated twice. Plots No. 1-40 designated Experiment (1); No. 41-100, Experiment (2); and No. 101-160, Experiment No. (3).

A single application was made in each experiment. The herbicide was applied from a truck-mounted mist blower (modified Fontan, Type R5A), using water as a diluent (Figure 4).

3.3 Chlorophenoxy Herbicide Formulations

The following formulations were employed for the 3 experiments:

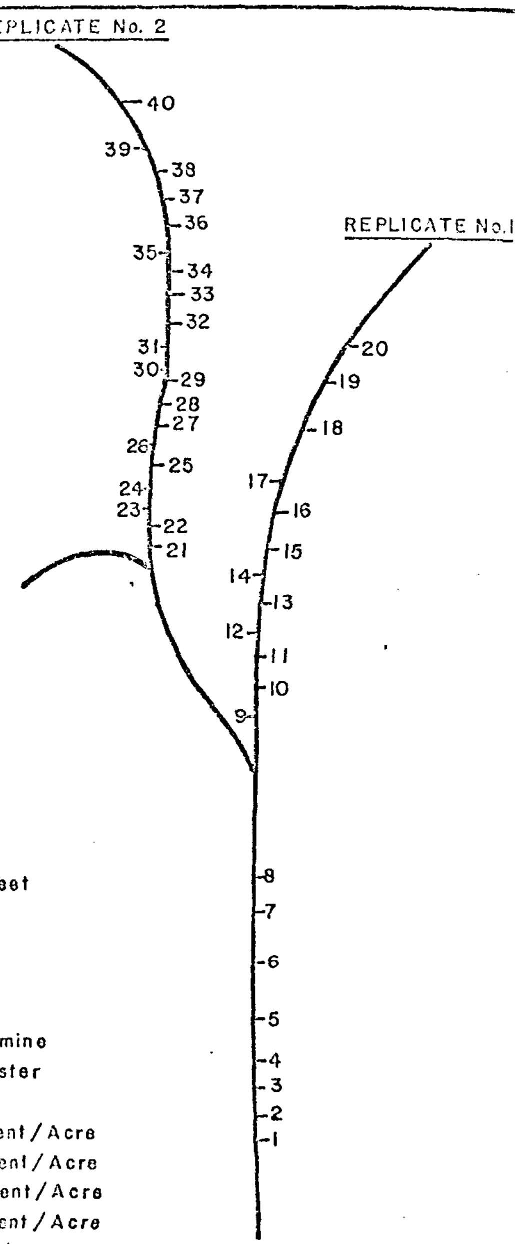
Experiment (1)

1. 2,4-D amine (Estemine 2,4-D = 80 oz. 2,4-D acid per Imp. Gal. formulated as a mixed dimethylamine/diethanolamine salt);
2. 2,4-D ester (2,4-D Ester 80 = Weed Killer = 80 oz. 2,4-D iso-octyl ester per Imp. gal.);
3. (2,4-D + 2,4,5-T) amine (Estemine Brush Killer = 40 oz. 2,4-D acid + 40 oz. 2,4,5-T acid per Imp. gal. formulated as a mixed monoethanolamine, diethanolamine, dimethylamine, and diethylamine salt);
4. (2,4-D + 2,4,5-T) ester (Guardsman Brush Killer = 32 oz. 2,4-D iso-octyl ester and 32 oz. 2,4,5-T iso-octyl ester mixed per Imp. gal.).

Experiments (2) and (3)

1. 2,4-D amine (Dacamine 4D = 76.8 oz. N-Oleyl-1, 3-propylene diamine salt of 2,4-D acid per Imp. gal.);

PLOT No.	TREATMENT
1	A_4
2	E_3
3	E'_0 *
4	E_2
5	E'_3
6	A'_2
7	E'_3
8	E_4
9	E'_1
10	A_3
11	E'_2 *
12	E_1
13	A_1
14	A'_1
15	A'_0
16	A'_4
17	A_2 *
18	A'_0
19	E_0
20	E'_4
21	E_4
22	A'_3
23	A'_4
24	A_4
25	A_3
26	E_3
27	E_0
28	E'_2
29	A'_0
30	E'_1
31	E'_3
32	A'_1
33	E_2 *
34	E'_4
35	E_1
36	A_0
37	E'_0
38	A_2
39	A_1
40	A'_2 *



Scale: 1" = 50 - 100 Feet

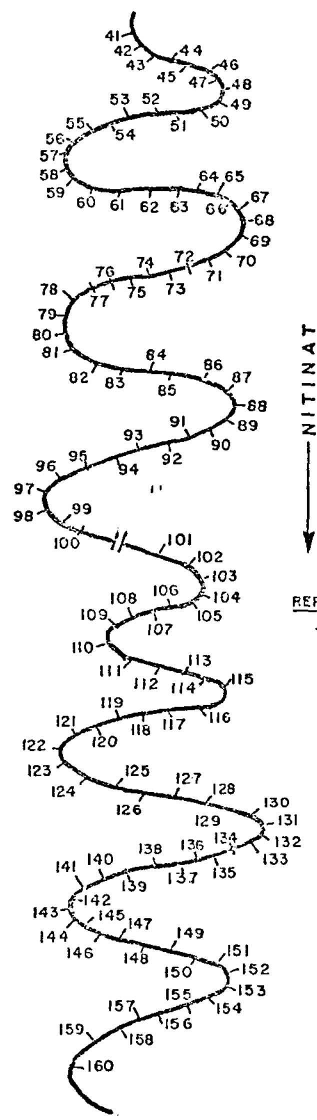
LEGEND

A = 2,4 - D Amine
E = 2,4 - D Ester
A' = (2,4 - D + 2,4,5 - T) Amine
E' = (2,4 - D + 2,4,5 - T) Ester
0 - Control
1 - 0.5 lb. Active Ingredient / Acre
2 - 1.0 lb. Active Ingredient / Acre
3 - 2.0 lb. Active Ingredient / Acre
4 - 4.0 lb. Active Ingredient / Acre
* Location of Petri Dishes

FIGURE 2. PLOT LAYOUT OF EXPERIMENT NO. 1 (NIXON CREEK)

EXPERIMENT No. 2

PLOT No.	TREATMENT	
41	E_1	REPLICATE No. 1
42	E'_0 *	
43	E'_4	
44	E'_0	
45	E_2 *	
46	E_3	
47	A_4	
48	T_0	
49	T'_1	
50	A'_2 *	
51	A_0	
52	T_1	
53	T'_3	
54	A'_1	
55	E_4	
56	A_3	
57	T'_2 *	
58	T'_0	
59	T_4	
60	A'_3	
61	T'_4	
62	E'_2 *	
63	E'_1	
64	T_2 *	
65	A_2 *	
66	T_3	
67	E'_3	
68	A_1	
69	E_0	
70	A'_4	
71	E_2	REPLICATE No. 2
72	T_0	
73	T'_1	
74	E'_2	
75	A_2	
76	E_1	
77	A'_0	
78	A'_2	
79	T_4	
80	A_0	
81	T'_2	
82	A_3	
83	A'_1	
84	E_3	
85	T'_3	
86	E_4	
87	T_2	
88	E'_0	
89	E'_1	
90	T'_0	
91	A_1	
92	T'_4	
93	E_4	
94	A_4	
95	E'_3	
96	A'_3	
97	T_1	
98	T_3	
99	E_0	
100	A'_4	



LEGEND

T = 2,4,5 - T Amine

T' = 2,4,5 - T Ester

A, A', E, E' - See Figure 2

* Locations of Petri Dishes

Scale: 1" = 100 - 200 Feet

EXPERIMENT No. 3

	PLOT No.	TREATMENT
REPLICATE No. 1	101	E'_1
	102	A'_4
	103	E_0
	104	E_4
	105	A'_2
	106	A_0
	107	T_1
	108	E'_3 *
	109	T_3 *
	110	A_4
	111	T'_3 *
	112	T_0
	113	A'_1
	114	T'_2
	115	E_2
	116	E'_4
	117	T_4
	118	A'_0 *
	119	E'_2
	120	E_1
	121	T'_0
	122	T_2
	123	A_1
	124	A'_3 *
	125	T_1
	126	T'_4
	127	E'_0
	128	E_3 *
	129	A_2
	130	A_3 *
REPLICATE No. 2	131	E_2
	132	T_1
	133	A'_4
	134	E'_3
	135	A'_0
	136	A'_1
	137	A'_3
	138	A'_4
	139	T'_0
	140	E_4
	141	A_4
	142	E_0
	143	E_3
	144	E'_1
	145	A_0
	146	T_4
	147	A_3
	148	T_3
	149	A_2
	150	T'_3
	151	E'_2
	152	A_1
	153	T'_2
	154	T'_1
	155	E_1
	156	T'_4
	157	A'_2
	158	E'_0
	159	T_2
	160	T_0

FIGURE 3 PLOT LAYOUT OF EXPERIMENTS No. 2 AND No. 3 (NITINAT)

2. 2,4-D ester (as in 2 of Experiment (1));
3. (2,4-D + 2,4,5-T) amine (Dacamine 2D/2T - 76.8 oz. of 50/50 mixture of N-Oleyl-1, 3-propylene diamine salt of 2,4-D and 2,4,5-T per Imp. gal.);
4. (2,4-D + 2,4,5-T) ester (as in 4 of Experiment (1));
5. 2,4,5-T amine (Dacamine 4T = 76.8 oz. of N-Oleyl-1-3-propylenediamine salt of 2,4,5-T of acid per Imp. gal.);
6. 2,4,5-T ester (130.7 oz. of 2,4,5-T iso-octyl ester per Imp. gal.).

Visual grading of leaf mortality was used to assess the reponse of alder to the different formulations of chlorophenoxy herbicides. (0 = no leaf mortality, 9 = complete destruction of entire plot.)

3.4 Residue Sampling

3.4.1 Drift Residues. Pyrex petri dishes (150 x 20 mm) were used for monitoring drift of different formulations of 2,4-D and 2,4,5-T. All dishes were rinsed with redistilled acetone and petroleum ether, and heated to 300°C for about 16 hours before use. They were laid out on pedestals at pre-determined distances of 0', 5', 10' etc., from each plot before spraying. The dishes in Experiment No. 1 were collected 3 hours after spray application, while those in Experiment No. 2 and 3 were collected 0.25 hours after spraying. All samples were immediately stored in dry ice and submitted to the Inland Water Directorate, Water Quality Laboratory and British Columbia Department of Agriculture Pesticide Residue Laboratory for the analysis of chlorophenoxy residues. The esters were extracted with redistilled benzene, and the amines with redistilled benzene plus 10% sulphuric acid. The clean-up extracts were injected to a gas liquid chromatograph (Model Micro-TEK 220).

Plots treated with 1 lb./Acre active ingredient (Experiment No. 1 and 2) and 2 lbs./Acre active ingredient (Experiment No. 3) were monitored to observe drift variations of different concentrations.

3.4.2 Soil/Litter Residues. Combined soil and alder litter samples were obtained at each sampling time from a 1' x 1' subplot in the plots treated at 4 lbs. per acre. All the vegetative trash was first collected and the top 2.5 inches of soil was then sampled by using a 1.25 inch diameter auger. Three cores of soil were taken at each sampling time, using separate augers for sampling different chlorophenoxy formulations. All samples collected were immediately stored in dry ice prior to residue analyses.

3.4.3 Water Residues. Water samples were taken at 4 locations in streams adjacent to treatment plots as illustrated in Figures 5 and 6. Samples were collected in 16 fluid oz. amber bottles at different time-intervals and quick frozen to -20°F. with dry ice. All bottles were rinsed with redistilled acetone and petroleum ether and heated to 300°C. for 12 hours prior to use.

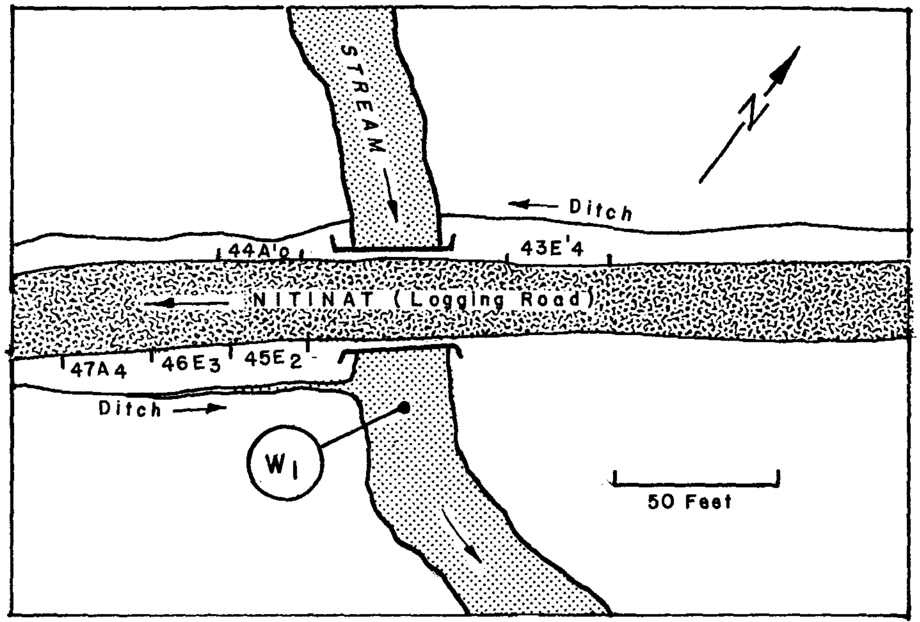
3.5 Biological Sampling

Arthropod samples from control and treated plots were collected by net sweeping. Thirty net sweeps per plot were made during each sampling time. Pre-spray samples were collected one week before spray application and post-spray samples between 20 and 30 hours after herbicide treatment. All samples collected were preserved in 50 per cent alcohol and stored in labelled bottles. Sorting, identification, and enumeration was conducted at the Environment Canada Fresh Water Biology Laboratory in North Vancouver, B.C.

The numbers of birds (grouse, hawks, jays, robins, sparrows) and wildlife (bears, deer, squirrels) observed before and after spray in the three experiments were recorded. Counts were based on visual and audio observations.

3.6 Fish Toxicity Tests

Fish toxicity tests (96 hour LC_{50}) of each formulation of 2,4-D and 2,4,5-T were conducted at the Environment Canada Laboratory (Cypress Creek), West Vancouver, B.C. Ten coho salmon (Oncorhyncus kisutch) fingerlings (av. length, 3.8 cm.; av. weight, 0.5 gm.) were used as test species. Capilano Reservoir tap water (pH = 6.3-7.0; hardness 7.5 ppm $CaCO_3$; temperature 7.5± 1°C.) was used for dilution. All bioassays were performed under static, aerated conditions without replacement at a loading density of 0.50 gm/litre.



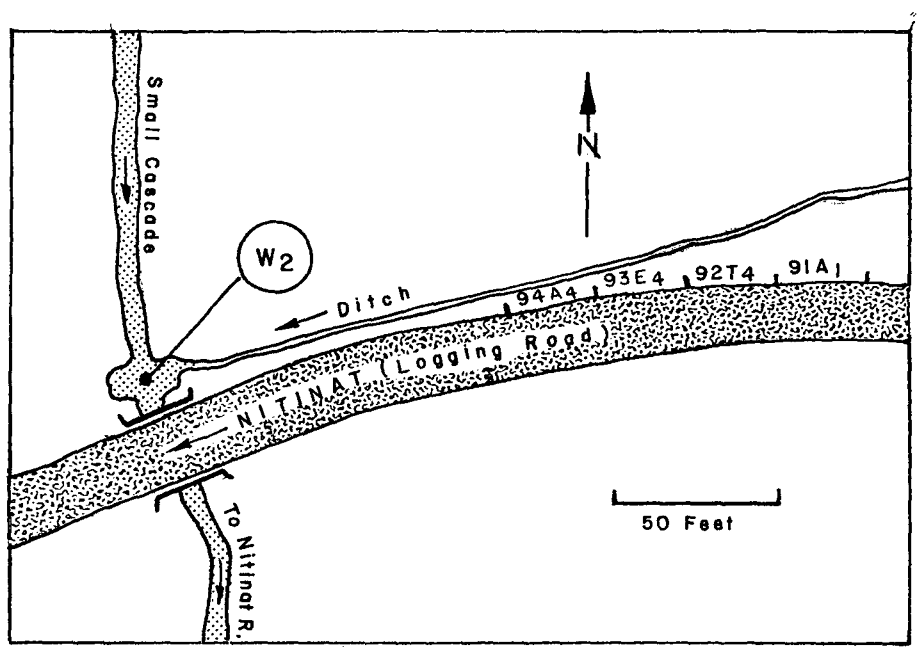
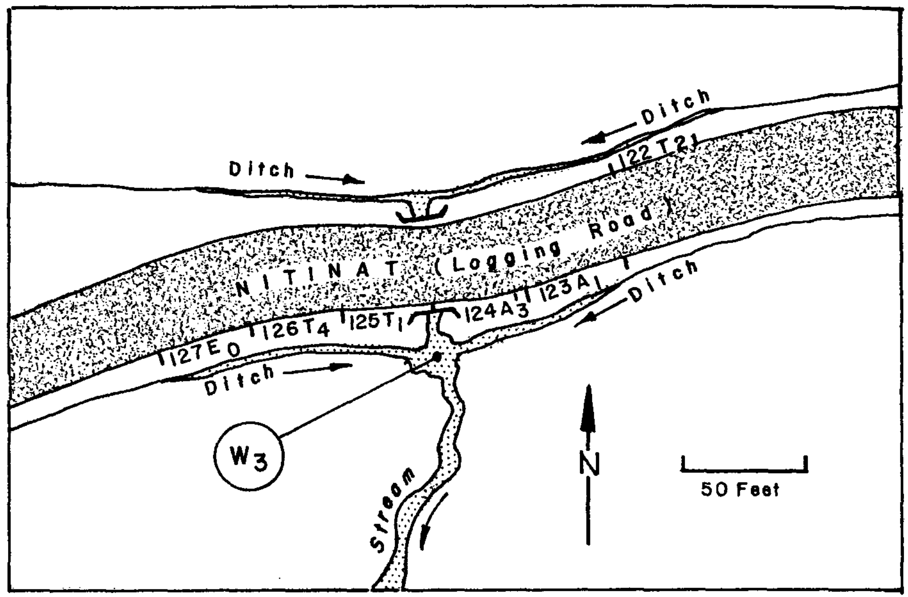


FIGURE 5 DIAGRAMMATIC SKETCH OF WATER STATIONS W_1 AND W_2 (See Figure 2 for meaning of Plot Numbers)



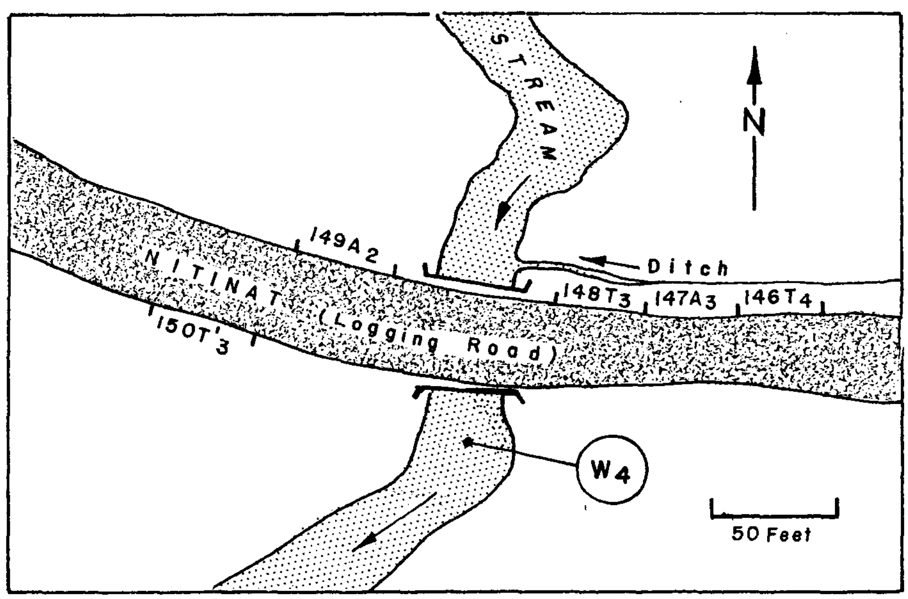


FIGURE 6 DIAGRAMMATIC SKETCH OF WATER STATIONS W_3 AND W_4 (See Figure 2 for meaning of Plot Numbers)

3.7 Sample and Data Analyses

The following analyses or variance were used to determine the responses of alder (visual grading of leaf mortality or stunt) with time to the various chlorophenoxy herbicide treatments:

1. 3-way anova, mean of 2 replications, 5 x 4 x 4 factorial design - Experiment No. 1;
2. 3-way anova, mean of 2 replications, 3 x 4 x 6 factorial design - Experiment No. 2;
3. 3-way anova, mean of 2 replications, 4 x 4 x 6 factorial design - Experiment No. 3.

A Hewlett-Packard computer was used to perform the calculations. A 3-way anova (2 x 6 x 5) factorial design was also made to compare the differences of means of non-target arthropod numbers collected before and after herbicide treatment in control and treated plots.

4. RESULTS

4.1 Effectiveness of Various Chlorophenoxy Formulations

Results of statistical analyses of variance of Experiment Number (1), (2), and (3) are presented in Appendices I, II, and III. Test conditions of the 3 experiments are listed in Appendix IV.

4.1.1 Alder Control of Late Summer Spray. The 3-way anova test (Appendix I) indicated that:

i. Concentrations of chlorophenoxy herbicides, formulation type, and the time interval post-application had great influence (P=0.01) on the mortality of the alder.

ii. No significant difference (P=0.01) was demonstrated in the effectiveness of amine versus ester formulations of chlorophenoxy compounds as alder control agents.

iii. Good control (P=0.01) was achieved 4 weeks after treatment with all chlorophenoxy formulations at 1-2 lbs. active material per acre (a.i./A.). Control at this rate persisted for at least 52 weeks.

iv. 2,4-D + 2,4,5-T amines and esters were more effective (P=0.10) as alder control agents than straight 2,4-D amines or ester formulations at 4 weeks post treatment. 2,4-D + 2,4,5-T esters were the most effective (P=0.10) alder control agents for at least 52 weeks.

4.1.2 <u>Alder Control of Dormant Spray</u>. The 3-way anova test (Appendix II) indicated that:

i. Concentrations of chlorophenoxy herbicides, formulation type, and the time interval post application had significant influence (P=0.01) on the degree of leaf stunt in alder.

ii. Differences (P=0.05) were demonstrated in the degree of stunt caused by amine and ester formulations of chlorophenoxy compounds.

iii. The greatest degree of leaf stunt was noted in plots treated with 4 lbs. a.i./A. and occurred between 2-4 weeks post treatment.

iv. Both the amines and esters of 2,4-D + 2,4,5-T mixtures caused significantly greater (P=0.05) leaf stunt than straight amines or esters of 2,4-D and 2,4,5,-T.

Dormant sprays with amine and ester formulations of chlorophenoxy compounds in water were not effective for alder control because complete tree recovery was noted 12-15 weeks post treatment.

4.1.3 <u>Alder Control of Early Summer Spray</u>. The 3-way anova test (Appendix III) indicated that:

i. Concentrations of chlorophenoxy herbicides, formulation type, and the time interval post application had significant (P=0.01) influence on the mortality of alder.

ii. No significant difference (P=0.01) in mortality of alder was observed between the use of straight amine and ester formulations of 2,4-D, 2,4,5-T, and 2,4-D + 2,4,5-T mixtures two weeks after herbicide treatment.

iii. Plots treated with 4 lbs. a.i./A. did not produce significantly greater (P=0.01) kill of alder than plots sprayed with 2 lbs. a.i./A. However, alder sprayed at 2 lbs. a.i./A. had significantly greater (P=0.01) mortality than alder treated at 1 lb. a.i./A. two weeks after chemical application. Control persisted for more than six months.

4.2 Chlorophenoxy Residues

4.2.1 Drift Residues. Tables 1, 2 and 3 present the results of analyses of chlorophenoxy residues collected on petri dish samples. In the three experiments, no substantial amounts of drift residue were found in the air at distances greater than 20 feet from the point of application.

4.2.2 Residues in Soil/Litter. Tables 4, 5 and 6 present the results of analyses of chlorophenoxy residues from forest litter and soil samples. Results obtained were variable and showed inconsistent trends. Generally high levels of 2,4-D and 2,4,5-T were found in the soil/forest litter 2-3 hours post herbicide application. In Experiment No. 1 (Table 4), minimal amounts of residue were detected after one week. However, substantial amounts of 2,4-D and 2,4,5-T residues were detected in samples of soil/forest litter collected one year post application. In Experiment No. 2 (Table 5), large amounts of chlorophenoxy residues were found in the forest soil samples 24 hours after treatment, but only small quantities were detected 1 week later. Results from Experiment No. 3 (Table 6) indicated substantial amounts of chlorophenoxy residues in the soil/forest litter during the first 2-3 hours after application. Small amounts of the herbicides were monitored three months post treatment.

4.2.3. Water Residues. No detectable amounts of 2,4-D and 2,4,5-T were found at Water Stations W1 and W2 from the dormant spray. Small but detectable quantities of chlorophenoxy compounds were found during the summer application at Water Stations W3 and W4. The highest concentration obtained was 2 ppb for 2,4-D and 1 ppb for 2,4,5-T, two hours after herbicide treatment.

TABLE 1 CHLOROPHENOXY DRIFT RESIDUES
(LATE SUMMER SPRAY - AUGUST, 1973)

Herbicide	Amount of residues in air (gm/M^2) at various distances from plots (1 lb. a.i./A.)				
	0'	10'	20'	40'	80'
Control	<0.06	<0.06	<0.06	N.D.	N.D.
2,4-D amine (Dimethylamine and Diethanolamine salt)	51.15	6.39	<0.06	<0.06	<0.06
2,4-D ester (Iso-Octyl ester)	2.18	<0.06	<0.06	<0.06	<0.06
(2,4-D + 2,4,5-T) amine (monoethanolamine, diathanolamine, dimethylamine, diethylamine salt)	71.86	3.76	0.21	<0.06	<0.06
(2,4-D + 2,4,5-T) ester (Iso-Octyl ester)	5.49	0.09	<0.06	<0.06	<0.06

N.D. - Not detected

Limit of Detection = 0.06 gm/M^2

TABLE 2 CHLOROPHENOXY DRIFT RESIDUES
(DORMANT SPRAY - APRIL, 1974)

Herbicide	Amount of residues in air (gm/M^2) at various distances from plots (1 lb a.i./A)			
	5'	10'	20'	40'
Control	N.D.	N.D.	N.D.	N.D.
2,4-D amine (N-Oleyl-1,3-propylene-diamine salt)	61.33	23.31	<0.01	N.D.
2,4-D ester (Iso-octyl ester)	14.26	10.75	N.D.	N.D.
2,4,5-T amine (N-Oleyl-1,3-propylene-diamine salt)	0.47	<0.01	<0.01	N.D.
2,4,5-T ester (Iso-octyl ester)	16.69	1.48	0.02	<0.01
(2,4-D + 2,4,5-T) amine (N-Oleyl-1,3-propylene-diamine salt) - Total	2.00	N.D.	N.D.	N.D.
(2,4-D + 2,4,5-T) ester (Iso-octyl ester) - Total	<0.01	N.D.	N.D.	N.D.

TABLE 3. CHLOROPHENOXY DRIFT RESIDUES
(EARLY SUMMER SPRAY - JUNE, 1974)

Herbicide	Amount of residues in air (gm/M^2) at various distances from plots (2 lb a.i./A)			
	5'	10'	20'	40'
Control	N.D.	N.D.	N.D.	N.D.
2,4-D amine (N-Oleyl-1,3-propylene diamine salt)	3.28	1.13	<0.01	N.D.
2,4-D ester (Iso-octyl ester)	5.83	0.69	N.D.	N.D.
2,4,5-T amine (N-Oleyl-1,3-propylene diamine salt)	12.73	N.D.	<0.01	*
2,4,5-T ester (Iso-octyl ester)	1.62	*	<0.01	<0.01
(2,4-D + 2,4,5-T) amine (N-Oleyl-1,3-propylene diamine salt) - Total	*	0.40	0.08	<0.01
(2,4-D + 2,4,5-T) ester (Iso-octyl ester) - Total	74.8	0.35	0.07	0.02

N.D. - Not detectable

* - Samples broken during transit

Limit of detection = <0.01 gm/M^2

TABLE 4 CHLOROPHENOXY RESIDUES IN THE SOIL AND FOREST LITTER (LATE SUMMER SPRAY - AUGUST,1973)

Formulation (4 lbs a.i./A)	Herbicide	Strata	pH (Mean)	Water Content (Mean %)	Residues of phenoxy compounds (ppm) at different sampling time (hours)				
					3	6	21	168	52 (Weeks)
Control	2,4-D	Soil	5.69	21.0	N.D.	0.085	N.D.	N.D.	N.D.
		Trash				0.035	0.275	----	N.D.
	2,4,5-T	Soil			N.D.	N.D.	N.D.	N.D.	N.D.
		Trash			1.715	0.005	0.075	N.D.	N.D.
2,4-D amine	2,4-D	Soil	5.54	23.4	0.025	0.005	0.025	N.D.	N.D.
		Litter			7.097	0.260	4.385	----	0.80
2,4-D ester	2,4-D	Soil	5.23	29.6	N.D.	0.080	1.170	0.160	0.85
		Litter			5.985	4.725	0.215	----	0.06
(2,4-D + 2,4,5-T) amine	2,4-D	Soil	5.18	21.0	0.140	N.D.	N.D.	0.090	0.09
		Litter			0.375	3.400	0.505	----	0.69
	2,4,5-T	Soil			N.D.	N.D.	N.D.	0.03	0.06
		Litter			0.420	2.800	7.450	----	----
(2,4-D + 2,4,5-T) ester	2,4-D	Soil	5.46	25.3	N.D.	0.200	0.040	N.D.	N.D.
		Litter			2.250	0.350	5.170	----	0.17
	2,4,5-T	Soil			N.D.	0.190	0.045	N.D.	0.04
		Litter			1.575	1.025	6.106	N.D.	0.14

TABLE 5 CHLOROPHENOXY RESIDUES IN THE SOIL AND FOREST LITTER (DORMANT SPRAY - APRIL, 1974)

Formulation (4 lbs a.i./A)	Herbicide	Strata	pH (Mean)	Water Content (Mean %)	Residues of chlorophenoxy compounds (ppm) at different sampling time (hours, days)							
					2 hr.	6	24	7 da.	14	28	56	112 (Rain)
Control	2,4-D 2,4,5-T	Soil & litter	5.52	24.34	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-D amine	2,4-D	Soil & litter	6.00	16.11	23.8	82.0	20.0	0.04	N.D.	N.D.	N.D.	N.D.
2,4-D ester	2,4-D	Soil & litter	5.73	10.48	3.85	1.70	0.79	0.09	N.D.	N.D.	N.D.	N.D.
2,4,5-T amine	2,4,5-T	Soil & litter	6.07	26.25	N.D.	N.D.	0.18	0.02	N.D.	N.D.	N.D.	N.D.
2,4,5-T ester	2,4,5-T	Soil & litter	5.81	17.21	3.75	0.42	0.37	0.14	0.02	N.D.	N.D.	N.D.
(2,4-D + 2,4,5-T) amine	2,4-D	Soil and litter	5.54	21.30	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	2,4,5-T				0.25	1.10	0.56	0.06	N.D.	N.D.	N.D.	N.D.
(2,4-D + 2,4,5-T) ester	2,4-D	Soil and litter	5.94	21.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	2,4,5-T				0.33	0.66	N.D.	0.02	N.D.	N.D.	0.01	N.D.

TABLE 6 CHLOROPHENOXY RESIDUE IN THE SOIL AND FOREST LITTER (EARLY SUMMER SPRAY - JUNE, 1974)

Formulation	Herbicide	Strata	Residues of chlorophenoxy compounds (ppm) at different sampling time (hours, days)							
			2 hr.	6	24	7 da.	14	28 (Rain)	56	112
Control	2,4-D	Soil & litter	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	2,4,5-T		N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-D amine	2,4-D	Soil & litter	0.04	0.14	N.D.	4.23	N.D.	N.D.	N.D.	0.01
2,4-D ester	2,4-D	Soil & litter	0.05	0.01	N.D.	0.80	0.88	0.19	N.D.	N.D.
2,4,5-T amine	2,4,5-T	Soil & litter	4.49	0.18	N.D.	0.80	1.87	0.79	0.49	0.28
2,4,5-T ester	2,4,5-T	Soil & litter	0.08	0.19	N.D.	0.86	0.32	0.03	N.D.	0.02
(2,4-D + 2,4,5-T) amine	2,4-D	Soil & litter	0.84	0.19	N.D.	1.09	0.69	N.D.	N.D.	0.05
	2,4,5-T		0.51	0.17	N.D.	0.57	0.42	0.03	N.D.	0.04
(2,4-D + 2,4,5-T) ester	2,4-D	Soil & litter	0.25	0.02	N.D.	0.06	0.45	N.D.	N.D.	N.D.
	2,4,5-T		0.20	0.02	N.D.	0.11	0.24	0.02	N.D.	0.04

4.3 Biological Obersations.

4.3.1 Non-Target Arthropods. Tables 7 and 8 present the total numbers and composition of arthropods obtained by net sweeping from control and treated plots of Experiments No. 1 and 3. Twelve groups of arthropods were recorded. In Experiment No. 1 the Order Hemiptera (plant bugs) seemed to be the most numerous, while in Experiment No. 3, Order Diptera (flies) represented the greatest number of arthropods. The total number of arthropods increased by 150 per cent after treatment in the control plots of late summer spray (August, 1973). In the treated plots a 58% reduction was indicated after treatment. In the early summer spray (June, 1974), the pre-versus-post application population of arthropods of control plot remained unchanged, but a 50% reduction in population was obtained in the treated plots. The decrease of arthropod numbers could possibly be attributed to the migration of the insects away from treated plots to untreated areas.

The 3-way anova (Appendix V) test indicated that:

1. Herbicides, their formulations, and the amount of active material had a great influence (P=0.05) on arthropod numbers;
2. The total arthropod population in all treated plots was significantly (P=0.01) lower after herbicide application than before treatment;
3. Arthropod numbers in plots treated with 2 lb./A. of ester differed significantly (P=0.01) from other plots (within treatment) before as well as after herbicide application;
4. There is consistent variation of arthropod population in all plots (high figure for coefficient of variation).

4.3.2 Fish Toxicity. The results of fish toxicity tests are presented in Table 9. Generally, the ester formulations of chlorophenoxy herbicide appear to be more toxic to coho fingerlings than their amine counterparts. Within the amine formulations, short-chained carbon compounds are less hazardous than long-chained carbon compounds. Iso-octyl ester of 2,4,5-T was demonstrated to be the most acutely toxic of the group tested.

4.3.3 Impact on Birds. Table 10 presents the number and composition of birds recorded near the experimental plots. In both cases there appeared to be no drastic change in their number after the spray operations.

TABLE 7 COMPOSITION OF ARTHROPODS AND POST-SPRAY CHANGES OF CONTROL AND TREATED PLOTS (NET SWEEP SAMPLES) OF EXPERIMENT NO. 1 (LATE SUMMER SPRAY, 1973)

Arthropods	Control Plots		Change*	Treated Plots		Change*
	Pre-Spray Aug.15	Post-Spray Aug.23		Pre-Spray Aug.15	Post-Spray Aug.23	
Arachnida	16	17	1.06	17	14	0.82
Coleoptera	5	8	1.60	0	1	----
Diplopoda	1	0	----	1	0	----
Diptera	25	46	1.84	42	28	0.67
Hemiptera	321	441	1.37	446	173	0.39
Hymenoptera	4	30	9.75	46	15	0.33
Lepidoptera	0	10	----	1	2	2.00
Mollusca	0	0	----	1	0	----
Neuroptera	0	0	----	2	0	----
Psocoptera	2	1	0.50	2	0	----
Thysanoptera	0	0	----	2	0	----
Trichoptera	0	1	----	0	0	----
Total Numbers	374	563	1.51	560	233	0.42

TABLE 8 COMPOSITION OF ARTHROPODS AND POST-SPRAY CHANGES OF CONTROL AND TREATED PLOTS (NET SWEEP SAMPLES) OF EXPERIMENT NO. 3 (EARLY SUMMER SPRAY, 1974)

Arthropods	Control Plots		Change*	Treated Plots (Total of all Treatment)		Change*
	Pre-Spray	Post-Spray		Pre-Spray	Post-Spray	
Arachnida	18	14	0.78	99	88	0.89
Coleoptera	6	12	2.00	69	40	0.58
Collembola	8	7	0.88	25	4	0.15
Diptera	140	183	1.31	1,047	615	0.59
Hemiptera	50	28	0.56	105	33	0.31
Homoptera	47	37	0.79	311	98	0.32
Hymenoptera	22	11	0.50	125	30	0.24
Lepidoptera	1	0	----	11	5	0.45
Neuroptera	0	0	----	0	1	----
Plecoptera	15	2	0.13	53	10	0.19
Psocoptera	3	2	0.67	30	21	0.70
Thysanoptera	0	1	----	1	0	----
Total Numbers	310	297	0.96	1,877	945	0.50

* Change = $\frac{\text{Post-spray numbers}}{\text{Pre-spray numbers}}$; >1 = increase, <1 = decrease

TABLE 9 FISH TOXICITIES OF DIFFERENT FORMULATIONS OF CHLOROPHENOXY COMPOUNDS

Compounds	Formulation	Toxicity (ppm)*	
		Threshold	96 Hr. LC_{50}
2,4-D amine	Dimethyl amine/ diethanolamine salts	>560	>1,350
2,4-D ester	Iso-octyl ester	>180	240
(2,4-D + 2,4,5-T) amine	Monoethanolamine/ diethanolamine/ dimethylamine/ diethylamine mixture	>100	620
(2,4-D + 2,4,5-T) ester	Iso-octyl ester	100	135
2,4-D amine	N-Oleyl-1,3-propylene-diamine salt	75	86
(2,4-D + 2,4,5-T) amine	N-Oleyl-1,3-propylene-diamine salts	56	64
2,4,5-T amine	N-Oleyl-1,3-propylene-diamine	32	36
2,4,5-T ester	Iso-octyl ester	10	13.5

* Coho fingerlings/frys

TABLE 10 NUMBERS OF BIRDS AND WILDLIFE NEAR EXPERIMENTAL PLOTS

Birds and Wildlife	Pre-Spray (August 15, 1973)	Post-Spray (August 24, 1973)
Late Summer Spray, 1973		
Bears	1	0
Birds (grouse, hawks, jays, robins sparrows)	15	17
Deer	3	1
Squirrels	2	2
TOTAL NUMBER	21	20
Early Summer Spray, 1974	(June 12, 1974)	(June 20, 1974)
Birds (crow, ducks, grouse, robins, songbirds, swallows, sparrows)	24	27

5. DISCUSSION

Alder (Alnus spp.) is an aggressive pioneer forming part of the secondary forest succession within the coastal forest of British Columbia. Logging activities, particularly the construction of logging roads, eliminate primary forest and promote the propagation of this plant. An effective control of the perennial woody weed is the use of herbicides, especially 2,4-D and 2,4,5-T because of the plant's susceptibility to these compounds (B.C. Department of Agriculture, 1973). The degree of control depends on the type of vegetation management required. In forest and rights-of-way management, it is desirable to have a complete alder kill to avoid annual chemical treatment.

The current recommended rate of foliar applications is 2 to 4 pounds of active ingredient per acre (lb. a.i./A.) of 2,4-D or 2,4,5-T ester formulations (Council of Forest Industries, 1972). Amine formulations are not recommended for use as foliar sprays because of their apparent poor leaf penetration. Often the highest permissible dose rate of ester formulation is employed to achieve total kill. The foliar application of ester formulations has prompted severe criticism by environmentalists because of several undesirable characteristics. They are more volatile, thereby causing greater drift and increased hazards to spray operators. Furthermore, ester forms of chlorophenoxy compounds are more toxic to fish and fish food organisms (Pimentel, 1971). Esters are insoluble in water and require the use of oil solvent and emulsifiers, which further increase toxicity to aquatic organisms.

The 1973 experiments suggest that both the amine and ester formulations of 2,4-D and 2,4,5-T were equally effective in controlling alder when applied as a foliar spray. Complete control toward the end of the growing season (end of August) was achieved with a dosage of 1-2 lb. a.i./A. of either 2,4,-D or 2,4-D + 2,4,5-T amines and esters even when trees were approaching a physiologically "resistant" state. It was found that doses of 1-2 lb. a.i./A. also achieved similar results when applied during active growing season (June) as indicated by the result of Experiment No. 3 (1974 summer spray).

While complete defoliation took place in plots treated with 2 lb. a.i./A. in August, 1973, some of the trees later formed buds. A further assessment conducted on the experimental plots of August, 1973, in the spring of 1974 showed that these buds were not viable. The formation of buds suggests that the alder had hardened off to some extent prior to treatment and this condition did not affect the efficacy of chlorophenoxy herbicides, demonstrating that they could be used towards the end of the growing season, and still successfully check plant growth. Furthermore, the use of leaf defoliation is a valid criterion for assessing the effects of chlorophenoxy compounds on alder tree mortality.

The dormant spray of April, 1974, indicates that poor alder control was obtained when chlorophenoxy chemicals were mixed with water. Although varying degree of leaf stunt was noted 2-3 weeks after treatment, no tree mortality was observed. One explanation for this unsatisfactory result was the physiological "resistant" state of the alder, which probably prevented the penetration of sufficient amount of toxic materials. April was also a relatively wet month (Appendix VI) and the rain could possibly have affected the applied concentrations of some of the chemicals.

Studies from drift plates did not demonstrate any definite or large differences in drift patterns between amine and ester formulations at different concentrations of application. During the late summer spray, greater amounts of drift deposits of 2,4-D and 2,4-D + 2,4,5-T amines were monitored than corresponding ester formulations. In the dormant application larger amounts of 2,4-D amine, 2,4-D ester and 2,4,5-T ester were detected. Substantially greater amounts of drift deposits of 2,4-D + 2,4,5-T ester were obtained during early summer foliar treatment. No differences in drift patterns were detected between short and long C-chained amines of 2,4-D and 2,4,5-T. The drift results of ester formulation of 2,4-D and 2,4,5-T were variable and this cannot be explained at present.

There was a difference in the persistence of chlorophenoxy compounds between residues from dormant and summer foliar sprays. Chlorophenoxy residues seemed to remain in the environment for a much shorter time in dormant spray than summer application. This difference could be attributed to the high rainfall prevalent during spring and the subsequent dilution and leaching of residues by runoff following precipitation.

The failure to detect any chlorophenoxy residues in water samples from Station W1 and W2 during dormant operation is probably due to two factors: limited quantity of chlorophenoxy chemicals reaching the ditches adjacent to the plots and dilution beyond limit of detection within 0.25 hours. In Station W3 and W4 of the summer spray, only trace amounts of 2,4-D and 2,4,5-T appear in the water 1 or 2 hours following treatment.

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APPENDICES

APPENDIX I. ALDER CONTROL AT SELECTED INTERVALS POST TREATMENT
(LATE SUMMER SPRAY, 1973)

Weeks post treatment	Formulations+	Amount of active ingredient/acre[a] 0.5	1.0	2.0	4.0	Mean
		CONTROL RATING*				
1 (August 30, 1973)	A	0	0	0.50	0.50	0.25
	E	0	0	1.00	5.40	1.60
	A'	0.75	0.50	0.25	0.50	0.50
	E'	1.75	1.50	4.65	1.75	2.41
	Mean	0.63	0.50	1.60	2.04	1.19
2 (Sept. 6, 1973)	A	0.25	1.00	4.50	5.25	2.75
	E	1.25	3.50	4.25	8.90	4.48
	A'	2.25	2.25	3.50	6.00	3.50
	E'	1.00	3.50	6.50	8.40	4.85
	Mean	1.19	2.56	4.69	7.14	3.90
4 (Sept. 21, 1973)	A	3.25	7.75	7.80	8.90	6.93
	E	3.15	5.70	8.65	9.00	6.63
	A'	7.90	7.25	8.30	9.00	8.11
	E'	6.10	8.70	9.00	9.00	8.20
	Mean	5.10	7.35	8.44	8.98	7.47
6 (Oct. 5, 1973)	A	1.05	6.05	6.40	8.40	5.48
	E	2.05	3.90	8.15	9.00	5.78
	A'	5.65	5.05	7.40	8.75	6.71
	E'	4.30	7.25	8.15	8.75	6.28
	Mean	3.26	5.56	7.50	8.75	6.28
52 (August 21, 1974)	A	5.00	8.38	9.00	9.00	7.85
	E	4.50	6.75	9.00	9.00	7.31
	A'	7.50	6.50	6.75	9.00	7.44
	E'	9.00	8.50	8.75	9.00	8.81
	Mean	6.50	7.53	8.38	9.00	7.85

Source of Variation	DF	SS	MS	FS	Sig.
Weeks post treatment (A)	4	495.99	124.00	134.18	***
Amount of active ingredient/ Acre (B)	3	168.22	56.07	60.68	***
Formulations (C)	3	27.94	9.31	10.08	**
A vs. B	12	37.50	3.13	3.38	**
A vs. C	12	15.57	1.29	1.40	N.S.
B vs. C	9	39.95	4.44	4.80	**
A vs. B vs. C	36	33.27	0.92	----	---
Total	79	818.38	----	----	---

		Between Treatment	Within Treatment (B vs. C)
LSD (P = 0.10)	=	----	1.24
LSD (P = 0.05)	=	0.68	1.49
LSD (P = 0.01)	=	0.89	1.97

Coefficient of variation = 17.7%

* 0 = no tree mortality; 9 = total tree mortality of entire plot; mean of 2 replicates.

\+ A = 2,4-D amine
E = 2,4-D ester
T = 2,4,5-T amine
A' = (2,4-D + 2,4,5-T)amine
E' = (2,4-D + 2,4,5-T)ester
T' = 2,4,5-T ester

a lbs. per acre

APPENDIX II. ALDER CONTROL AT SELECTED INTERVALS POST TREATMENT (DORMANT SPRAY, 1974)

Weeks post treatment	Formulations[+]	Amount of active ingredient/acre[α] 0.5	1.0	2.0	4.0	Mean
		RATING OF TREE STUNTING *				
2 (April 23 1974)	A	4.60	5.50	7.50	6.50	6.03
	E	3.50	5.00	6.50	8.50	5.88
	T	1.50	3.00	4.50	3.75	3.19
	A'	4.00	5.55	7.00	8.50	6.26
	E'	3.50	6.75	4.50	7.00	5.44
	T'	3.50	6.00	5.50	7.60	5.65
	Mean	3.43	5.30	5.92	6.98	5.41
4 (May 7 1974)	A	2.50	3.25	8.15	7.65	5.30
	E	2.25	4.85	7.40	8.00	5.63
	T	0.50	1.25	1.00	1.50	1.06
	A'	5.50	6.00	8.25	8.25	7.00
	E'	7.00	7.50	6.75	8.50	7.44
	T'	2.75	6.00	6.25	7.50	5.63
	Mean	3.42	4.81	6.30	6.90	5.36
6 (May 21 1974)	A	1.50	3.00	7.00	8.00	4.88
	E	0.50	1.75	4.50	7.00	3.44
	T	0.50	0.25	0.25	0.25	0.31
	A'	3.25	5.00	7.15	8.00	5.85
	E'	5.00	8.00	5.50	6.50	6.25
	T'	0.50	5.50	3.00	6.75	3.94
	Mean	1.88	3.92	4.57	6.08	4.14

Source of Variation	DF	SS	MS	FS	Sig.
Weeks post treatment (A)	2	25.87	12.94	19.49	**
Amount of active ingredient/ Acre (B)	3	136.05	45.35	68.34	***
Formulations (C)	5	192.64	38.53	58.06	***
A vs. B	6	2.52	0.42	0.63	N.S.
A vs. C	10	27.48	2.75	4.14	**
B vs. C	15	57.47	3.83	5.77	**
A vs. B vs. C	30	19.91	0.66	----	---
Total	71	461.94	----	----	---

		Between Treatment	Within Treatment (B vs. C)
LSD (P = 0.05)	=	0.47	1.13
LSD (P = 0.01)	=	0.62	1.50

Coefficient of variation = 16.2%

* 0 = no leaf stunt; 9 = complete leaf stunt of entire plot; mean of 2 replicates.

+ See Appendix I for meaning of A, E, T, A', E', T'.

α lbs. per acre

APPENDIX III. ALDER CONTROL AT SELECTED INTERVALS POST TREATMENT (EARLY SUMMER SPRAY, 1974)

Weeks post treatment	Formulations+	Amount of active ingredient/acre α 0.5	1.0	2.0	4.0	Mean
		CONTROL RATING*				
1 (June 20 1974)	A	4.25	7.50	7.75	8.25	6.94
	E	4.25	6.25	8.25	9.00	6.94
	T	6.00	6.00	7.65	8.50	7.04
	A'	5.50	6.75	7.20	8.25	6.43
	E'	3.75	7.00	8.00	8.40	6.79
	T'	4.50	4.25	5.85	6.75	5.34
	Mean	4.71	6.29	7.45	8.19	6.66
2 (June 27 1974)	A	6.25	7.00	8.50	6.50	7.06
	E	4.25	6.00	9.00	9.00	7.06
	T	6.50	8.00	6.50	9.00	7.50
	A'	4.75	5.25	5.25	7.25	5.63
	E'	4.75	6.50	8.50	8.75	7.13
	T'	3.00	7.75	8.00	8.75	6.88
	Mean	4.92	6.75	7.63	8.21	6.88
3 (July 4 1974)	A	7.50	7.75	8.75	9.00	8.25
	E	4.00	8.00	8.50	9.00	7.38
	T	7.00	8.00	7.75	9.00	7.94
	A'	5.00	6.50	8.75	8.75	7.13
	E'	5.00	7.65	9.00	9.00	7.66
	T'	4.25	6.50	8.50	8.25	6.88
	Mean	5.46	7.40	8.46	8.83	7.54
4 (July 11 1974)	A	7.50	7.80	8.75	9.00	8.27
	E	4.25	8.00	8.50	9.00	7.44
	T	7.25	8.25	7.75	9.00	8.06
	A'	5.00	6.75	8.50	9.00	7.31
	E'	5.00	7.75	9.00	9.00	7.69
	T'	4.50	6.50	8.75	8.50	7.06
	Mean	5.58	7.51	8.54	8.92	7.64

Source of Variation	DF	SS	MS	FS	Sig.
Weeks post treatment (A)	3	16.80	5.60	10.91	***
Amount of active ingredient/ Acre (B)	3	159.28	53.09	103.47	***
Formulations (C)	5	16.43	3.29	6.40	**
A vs. B	9	0.70	0.08	0.15	N.S.
A vs. C	15	9.92	0.66	1.29	N.S.
B Vs. C	15	25.55	1.70	3.32	**
A vs. B vs. C	45	23.09	0.51	----	---

	Between Treatment	Within Treatment (B vs. C)
LSD (P = 0.05) =	0.42	0.77
LSD (P = 0.01) =	0.56	1.02

Coefficient of variation = 9.84%

* 0 = no tree mortality; 9 = complete tree mortality of entire plot; mean of 2 replicates.

+ See Appendix I for meaning of A, E, T, A', E', T'.

α lbs. per acre

APPENDIX IV. TEST CONDITIONS RECORDED DURING SPRAY APPLICATION OF EXPERIMENT NO. 1, 2, AND 3

	Experiment No. 1	Experiment No. 2	Experiment No. 3
Time of spraying	0930-1130	0800-1115	0830-1120
Weather	Variable, some sunny periods	Hazy days	Sunny
Temperature	Start 58°F, finish 65°F	Start 54°F, finish 56°F	Start 61°F, finish 69°F
Humidity	56%	68%	63%
Rain	Nil	Nil	Nil
Wind	<1 mph	<3 mph	<3mph
Drift	Slight	Moderate	Moderate
Foliage	Dry	Dry	Dry
Soil type	Glacial till	Sandy loam	Sandy loam
Soil moisture	24%	20%	23%
Sprayer throughput	7.1 ml/sec	4 ml/sec	4.5 ml/sec
Total volume/plot	150 ml	150 ml	150 ml
Plot size	30x3, 10-50 ft buffer zone	As in Expt. No. 1	As in Expt. No. 1
Plant species	99% roadside alder	98% roadside alder, some willow	As in Expt. No. 2
Stage of growth	Late summer 3-8 feet in height	Dormant spray 5-15 feet in height	Early summer spray, 3-15 feet in height

APPENDIX V. EFFECTS OF CHLOROPHENOXY COMPOUNDS ON NON-TARGET ARTHROPODS (EARLY SUMMER SPRAY, 1974)

		Total Arthropod Numbers/Plot*					
		Amount of active ingredient/Acre					
Treatment	*Formulations*+	*0*	*00.5*	*1.0*	*2.0*	*4.0*	*Mean*
Pre-Treatment	A	40.5	45.5	23.5	30.0	62.5	40.4
	E	17.5	26.0	19.0	216.5	35.5	62.9
	T	40.5	33.5	37.0	36.5	14.5	32.4
	A'	26.5	30.5	26.0	52.0	16.0	30.2
	E'	18.0	58.5	26.0	8.0	17.5	25.6
	T'	13.0	30.5	21.5	30.5	31.0	25.3
	Mean	26.0	37.4	25.5	62.3	29.5	36.1
Post-Treatment	A	39.5	12.5	22.5	22.5	16.5	23.3
	E	21.5	12.0	8.0	96.0	24.0	32.3
	T	14.0	8.5	18.0	20.5	9.5	14.1
	A'	36.5	31.0	23.0	29.5	8.5	25.7
	E'	16.0	14.0	21.5	18.5	9.0	15.8
	T'	16.0	20.5	22.5	13.0	13.5	17.1
	Mean	23.9	16.4	19.8	33.0	13.5	21.4

Source of Variation	DF	SS	MS	FS	Sig.
Weeks post treatment (A)	1	3,263.44	3,263.44	10.73	***
Amount of active ingredient/ Acre (B)	4	5,644.81	1,411.20	4.64	**
Formulations (C)	5	5,176.27	1,035.25	3.40	*
A vs. B	4	1,448.29	362.07	1.19	N.S.
A vs. C	5	1,104.54	220.91	0.73	N.S.
B vs. C	20	26,734.04	1,336.70	4.39	***
A vs. B vs. C	20	6,084.86	304.24	----	---
Total	59	49,456.25	-----	----	---

		Between Treatment	Within Treatment (B vs. C)
LSD (P = 0.05)	=	9.05	18.88
LSD (P = 0.01)	=	12.06	25.30

Coefficient of Variation = 59.6%

* Mean of 2 replicates

+ *See Appendix I for meaning of A, E, T, A', E', T'.*

APPENDIX VI. MONTHLY RECORDS OF RAINFALL (TOTAL IN INCHES) - CAYCUSE (5 MILES FROM NIXON CREEK AND 25 MILES FROM NITINAT) 1974

Month	Rainfall (inches)
March	21.55
April	7.92
May	6.43
June	2.81
July	4.92
August	0.20
September	1.59
October	3.76
November	22.08