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WESTERN SPRUCE BUDWORM
A PILOT CONTROL PROJECT WITH CARBARYL AND TRICHLORFON
1975

Environmental monitoring of aquatic organisms, birds, and insect pollinators

USDA Forest Service
State and Private Forestry

Northern Region
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PILOT PROJECT OF CARBARYL AND TRICHLORFON AGAINST THE WESTERN SPRUCE BUDWORM BEAVERHEAD NATIONAL FOREST, MONTANA, 1975

by

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SUMMARY

A pilot project designed to evaluate effectiveness of carbaryl (Sevin 4-Oil) and trichlorfon (Dylox 4) for control of western spruce budworm, *Choristoneura occidentalis* Freeman, and their environmental effects was conducted in July 1975 on the Beaverhead National Forest, Montana. Insecticides were applied with a Bell 205A helicopter at 1 pound active ingredient per acre (1.12 kg/hectare). Sevin was diluted 1:1 with diesel oil and applied at 1/2 gallon per acre (4.7 L/hectare), while Dylox 4 was diluted 1:3 with Panasol AN3 and applied at 1 gallon per acre (9.4 L/hectare). Sprays were delivered with Spray Systems Company 8010 flat fan T jet nozzles from a helicopter flying 50 feet above the trees at 90 mi/hr (145 km/hr).

Each treatment, plus checks, was replicated three times. Treatment blocks ranged in size from 1,086 acres (439 hectares) to 1,359 acres (550 hectares). Application was made when ca. 90% of the larvae were in the fourth, fifth, and sixth instar. Larval population densities were measured 48 hours prior to spraying and at 7, 14, and 21 days postspray. Population measurements were made on 25 three-tree clusters distributed throughout each block to estimate the mean larval density/100 buds. Data were analyzed using covariance analysis.

Results showed trichlorfon caused a 76.88% reduction and carbaryl an 81.8% reduction in the larval population. These data are corrected for natural mortality by covariance analysis. Foliage protection was estimated at 34.3% for carbaryl and 23.49% for trichlorfon. There was a significant difference (P = 0.01) between treatments and controls, but not between insecticides.

Effect of treatments on spruce budworm parasites was negligible. Parasitism actually increased significantly in the carbaryl blocks between the 7- and 14-day postspray samples.

Insecticide application caused a significant increase in number of drifting aquatic organisms. Sevin had the greatest impact, causing the volume of drifting aquatic organisms to increase from less than 1 ml to 200 ml. Trichlorfon had little effect, causing a 30-ml increase in drift over prespray samples only in one stream. Both insecticides caused a significant redirection in brain cholinesterase activity in rainbow trout in slow-moving streams.

No discernible effects of the treatments were found on bird nesting success, breeding bird densities, or bird mortality. In addition, there was little effect on brain cholinesterase activity when these materials were applied at 1 pound active ingredient per acre.

No significant differences in bee densities were observed in trap collections between treatments and controls. There was, however, a significant reduction in small bees as a percentage of total bee pollinators in two of the trichlorfon-treated sites at the time of the latest collection period. Snowberry, *Symphorocarpos albus*, fruit production was significantly lower on all spray sites relative to the control site.

This project was accomplished through the cooperative effort of many individuals, Federal and State governmental agencies, and private organizations. Meteorological and spray deposit assessment services were provided by the Department of the Army, Dugway Proving Ground, Dugway, Utah, and the U.S. Forest Service Missoula Equipment Development Center. Monitoring the effects of treatments on birds was done by the U.S. Department of the Interior Fish and Wildlife Service, Denver Wildlife Research Center; and on fish and aquatic insects by the U.S. Forest Service, Zone Fisheries Biologist. A study to evaluate treatment effects on pollinating insects was contracted to Olson-Elliott and Associates. Residue analyses were done by the Warf Institute, Inc., and U.S. Forest Service, Insecticide Evaluation Project.

INTRODUCTION

Pesticides are occasionally needed to suppress epidemic populations of western spruce budworm, *Choristoneura occidentalis* Freeman, in forests of the western United States. From 1953 to 1966, 50 operational control projects covering a total of 5,918,280 acres were conducted in Idaho, Montana, and Wyoming (Johnson and Denton 1975). Forty-eight of these projects used DDT prior to its being banned by the Environmental Protection Agency in 1972. Malathion and Zectran were subsequently registered for use against western spruce budworm, and malathion was used for operational control projects in Montana in 1966 and Washington in 1976. Zectran production ceased in 1972, leaving malathion as the only registered pesticide available for budworm control in the West. In order to insure availability of effective direct control alternatives which could be used safely under a variety of environmental conditions, the U.S. Forest Service initiated this pilot project to evaluate carbaryl (Sevin 4-Oil) and trichlorfon (Dylox 4) for effectiveness in western spruce budworm control.

Objectives of this project were:

1. Evaluate and compare effectiveness of an aerial application of Sevin 4-Oil and Dylox in reducing western spruce budworm populations under operational conditions.

2. Measure effect of treatment in protecting foliage, both the year of treatment and the following year, when only relatively small portions of an infestation are sprayed.

3. Identify and resolve problems in formulation and application of larger volumes of these materials.

4. Measure effect of these treatments on western spruce budworm parasites.

5. Evaluate the effects of treatment on water quality and nontarget organisms; i.e., birds, fish, aquatic invertebrates, and insect pollinators.

6. Measure residue levels, over time, on selected grasses, herbacious foliage, and Douglas-fir foliage.

MATERIALS AND METHODS

Insecticides

Carbaryl[1/] (Sevin 4-Oil) and trichlorfon[2/] (Dylox 4) were selected for this pilot project on the basis of field tests conducted on spruce budworm in the United States and Canada. In addition, data on the impact of these pesticides on nontarget species suggested they would have minimal adverse environmental effects.

Carbaryl, a carbamate insecticide, is a product of Union Carbide Corp. It is widely used in forestry and agricultural spraying for control of a variety of insect pests. Registered uses in forestry include control of various species of tent caterpillars, gypsy moth, elm leaf beetle, and others. In field experiments, Sevin 4-Oil has been shown very toxic to budworm larvae (Hildal and DeBoo, 1973; Diamond, 1974; Beach and Dolan, 1973). In this pilot project, Sevin 4-Oil was formulated (diluted 1:1 diesel oil) and applied at 1 pound (1.12 kgs.a.i.) of Sevin in enough carrier (No. 2 fuel oil) to make one-half gallon per acre (4.7 L/hectare).

Trichlorfon is a short-lived organophosphate insecticide manufactured by Mobay Chemical Corp., Chemagro Agricultural Division. The formulation used in this project was 1 pound of active ingredient in enough Panasol AN3 (a petroleum solvent) to make 1 gallon total material per acre (1.12 kg/9.4 liters/hectare). Trichlorfon has been field tested against budworm in both Canada (Kettela, 1974; Randall, 1970) and the United States[3/] with encouraging results.

Samples of each batch of pesticide mixed were collected and analyzed to determine the actual concentration of active ingredient.

Experimental Design

A completely randomized block design was used with nine blocks ranging in size from 1,086 to 1,359 acres (439 to 550 hectares) selected from budworm-infested spruce/fir forests on the Beaverhead National Forest, Montana. Selection of blocks was based on estimated budworm population levels, ease of access, and readily definable topographic block boundaries. Each treatment, including controls, was replicated three times. Blocks were separated by at least 1 mile (1.83 km) or by a prominent ridge to avoid cross-contamination by the insecticides.

1/ 1-Naphthyl N-methylcarbamate.

2/ Dimethyl (2, 2, 2-trichloro-1-hydroxyethyl) phosphonate.

3/ Letter from U.S. Forest Service, Region 5, to U.S. Forest Service, FI&DM, Washington, D.C.

Treatments were assigned by the order in which the blocks met the spray criteria; i.e., when ca. 90% of the larvae were in the fourth, fifth, and sixth instar. Carbaryl was applied to the first three blocks ready for spraying; Dylox to the next three. Check blocks were paired to treatment blocks and sampled, using the same criteria as for spray blocks.

Location

Treatment blocks (Fig. 1) sprayed with insecticides are as follows:

Carbaryl

Block 2. 1,086 acres (439 hectares). Elevation 6,200-7,350 feet (1,889-2,240 meters). Primarily northeast exposure with moderate to steep slopes. Drained into Meadow Creek on east side of Tobacco Root Mountains.

Block 6. 1,257 acres (509 hectares). Elevation 6,600-7,800 feet (1,890-2,377 meters). Mostly northerly exposure in the Gravelly Mountain Range. Moderate slopes at higher elevations, breaking into steep, narrow canyons in the lower portion of the block.

Block 8. 1,144 acres (463 hectares). Elevation 6,200-7,800 feet (1,890-2,377 meters). Block located on a ridgetop in the Gravelly Mountain Range with steep east and northeast drainages flowing into the Madison River.

Trichlorfon

Block 4. 1,206 acres (488 hectares). Elevation 6,800-7,500 feet (2,073-2,286 meters). East-facing moderate slope in the Gravelly Mountain Range, draining into the Ruby River.

Block 5. 1,227 acres (497 hectares). Elevation 6,200-7,200 feet (1,890-2,194 meters). Ridgetop in the Gravelly Mountain Range, breaking away into a steep north slope.

Block 7. 1,359 acres (550 hectares). Elevation 6,600-7,800 feet (2,012-2,377 meters). Block had a north to northeast exposure in the Gravelly Mountain Range with steep slopes on the northeast side, changing to moderate on the north face.

See Appendix B for detailed description of block vegetation.

Population Sampling

Budworm population densities were estimated for each block by sampling midcrown branches from 25 clusters of three trees each (a total of 75 trees/block).

Clusters were located at points of opportunity throughout the block. Open-grown Douglas-fir trees 30 to 40 feet (9 to 12 meters) tall with full crowns were selected as sample trees. Five foliage collections were made from each cluster during the project: (1) prespray, (2) 7-day postspray,

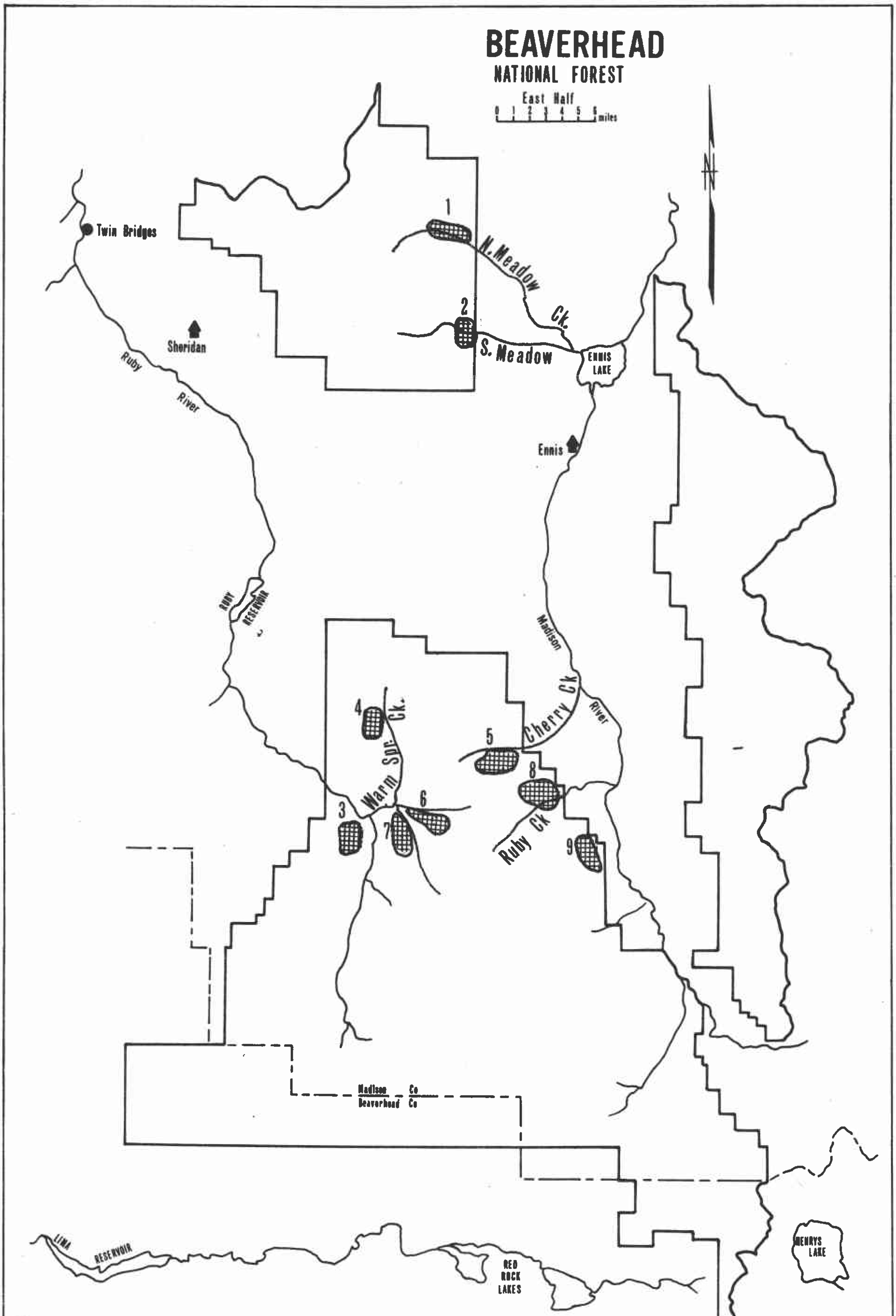

Figure 1. Location of treatment blocks, Madison and Sheridan Ranger Districts, Beaverhead National Forest, Montana, 1975.

(3) 14-day postspray, (4) 21-day postspray, and (5) a sample to estimate foliage protection.

Blocks were scheduled for spraying when 90% of larvae were in the fourth, fifth, and sixth instars (Table 1). Larval development samples were taken from 10 widely scattered 3-tree clusters independent of the population cluster samples. Two midcrown 15-inch (38 cm) long branches were clipped from each tree. Budworm larvae were collected in the laboratory, killed in alcohol, and examined microscopically for instar determination. Instars were separated on the basis of morphological characteristics of the larvae. Development sampling was initiated at budbreak and continued on an "every other day" basis until 50% of the larvae were in fourth, fifth, and sixth instars. After this, samples were taken daily.

Table 1.--Prespray larval instar distribution of western spruce budworm, Beaverhead National Forest, Montana, 1975

Treatment	Date collected	Date treated	Instar distribution (%)					
			2nd	3rd	4th	5th	6th	4th, 5th, & 6th
Carbaryl								
Block 2	7/09/75	7/10/75	1	22	63	11	3	77
Block 6	7/10/75	7/11/75	0	13	60	26	1	87
Block 8	7/11/75	7/12/75	0	13	50	33	4	87
Trichlorfon								
Block 4	7/12/75	7/14/75	0	10	55	35	0	90
Block 5	7/14/75	7/16/75	2	16	55	25	2	82
Block 7	7/16/75	7/17/75	0	5	27	34	34	95
Check								
Block 1	7/08/75		4	26	55	14	1	70
Block 3	7/12/75		0	8	39	43	10	92
Block 9	7/11/75		0	2	26	34	38	98

Prespray samples also consisted of two 15-inch (38 cm) long branches taken from opposite sides of the midcrown of each sample tree. Postspray and foliage assessment samples included four 15-inch (38 cm) long branches per tree. Samples were taken with a 24-foot (7.3 m) sectional aluminum pole pruner fitted with a circular nylon catch bag 18 inches (46 cm) in diameter and 36 to 40 inches deep (about 1 m). Collections from check blocks were scheduled for sampling as if they were actually sprayed.

Branch samples were placed individually in paper bags, stapled closed, and labeled to identify block, cluster, tree, and branch number. Samples from each cluster were grouped in a nylon net laundry bag. Bags were kept shaded as much as possible while in transit to the laboratory. There they were stored overnight in field walk-in coolers held at 3° C. Data taken in the laboratory included the number of buds, budworm larvae, and "other defoliator larvae" per branch. Budworm population densities were expressed as the number of larvae per 100 buds.

Samples to evaluate foliage protection were collected after all larval feeding was completed. Defoliation was estimated to the nearest 10% on 25 apical shoots of new growth from each of the four branches collected per tree and the mean level of defoliation calculated.

Data Analysis

Treatment effectiveness was evaluated by a comparison of 14-day postspray mortality or residual larval densities among treated and untreated plots. Analysis of covariance in an experimental design was used. Comparability was maintained through an adjustment of postspray population means (Y_n) to minimize effect due to variation among prespray larval densities, and covariate (X_i). Comparability among independent covariates was provided by measuring prespray population densities at the same stage in larval development.

Estimates of larval densities per plot were computed for each sampling period and denoted as follows:

$$x_i = \text{prespray larval density}$$

$$y_n = n^{th} \text{ postspray larval density}$$

Measurements of budworm larval density were made from population counts expressed as a number of larvae or pupae per 100 shoots. Larval densities were calculated for each branch sample. Mean larval densities for each plot were calculated in a multistage context (Hazard and Stewart, 1974); i.e., larval densities over branches, trees, and clusters as follows:

$$\bar{\bar{y}} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{l=1}^{k}}{nmk}$$

y = per plot mean larval density computed over all sample stages
n = number of clusters (first-stage unit)
m = number of trees (second-stage unit)
k = number of branches (third-stage unit)
y_{ijl} = an observation (budworm larvae per 100 shoots) of the i^{th} third-stage unit within the j^{th} second-stage unit within the i^{th} first-stage unit.

Mean larval densities were analyzed in an analysis of covariance computer program. Postspray larval densities were adjusted (y_i) and corresponding F test performed. Test of significance was considered at $P = 0.1$, highly significant at $P = 0.05$, and very highly significant at $P = 0.01$.

Regression analysis of the spray deposit data was made to determine the relationship between spray coverage and budworm mortality.

Mixing and Handling of Insecticides

Insecticides were mixed the evening before spraying in 500-gallon (1,892.5 L) stainless steel tanks specially made for handling pesticides. The tanks were mounted on a flatbed truck. A Deming Division, Crane Company, gear pump driven by a 9-hp engine was used to transfer insecticides and diluents from 55-gallon (208 L) drums through a 2-inch (5.08 cm) chemical grade hose. Loading of the helicopters was done with an MP Pump, Inc. centrifugal pump powered by a 4-hp engine. Insecticides were pumped through a 2-inch chemical grade hose fitted with a Kam va lok ® dry coupling for attachment to the helicopter spray tank. A 2-inch (5.08 cm) Neptune flow meter was used to measure each load as it was pumped into the helicopter spray tank. This system was capable of pumping 100 gal/min (378.5 L) (limit set by flow meter).

Aerial Application

A Bell 205A helicopter equipped with a 15.24 m spray boom was used to apply each insecticide. Nozzles were spaced at 12-inch (30 cm) intervals, using all but the outer 1 meter of the boom. This configuration gave an effective swath width of 200 feet (61 meters). Sprays were applied through flat fan T jet nozzles No. 8010 oriented 45^{o} forward at a boom pressure of 40 psi (2.8 kms/cm^2). Spray release was about 50 feet (15 m) above the trees at a speed of approximately 90 mi/hr (144 kms/hr). Thirty-seven nozzles were used to apply Dylox at a rate of 1 gal/acre (9.4 L/hectare). Eighteen of the same size nozzles were used for the Sevin application at 1/2 gal/acre (4.7 L/hectare).

Teflon diaphrams were placed behind neoprene diaphrams in the diaphram check valve when spraying trichlorfon. This is necessary to prevent swelling of the neoprene diaphrams. This formulation of trichlorfon also caused rapid deterioration of old hoses in the spray system. One hose ruptured during spraying. The manufacturer does recommend that new hoses, preferably chemical grade, be used when applying this material.

Spraying began between 5:30 a.m. to 6:00 a.m. and was generally completed by 10:00 a.m. Preestablished limits on wind speed and temperature were 6 m.p.h. (9.65 km/h) and 65^{o} F. (18.33^{o} C) respectively.

Spraying was observed from a Bell 206 or Bell 47GB-1 helicopter to assure a safe operation and to monitor the spray system and coverage of the block.

Mechanical problems with the aircraft and a broken hose in the spray system caused substantial delays in completing Block 5 (trichlorfon). As spraying conditions were rapidly becoming marginal when the aircraft was again operational, the pilot was directed to spray certain areas of the block containing cluster samples. Spray swaths were placed in a normal pattern. However, examination of spray deposit cards from clusters located along one edge of Block 5 showed no trace of spray. Assuming that these clusters had been missed, they were treated the following day. Data from these clusters were not used in the deposit-mortality analysis.

Meteorological Monitoring

Meteorological conditions were monitored during spraying by personnel from the U.S. Forest Service Missoula Equipment Development Center and meteorologists from the U.S. Army Dugway Proving Ground, Utah. A 2-meter wind set and chart recorder were placed in a suitable clearing the evening prior to spraying. Temperature profiles at 20-foot (6.1 m) intervals to 200 feet (60.96 m) and wind speed 50 feet (15.24 m) above the canopy were measured using a wiresonde and hot-wire anemometer attached to a tethered weather balloon.

Spray Deposit Monitoring

Spray deposit for each tree cluster was measured at ground level with 16.9- by 11-cm white Printflex cards. Cards were placed in a 3- to 5-foot (1- to 2-m) diameter area on the ground which had been cleared of grass and shrubs. One card was placed on the ground at each cardinal direction below the drip line of each sample tree. Plastic cardholders were used to protect the cards and to avoid smudging drops during handling and to hold the card flat and secure.

Field crews positioned cards just prior to spraying and completed card pickup within 2 hours after spraying.

Deposit cards were analyzed by personnel of the ERDA, Los Alamos Scientific Laboratory, with a Quantimet to determine drops/cm^2, drop size (volume median diameter, VMD), and gal/acre. Data from the 12 cards per cluster were averaged for regression analysis of larval mortality on spray deposit. Spray deposit cards also were placed in selected forest openings to obtain an index ratio of canopy penetration as a function of drop size (see Appendix B). A canopy penetration model was used for each block (except Block 5) to determine which drop size was most effectively penetrating the canopy.

RESULTS AND DISCUSSION

A high proportion of the larval population pupated by the 21-day postspray sample. Because of the probability that a substantial number of larvae had "spun down" prior to pupating, the 21-day postspray sample was discarded. The 14-day postspray data were used to determine insecticide efficacy.

Covariance analysis indicates that trichlorfon caused a 76.88% reduction in the larval population and carbaryl an 81.8% reduction (Table 2). These figures are very close to the uncorrected population reduction figures due to the unusually low mortality in check areas. There was a significant difference ($P = 0.01$) between insecticides and controls, but not between insecticides.

When compared to the checks, carbaryl was estimated to have saved 34.3% of the foliage and trichlorfon 23.49% (Table 3).

Table 2.--Western spruce budworm larval population densities/100 buds and percent population reduction calculated by covariance analysis and uncorrected for natural mortality, Beaverhead National Forest, Montana, 1975

Treatment and block No.	Prespray population a/	7-day postspray Population a/	7-day postspray Percent control b/	14-day postspray Population a/	14-day postspray Percent control b/	Population reduction c/
Check 1	27.37	27.67	--	22.76	--	
Check 3	17.42	17.99	--	18.39	--	
Check 9	13.31	12.37	--	8.38	--	
Mean	19.36	19.34		16.51		
Carbaryl 2	18.45	6.05	68.62	3.99	75.70	
Carbaryl 6	13.70	2.50	87.03	1.87	88.61	
Carbaryl 8	25.47	6.50	66.28	3.12	80.94	
Mean	19.20	5.01	74.00*	2.99	81.80*	84.40
Trichlorfon 4	25.48	8.02	64.75	5.14	74.96	
Trichlorfon 5	19.34	6.24	67.89	4.40	73.39	
Trichlorfon 7	11.59	3.79	72.83	1.64	82.30	
Mean	18.80	6.01	68.49	3.72	76.88	80.21

a/ Average number of budworm larvae per 100 buds.
b/ Mortality attributed to pesticide.
c/ Natural and pesticide mortality combined.
* Significant at the 0.01 level.

Table 3.--Foliage protection afforded by treatments applied when 90 percent of spruce budworm larvae were in the fourth, fifth, and sixth instars, Beaverhead National Forest, Montana, 1975

Treatment and block No.	Percent defoliation[a/]	Percent foliage saved[b/]
Check 1	88.95	
Check 3	83.00	
Check 9	94.14	
Carbaryl 2	39.91	41.40*
Carbaryl 6	36.47	43.40*
Carbaryl 8	66.11	18.00*
Mean		34.30*
Trichlorfon 4	44.26	36.39
Trichlorfon 5	60.30	20.35
Trichlorfon 7	66.90	13.75
Mean	57.15	23.49*

a/ Adjusted mean percent defoliation based on covariance analysis for each treatment and check block.

b/ Difference in percent defoliation between adjusted mean of all checks and individual sprayed block.

* Significant at the 0.01 level.

Table 4.--Summary of spray deposit data from cards placed beneath sample trees, Beaverhead National Forest, Montana, 1975

Treatment	Spray recovery Gallons/acre	Spray recovery Liters/hectare	Recovery (%)	Drops/cm^2	VMD (µm)
Carbaryl					
Block 2	0.12	1.12	24	10	223
Block 6	.43	4.02	86	25	279
Block 8	.38	3.55	76	21	282
Trichlorfon					
Block 4	.74	6.92	74	29	279
Block 5	.43	4.02	43	13	288
Block 7	.51	4.77	51	17	277

Spray deposit for carbaryl ranged from 0.12 to 0.43 gal/acre (1.12 to 4.02 L/hectare) with droplet VMD's ranging from 277 to 288 µms. Spray deposit for trichlorfon ranged from 0.43 to 0.74 gal/acre (4.02-6.92 L/hectare) with droplet VMD's ranging from 269 to 288 µms (Table 4).

Regressions of mortality over spray deposit in terms of mass recovery (gallons per acre) and drops per cm^2 show a trend toward increased mortality with increased deposit recoveries (Figs. 2-5). A mass recovery of 20% (0.1 gallon per acre) virtually assured in excess of 80% population reduction in the carbaryl treatments (Fig. 2). This trend was less evident in the trichlorfon plots as indicated by the lower coefficient of determination (R^2) for the regression models and with low mortality ($<$ 80%) occurring in some sample points that received the high spray deposits (Figs. 4-5).

Spray deposit data indicate inconsistencies in spray application over the treatment blocks. For example, in the carbaryl treatments, three sample points received less than 0.1 gallon per acre deposit and less than 10 drops per square centimeter with corresponding low insect mortality (Figs. 2-3). In addition, five clusters received in excess of 0.6 gal/acre deposit (Fig. 2). Since the targeted application rate was 0.5 gal/acre and an adequate recovery is considered to be ca. 20-40% of the total volume released, we must conclude that sample points received multiple applications of spray. A similar pattern exists in the trichlorfon treatments with many sample points receiving an excess of the intended 1 gallon per acre (Fig. 4-5). Improved application quality through use of more experienced pilots and guidance may have significantly increased overall insect mortality throughout the treatment blocks.

Analysis of formulated materials collected from mixing tanks was done by the U.S. Forest Service Insecticide Evaluation Project, with the following results:

Block number	Desired gm/L.	Actual gm/L.
	Carbaryl	
2	239.67	236.08
6	239.67	239.67
8	239.67	230.08
	Dylox	
4	119.84	112.89
5	119.84	116.83
7	119.84	119.84

Using traditionally acceptable criteria for judging efficacy, carbaryl and trichlorfon would not be considered satisfactory for a population reduction strategy against the western spruce budworm (< 3 insects/100 buds) although the carbaryl treatment approached this level. They would give satisfactory results for a foliage protection strategy where annual or biannual treatment was feasible.

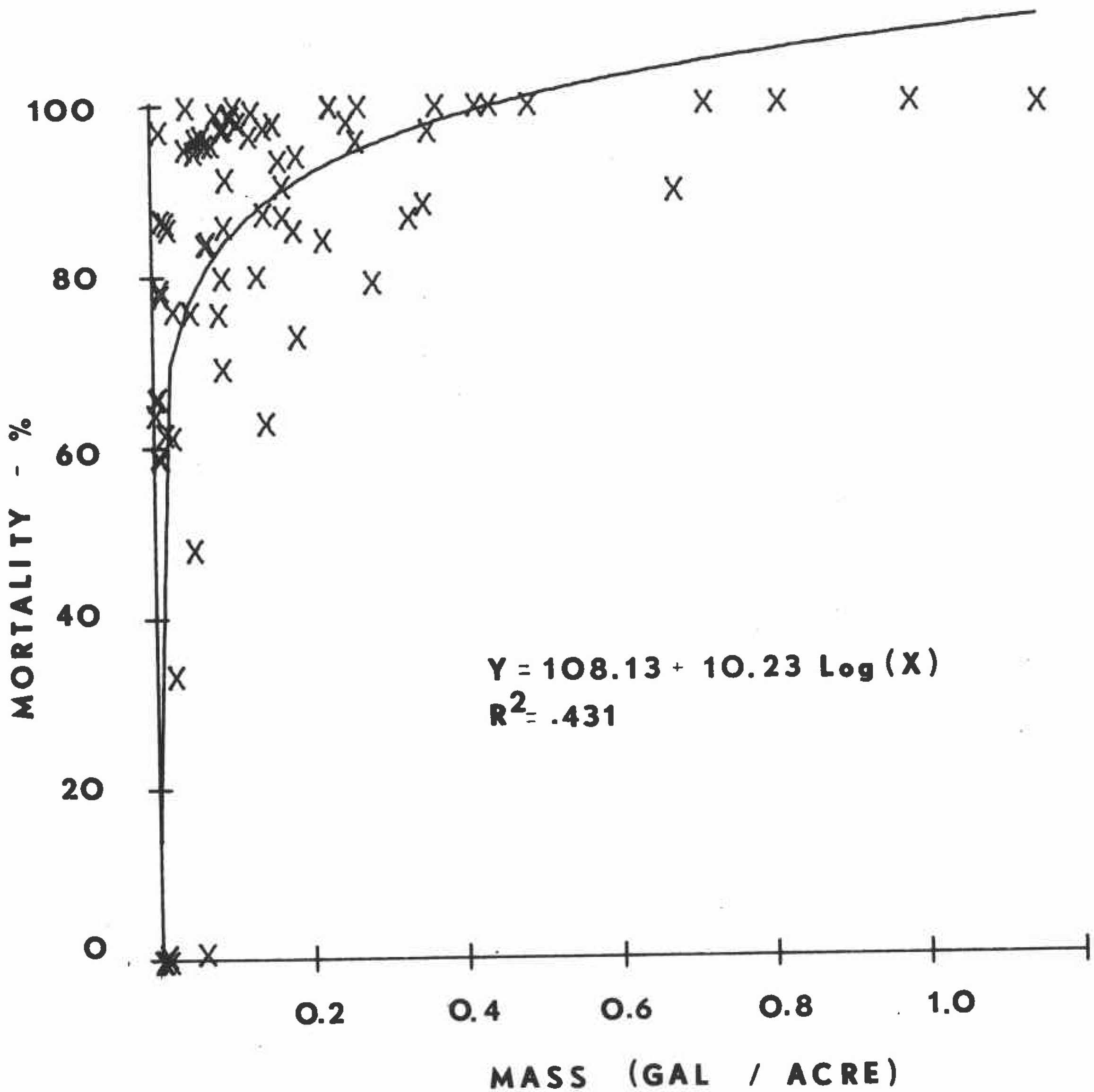

Figure 2.--Regression of carbaryl (Sevin 4-Oil) spray deposit (mass) on western spruce budworm larval mortality, Beaverhead National Forest, Montana, 1975.

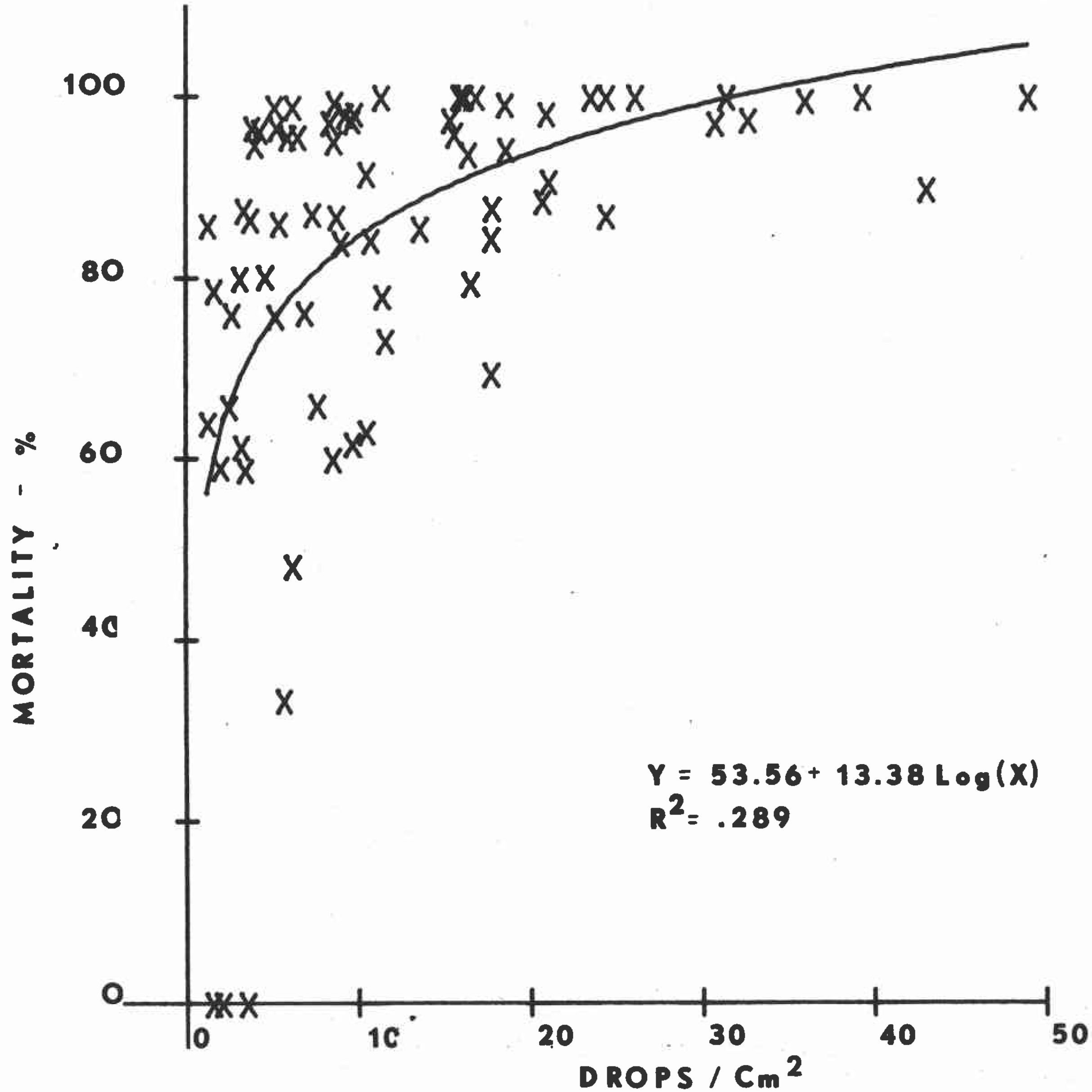

Figure 3.--Regression of carbaryl (Sevin 4-Oil) spray deposit (drops/cm^2) on western spruce budworm larval mortality, Beaverhead National Forest, Montana, 1975.

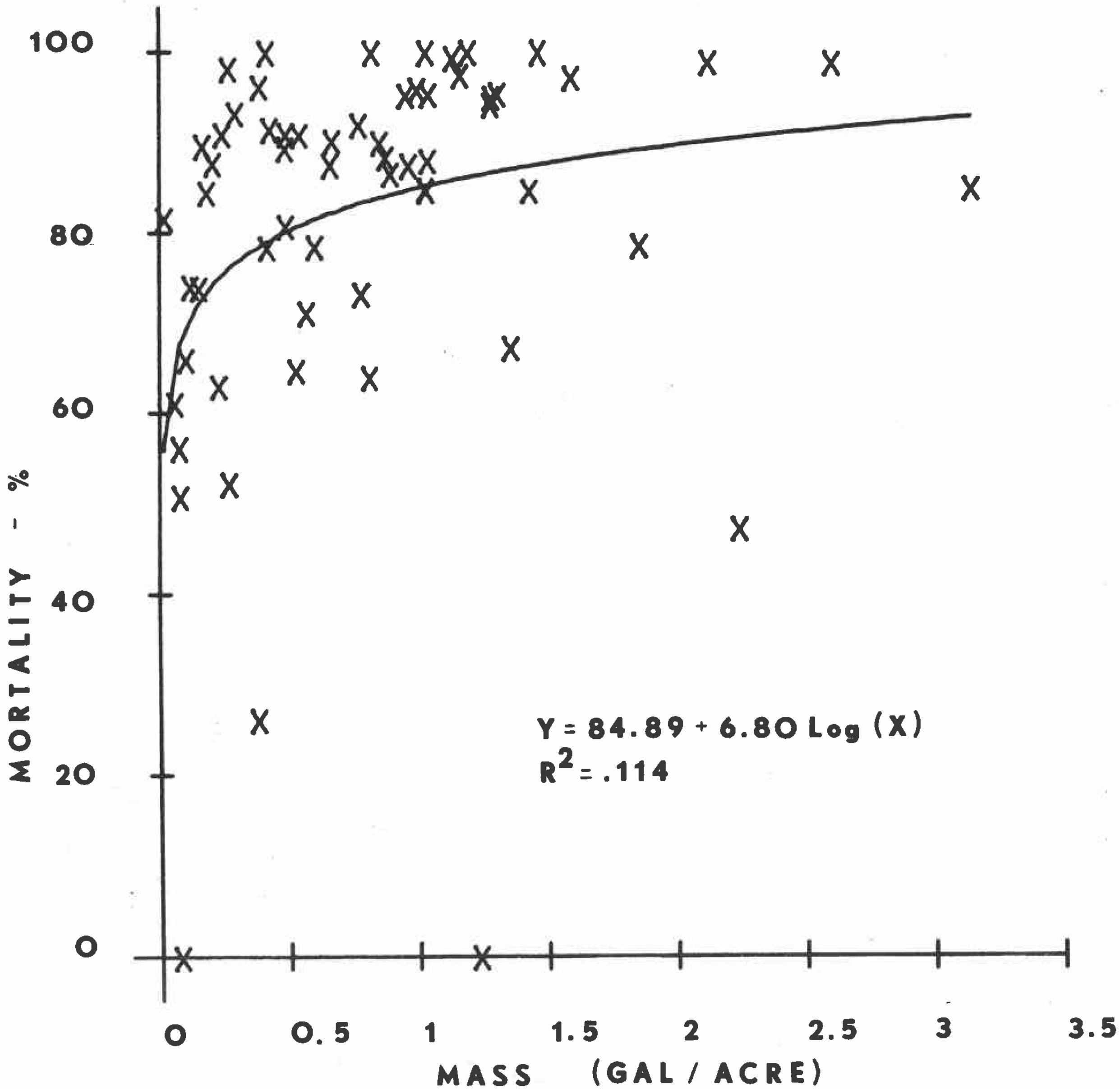

Figure 4.--Regression of trichlorfon (Dylox 4) spray deposit (mass) on western spruce budworm larval mortality, Beaverhead National Forest, Montana, 1975.

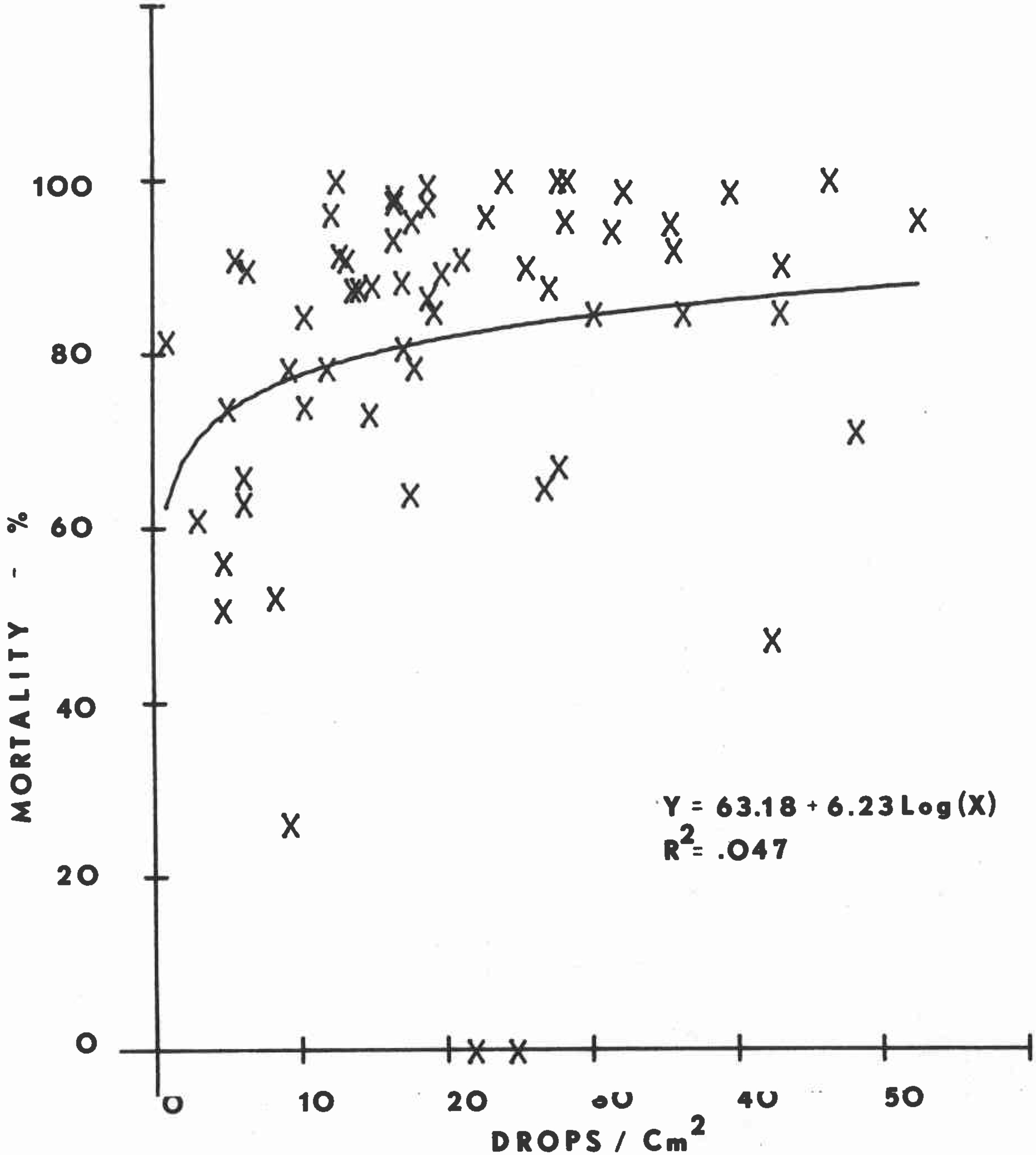

Figure 5.--Regression of trichlorfon (Dylox 4) spray deposit (drops/cm^2) on western spruce budworm larval mortality, Beaverhead National Forest, Montana, 1975.

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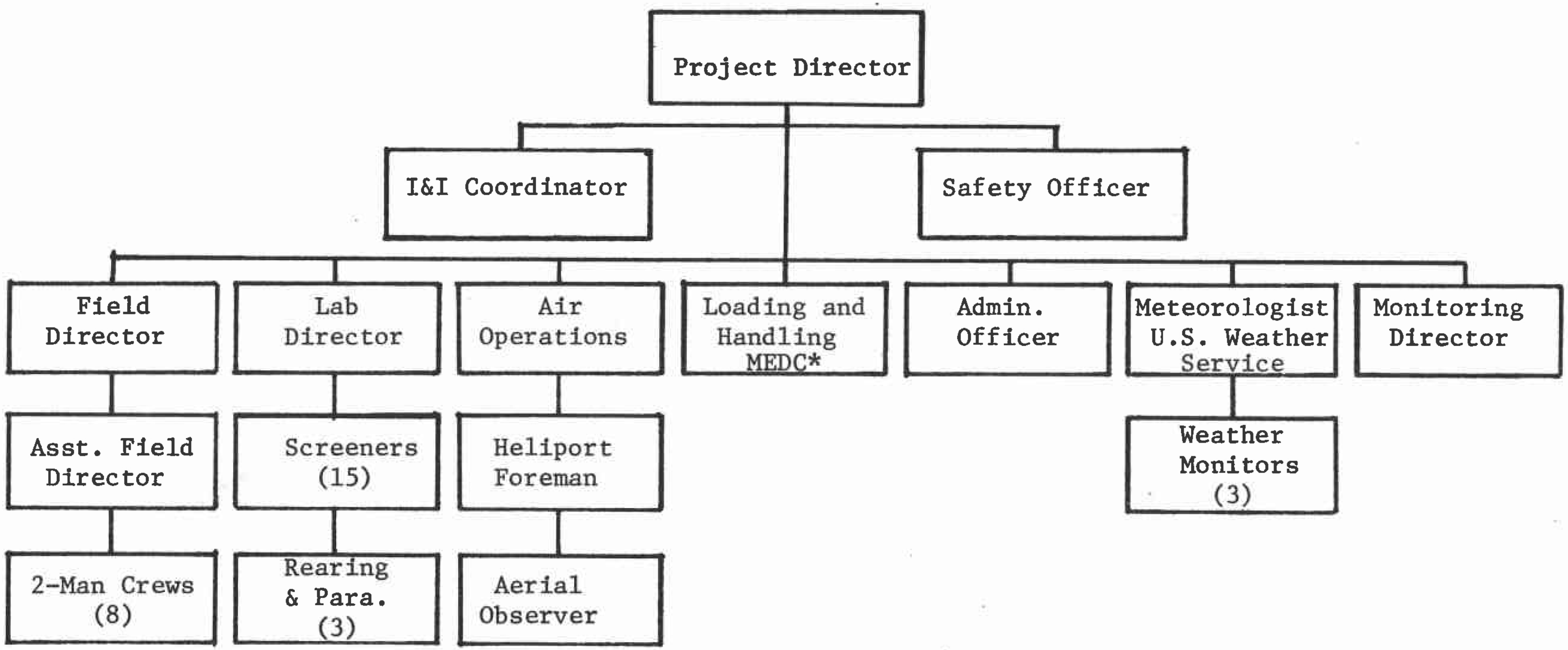
Organization chart for 1975 pilot control project (Beaverhead National Forest).



*Missoula Equipment Development Center

BLOCK 2: CARBARYL

Block 2 is an east-facing plot that South Meadow Creek passes through. The plot varies from barren south slopes to aspen groves in flat bottoms to dense north-slope draws.

The steep south slopes have a few small Douglas-fir and some 10- to 15-foot Rocky Mountain juniper. Most of the forest is on the ridge-tops, where Douglas-fir is present. The large open area is covered with 2-foot high sagebrush, which thins out as it approaches the forest. The forest itself has almost no understory. There are a few snowberry bushes but no understory exceeding 2 feet high. The forest has many small grass-covered openings.

The bottoms are much less uniform. Small draws are full of 3- to 4-foot tall shrubs, mostly snowberry, chokecherry, and serviceberry. Tall forbs such as lupine (*Lupinus* sp.) and balsamroot (*Balsamorhiza sagittata*) are common along the upper edges of the draws. Aspen clumps dot the bottoms, usually on the edges of meadows. Douglas-fir grows well in these bottoms, with a few reaching heights of greater than 100 feet. The forest is generally open, with large, widely-spaced trees.

The north- and east-slope forests are moderately dense Douglas-fir. There are many openings and almost no understory of any significance. A few clumps of snowberry are present, seldom reaching 3 feet tall. No small reproduction is evident, with only a few advanced reproduction. The canopy height is approximately 50 feet. The trees are widely spaced, with relatively wide crowns.

BLOCK 6: CARBARYL

Block 6 is on a steep north-facing slope along the Middle Fork of Warm Springs Creek. The ridge at the top of the plot is a sagebrush-covered flat. The draw at the bottom is a relatively open forest. Slopes of 70% are not uncommon between the ridge and the draw.

The draw is mesic, supporting large stands of aspen with a thick understory of sedges (*Carex* spp.). The area is full of springs which have produced boggy conditions over much of the area. Douglas-fir grows in thick stands with large fingers of openings protruding uphill.

Uphill from the draw the forest is very dense with thick stands of Douglas-fir and "doghair" lodgepole pine. Very little understory is present under the canopy itself. Some rose (*Rosa* sp.) and snowberry are scattered around, but they seldom form large clumps. Grasses and forbs are short.

The small draws near the ridge are dense, moist areas. Spruce is dominant here, with their 40-foot high crowns extending to ground level. Understory is thick, almost impassable. The shrubs range from 3 to 4 feet tall. Whenever an opening occurs, sedges and tall forbs completely occupy the site. Deadfall covers the ground in some spots.

Just below the open ridge, the forest reverts back to Douglas-fir and lodgepole pine. The forest floor is nearly bare of shrubs; even the remaining snowberry is rarely taller than 2 feet. The forest canopy ranged from 40 to 50 feet high, with large thick crowns.

BLOCK 8: CARBARYL

Block 8 is on the eastern end of Johnny Ridge. It contains a relatively flat bench on the ridgetop and a steep north and south slope.

The ridgetop has an east aspect with a slope of 15 to 20%. Many small openings occur in the forested area. The forest has a fairly open canopy with little understory. Snowberry and rose are found under the canopy over the whole plot. These shrubs are not in large clumps but are scattered over the plot. There is nothing taller than 2 feet except dead reproduction and full-grown trees.

The forest is much denser in a few places, mostly on the north slopes. There is virtually no understory over 1 foot tall in these areas.

Large openings on the ridge have very thick patches of big sagebrush and balsamroot. Reproduction of Douglas-fir is moderate along the edges. A few small limber pines are also on the edges of the openings.

BLOCK 4: TRICHLORFON

Block 4 is on an east-facing slope above Timber Creek on the west side of the Gravelly Range. The plot is on a moderate slope of about 20 to 25%. A large open area of sagebrush occupies the lower portion of the plot. Several small streams run across the plot to Timber Creek. Along the ridges between the streams, fingers of Douglas-fir and lodgepole pine jut into the open area.

The forested area is dotted with many small openings. These openings generally have several small Douglas-fir saplings and thick stands of snowberry, common juniper, buffaloberry, and big sagebrush. Several tall forbs are also dense in the openings.

The forest itself is quite open, with very little understory. Reproduction is slight, with most of the reproduction stagnating at about 12 feet high. The understory is mainly snowberry about 2 feet high and grasses and forbs, seldom exceeding 1.5 feet. The forest canopy is open with a few dense thickets. Generally the trees are less than 40 feet high with narrow crowns. Clumps of aspen are located throughout the forest, usually near openings.

In some of the more protected microsites thickets of dense narrow-crowned Douglas-fir about 45 feet high have nearly eliminated all understory. On these sites the litter is a thick mat of needles.

BLOCK 5: TRICHLORFON

Block 5 is an extremely steep plot on the south side of the Cherry Gulch drainage. The plot, which has an elevational change of 1,600 feet, has two major drainages, both flowing north.

One drainage contains a huge sagebrush-covered hillside completely bare of trees. Near the ridge the forest starts abruptly. Some big sagebrush grows on the forest edge. At the edge of the forest limber pine (*Pinus flexilis*) is the most frequent tree. Deeper into the forest Douglas-fir is dominant, with substantial numbers of Engelmann spruce and limber pine. Openings in the forest canopy are surrounded by limber pine and a few lodgepole pine. Both pines have very thin crowns. The limber pine crowns are high and wide but consist of only a few rather barren branches. The forest understory is very sparse. Grass and forbs rarely exceed 1 foot high. Buffaloberry and snowberry are the major shrub species. They are quite scattered and in very thin stands, even in the openings. Big sagebrush is found in the edges of the openings, but seldom throughout the openings.

The other drainage is more heavily forested. The bottom is open, with thick snowberry dominating the site. Patches of 25- to 30-foot aspen are on both sides of the draw. Advancing into the forest to the west of the draw, the dominant tree is Douglas-fir, with some lodgepole pine surrounding the openings. The forest is not densely stocked, with about 250 to 300 trees per acre. The understory is fairly thin, with a few large, thick patches of snowberry in the openings. This slope has a lot of very young Douglas-fir, most of it less than 3 feet tall.

BLOCK 7: TRICHLORFON

Block 7 runs north-south along the South Fork of Warm Springs Creek. The majority of the plot is on the east-facing slope, a slope of 35 to 70%.

The bottomlands are very open and very dry. Long, narrow patches of aspen follow the minor drainages. A few small patches of Douglas-fir are found in the bottoms. There is virtually no understory on the bottom; whatever might grow is knocked down by very heavy cattle grazing. A few patches of big sagebrush remain, generally in large openings. Reproduction of Douglas-fir is widespread but not thick. The upper part of the draw has Engelmann spruce as the dominant tree species instead of Douglas-fir.

The east slope is very dry with many rock outcrops and patches of bare ground. Aspen occur in almost all small draws. The openings have much big sagebrush and other shrubs. Rocky Mountain juniper is found in all the openings, sometimes reaching 15 feet high.

The forested parts of the slope are covered by a dense stand of Douglas-fir. Understory is very slight in these stands. Rose, snowberry, and buffaloberry are all in the understory, but seldom exceed 1.5 feet high. The canopy cover is dense, caused not by the large size of the crowns but by the number of small crowns.

Along the ridge the forest thins out, with big sage and some tall bunchgrasses filling in between the trees.

EFFECT OF TRICHLORFON (DYLOX 4) AND CARBARYL (SEVIN 4-OIL) ON PARASITES OF THE WESTERN SPRUCE BUDWORM

by

Scott Tunnock

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METHODS

Assessment of the insecticide's effect on the level of budworm parasitism was made by rearing budworm larvae collected during the population sampling. Up to 30 larvae per tree per sample period were taken from branch samples and placed in plastic Petri dishes (10 larvae per dish) with artificial food (McMorran, 1965). Each dish was labeled to identify sampling period, block, cluster, and tree. Food material was changed as needed, generally about once every 5 to 7 days. As parasites emerged, they were placed individually in No. 000 gelatin capsules which were labeled the same as the Petri dish. After parasite emergence was completed, they were identified to genera and counted. Representative specimens of each group were submitted to the Agricultural Research Service Insect Identification and Beneficial Insect Introduction Institute for positive identification.

Data were summarized by cluster and anlyzed using covariance analysis to determine if changes had occurred in the level of budworm parasitism from prespray to postspray samples.

RESULTS

Twelve species of parasites listed below were identified by the U.S. National Museum. *Glypta fumiferanae* (Vier.) was the most abundant parasite, followed by *Apanteles fumiferanae* (Vier.) (Table 1).

Diptera
- Tachinidae[1/]
  - *Ceromasia auricaudata* Tns.
  - *Madremyia saundersii* (Will.)

Hymenoptera
- Ichneumonidae[2/]
  - *Glypta fumiferanae* (Vier.)
  - *Phaeogenes hariolus* (Cr.)
  - *Enytus montanus* (Ash.)
  - *Mesochorus tachypus* (Holm.)
  - *Ephialtes ontario* (Cr.)
  - *Itoplectis quadricingulata* (Prov.)
  - *Temelucha* sp.
- Pteromalidae[3/]
  - Pteromalini
- Braconidae[4/]
  - *Apanteles fumiferanae* Vier.
  - *Meteorus trachynotus* Vier.

1/ Determined by C. W. Sabrosky, U.S. National Museum
2/ Determined by R. W. Carlson, U.S. National Museum
3/ Determined by G. Gordh, U.S. National Museum
4/ Determined by P. M. Marsh, U.S. National Museum

Total parasitism on the nine plots ranged from 11.4% to 22.9%, the highest being Plot 7. Out of 28,710 budworm reared, 4,398, or 15.3%, were parasitized (Table 1).

Parasitism by *Glypta* sp. increased from the prespray samples to the 14-day postspray samples on all plots. Parasitism by *Apanteles* sp. stayed about the same during the three sample periods on check plots, increased after 14 days on Sevin plots, and decreased after 14 days on Dylox plots. Tachinids were more abundant in 14-day postspray samples because they attack later instars (Table 2).

Total parasitism increased from the prespray samples to the 14-day postspray samples on the check, Sevin, and Dylox plots (Table 2). T-tests were run on total percent parasitism during the 14-day postspray samples between check plots and spray plots and between spray plots. There was a significant difference at the 99% level between Sevin versus check and Sevin versus Dylox, but no difference between Dylox versus check. This indicated parasitism was significantly higher (31.9%) in the Sevin plots during the 14-day postspray period. Carbaryl would appear to have a differential effect on parasitized and nonparasitized larvae; i.e., parasitized larvae being less active may be less likely to contact the insecticide during feeding.

In summary, the application of Sevin and Dylox to the forest environment did not adversely affect the degree of parasitism; in fact, percent parasitism was higher 14 days after spraying on the treated areas than in the checks.

Table 1.--Western spruce budworm parasite complex in check and spray plots during 1975 pilot test.

Parasites	Plot No. 1			2			3			4			5			6			7			8			9			Total No.	Total No. Hosts	Per-cent
	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%	No.	No. Hosts	%			
Hymenoptera																														
Glypta	921		12.1	229		10.8	478		9.7	293		8.8	241		11.1	144		10.6	169		15.9	198		8.3	376		10.1	3,049		10.6
Apanteles	169		2.2	62		2.9	78		1.6	57		1.7	52		2.4	73		5.4	48		4.5	79		3.3	115		3.1	733		2.5
Phaeogenes	1		0.0	3		0.1	2		0.0				2		0.1										13		0.3	21		0.1
Meteorus							2		0.0																			2		0.0
Mesochorus																1		0.1										1		0.0
Enytus							1		0.0							1		0.1										2		0.0
Ephialtes	1		0.0																									1		0.0
Itoplectis																									1		0.0	1		0.0
Unrecognizable	146		1.9	40		1.9	97		1.9	23		0.7	28		1.3	27		1.9	18		1.6	30		1.2	24		0.6	433		1.5
Diptera																														
Tachinids	19		0.2				37		0.7	7		0.2	11		0.5	3		0.2	8		0.7				70		1.8	155		0.5
TOTALS	1257	7,630	16.5	334	2,117	15.8	695	4,942	14.1	380	3,343	11.4	334	2,160	15.5	249	1,355	18.4	243	1,059	22.9	307	2,395	12.8	599	3,709	16.1	4,398	28,710	15.3

Table 2.--Average percent parasitism during prespray and postspray periods in check plots and plots sprayed with Sevin and Dylox in 1975.

Parasites	Percent parasitism								
	Check			Sevin			Dylox		
	Pre-spray	Post-spray 7 days	Post-spray 14 days	Pre-spray	Post-spray 7 days	Post-spray 14 days	Pre-spray	Post-spray 7 days	Post-spray 14 days
Glypta	8.0	13.3	10.0	5.7	12.1	18.1	9.5	12.0	13.4
Apanteles	2.7	2.4	2.3	3.1	6.1	6.7	3.4	3.9	2.1
Tachinids	.1	.8	1.5	.1	.1	1.8	.2	.1	.5
Others	.8	.9	2.7	1.4	1.8	5.3	.5	1.5	2.2
Total	11.6	17.4	16.5	10.3	20.1	31.9	13.6	17.5	18.2

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McMorran, Arlene M. 1965. A synthetic diet for the spruce budworm *Choristoneura fumiferana* Clem. (Lepidoptera: Tortricidae). Can. Ent. 97(1): 58-61.

EFFECTS OF SPRUCE BUDWORM CONTROL

ON POLLINATING INSECTS

For: U.S.D.A. Forest Service
Region 1
Missoula, Montana 59801

January 29, 1976

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I. Summary

The impact of a spruce budworm spray program using Carbaryl (Sevin) and Trichlorfon (Dylox) on flower pollination was studied in southwestern Montana during July, August, and September of 1975, The results included the following:

1. A large number of insect species contribute to the pollination of flowering plants in the study area, with the honey bee playing a minor role. The various species of bumblebees were the most common pollinators.

2. No significant difference in bee densities was observed when the numbers collected per unit trap effort on control sites were compared with those on spray sites.

3. A significant reduction in small bees (including the families Megachilidae, Adrenidae, Halictidae, and Colletidae) as a percentage of total bee pollinators was observed in two of the Trichlorfon-treated sites for the latest collection period.

4. No consistent reduction in small bees as a percentage of total bees was observed in the Carbaryl-treated sites.

5. Snowberry (*Symphoricarpos oreophilus*) fruit production was significantly lower on all spray sites than on the control sites. Consistent reductions in fruit production on the sprayed areas were not observed for any other plant species.

6. With the exception of some species of Compositae fruit or seed production is benefited by adequate numbers of pollinating insects. This conclusion is supported by our study and a review of the literature.

Other subjects considered in this report include the effectiveness of various insect trapping techniques, relative coverage of the flowering plant species and vegetation types of the study sites, flowering phenology of the common flowering species, variability in the flowering canopy coverage of the various sites, and correlations between the vegetation studies and the bee studies. Recommendations are included in the discussion section which suggest other aspects of the pollination ecology that should be investigated in future monitoring studies.

II. Introduction

We conducted a study during the summer of 1975 in southwestern Montana to determine the impact of a spruce budworm spray program using the compound Sevin (Carbaryl) and Dylox (Trichlorfon), on the primary pollinating insects. In conjunction with the insect study, we surveyed vegetation to determine whether seed or fruit production was affected by the spray. We also studied the dominant flowering plants to determine whether they depend on insects for successful pollination.

This report contains the results of these studies, and a review of the pertinent literature on insect pollination of flowering plants. We have discussed the implications of the results and problems encountered in the study, and have included suggestions for future studies.

III. Literature Review

The ecology of the pollination of flowering plants by insects has received increased attention in recent years. As much as 15% of our country's food supply may come from plants requiring insect pollination, and insect-requiring legumes are very important to the beef and dairy industries (McGregor, 1973). The importance of insect pollination to wildlife is also stressed by McGregor (1973), who states, "Without insect pollination to produce the fruits, berries and seeds of non-cultivated plants, essential to a well-balanced wildlife population, many forms of wildlife also would disappear."

The symbiotic relationships between pollinating insects and wild and cultivated plants have been widely researched (Bohart and Todd, 1961; Grant, 1950; Nye, 1971; Free, 1970; and Macior, 1974). The co-evolution of floral structure and development with insect behavior has been such that many plants are obligately or facultatively dependent on pollinators for successful sexual reproduction; the pollinating insects in turn, are dependent on the plant for pollen and nectar. Free (1970) discussed the role of pollinating insects in fruit and seed production in agricultural crops. He distinguished between plants that require pollinating insects and those that reproduce to some extent without the aid of insects. In almost all situations, seed and fruit production is greatly enhanced if pollinating insects are plentiful. Non-cultivated flowering plants also appear to be heavily dependent on insect pollinators. Macior (1974) studied 29 species of flowering plants in the Rocky Mountains of Colorado and found that 27 of them were highly dependent on pollinating insects for seed production. Many of those species are also found in our study area. Mosquin (1971) found that many of the species occurring in the northern Rocky Mountain area near Banff required pollinators. He concluded that during the peak of flowering the number of pollinators is inadequate, and the plants are actually competing for pollinators. Fryxell (1957) compared reproductive systems in flowering plants and concluded that Composites are less likely to require cross pollination.

The impact of insecticides on beneficial forest insects has received some study. The effects of various Tussock moth control treatments on beneficial insects are currently being investigated in parts of Idaho and Oregon by Washington State University.[1] A detailed study on the impact of Malathion on a forested watershed in Ohio was conducted by Giles (1970). The study showed that arthropod populations decreased after spraying, but then recovered

[1]Personal communication, U.S. Forest Service, July, 1975.

rapidly; arthropod community structure, however, continued to be altered. The study did not specifically discuss the impact of Malathion on pollinating insects.

Johansen (1972) conducted toxicity tests of many commonly used pesticides, including Carbaryl and Trichlorfon (the pesticides used on our study area). Johansen reported that residues appeared to be highly toxic when 80% Carbaryl was applied at the rate of 1 lb. per acre, even when the residues had field-aged for 2 days. The tests indicated that in general the smaller bees, such as the alkali bee, *Nomia melanderi* (Family Halictidae), and the alfalfa leafcutter bee, *Megachile rotundata* (Family Megachilidae), were more susceptible to Carbaryl than were the honey bee, *Apis mellifera*, or the bumblebee, *Bombus centralis* (Family Apidae).

The insecticide Trichlorfon (80%) applied at the rate of 1 lb. per acre was generally less toxic than Carbaryl, but it did cause significant mortality after 3 hours in all groups of bees. The smaller bees were less sensitive to this insecticide. The results indicated that the toxicity of various insecticides was strongly related to bee size. Usually insecticides are more toxic to small bees than to large bees. However, Trichlorfon is an exception in that it is more toxic to the honey bees and bumblebees than to the smaller bees. Ahmad and Johansen (1973) later confirmed this difference in toxicity by directly applying Trichlorfon and Carbaryl to honey bees and the alfalfa leaf cutting bees.

Johansen and Brown (1972) reported that Carbaryl can cause severe damage to commercial bee operations. Contaminated pollen can be returned to the hives and result in heavy mortality of larvae and newly emerged adults. The toxicity of Carbaryl-contaminated pollen to beehives was also established by Moffet *et al*. (1970).

In summary, the insecticides used on our study area have been established as being toxic to honey bees and native pollinating insects. The effects of spray application of Trichlorfon and Carbaryl for spruce budworm control on populations of native pollinating insects has not been previously reported in the literature we have reviewed.

IV. Pollinator Insect Study

A. Methods and Materials

1. Site locations.

This study was conducted at sites established by the U.S. Forest Service for treatment with Trichloron and Carbaryl in the Tobacco Root and Gravelly Mountains of southwestern Montana. The locations of the six spray sites and three control sites are depicted in Figures 1 and 2. Subplot locations within each of the sites are also depicted in these maps. The subplots indicate the locations of the drop traps, which we used to capture most of the insects in this study.

We selected two control sites which were different from those established by the Forest Service (F.S.). Our initial examination of one F.S. control area indicated heavy utilization by cattle and destruction of most of the flowering plants by grazing or trampling. The other site was at a lower altitude and had a flora quite dissimilar from that of the selected spray sites. We selected site 9 as a control site for spray sites 4, 6, and 7, while we chose site 3 as a control site for spray sites 5 and 8. Figures 3 (Site 2), 4 (Site 6), and 5 (Site 7) reveal the landform and general vegetative cover of the different study sites.

2. Trap Type Description.

To insure a representative sample of the many species of pollinating insects present in the study area, several trap designs were employed.

Sticky traps (Figures 6 and 7) based on the design of Williams (1973) were used with Tack Trap as a catching agent. Insects were removed weekly by use of a solvent to dissolve the Tack Trap. The traps were collected the final time by wrapping them with cellophane. The collected insects were then identified with a variable power binocular microscope.

Sweep nets were used throughout the study to collect pollinating insects directly from the flowers on which they were foraging. We kept records of time spent collecting and in some cases we recorded the flower species on which the insects were captured. This was done to compare the effectiveness of sweep netting with that of the other trapping techniques.

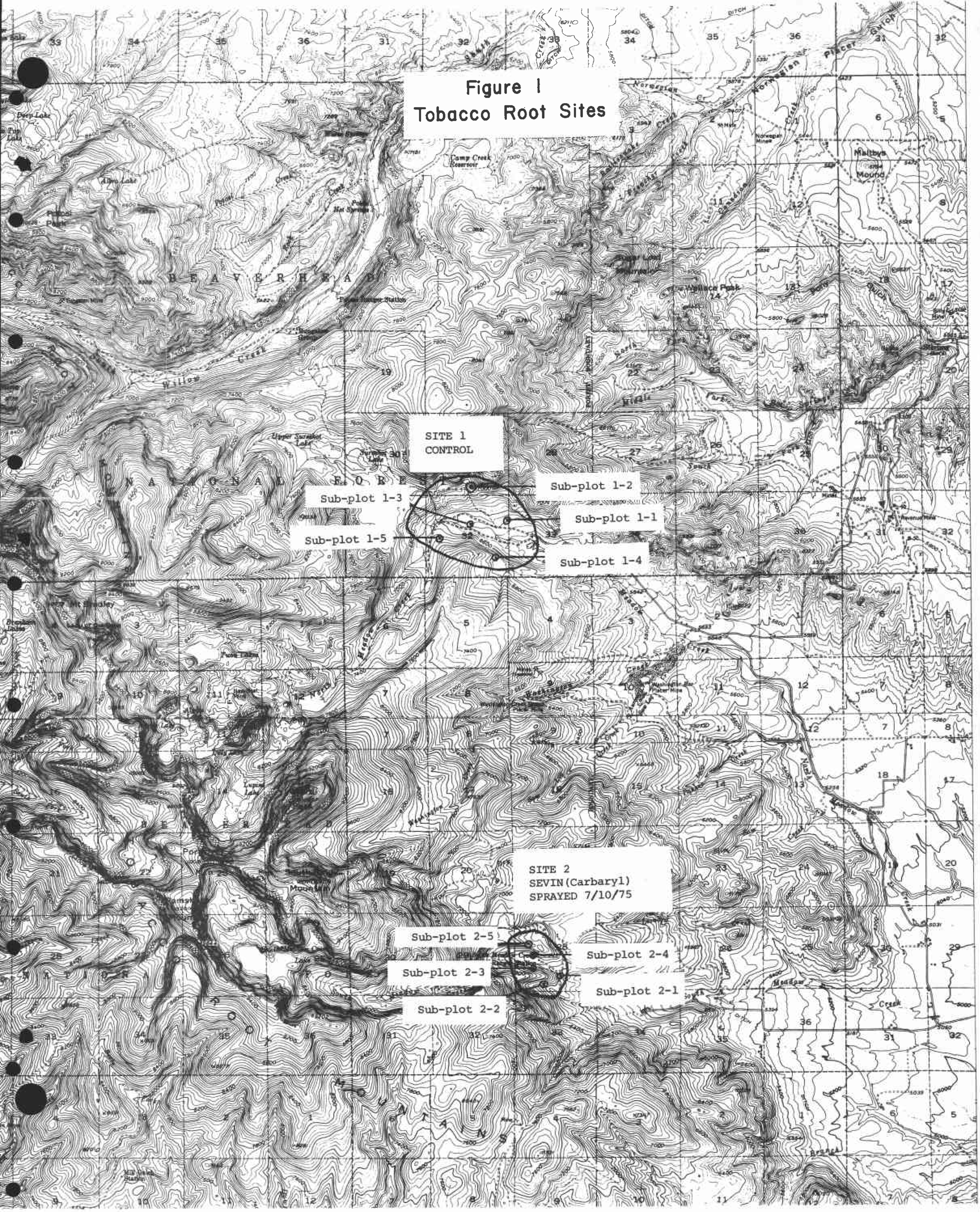


Figure 1
Tobacco Root Sites
SITE 1
CONTROL
Sub-plot 1-2
Sub-plot 1-3
Sub-plot 1-1
Sub-plot 1-5
Sub-plot 1-4
SITE 2
SEVIN (Carbaryl)
SPRAYED 7/10/75
Sub-plot 2-5
Sub-plot 2-4
Sub-plot 2-3
Sub-plot 2-1
Sub-plot 2-2

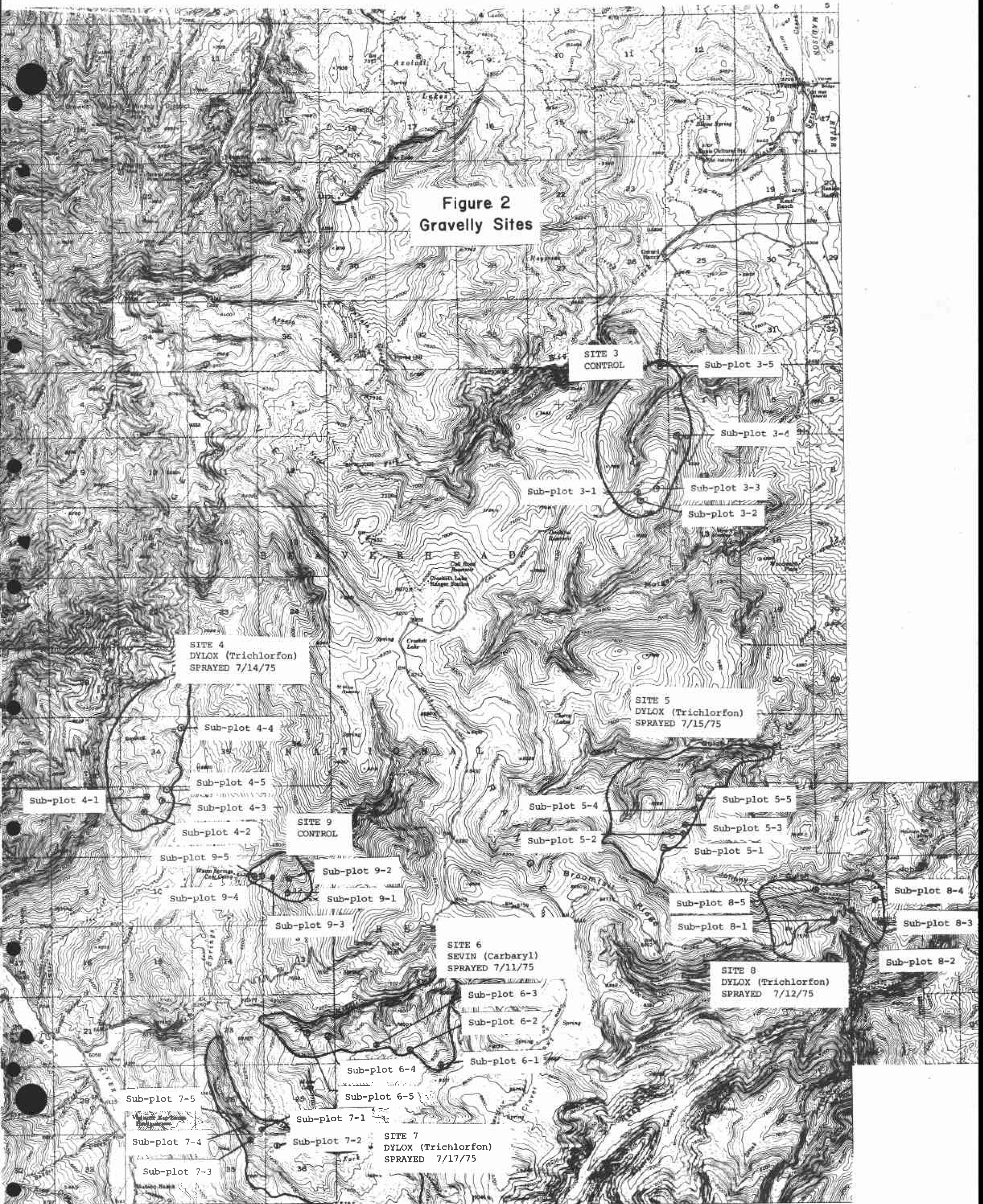


Figure 2
Gravelly Sites
SITE 3
CONTROL
Sub-plot 3-5
Sub-plot 3-4
Sub-plot 3-1
Sub-plot 3-3
Sub-plot 3-2
SITE 4
DYLOX (Trichlorfon)
SPRAYED 7/14/75
Sub-plot 4-4
Sub-plot 4-5
Sub-plot 4-1
Sub-plot 4-3
Sub-plot 4-2
SITE 5
DYLOX (Trichlorfon)
SPRAYED 7/15/75
Sub-plot 5-5
Sub-plot 5-4
Sub-plot 5-3
Sub-plot 5-2
Sub-plot 5-1
SITE 9
CONTROL
Sub-plot 9-5
Sub-plot 9-2
Sub-plot 9-4
Sub-plot 9-1
Sub-plot 9-3
Sub-plot 8-4
Sub-plot 8-5
Sub-plot 8-1
Sub-plot 8-3
Sub-plot 8-2
SITE 8
DYLOX (Trichlorfon)
SPRAYED 7/12/75
SITE 6
SEVIN (Carbaryl)
SPRAYED 7/11/75
Sub-plot 6-3
Sub-plot 6-2
Sub-plot 6-1
Sub-plot 6-4
Sub-plot 6-5
Sub-plot 7-5
Sub-plot 7-1
Sub-plot 7-4
Sub-plot 7-2
Sub-plot 7-3
SITE 7
DYLOX (Trichlorfon)
SPRAYED 7/17/75

Figure 3. Site 2 showing south facing slope with scattered Douglas fir and big sage.

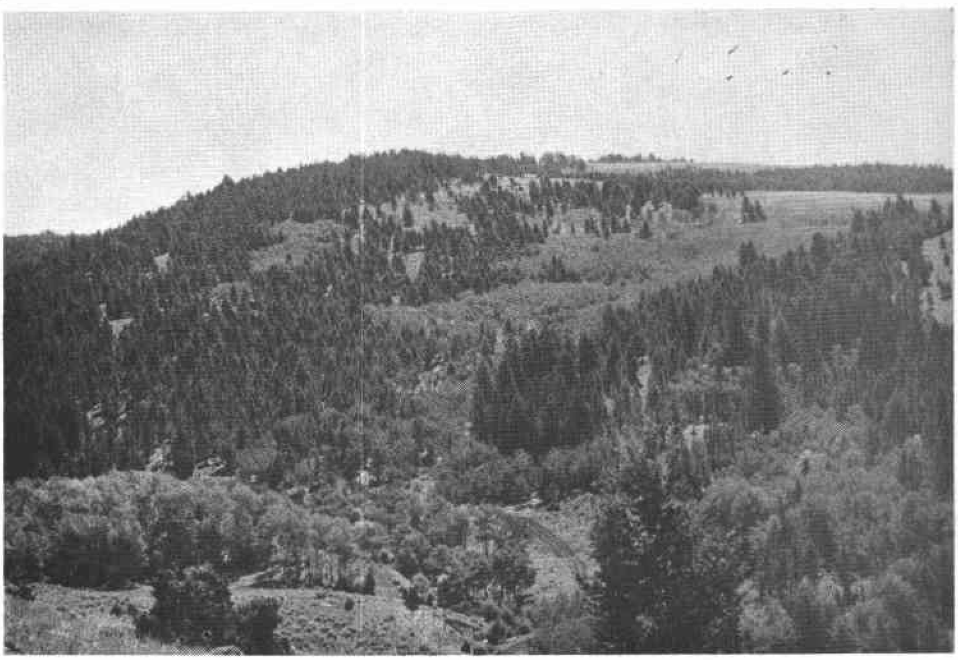


Figure 4. Site 6 showing north facing slope with Douglas fir and aspen.

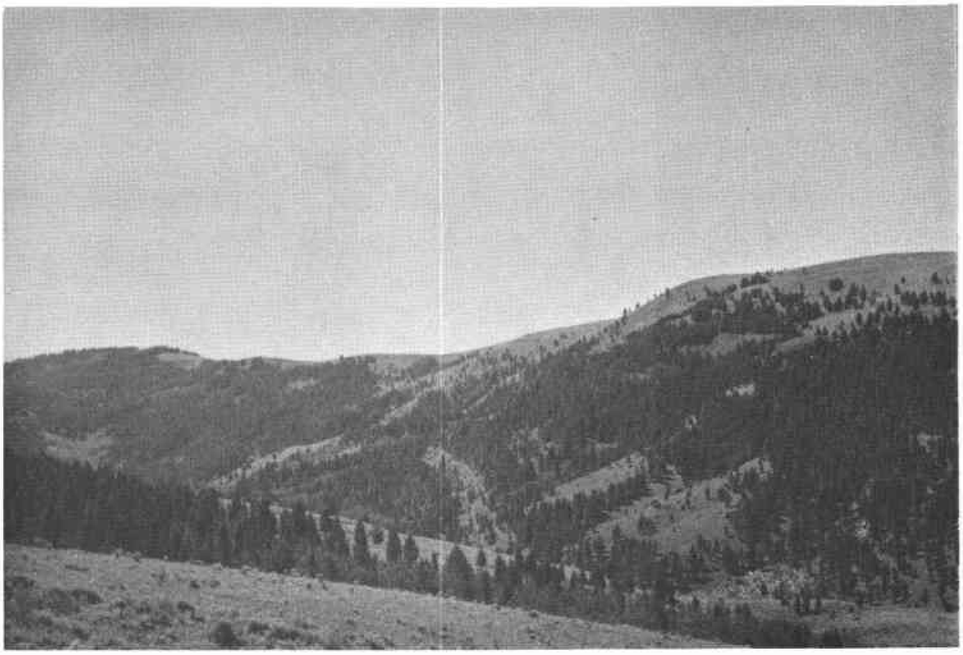


Figure 5. Site 7 showing northeast facing slope with Douglas Fir and meadows.

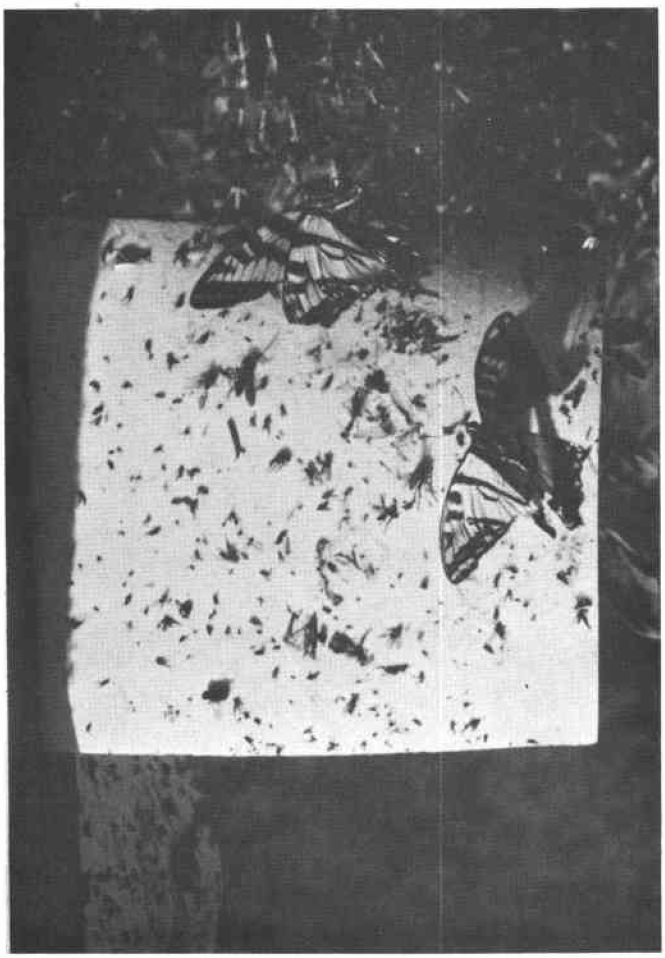


Figure 6. Sticky trap with various insects attached.

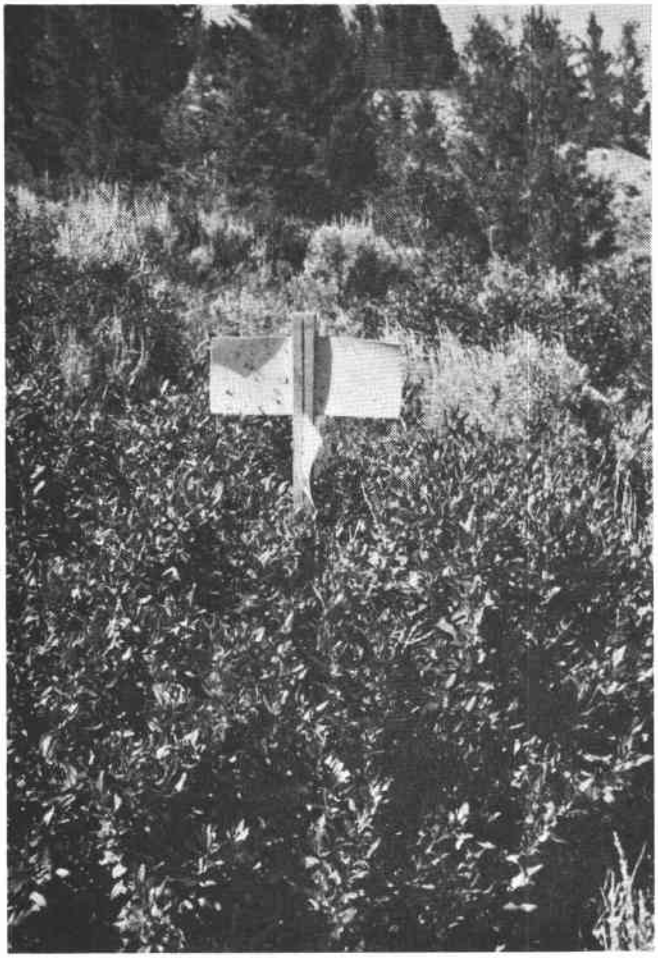


Figure 7. Sticky trap typically placed in forest clearing.

Figure 8. Malaise trap located in dense stand of Helianthella uniflora.

A molasses trap was used initially to collect insects. Giles (1970) described this trap type and reported it to be particularly effective in capturing bees. The trap consists of a one-gallon plastic bucket containing a 10:1 solution of molasses and water. The trap was suspended 6 to 7 feet above the ground to avoid damage from bears or livestock.

Malaise traps were installed at three of the experimental sites (Sites 3, 4, and 8). These were placed in heavy stands of Helianthella uniflora (Figure 8), and samples were removed on a weekly basis.

A light trap was employed for a short time during the early part of the study. The trap had a lantern as a light source and was similar in design to the trap described by Oldroyd (1958). This was ineffective and was discontinued after little use.

Drop traps were relied on to catch most of the insects during the study. The trap was designed following suggestions from researchers at the Agricultural Experiment Station, Montana State University, Bozeman.[2] Each trap (Figure 9) consisted of a white, plastic, cone-shaped, disposable coffee cup with the bottom removed. This was inserted into the mouth of a 14-ounce disposable plastic beverage cup and held in place with tape. The cup was buried, leaving only the upper inch above ground. The elevated lip of this trap was intended to exclude non-flying insects. Approximately 1 inch of water was added to the cup after installation. At about 10-day intervals, the insects were removed and preserved in alcohol for further analysis. Two of these traps were initially installed at each of the subplots at all sites. Later, two more were added at each subplot to insure an adequate insect sample. The number of insects captured per trap day was calculated during analysis. Traps tipped over by cattle or wildlife were salvaged when possible and were considered to have been in place for half the sampling period. Destroyed or tipped samplers that contained no insects were not included in the data analysis.

3. Data Analysis

a. Taxonomy

Insects collected were generally preserved in 80% alcohol in the field, although some of the sweep net and Malaise trap samples were pinned and mounted. Alcohol preservation of the samples was necessary for

[2] Personal Communication with the Agricultural Experiment Station, MSU, Bozeman, Mt. June, 1975.

Figure 9. Drop trap in place at a typical site location.

efficient handling, but often altered the specimens so that identification to species was difficult. Because of this, most specimens were identified to genus only. All insects collected were recorded and their numbers listed. Insects of the orders Lepidoptera, Coleoptera, Diptera, and Hymenoptera were classified as primary or secondary pollinators based on literature review and amount of pollen observed on them during the early part of the study. The families Apidae, Anthophoridae, Halictidae, Adrenidae, Colletidae, and Megachilidae in the order Hymenoptera were considered primary pollinators. A single species of beetle of the family Cleridae, Trichodes ornatus, was also considered a primary pollinator because of the large amounts of pollen attached to its body and its common occurence on flowers in the study area. The families Pericopidae, Sphingidae, Satyridae, Lycaenidae, Nymphalidae, Papilionidae, and Pieridae in the order Lepidoptera were considered secondary pollinators. The dipteran families Syrphidae and Bombyliidae were also considered secondary pollinators. Our classification system is supported by the data of Nye and Anderson (1974), with the exception of individual genera within families. These authors considered the genus Hylaeus of the family Colletidae to be a secondary pollinator, and the genus Eristalis of the family Syrphidae to be a major pollinator. Thrips (Order Thysanoptera) also are pollinators but were not collected by the techniques used during this study. Some specimens of this order were collected from a flower that was preserved in alcohol for pollen analysis. These forms probably occur commonly on many of the flowering plants in the study area, but their importance as pollinators could not be evaluated.

Identification to genus and species was performed using several taxonomic references. The Hymenoptera were identified to genus and occasionally species using the two volume reference by Mitchell (1960; 1962). Because these volumes concern the bees of the eastern United States, some of the western genera occurring in the study area may not have been included in this key and consequently could have been incorrectly identified.

Members of the family Megachilidae were the most difficult to identify to genus. The genus Ashmeadiella was grouped with the genus Osmia and possibly other genera were included inadvertently. Members of the genus Bombus were identified to caste but could not be consistently identified to species. Specimens of the genus Psithyrus were identified to sex but not to species.

Identifying most insects to the species level would have meant submitting specimens to a taxonomic expert working in each of the groups being considered. Data were analyzed at the family level or above to insure adequate sample size.

The dipteran families Syrphidae and Bombyliidae were identified to genus using the key of Cole (1969). The beetles were identified using the taxonomic key of Hatch (1961). The Lepidoptera were identified using the descriptions of Holland (1931; 1968) and the keys of Elrod (1906) and Hodges (1971).

b. Mathematical Analysis

Tests of significance between the mean bee density at each site were conducted using standard T test statistics (Arkin and Colton, 1967). Where appropriate, the test was corrected for small sample sizes.

When it was necessary to group site data for evaluation of overall effects of the spray treatment on the study area, each site was treated as a randomized stratified sample and standard errors were calculated using the formula:

$$S_{\bar{x}} = \sqrt{\frac{\sum_{i=o}^{s} \left(N_i^2 \; S_{\bar{x}_i}^2\right)}{N^2}}$$

where

$S_{\bar{x}}$ = standard error of the mean of a stratified sample,

N_i = number of observations in the i^{th} stratum,

N = number of observations in the entire population, and

$S_{\bar{x}_i}$ = standard error of the mean i^{th} stratum computed separately.

The significance tests of proportions were also performed using standard error estimates calculated from the formula:

$$S_{d\%} = \sqrt{pq \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

where

$S_{d\%}$ = standard error of the difference between proportions p and q,

p = the total percentage of occurrence,

q = 1-p,

n_1 = number in first sample, and

n_2 = number in second sample.

This statistical test was done to determine the significant differences in small bee percentages between sites.

B. Results

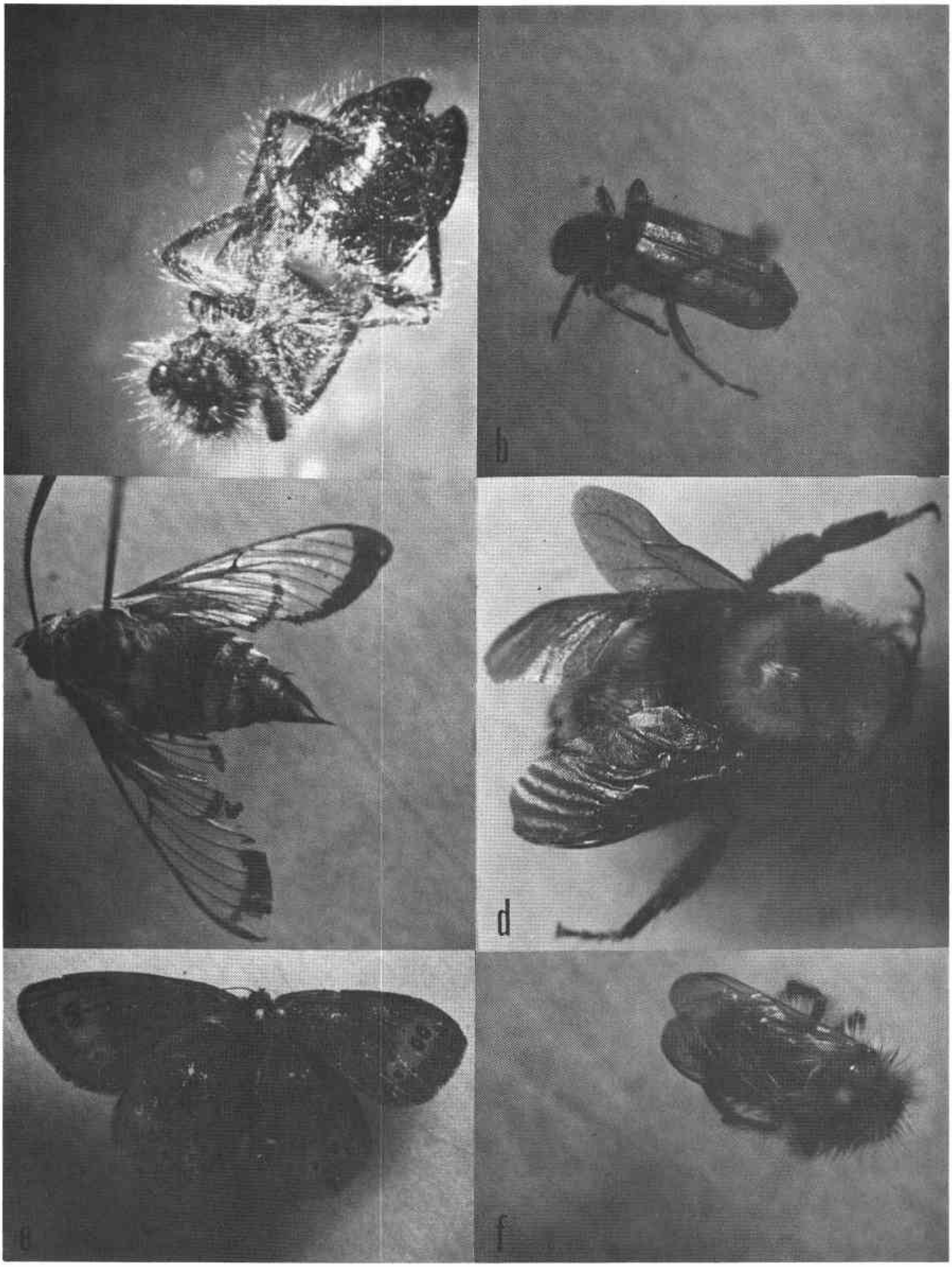
1. Pollinator species present in the study area

The list of the genera and species identified during the study is included in Appendix A. Twenty-nine genera of primary pollinators and 39 genera of secondary pollinators were collected. Because of the small numbers of secondary pollinators collected, primary pollinators were most thoroughly analyzed. More than one species of many genera were identified, particularly in the genus *Osmia* of the family Megachilidae and in *Adrena* of the family Adrenidae. The total number of pollinating insect species occurring in the study area would probably be in the hundreds.

Some of the more common primary and secondary pollinators are depicted in figures 10 and 11. One species of beetle, *Trichodes ornatus* (Figure 10, a and b), was found throughout most of the study area. This beetle was interesting in that it had large amounts of pollen attached to the sticky hairs on its body. Members of the genus *Bombus* were the most common pollinating insects. Identification of pinned specimens indicated at least six species, although only *Bombus nevadensis* (Figure 10d) and *Bombus borealis* were positively identified. The honey bee (*Apis mellifera*) occurred in the study areas, but was quite rare and thus

Figure 10. Representative Pollinating Insects Collected from the Study Area.

a. *Trichodes ornatus*, Family Cleridae, Ventral View
b. *Trichodes ornatus*, Family Cleridae, Dorsal View
c. *Hemaris sp.*, Family Sphingidae
d. *Bombus nevadensis*, Family Apidae, Queen
e. *Erebia epipsodea*, Family Satyridae
f. *Bombus sp.*, Family Apidae, Drone


b
d
f

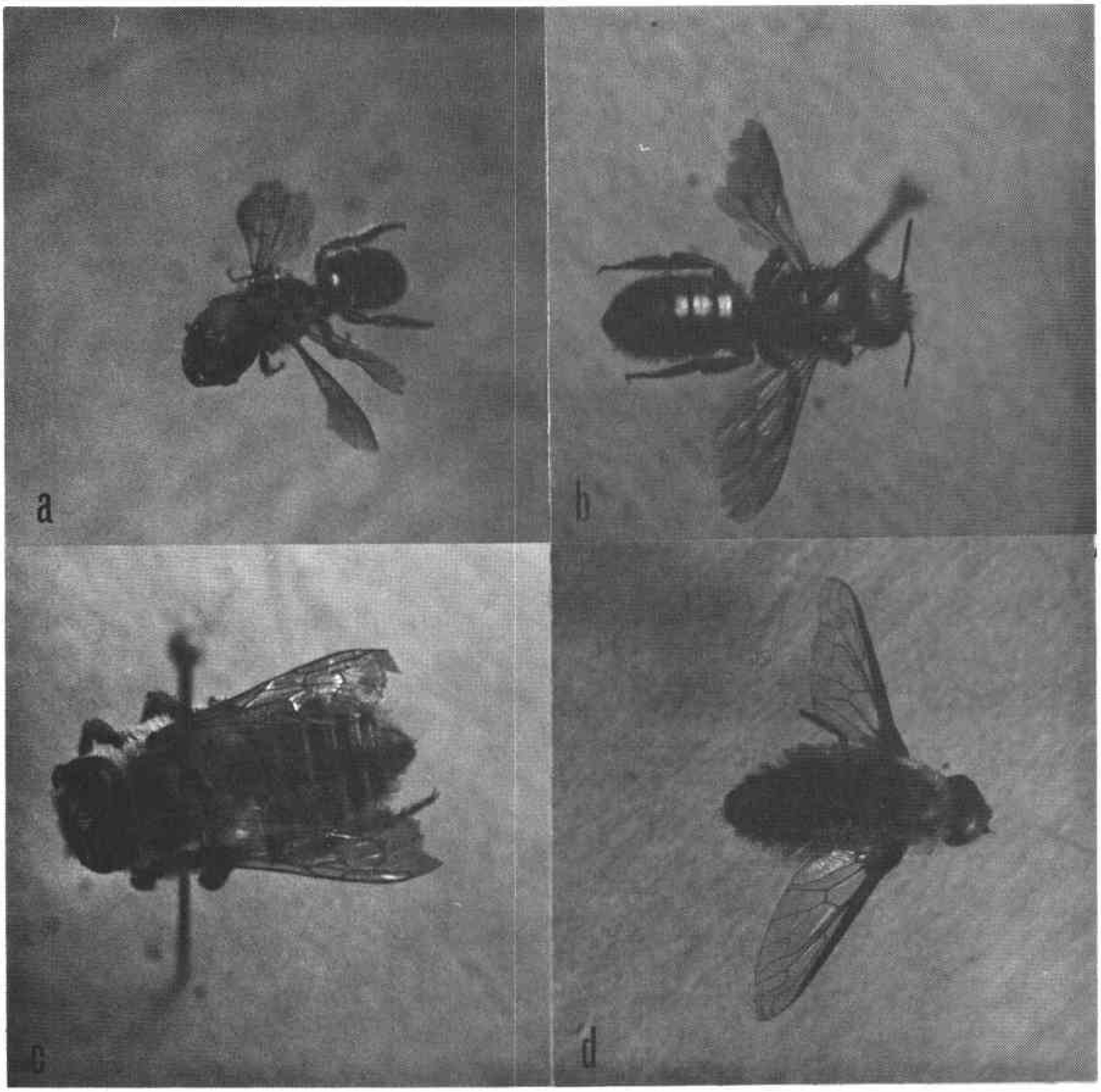


Figure 11. Representative pollinating insects of the study area.
a. *Hoplitis clypeata*, Family Megachilidae
b. *Osmia sp.*, Family Megachilidae
c. *Megachile sp.*, Family Megachilidae
d. *Villa sp.*, Family Bombyliidae

unimportant as a pollinator. Commercial bee hives were located in the foothills near some of the study sites, and bees from these hives may have played an important role in pollination at lower elevations.

The family Megachilidae was the next most important group of insects, with the genus Osmia occurring commonly. The families Colletidae and Adrenidae, although collected rarely with the drop traps, were widely distributed. Sweep netting samples collected from Prunus virginiana showed an abundance of an unidentified species of the genus Adrena associated with this plant. Many genera of the family Halictidae were also found commonly on the study area.

2. Trap effectiveness

Although many different types of insect traps were employed to insure an adequate data base, most of them proved to be ineffective for catching pollinators. A summary of the collection data, including the numbers of pollinators per trapping effort and the numbers of other groups of invertebrates, are listed in Table I. Only a limited number of the molasses and sticky trap samples are included for comparison. Sweep nets, drop traps, and the Malaise traps (when they were not damaged) appeared to be the most effective for collecting pollinating species. Sticky traps were most effective in collecting butterflies, while the molasses traps were ineffective. Two of the Malaise traps were destroyed by bears within 2 weeks of instalation. The intact trap was effective, but this method was unreliable because of its vulnerability to bears. Because of the ineffectiveness of the light traps, sticky traps, and molasses traps, they were discontinued early in the study; the drop traps and sweep netting were relied upon for the remainder. The drop trap was effective and would have been more valuable if larger numbers had been used.

Inconsistencies in collecting pollinators with sweep nets occurred because of the variability in insect foraging activity and individual netting technique. Thus it is difficult to make meaningful comparisons between control site and spray site data.

3. Effects of the spray program on pollinating insect populations

The numbers of insects collected sweep netting for the pre-spray and post-spray periods are listed in Table II. The total number of each taxa is listed on this Table. Differences between spray and control sites were not apparent.

Table I. Summary of Insect Collection Data and a Comparison of the Different Trapping Methods Used in this Study.

Taxa: Order	Family	Number of Individuals, Trapping Method[1]: D	Sw.	Mo.	Ma.	St.	Taxa as Percent of Total, Trapping Method: D	Sw.	Mo.	Ma.	St.
PRIMARY POLLINATORS											
Coleoptera	-Cleridae	342	18	--	2	--	2.5	1.1	--	.2	--
Hymenoptera	-Apidae	1122	736	--	18	--	8.3	44.3	--	1.7	--
	-Anthophoridae	24	6	--	--	--	.2	.4	--	--	--
	-Megachilidae	440	49	--	--	--	3.3	3.0	--	--	--
	-Colletidae	67	2	--	--	--	.5	.1	--	--	--
	-Adrenidae	171[2]	105	--	--	2	1.3	6.3	--	--	.4
	-Halictidae	470	44	--	1	--	3.5	2.7	--	.1	--
SECONDARY POLLINATORS											
Diptera	-Syrphidae	29	74	--	24	--	.2	4.5	--	2.3	--
	-Bombyliidae	33	24	--	14	--	.2	1.4	--	1.4	--
Lepidoptera	-Sphingidae	2	11	--	--	1	tr[3]	.7	--	--	.2
	-Pericopidae	6	130	--	--	--	tr	7.8	--	--	--
	-Satyridae	3	21	--	1	--	tr	1.3	--	.1	--
	-Papilionidae	5	3	--	--	16	tr	.2	--	--	3.1
	-Nymphalidae	16	32	--	--	--	.1	1.9	--	--	--
	-Lycaenidae	36	38	--	--	--	.3	2.3	--	--	--
	-Pieridae	2	11	--	--	1	tr	.7	--	--	.2
OTHER INVERTEBRATES		10,723	356	202	977	501	79.5	21.4	100.	94.2	96.2
Total Primary Pollinators		2,636	960	--	21	2					
Total Secondary Pollinators		132	344	--	39	18					
Total Pollinators		2,768	1304	--	60	20					
Total Insects per Unit Trap Effort[4]		1.51	32.1	4.4	15.3	10.6					
Total Pollinators per Unit Trap Effort		.31	25.17	--	.9	.4					

[1] Trap type abbreviations as follows: D-Drop traps, Sw-Sweep Nets, Mo.-Molasses traps, Ma.-Malaise traps, St.-Sticky traps.

[2] 60 individuals of this taxa were collected at site 1.

[3] tr-trace; Recorded for all values of less than .05.

[4] Unit Trap Effort in units of Insects/100 Trap Days. Sweep netting is recorded in units of Insects/man hour trapping effort.

Table II. Number of Individual Pollinators Collected with Sweep Nets before and after Spraying.

Order	Family	Genus	Pre-Spray C[1]	Pre-Spray D[2]	Pre-Spray S[3]	Post-Spray C	Post-Spray D	Post-Spray S
Coleoptera	-Cleridae	-Trichodes	1	4	-	2	2	9
Diptera	-Bombyliidae	-Anastoechus	1	-	-	2	1	2
		-Bombylius	-	-	4	-	3	1
		-Phthiria	-	-	-	-	-	1
		-Villa	-	-	-	5	2	2
	-Syrphidae	-Didea	-	-	-	-	1	-
		-Epistrophe	-	-	1	1	-	-
		-Eristalis	6	-	7	7	12	3
		-Leucozona	-	-	-	5	1	-
		-Metasyrphus	-	-	-	1	-	-
		-Sericomyia	1	-	-	-	-	1
		-Syrphus	1	1	5	2	1	3
		-Volucella	-	-	3	1	1	7
		-Xanthogramma	-	-	-	1	-	-
Hymenoptera	-Anthophoridae	-Anthophora	-	-	4	-	-	2
	-Apidae	-Bombus queen	2	6	18	17	18	18
		-Bombus male	-	-	-	22	51	16
		-Bombus worker	-	6	2	156	149	180
		-Psithyrus queen	1	2	7	4	7	13
		-Psithyrus male	-	-	-	10	7	13
		-Apis mellifera	-	-	8	1	-	2
	-Adrenidae	-Adrena	68	2	16	1	6	7
		-Panurginus	4	-	-	-	-	1
	-Colletidae	-Hylaeus	-	-	-	-	-	2
	-Halictidae	-Augochloropsis	-	-	-	-	-	2
		-Dialictus	10	5	8	-	1	1
		-Halictus	2	1	2	3	-	7
		-Sphecodes	-	-	-	-	-	1
		-other	-	-	-	-	-	1
	-Megachilidae	-Hoplitus	-	-	-	1	-	2
		-Megachile	-	-	-	2	5	8
		-Osmia	2	1	10	5	6	7
Lepidoptera	-Lycaenidae	-Lycaea	2	-	-	11	3	22
	-Nymphalidae	-Argynnis	-	-	-	15	4	3
		-Phyciodes	-	-	-	6	2	1
		-Polygonia	-	-	-	-	-	1
	-Papilionidae	-Parnassius	-	-	-	3	-	-
	-Pieridae	-Euchloe	-	-	-	-	-	5
		-Pieris	-	-	-	-	-	6
	-Pericopidae	-Gnophaela	-	-	-	65	53	12
	-Satyridae	-Cercyonis	-	-	-	5	-	-
		-Coenonympha	-	1	-	-	1	7
		-Erebia	-	-	-	-	-	3
		-Oenus	-	-	-	1	1	1
	-Sphingidae	-Hemaris	-	1	4	-	2	1
Other Invertebrates (non-pollinators)			99	30	20	79	53	77

1- Control sites combined (C).
2- Dylox sites combined (D).
3- Sevin sites combined (S).

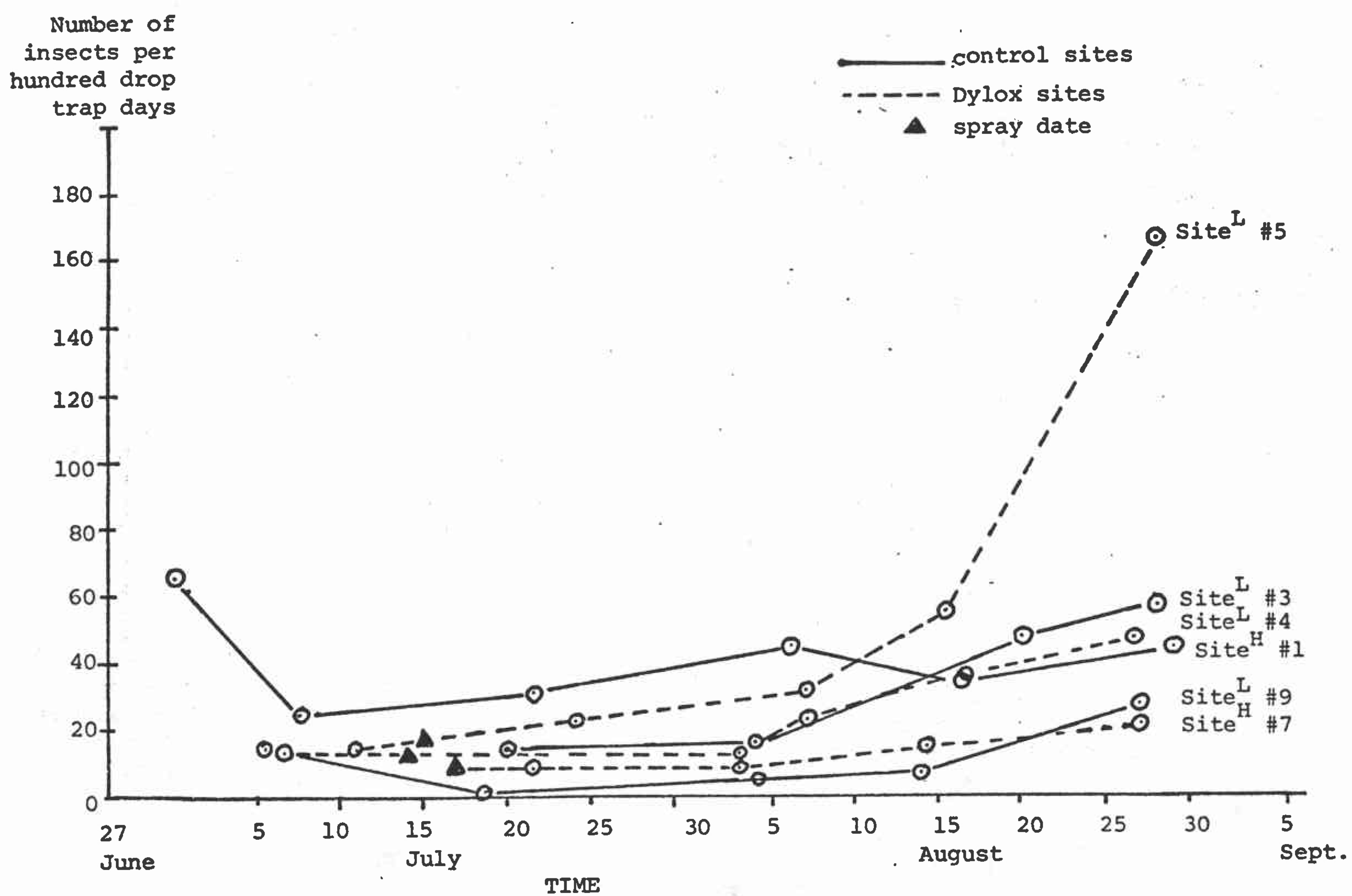
The drop traps proved to be most consistent for collecting pollinating insects. However, the initial sampling periods indicated an inadequate number of insects were being collected by this method. The number of traps were subsequently increased for the remainder of the study. Over 2,000 primary pollinators were collected in these traps, as well as many secondary pollinators. The total numbers of insects caught during each trapping period are recorded in Appendix B. Figures 12 and 13 depict the numbers of primary pollinators collected per 100 trap hours at each of the study sites during the different time periods. The data indicate no significant differences between the controls and treated areas. However, the data was quite variable among sites, and substantial differences would have had to occur to be statistically significant. Note the increase in the number of primary pollinators collected per unit trapping effort at all sites toward the end of the study.

The incidence of small bees expressed as a percentage of the total number of bees was examined to determine if any differences could be observed between sites. This was done to reduce the influence of site variability caused by the relative abundance of flowering plants, grazing pressure, trap placement, and other factors. We assumed these factors would have less effect on the percentage that small bees make up of the bee pollinators. Since different insecticides have been shown in the past to affect bees differently, a comparison of the ratios of the different groups of bees may reflect this differential toxicity. The number of bees collected was adequate for analysis only during the last sampling period. No consistent difference between spray sites and controls was observed (Table III) during this period, but site 5 (Dylox-treated) had a consistently lower percentage of small bees. The percentage of small bees at site 4 (also Dylox-treated) was also significantly lower than at control sites 1 and 3. Site 7 was the only Dylox-treated site not significantly different from the controls. Site 8 was the only Sevin-treated site at which the percentage of small bees was significantly less than a control. This decrease could be discerned only when site 8 was compared with control site 1.

Attempts at analyzing the data at lower taxonomic levels did not prove fruitful; the number of individuals were usually too small.

Figure 12.

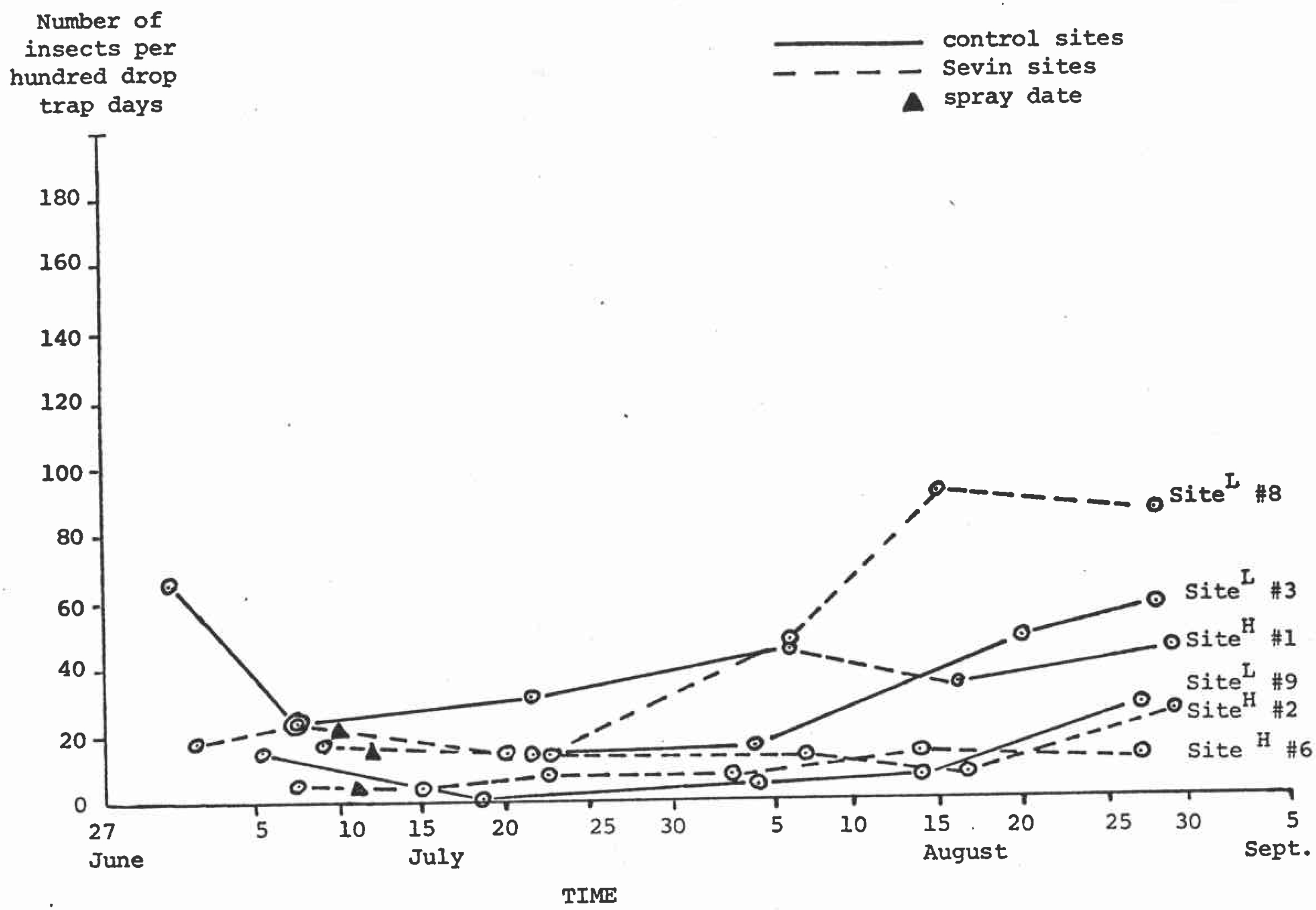
Number of primary pollinators per hundred drop trap days versus time for control and Dylox sites[1]



1 - Points on graph correspond to the midpoint of each sampling period
L - Light grazing pressure
H - Heavy grazing pressure

Figure 13.

Number of primary pollinators per hundred drop trap days versus time for control and Sevin sites[1].



1 - Points on graph correspond to the midpoint of each sampling period
L - Light grazing pressure
H - Heavy grazing pressure

Table III. A Comparison of Differences in the Relative Percentage of Small Bees Occurring between Sites. Based on Drop Trap Data from the Last Sampling Period.

Treatment	Site Number	Percentage Small Bees[1]	Total Number Bees Collected[2]
Control	1	44.4	133
Control	3	41.5	176
Control	9	37.8	82
Control Average		41.7[a]	
Dylox	4	28.3[b]	127
Dylox	5	20.5[c]	307
Dylox	7	36.5	63
Dylox Average		24.5	
Sevin	2	46.3	80
Sevin	6	43.2	37
Sevin	8	34.3[d]	86
Sevin Average		37.4	

1-Small bees consisted of the families Halictidae, Adrenidae, Megachilidae and Colletidae.
2-The total number of bees collected includes all pollinating families in order Hymenoptera.
a-Significantly different from the Dylox Average (p=.99),but not significantly different from the Sevin Average.
b-Significantly different from Control-1 (p=.99), Sevin-2 (p=.99) and Control-3 (p=.95).
c-Significantly different from Sites 1,3,9,2,6,8, and 7 (p=.99), but not significantly different from Dylox-4.
d-Significantly different from Dylox-5 (p=.99), Control-1 (p=.95) and Sevin-2 (p=.95)

The secondary pollinator data (See Appendix B) were also analyzed for significant differences between spray sites. However, the sample size was too small to show significant population trends, and these data were not considered further.

We also correlated the results of the bee collections with the portions of the study concerning fruit production. Results of these correlations aare presented in Section V. B.

V. Flowering Plant Study

The flowering plant study consisted of the following: a) determining the canopy cover of the various flowering plant species in the study area; b) determining the effects of muslin bud covers and fiberglass screen exclosure cages on fruit production; c) observing the phenology of the flowering plants; d) determining significant differences in fruit production between control and sprayed areas. Because the results from this study are related to those from the pollinator insect study, they are discussed together in the discussion section (p. 41).

A. Methods and Materials

1. Transect methodology and locations

The species composition and coverage of each of the nine experimental sites (see Figure 1) were quantitatively sampled using techniques described by Daubenmire (1959). Two permanent vegetation transects were evaluated for each site during two periods. The relations between flower development and grazing were recorded for each species in the transects.

2. Pollen analysis

To show which plant species were visited by dominant bees, bees were netted from specific flowers. Also, an attempt was made to identify plant species by pollen removed from the corbicula of bumblebees. This information was to be used to determine which flowering plants were used by the bees at different times during the study. Pollen was identified microscopically using a key of Kapp (1969), and also by comparison with photomicrographs of pollen from dominant species in the study area (pollen of 32 species were photographed). Figure 14 shows pollen from representative species used as a key to aid in identification.

3. Fruit collection and analysis

Fruiting heads or stalks were collected in the field from the following plant species: *Arnica sororia*, *Astragalus miser*, *Geranium viscosissimum*, *Helianthella uniflora*, *Lupinus* sp, *Myosotis sylvatica*, *Prunus virginiana*, *Symphoricarpos albus*, *Symphoricarpos oreophilus*, *Zygadenus venenosus*,

FIGURE 14 - MICROPHOTOGRAPHS OF POLLEN FROM COMMON SPECIES IN STUDY AREA

a) *Frasera speciosa*

b) *Astragalas miser*

c) *Myosotis sylvatica*

d) *Helianthella uniflora*

e) *Taraxacum officinale*

f) *Symphoricarpos oreophilus*

g) *Lomatium* sp.

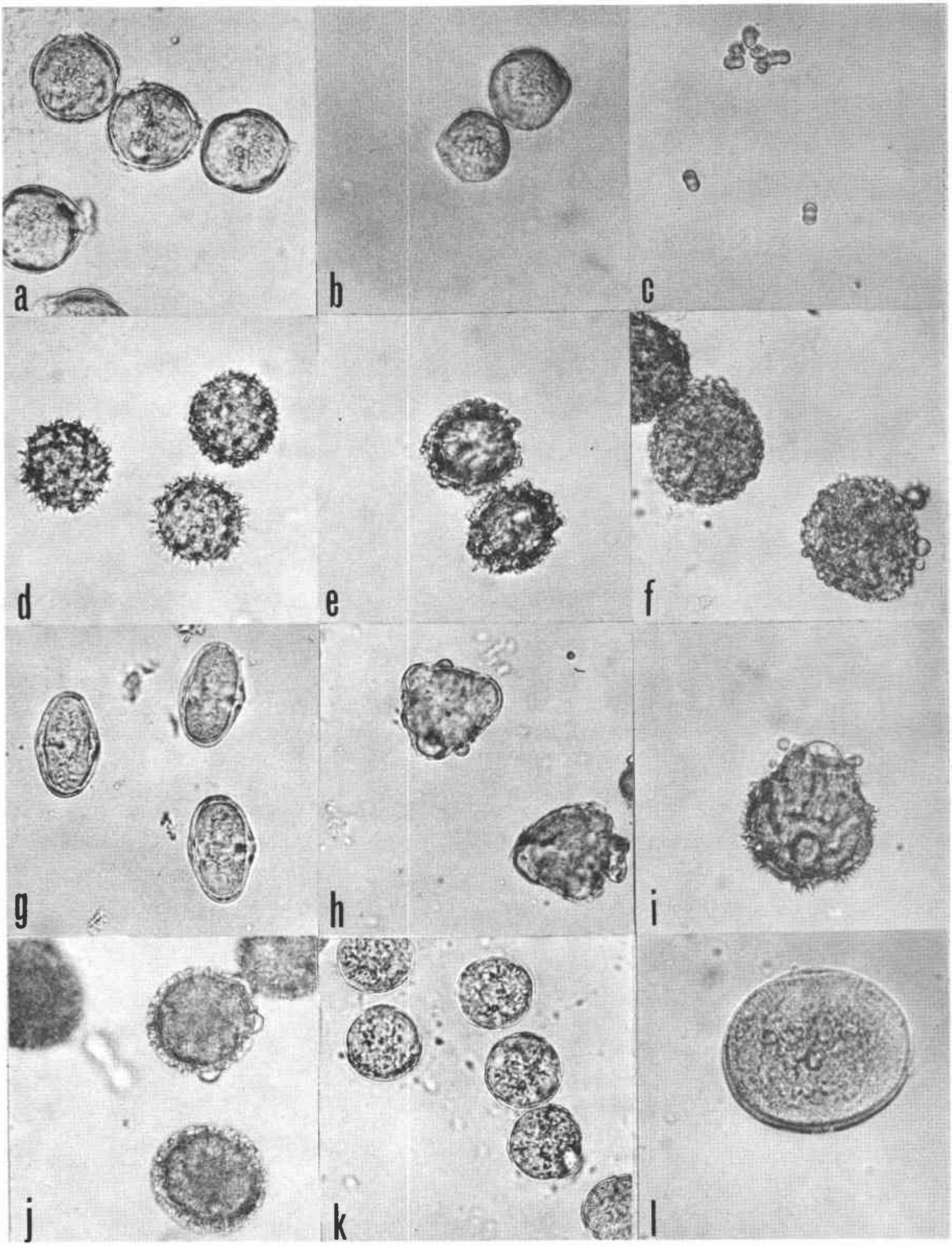
h) *Prunus virginiana*

i) *Solidago* sp.

j) *Phlox longifolia*

k.) *Delphinium bicolor*

l.) *Monarda fistulosa*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and Vaccinium scoparium. Approximately 50 stalks or heads were collected at each site. Because its fruiting bodies would not remain attached during collection and transport, flower development and fruit setting of Vaccinium scoparium was recorded in the field. For all species, the number of fruits developing or set and the number of undeveloped fruits or flowers were recorded for each specimen.

4. Exclosure and bagging experiments

To prevent insect pollination, some of the plants were enclosed in a fiberglass screen cage or the unopened flower buds were covered with a muslin cloth bag. Figure 15 shows the fiberglass screen cage that was used at several locations within the study area. The cages covered approximately 9 square feet. At each site, the fruit production within the cage was compared with that of a sample collected adjacent to the caged area. Species that occurred frequently enough within the cages for evaluation were Erythronium grandiflorum, Castilleja sp., Pedicularis contorta, and Vaccinium scoparium.

Muslin bags were placed over the flowers of Balsamorhiza sagittata, Smilacina racemosa, and Mertensia ciliata. Figure 16 illustrates a bagged Balsamorhiza sagittata flower bud.

5. Data analysis

a. Taxonomy

Plants collected or evaluated during the study were identified to species using Hitchcock (1973). Questionable specimens were pressed in the field and returned for identification in the laboratory. Flowers collected for pollen analysis were preserved in alcohol in the field and identified to species by laboratory examination.

b. Mathematical analysis

Plant cover by species was recorded for each vegetation transect. Flowering dates were also recorded for each species.

Fruit production from enclosed and control plants were evaluated using Student T test (Arkin and Colton, 1967) to determine significant differences of means for those plants having adequate data. The significance level of the test was recorded for each species.

Figure 15. Fiberglass mesh exclosure cage.

Figure 16. Muslin bag covering Balsamorhiza sagitata flower.

The fruit production data collected from the control and spray sites were also analyzed using the T test to determine significant differences between means. The data from the controls and from the spray plots were grouped, with the standard error calculated using a formula for determining the standard error of stratified random samples. Each of the separate sites was treated as a stratified random sample for the calculations.

Fruit production data was further analyzed by using linear correlation analysis. The methods of Arkin and Colton (1967) were used to correlate the results from the vegetation analysis with those from the pollinator insect analysis and with other parameters.

B. Results

1. Flowering plant coverages and phenology

The vegetation transects provided a relative indication of the canopy coverages of flowering plants at typical locations on each site. Of the 188 species recorded in the vegetation transects, 100 produced showy flowers. Of the 100 species, 49 bloomed during the early sampling period (July 1 - July 6) before the spray treatment, 70 bloomed during the late sampling period (July 26 - August 3), and 19 bloomed during both sampling periods. A species list with the relative canopy coverages of all plants collected in the study area is included in Appendix C. The percentage of plants having blossoms at each site is shown in Table IV. Grazing apparently decreased the coverage of blossoms available for pollinating insects at some sites.

The phenology of flowering plants for dominant species in the study area is shown on Table V. This is based on data of Mueggler (1972), Budd and Campbell (1958), and Nye (1971), and on our field observations. Because of variation in altitude of the study sites, species on different sites were not in the same stage of flower development at a given time. Therefore, the phenological observations were grouped into three broad categories: early summer flowering species, mid-summer flowering species, and late flowering species. The plants that bloom in mid-summer or late summer were of most concern during this study, because this group would be most affected if pollinators were reduced due to the spray applications (applications were from July 10 to July 17).

Table IV-Coverage Data for Dominant Flowering Plants

Site Number	Date	% Average Canopy Coverage of Flowering Plant Species	% Average Canopy Coverage of Flowering Plant Species in Blossom	% Canopy Coverage of Flowering Plant Species in Blossom
1a	7/4/75	6.78	2.42	35.69
1b	7/4/75	4.52	1.25	29.41
2a	7/5/75	4.62	.84	18.18
2b	7/5/75	4.75	.27	5.68
9a	7/1/75	4.52	.08	1.75
9b	7/1/75	2.84	.58	20.42
4a	7/3/75	2.17	.69	31.80
4b	7/3/75	6.14	2.37	38.60
5a	7/6/75	2.88	.43	14.93
5b	7/6/75	3.62	0	0
6a	7/3/75	2.44	.20	8.20
6b	7/3/75	2.77	.27	9.75
7a	7/2/75	5.83	.37	6.35
7b	7/2/75	3.12	1.06	33.97
8a	7/6/75	2.76	.25	9.06
8b	7/6/75	4.46	.22	4.93
1a	8/1/75	7.20	3.52	48.89
1b*	8/1/75	2.22	.40	18.02
2a*	8/2/75	3.79	1.41	37.20
2b*	8/2/75	3.00	.09	3.00
3a	7/29/75	2.86	1.03	36.01
3b	7/29/75	4.32	.62	14.35
9a	7/27/75	7.08	1.52	21.47
9b	7/27/75	3.03	1.06	34.98
4a	7/28/75	4.73	1.57	33.19
4b	7/28/75	6.92	4.76	68.79
5a	8/3/75	2.63	.73	27.76
5b	8/3/75	3.05	.47	15.41
6a*	7/26/75	2.34	.27	11.54
6b*	7/26/75	1.52	.15	9.87
7a*	7/26/75	4.94	.63	12.75
7b*	7/26/75	2.70	.44	16.30
8a	8/2/75	2.77	.52	18.77
8b	8/3/75	7.62	.75	9.84

*-Grazed

Table V

General Phenology of Flowering of Dominant Species in the Study Area (species with .5% or greater flowering canopy coverage)

Species	Summer Flowering Period	Relative Flowering Canopy Coverage (%)[1] Early[2]	Late
Achillea millefolium	mid-late	----	2.38
Agoseris glauca	early	1.60	----
Antennaria sp.	mid	----	2.14
Arenaria congesta	mid	----	3.75
Arnica cordifolia	mid	----	1.53
Arnica sororia	mid	----	.83
Artemisia tridentata	late	----	1.26
Aster sp. #1	late	----	1.09
Astragalus miser	mid-late	.26	11.52
Balsamorhiza sagittata	early	2.28	----
Cerastium arvense	mid	1.84	----
Claytonia lanceolata	early	1.94	----
Collinsia parviflora	early-mid	9.41	----
Collomia linearis	early-mid	8.12	11.85
Delphinium bicolor	early	4.99	----
Dodecatheon conjugens	early	1.53	----
Draba verna	early	3.36	----
Erigeron speciosus	mid-late	----	1.26
Erigeron sp.	mid-late	----	1.14
Eriogonum umbellatum	mid	----	5.82
Erythronium grandiflorum	early	2.20	----
Fragaria vesca	early-mid	3.54	----
Galium boreale	mid	----	1.84
Geranium viscosissimum	mid	----	5.34
Geum triflorum	early	.11	.52
Helianthella uniflora	late	----	4.21
Lithophragma parviflora	early	13.88	----
Lithospermum ruderale	early	1.63	----
Lomatium triternatum	early	1.60	1.45
Lupinus sp.	mid-late	----	10.33
Myosotis sylvatica	mid	1.50	.20
Nemophila breviflora	early	6.00	.26
Phlox longifolia	early	1.10	.96
Polygonum douglasii	early-mid	----	9.29
Potentilla glandulosa	mid-late	----	6.11
Ranunculus glaberrimus	early	2.05	----
Rosa sp.	mid	----	1.60
Smilacina racemosa	early	6.90	----
Symphoricarpos oreophilus	late	----	2.36
Thalictrum occidentale	early	3.05	----
Valeriana sitchensis	early	2.02	----
Viola nuttallii	early	2.38	----

[1] Relative Flowering Canopy coverage for each species is listed as the percentage of the total coverage of flowering plants at all sites for the time period in question.

[2] Early transect data was collected for all sites between July 1 and July 6, 1975, while the late transect data was collected between July 26 and August 3, 1975.

2. Plant pollen associated with insects

To determine which plant pollens were most commonly collected by bumblebees during mid-summer after the spray program had begun, pollen samples were removed from the corbicula of pinned bees and identified to species. Unfortunately, the most commonly collected pollens were similar in appearance and difficult to differentiate. The bumblebees were separated into different species but were not identified as to specific name with the exception of Bombus borealis, Table VI lists the percentages of the different pollen types found on the bee species. Pollen of Helianthella uniflora, Potentilla sp., Lupinus sp., and Frasera sp. was the most common. Associating bee species with flower species may be more effectively performed by field observation of foraging activities.

3. Effects of the spray program on fruit production

Some of the more common midsummer blooming species were analyzed for significant differences in seed or fruit production between control and spray sites. The results are summarized in Table VII. Although significant increases and decreases in fruit production were observed between control and spray sites for many of the plants collected, the reasons are not readily apparent.

Of the species showing significant differences, only Symphoricarpos oreophilus occurred at a large number of sites and consistently demonstrated a significant decrease in fruit production in the sprayed area. Since fruit production may be affected by factors other than pollinating insect populations, differences between sites were examined in more detail only when there was a consistent decrease in fruit production at the spray sites.

The average percentage fruit production per plant of Symphoricarpos oreophilus was correlated with altitude ($r = .03$), bee density ($r = .10$), and bee density per unit flowering canopy coverage ($r = .07$). Bee density from the subplot nearest the Symphoricarpos oreophilus collection sites were also correlated with fruit production for this species. This increased the correlation value ($r = .34$) but it was still relatively small.

The fruit production data for Symphoricarpos oreophilus, computed as the percentage fruits produced for all plants collected at a site was correlated with the percentage that small bees make up of the bee pollinators at each site (Figure 17). This correlation coefficient was rather low ($r = .40$) but it should be noted that the divergent points on the illustration are those sites at which the smallest number of bees were collected.

Figure 17. Percentage small bees collected during last sampling period versus percent of *Symphoricarpos oreophilus* flowers that developed fruit.

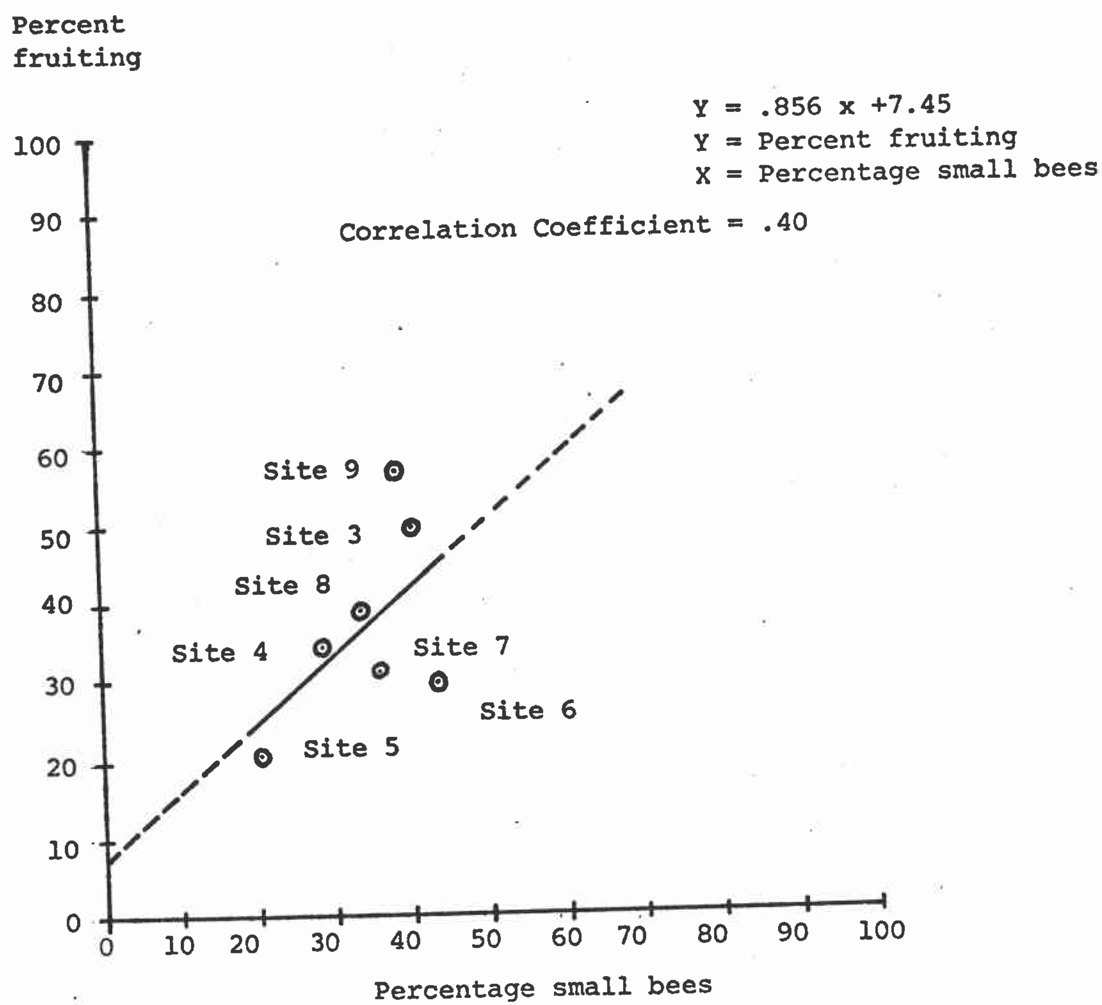

Table VI. Pollen Types Associated with Bumblebees

Date	Bee Species	Pollen type	Percentage of each pollen types
8/9/75	Bombus sp. a[2]	Helianthella uniflora	90%
		Sedum sp.	10%
8/9/75	Bombus borealis	Lupinus sp.	100%
8/9/75	Bombus borealis	Lupinus sp.	80%
		Helianthella uniflora	20%
8/11/75	Bombus sp. b	Lupinus sp.	90%
		Helianthella uniflora	10%
8/11/75	Bombus borealis	Lupinus sp.	90%
		Helianthella uniflora	10%
8/11/75	Bombus borealis	Agastache urticifolia[1]	50%
		Lupinus sp.	50%
8/12/75	Bombus sp. c	Lupinus sp.	80%
		Aster sp.	20%
8/18/75	Bombus sp. a	Compositae	50%
		Lupinus sp.	50%
8/21/75	Bombus sp. c	Agastache urticifolia[1]	100%
8/21/75	Bombus borealis	Potentilla sp.	60%
		Agastache urticifolia[1]	40%
8/21/75	Bombus borealis	Potentilla sp.	100%
9/4/75	Bombus sp. c	Potentilla sp.	50%
		Compositae	40%
		unknown	10%

[1]Recorded as occurring in highly aggregated stands but not recorded for any transects

[2]The specific names of the different species of bumblebee workers designated a.b, and c, were not identified.

Table VII. FRUIT PRODUCTION DATA
(Average % Developed Fruits per Flowering Stem or Plant)

Species	Control				Sevin				Dylox			
	Site Number				Site Number				Site Number			
	1	3	9	Mean	2	6	8	Mean	4	5	7	Mean
Arnica sororia [1]	44.0±3.0	59.8±3.3	---	57.5	53.5±1.9	67.0±2.2	---	59.9	---	---	---	--
Astragalus miser	70.0±3.0	62.3±2.4	34.3±2.7	55.7	74.4±3.3	54.8±2.6	42.1±2.0	57.2	40.0±2.5	46.1±2.0	---	43.4 [4]
Geranium viscosissimum	49.0±3.0	---	57.4±2.2	53.8	56.9±2.5	62.6±2.4	73.9±2.7	63.4 [4]	59.7±3.3	62.4±3.6	52.2±2.7	57.8
Helianthella uniflora [1]	---	39.3±1.3	39.0±2.0	39.2	23.2±1.6	35.8±3.2	41.2±1.5	35.3 [3]	43.2±1.4	35.1±1.3	31.2±2.0	37.9
Lupinus sp.	18.9±1.1	---	---	18.9	14.4±1.4	---	28.7±1.6	21.0	---	---	---	--
Myosotis sylvatica	---	94.3±1.2	90.3±1.4	92.7	---	85.8±1.9	72.0±2.0	77.5 [4]	88.8±1.6	---	---	88.8 [3]
Prunus virginiana	16.7±1.0	24.0±1.5 *	---	20.2	11.1±1.0	---	14.1±1.0	12.6 [4]	---	---	---	--
Symphoricarpos albus	17.2±4.1	---	---	17.2	28.7±2.2	---	---	28.7 [3]	---	---	---	--
Symphoricarpos oreophilus	---	46.6±3.6	55.9±2.5	52.8	---	30.2±1.7	40.3±3.9	31.6 [4]	33.2±1.7	37.8±2.9	31.9±2.8	35.6 [4]
Zygadenus venenosus	60.7±2.5	82.5±1.7	50.5±3.6	64.0	53.5±2.9	66.9±2.9	64.1±2.2	61.6	57.9±3.4	48.2±3.5	---	52.9 [4]
Vaccinium scoparium [2]	13.7	---	---	13.7	38.3	---	---	38.3	---	---	---	--

*-Sample collected at a control site about 2 miles East of site #2 and within 2 miles of commercial honey bee colonies.

1-Data in this row represents number of achenes per flowering head.

2-Data in this row represents number of set berries per hundred plants.

3-Mean value is significantly different from control at the .95 confidence level.

4-Mean value is significantly different from control at the .99 confidence level.

4. Effects of exclosures and bagging on fruit production

The dependency of a plant species on pollinators was inferred from the studies we conducted and from a review of available literature. The results of the exclosure studies and the bagging experiments are given in Table VIII. This data reflects the combined effects of cages or bags and pollinator exclusion. These two effects cannot be differentiated with the procedure used, therefore, the results should be considered preliminary.

There was a significant reduction in fruit production in Vaccinium scoparium, Castilleja sp., and Smilacina racemosa. Erythronium grandiflorum also appeared to be affected but the sample was too small for statistical analysis. Fruit production of Pedicularis contorta was reduced significantly but much less than the other species collected. Balsamorhiza sagittata showed a significant increase in seed production for flowers enclosed in a muslin bag.

Some caging and bagging experiments of the species were not successful because of damage from livestock or because the plants were consumed by insects.

Table VIII-Fruit Production Data for Plants (%) Enclosed in Muslin Bags or Mesh Exclosures

Species		Fruit Production (%±S.E.) of Enclosed Plants	Fruit Production (%±S.E.) of Control Plants
Balsamorhiza sagittata		60.3±5.9*	30.5±4.6*
Castilleja spp.		15.4±5.2**	63.6±1.8**
Pedicularis contorta		31.7±5.0**	47.4±3.6**
Erythronium grandiflorum		0**	4.3**
Smilacina racemosa		0.5±0.3**	32.3±2.7**
Vaccinium scoparium	Cage 1	30.0 ***	213.0 ***
	Cage 2	6.2 ***	13.7 ***

*-Data reported as achenes per flowering head.
**-Data reported as fruits per plant
***-Data reported as number of berries per hundred plants.

VI. Discussion and Conclusions

This study was designed to monitor the pollination of flowering plants in areas sprayed with Dylox and Sevin for the control of the spruce budworm. The following section discusses the findings and points out ways in which future surveys could be improved.

The drop traps we designed appear to be effective if enough of them are installed. These traps may act as flower imitators or as nesting sites, thus attracting the various bees. The traps should probably not be left in place for much more than 5 days, per sampling period, as the traps left in place for 2 weeks did not catch as many insects per unit trapping effort as did those that were more frequently sampled and rejuvinated. Also, insects began to decay after about 10 days in the trap, making identification difficult. Effectiveness also varied with season, becoming much higher after the number of plants in blossom decreased.

Sweep netting, although the most efficient technique for catching large numbers of bees, varies among individual netters and with weather and location. Differences in bee foraging activity and abundance of flowering species also influenced the effectiveness of this technique. That a much higher percentage of large bees was collected in sweep nets than in drop traps may mean that netters see and hence collect more large bees, or that the drop traps tend to collect smaller bees because of a lower flower constancy in these species than in the larger bees.

Molasses traps were described by Giles (1970) as being highly effective for collecting many types of insects, particularly bees. Our experience found them ineffective for collecting pollinating insects. This was probably because they were placed at least 6 feet above the ground to avoid animal disturbance. This height above the ground apparently discouraged bees and accounted for the lack of success.

Malaise traps were reasonably effective for collecting the large pollinating insects when the traps were not disturbed. However, during the 2-week period that these traps were installed at sites 3, 5, and 8, two were severely damaged by bears and thus not effective in collecting insects. The third trap did not collect a large sample.

Sticky traps coated with Tack Trap collected large numbers of small dipterans and some butterflies. They were relatively ineffective for collecting bees. These traps were often damaged by livestock and wildlife and therefore could not be relied upon.

A light trap using a white light source was also ineffective. An ultra-violet light trap would probably be much more effective but would be quite expensive for a large survey.

Other methods of monitoring pollinating insects may be more effective in certain studies; for instance, a split-board nesting trap has been used by other researchers for collecting megachilid bees and could be quite effective in monitoring the abundance of these bees. Observation of bee foraging activity on a certain plant species would probably be the best technique for quantifying bee pollination. This would require much manpower but would be valuable when only a few plant species were being investigated. The pollinators could be collected and identified to species during the observations by use of sweep nets or other techniques.

The analyses of pollinating insect data were confined to the drop traps. Pre-spray data were not adequate to determine pollinating insect population changes using the modified Abbott's formula, an equation often used to estimate insect population changes. Instead, two alternative methods of analysis were used for evaluating only the primary pollinator data, since insufficient numbers of secondary pollinators were collected. The sites were compared using; 1) the number of primary pollinators collected per 100 trap days, and 2) the percentage of small bees composing the bee pollinator populations.

No significant differences in the densities of bees at the control and spray sites were observed. However, the percentage of small bees in the population was reduced at two of the three Dylox-treated sites. This reduced percentage of small bees on Dylox-treated sites would appear contrary to the literature, since Johansen (1972) observed Dylox to be most toxic to larger bees (the opposite of what occurs with most pesticides). However, the small bees (families Adrenidae, Halictidae, Colletidae, and Megachilidae) would most likely be subjected to the spray programs in woody areas, since many of these species are twig nesters. The bumblebees, on the other hand, are ground nesters and are found more commonly in open meadows. Although the spray sites included both meadows and forested areas they were predominantly woody with larger adjacent unsprayed meadows. Since many of the collection locations in the spray sites were along the edge of the spray areas near the unsprayed meadows, insects may have foraged from the meadows to the nearby traps.

Another explanation for the significant difference in the percentage of small bees could be related to differences in the trapping sites on sprayed areas compared with those of the controls, although there did not appear to be any obvious consistent differences between the spray sites and the controls. The past grazing history of the sites could also affect one group of bees more than another, and thus affect the percentage of small bees. Examination of sites with heavy grazing this year did not show any definite trend with respect to the percentage of small bees. Further study of small bee populations on Dylox-treated sites would be necessary to discover the cause of the observed differences.

The vegetation of the study area was described by the use of vegetation transects and observations. The various forested sites in the study areas had similar habitat types (Pfister _et al_. (1974) and similar climatic conditions. Most of the plant communities dominated by trees were of the Douglas-fir series and usually of the Douglas-fir/_Calamagrostis rubescens_ or Douglas-fir/_Arnica cordifolia_ habitat types. Field observations indicated that the forested areas were not relied upon by foraging pollinators as much as the adjacent grass and forb meadows. The meadow communities were difficult to classify to habitat type (Mueggler and Handl, 1974) because of alterations caused by introduced, non-native grass species, sagebrush removal programs, and variable grazing pressure. Flowering plant coverages were small when compared with the total vegetative coverages. Often, plant species providing adequate sources of pollen and nectar for foraging insects were concentrated in relatively small portions of the study areas, thus concentrating the bees. Dense stands of _Helianthella uniflora_ often had large concentrations of bees. _Geranium viscosissimum_ was also found commonly throughout the study area and provided an abundant source of nectar and pollen for foraging bees. Many flowering species were also found aggregated in restricted habitats and were not evenly distributed over the study areas. This uneven distribution of flowering plants probably affects the distribution of pollinating insects; consequently, the placement of insect traps greatly affects the success of the trapping effort.

The sequence of flower development in the study area is important in evaluating the impact of the spray program on insect pollination. Plants blooming before the spray program started would probably not be affected unless pollinators were reduced the following year. Generally, the spring and early summer blooming forms were probably not affected by the spray program this year because they should have been pollinated before the sites were sprayed. Plants blooming in midsummer or later in the year would be most likely to be affected by the spray program. One of the midsummer-blooming plant species, _Symphoricarpos oreophilus_, demonstrated a significantly lower fruit production on all spray sites than on the controls. Our data indicated that this species did not blossom until after the spray program had begun.

The pollen baskets of the bumblebees collected during the study did not provide an adequate data base for evaluating the pollens most commonly collected. Studying the foraging activity of the bees on a specific flower would probably be more revealing in determining the pollens most heavily relied upon.

Significant differences in the percentage fruit production per plant between sites were noted for many species. This included increases as well as decreases. Only Symphoricarpos oreophilus demonstrated a consistant decrease in fruit production on the sprayed areas. This was of particular interest because the species was in bloom only after the spray program had begun. Although we did not investigate its dependence on pollinating insects for fruit production by use of insect exclosures, it would not be surprising if fruit production would improve when insect pollinators were present. A review of the literature indicates that this is usually the case. Further, Nye (1971) has indicated that this species is a minor source of pollen for honey bees in Utah. This fact, and the conclusion by Mosquin (1971) that plants blossoming in mid-summer compete with each other for pollinators, would suggest that Symphoricarpos oreophilus is vulnerable to pollinator reduction.

Because this species decreased in fruit production in the spray areas, we investigated it in more detail. Our initial correlation analysis attempted to relate percentage fruit production per plant with altitude, primary pollinator populations per unit of flower coverage, and primary pollinator populations. The analysis was refined by using for the correlations only the drop trap pollinator subsample data collected near the Symphoricarpos oreophilus plants at each site. None of the parameters considered were closely correlated with fruit production. The low correlations were probably caused by small pollinator sample sizes or by other unknown factors that influence fruit production. We also correlated the percentage fruits produced from all flowers of Symphoricarpos oreophilus collected at each site with the small bee percentages observed at each respective site in the drop trap samples from the last sampling period (the only time period from which an adequate sample was collected). Although this correlation was rather low it was higher than that observed with the other correlations that were conducted with Symphroicarpos oreophilus percentage fruit productions per plant with the other parameters. Since the small blossoms of Symphoricarpos oreophilus may be more readily available to the smaller bees a reduction in small bee populations could be expected to affect fruit production. This correlation is not definitive but suggests an avenue for future studies.

The restricted amount of data for most of the other species did not allow for detailed analysis of the relationships between fruit production and primary pollinator concentrations. Helianthella uniflora, Astragalus miser, and Geranium viscosissimum were collected at most of the sites but showed no consistent decrease in fruit production on the spray sites. This may be because their reproductive systems do not obligately require pollinating insects, as is probably the case for the composite species such as Helianthella uniflora. Species such as Geranium viscosissimum are rated as important pollen sources to bees by Nye (1971) and may attract a larger number of pollinating insects, thereby outcompeting the other plant species. Pollinating insects may not be a limiting factor in fruit production until pollinator insect populations have been reduced to a critical level. Astragalus miser is rated by Nye (1971) as having some importance as pollen source and may also not be limited in fruit production by the lack of pollinators.

From the previous discussion, it can be seen that the plant species most likely to be affected by spray programs are those which bloom in mid-summer and are the least successful competitors for insect pollinators. These least successful competitors are usually rated as minor sources of pollen for bees. Thus, the abundant pollen and nectar sources would attract the most pollinating insects to the detriment of minor sources. Also, according to our results and the literature review, composites are less likely to require pollinators than others and may be less affected by reduced densities of pollinators. Further investigation of the effects of pollinator reduction on fruit production should be concentrated on species meeting the above criteria.

The results of the caging and bagging experiments indicated that removal of insects from most of the study area plants would be expected to decrease fruit production, with the exception of Compositæ, Balsamorhiza sagittata. This is also generally supported by the literature.

Future studies should concentrate on plant species most likely to be affected by reductions in pollinators. The fruits or berries of such species may be of importance to wildlife, and large-scale spray programs could have an impact on the wildlife of an area. It is doubtful that a one-season spray program would have any longterm affect on the vegetative composition of an area, as most species produce an excess of seeds. Our data also indicate that the small bees should receive more investigation as this group may have been affected by the Dylox (Trichlorfon) treatments.

Appendix A-Insect Species List

PRIMARY POLLINATORS

Order	Family	Genus
Coleoptera	-Cleridae	-Trichodes ornatus
Hymenoptera	-Apidae	-Bombus[1]
		-Apis mellifera
		-Psithyrus
	-Anthophoridae	-Anthophora
		-Emphoropsis
		-Melissodes
		-Tetralonia
	-Megachilidae	-Lithurgus
		-Stelis
		-Anthidium
		-Coelioxys
		-Megachile
		-Hoplitis
		-Prochelostoma
		-Osmia[2]
	-Colletidae	-Hylaeus
		-Colletes
	-Andrenidae	-Adrena
		-Panurginus
	-Halictidae	-Sphecodes
		-Dialictus
		-Dufourea
		-Agapostemon
		-Augochloropsis
		-Augochlora
		-Paralictus
		-Halictus
		-Lasioglossum

SECONDARY POLLINATORS

Order	Family	Genus
Diptera	-Syrphidae	-Microdon
		-Volucella
		-Paragus
		-Leucozona
		-Xanthogramma
		-Didea
		-Eupeodes
		-Syrphus
		-Metasyrphus
		-Epistrophe
		-Platychirus
		-Melanostoma
		-Sericomyia
		-Eristalis
	-Bombyliidae	-Bombylius
		-Anastoechus
		-Phthiria
		-Anthrax
		-Villa
Lepidoptera	-Sphingidae	-Hemaris
	-Pericopidae	-Gnophaela vermiculata
	-Satyridae	-Cercyonis sylvestris
		-Erebia epipsodea
		-Coenonympha haydeni
		-Oenus chryxus
	-Papilionidae	-Papilo rutulus
		-Parnassius smintheus
	-Nymphalidae	-Polygonia zephyrus
		-Argynnis
		-Phyciodes
		-Meliteae
		-Lemohias
	-Lycaenidae	-Lycaea
	-Pieridae	-Pieris napi
		-Euchloe sara
		-Euchloe ausonoides
		-Colias alexandria
Thysanoptera		

[1]Includes species from the major subgenera Bombus, Megabombus, & Pyrobombus. Only the species B. nevadensis and B. borealis could be positively identified.

[2]Ashmeadiella was grouped with this genus.

APPENDIX B. Drop Trap Data
Collection Site Number 1

Family	Genus	7/4	7/11	8/1	8/11	8/21	9/6
Collection Dates		7/4	7/11	8/1	8/11	8/21	9/6
Mid Date of Sampling Period		6/30	7/7	7/21	8/6	8/16	8/29
Trap Days (# traps x # sampling days)		56	49.5	247.1	156.2	166.3	285.8
Cleridae	Trichodes ornatus	9	--	23	15	3	--
Apidae	Bombus Q	1	--	--	--	--	2
	Bombus M	--	--	--	--	--	10
	Bombus W	--	--	--	13	3	60
	Psithyrus Q	--	--	1	1	--	--
	Psithyrus M	--	--	--	--	1	2
	Apis mellifera	--	--	--	--	--	--
Anthophoridae	Anthophora	--	--	1	3	--	--
	Melissodes	--	--	--	--	--	--
	Tetralonia	--	--	--	--	--	--
	Emphoropsis	--	--	--	--	--	--
Megachilidae	Lithurgus	--	--	--	--	--	--
	Stelis	--	--	--	3	--	1
	Anthidium	--	--	1	--	--	--
	Coelioxys	--	--	--	--	--	--
	Megachile	--	--	--	2	2	1
	Hoplitis	--	--	1	--	--	1
	Osmia	23	11	19	9	6	19
	Prochelostoma	--	--	--	--	--	--
Colletidae	Hylaeus	--	--	--	5	12	13
	Colletes	--	--	--	--	--	--
Adrenidae	Adrena	--	--	1	3	3	6
	Panurginus	--	--	22	14	14	10
Halictidae	Sphecodes	--	1	2	--	1	1
	Dialictus	1	--	--	--	3	4
	Dufourea	--	--	3	--	2	--
	Agapostemon	--	--	--	--	--	--
	Augochloropsis	--	--	1	1	--	--
	Augochlora	--	--	--	--	--	--
	Paralictus	--	--	--	--	--	--
	Halictus	3	--	--	--	5	3
	Lasioglossum	--	--	--	--	--	--
Total Large Bees		1	--	2	17	4	74
Total Small Bees		27	12	50	37	48	59
Total Primary Pollinators		37	12	75	69	55	133
Syrphidae	Microdon	--	--	--	--	--	--
	Paragus	--	--	--	--	--	--
	Leucozona	--	--	--	--	1	--
	Didea	--	--	--	--	--	--
	Eupeodes	--	--	--	--	--	--
	Syrphus	--	--	--	1	--	--
	Platychirus	1	--	--	--	--	--
	Melanostoma	--	--	--	--	--	1
	Eristalis	--	--	--	--	--	--
Bombyliidae	Anthrax	--	--	--	--	--	2
	Villa	--	--	--	1	1	3
Sphingidae	Hemaris	--	--	--	--	--	--
Pericopidae	Gnophaela	--	--	--	--	--	1
Satyridae	Cercyonis	--	--	--	--	--	--
	Oenus	--	--	--	--	--	--
Papilionidae	Papilo	--	--	--	--	--	--
	Parnassius	--	--	--	--	--	--
Nymphalidae	Polygonia	--	--	--	--	--	--
	Argynnis	--	--	--	--	--	--
	Phyciodes	--	--	--	--	--	--
Lycaenidae	Lycaea	--	--	--	--	--	1
Pieridae	Pieris	--	--	--	--	--	--
Total Secondary Pollinators		1	--	--	2	2	8
Other Invertebrates		95	20	311	372	242	334

APPENDIX B. Drop Trap Data

		Collection Site Number 2						Collection Site Number 3			
Collection Dates		7/5	7/10	8/2	8/12	8/21	9/6	7/29	8/10	8/20	9/5
Mid Date of Sampling Period		7/1	7/7	7/21	8/7	8/16	8/29	7/20	8/4	8/15	8/28
Trap Days (# traps x # sampling days)		70	47	354	178.6	184.8	309.1	321.4	204.3	154.0	317.0
Family	Genus										
Cleridae	Trichodes ornatus	--	2	8	7	--	2	20	5	2	6
Apidae	Bombus Q	--	--	2	--	--	1	--	--	1	1
	Bombus M	--	--	--	--	--	15	--	--	11	33
	Bombus W	--	--	4	1	8	27	--	5	17	53
	Psithyrus Q	--	--	--	--	--	--	2	1	--	1
	Psithyrus M	--	--	--	--	2	--	--	--	2	15
	Apis mellifera	--	1	--	--	--	--	--	2	1	--
Anthophoridae	Anthophora	--	--	--	1	--	--	--	--	--	--
	Melissodes	--	--	--	--	--	--	1	--	--	--
	Tetralonia	--	2	--	--	--	--	--	--	--	--
	Emphoropsis	--	--	--	--	--	--	--	--	--	--
Megachilidae	Lithurgus	--	--	--	--	--	--	--	--	--	--
	Stelis	--	--	--	--	--	--	--	--	1	--
	Anthidium	--	--	--	--	--	--	--	--	--	--
	Coelioxys	--	--	1	--	--	1	--	--	1	--
	Megachile	--	--	--	--	1	5	1	2	2	2
	Hoplitis	1	--	--	1	--	--	1	1	--	--
	Osmia	5	4	18	4	3	23	7	2	6	4
	Prochelostoma	--	--	--	--	--	--	--	--	--	--
Colletidae	Hylaeus	--	--	--	3	--	--	--	1	1	2
	Colletes	--	--	--	--	--	--	--	--	--	--
Adrenidae	Adrena	5	1	4	1	--	--	9	1	1	1
	Panurginus	--	--	5	--	--	1	--	--	--	2
Halictidae	Sphecodes	--	--	1	--	--	1	--	--	1	11
	Dialictus	2	--	--	1	--	3	1	--	3	8
	Dufourea	--	--	--	2	--	2	--	1	--	--
	Agapostemon	--	--	--	--	--	--	--	--	--	--
	Augochloropsis	--	--	1	--	--	--	2	--	4	2
	Augochlora	--	--	--	--	--	1	--	3	--	3
	Paralictus	--	--	--	--	--	--	--	--	--	3
	Halictus	--	1	5	1	--	--	1	7	9	22
	Lasioglossum	--	--	--	1	1	--	--	2	--	13
Total Large Bees		--	3	6	2	10	43	3	8	32	103
Total Small Bees		13	6	35	14	5	37	22	20	29	73
Total Primary Pollinators		13	11	49	23	15	82	45	33	63	182
Syrphidae	Microdon	--	--	--	--	--	--	--	--	--	--
	Paragus	--	--	--	--	--	--	--	--	--	--
	Leucozona	--	--	--	--	--	--	--	--	--	--
	Didea	--	--	--	--	--	--	--	--	--	--
	Eupeodes	--	--	--	--	--	--	--	--	--	--
	Syrphus	--	1	--	1	1	--	--	--	--	--
	Platychirus	--	--	--	1	--	--	--	--	--	--
	Melanostoma	--	--	--	--	--	1	--	--	--	--
	Eristalis	--	--	--	--	--	--	--	--	--	--
Bombyliidae	Anthrax	--	--	--	--	1	1	--	--	--	--
	Villa	--	--	--	--	--	--	--	1	--	--
Sphingidae	Hemaris	--	--	--	--	--	--	--	--	--	--
Pericopidae	Gnophaela	--	--	--	--	2	--	--	--	--	--
Satyridae	Cercyonis	--	--	1	--	--	--	--	--	--	--
	Oenus	--	--	--	--	--	--	--	--	--	--
Papilionidae	Papilo	--	--	--	--	--	--	--	--	--	--
	Parnassius	--	--	--	--	--	--	--	--	--	--
Nymphalidae	Polygonia	--	--	--	--	--	--	--	--	--	--
	Argynnis	--	--	--	--	--	--	--	1	1	2
	Phyciodes	--	--	--	--	--	--	--	--	--	1
Lycaenidae	Lycaea	--	1	--	--	--	--	--	3	3	3
Pieridae	Pieris	--	--	--	--	--	--	--	--	--	--
Total Secondary Pollinators		--	2	1	2	4	2	--	5	4	6
Other Invertebrates		111	21	177	120	102	443	172	430	264	506

APPENDIX B. Drop Trap Data

		Collection Site Number 4					Collection Site Number 5				
Collection Dates		7/14	7/27	8/8	8/18	9/4	7/15	8/3	8/11	8/20	9/5
Mid Date of Sampling Period		7/6	7/20	8/2	8/7	8/26	7/10	7/24	8/7	8/15	8/28
Trap Days (# traps x # sampling days)		121	183.5	190.6	178.5	270.0	90.0	360.7	160.4	167.1	190.5
Family	Genus										
Cleridae	Trichodes ornatus	7	10	--	1	1	6	54	20	6	11
Apidae	Bombus Q	--	--	--	--	--	--	2	2	1	2
	Bombus M	--	--	--	--	24	--	--	1	11	58
	Bombus W	--	--	5	7	67	--	4	10	43	178
	Psithyrus Q	--	--	--	--	--	--	--	--	--	--
	Psithyrus M	--	--	--	--	--	--	--	--	2	6
	Apis mellifera	--	--	--	--	--	--	--	--	--	--
Anthophoridae	Anthophora	--	--	--	--	--	--	--	--	--	--
	Melissodes	--	--	--	--	--	--	--	--	--	--
	Tetralonia	--	--	--	--	--	1	--	--	--	--
	Emphoropsis	--	--	--	--	--	1	1	--	--	--
Megachilidae	Lithurgus	--	--	--	1	--	--	--	1	--	--
	Stelis	--	--	--	--	--	--	--	--	--	--
	Anthidium	--	--	--	--	--	--	--	--	--	--
	Coelioxys	--	--	--	1	--	--	--	1	2	1
	Megachile	1	--	--	1	3	--	--	1	1	5
	Hoplitis	1	--	--	2	--	--	1	1	--	--
	Osmia	4	5	15	14	18	3	8	1	4	6
	Prochelostoma	1	--	--	--	--	--	--	--	--	--
Colletidae	Hylaeus	--	2	1	3	--	--	1	--	2	3
	Colletes	--	--	--	--	--	--	--	--	--	1
Adrenidae	Adrena	1	2	--	2	--	1	4	2	3	2
	Panurginus	--	1	--	2	2	--	--	--	--	--
Halictidae	Sphecodes	2	1	--	--	4	--	--	1	--	14
	Dialictus	--	2	--	1	5	1	--	--	1	6
	Dufourea	--	1	3	5	--	--	--	2	1	1
	Agapostemon	--	--	--	--	--	--	--	--	--	--
	Augochloropsis	--	--	--	1	--	-	--	1	3	--
	Augochlora	--	--	--	--	1	--	1	1	1	5
	Paralictus	--	--	--	--	--	--	--	1	--	--
	Halictus	--	--	--	--	3	--	--	5	10	5
	Lasioglossum	--	--	--	--	--	--	--	--	2	14
Total Large Bees		--	--	5	7	91	2	7	13	57	244
Total Small Bees		10	14	19	33	36	5	15	18	30	63
Total Primary Pollinators		17	24	24	41	128	13	76	51	93	318
Syrphidae	Microdon	--	--	--	--	--	--	--	--	--	--
	Paragus	--	--	--	--	--	--	--	--	--	--
	Leucozona	--	--	--	--	--	--	--	--	--	--
	Didea	--	--	--	--	--	--	--	--	--	1
	Eupeodes	--	--	--	--	--	--	--	--	--	--
	Syrphus	--	--	--	--	--	--	--	--	1	--
	Platychirus	--	--	--	--	--	--	--	--	--	--
	Melanostoma	--	--	--	--	--	--	--	--	--	--
	Eristalis	--	--	--	--	--	--	--	--	1	--
Bombyliidae	Anthrax	--	--	--	1	1	--	--	--	--	1
	Villa	--	1	1	1	--	--	--	--	1	2
Sphingidae	Hemaris	--	--	--	--	--	--	--	--	1	--
Pericopidae	Gnophaela	--	--	--	--	--	--	--	--	1	1
Satyridae	Cercyonis	--	--	--	--	--	--	--	--	--	--
	Oenus	--	--	--	--	--	--	1	--	--	--
Papilionidae	Papilo	--	--	--	--	--	--	1	--	--	--
	Parnassius	--	--	--	--	--	--	--	--	--	3
Nymphalidae	Polygonia	--	--	--	--	--	--	--	--	--	--
	Argynnis	--	--	--	--	2	--	--	--	1	3
	Phyciodes	--	--	--	--	1	--	--	--	--	--
Lycaenidae	Lycaea	--	--	--	--	--	--	1	2	--	5
Pieridae	Pieris	--	--	--	--	--	--	--	--	--	1
Total Secondary Pollinators		--	1	1	2	4	--	3	2	6	17
Other Invertebrates		186	292	317	221	161	27	292	567	619	311

APPENDIX B. Drop Trap Data

		Collection Site Number 6						Collection Site Number 7			
Collection Dates		7/12	7/18	7/27	8/9	8/19	9/4	7/26	8/9	8/19	9/4
Mid Date of Sampling Period		7/7	7/15	7/22	8/2	8/14	8/27	7/21	8/2	8/14	8/27
Trap Days (# traps x # sampling days)		45	97.1	162.1	209.6	155.5	316.8	74.2	112.3	184.5	303.8
Family	Genus										
Cleridae	Trichodes ornatus	1	--	3	6	1	--	3	--	2	1
Apidae	Bombus Q	--	1	--	--	--	--	1	1	--	--
	Bombus M	--	--	--	--	--	5	--	1	--	10
	Bombus W	--	--	3	1	7	14	2	2	6	27
	Psithyrus Q	--	--	--	2	--	--	--	--	--	--
	Psithyrus M	--	--	1	--	--	--	--	--	--	1
	Apis mellifera	--	--	--	--	--	--	--	--	--	--
Anthophoridae	Anthophora	--	1	--	--	--	2	--	1	1	2
	Melissodes	--	--	--	--	--	--	--	--	--	--
	Tetralonia	--	--	--	--	--	--	--	--	--	--
	Emphoropsis	--	--	--	--	--	--	--	--	--	--
Megachilidae	Lithurgus	--	--	--	--	--	--	--	--	--	--
	Stelis	--	--	--	--	--	--	--	--	--	--
	Anthidium	--	--	1	--	--	--	--	--	--	--
	Coelioxys	--	--	--	--	--	--	--	--	--	--
	Megachile	--	--	--	--	3	2	--	2	4	2
	Hoplitis	--	--	--	--	--	--	--	--	--	--
	Osmia	1	--	2	2	4	11	--	2	3	7
	Prochelostoma	--	--	--	--	--	--	--	--	--	--
Colletidae	Hylaeus	--	--	--	--	--	1	--	--	1	2
	Colletes	--	--	--	--	--	--	--	--	--	--
Adrenidae	Adrena	--	1	1	--	--	--	--	--	1	1
	Panurginus	--	--	--	--	1	--	--	--	--	2
Halictidae	Sphecodes	--	--	--	--	--	1	--	--	1	--
	Dialictus	--	--	1	--	--	--	--	--	--	1
	Dufourea	--	--	--	1	2	1	--	1	1	--
	Agapostemon	--	--	--	--	--	--	--	--	--	--
	Augochloropsis	--	--	--	1	2	--	--	--	2	--
	Augochlora	--	--	--	--	--	--	--	--	--	--
	Paralictus	--	--	--	--	--	--	--	--	--	--
	Halictus	--	--	1	--	1	--	1	--	3	9
	Lasioglossum	--	--	--	--	--	--	--	--	--	--
Total Large Bees		--	2	4	3	7	21	3	5	7	40
Total Small Bees		1	1	6	4	13	16	1	5	16	24
Total Primary Pollinators		2	3	13	13	21	37	7	10	25	65
Syrphidae	Microdon	--	--	--	--	--	--	--	--	--	--
	Paragus	--	--	--	--	--	--	--	--	--	--
	Leucozona	--	--	--	--	--	--	--	--	--	--
	Didea	--	--	--	--	--	--	--	--	--	--
	Eupeodes	--	--	--	--	--	--	--	--	--	--
	Syrphus	--	--	--	--	--	--	--	--	--	--
	Platychirus	--	--	--	--	--	--	--	--	--	1
	Melanostoma	--	--	--	--	1	--	--	--	--	--
	Eristalis	--	--	--	--	--	--	--	--	--	--
Bombyliidae	Anthrax	--	--	--	--	--	--	--	--	--	--
	Villa	--	--	--	1	1	1	--	1	--	2
Sphingidae	Hemaris	--	--	--	--	--	--	1	--	--	--
Pericopidae	Gnophaela	--	--	--	--	--	--	--	--	--	--
Satyridae	Cercyonis	--	--	--	--	--	--	--	--	--	--
	Oenus	--	--	--	--	--	--	--	--	--	--
Papilionidae	Papilo	--	--	--	--	--	--	--	--	--	--
	Parnassius	--	--	--	--	--	--	--	--	--	--
Nymphalidae	Polygonia	1	--	--	--	--	--	--	--	--	--
	Argynnis	--	--	--	--	--	--	--	--	--	--
	Phyciodes	--	--	--	--	--	--	--	--	--	--
Lycaenidae	Lycaea	--	--	--	--	--	1	--	--	--	--
Pieridae	Pieris	--	--	--	--	--	--	--	--	--	--
Total Secondary Pollinators		1	--	--	1	2	2	1	1	--	3
Other Invertebrates		50	115	168	300	222	351	86	104	222	314

APPENDIX B. Drop Trap Data

		Collection Site Number 8					Collection Site Number 9				
Collection Dates		7/12	8/2	8/10	8/20	9/5	7/12	7/28	8/9	8/19	9/4
Mid Date of Sampling Period		7/9	7/22	8/6	8/15	8/28	7/5	7/19	8/3	8/14	8/27
Trap Days (# traps x # sampling days)		48	418.7	162.5	191.8	317.0	63.5	314.9	238.8	196.0	299.5
Family	Genus										
Cleridae	Trichodes ornatus	1	57	16	20	20	1	--	--	--	--
Apidae	Bombus Q	--	--	--	1	--	--	1	--	--	2
	Bombus M	--	--	1	5	45	--	--	--	1	20
	Bombus W	--	--	10	51	107	--	--	4	3	29
	Psithyrus Q	--	--	1	1	1	--	--	--	--	--
	Psithyrus M	--	--	--	9	12	--	--	--	--	--
	Apis mellifera	--	--	--	--	--	--	--	--	--	--
Anthophoridae	Anthophora	--	--	--	--	--	--	--	--	--	--
	Melissodes	1	2	1	--	--	--	--	--	1	--
	Tetralonia	--	--	--	--	--	1	--	--	--	--
	Emphoropsis	--	--	--	--	--	--	--	--	--	--
Megachilidae	Lithurgus	---	--	--	1	1	--	--	1	--	--
	Stelis	--	1	--	--	--	--	--	--	--	--
	Anthidium	--	--	--	--	--	--	--	--	--	--
	Coelioxys	--	--	--	--	--	--	--	--	--	--
	Megachile	--	1	--	1	2	--	--	--	--	1
	Hoplitis	1	1	1	1	--	--	--	--	--	--
	Osmia	2	19	7	12	6	3	--	6	9	17
	Prochelostoma	1	--	--	--	--	--	--	--	--	--
Colletidae	Hylaeus	--	1	--	2	7	--	--	--	1	2
	Colletes	--	--	--	--	--	--	--	--	--	--
Adrenidae	Adrena	1	4	7	11	6	1	1	--	--	--
	Panurginus	2	5	--	--	--	--	--	--	--	--
Halictidae	Sphecodes	--	--	2	2	--	1	--	--	1	--
	Dialictus	--	2	3	7	15	--	--	--	--	2
	Dufourea	--	--	1	3	1	--	--	--	--	--
	Agapostemon	--	1	--	--	--	--	--	--	--	--
	Augochloropsis	--	1	3	4	6	--	--	--	--	--
	Augochlora	--	3	3	--	7	--	--	--	--	--
	Paralictus	--	--	--	--	--	--	--	--	--	--
	Halictus	1	2	17	41	26	3	3	1	--	8
	Lasioglossum	--	--	3	2	9	--	--	--	--	1
Total Large Bees		1	2	13	67	165	1	1	4	5	51
Total Small Bees		6	41	47	87	86	8	4	8	11	31
Total Primary Pollinators		8	100	76	174	271	10	5	12	16	82
Syrphidae	Microdon	--	--	--	--	--	--	1	--	--	--
	Paragus	--	--	1	--	--	--	--	--	--	--
	Leucozona	--	--	--	--	--	--	--	--	--	1
	Didea	--	--	--	--	--	--	--	--	--	--
	Eupeodes	--	--	--	1	--	--	--	--	--	--
	Syrphus	--	--	1	--	1	--	--	--	--	--
	Platychirus	--	--	--	--	--	--	1	--	--	--
	Melanostoma	1	1	1	--	--	--	--	--	--	--
	Eristalis	--	--	--	--	--	--	--	--	--	--
Bombyliidae	Anthrax	--	--	--	--	--	--	--	--	--	1
	Villa	--	--	1	2	--	--	--	2	1	1
Sphingidae	Hemaris	--	--	--	--	--	--	--	--	--	--
Pericopidae	Gnophaela	--	--	--	--	--	--	--	--	--	1
Satyridae	Cercyonis	--	--	--	--	--	--	--	--	--	--
	Oenus	--	--	--	--	--	--	--	1	--	--
Papilionidae	Papilo	--	--	--	--	--	--	--	--	--	--
	Parnassius	--	1	--	--	--	--	--	--	--	--
Nymphalidae	Polygonia	--	--	--	--	--	--	--	--	--	--
	Argynnis	--	--	--	--	1	--	--	--	--	1
	Phyciodes	--	--	--	--	--	--	--	--	--	--
Lycaenidae	Lycaea	1	3	3	5	4	--	--	--	--	--
Pieridae	Pieris	--	--	--	--	--	--	--	1	--	--
Total Secondary Pollinators		2	5	7	8	6	--	2	4	1	5
Other Invertebrates		43	138	229	297	408	99	214	261	123	272

APPENDIX B. Data summary for sweep netting, mollasses trap, Mailaise traps, and sticky traps for all sampling periods.

Family	Genus		Sweep Net	Molasses Trap	Malaise Trap	Sticky Trap
		TRAPPING EFFORT	51.8*	46**	68**	49**
Cleridae	Trichodes ornatus		18	---	2	---
Apidae	Bombus Q		79	---	3	---
	Bombus M		89	---	1	---
	Bombus W		493	---	11	---
	Psithyrus Q		34	---	---	---
	Psithyrus M		30	---	1	---
	Apis mellifera		11	---	---	---
Anthophoridae	Anthophora		6	---	---	---
Megachilidae	Megachile		15	---	---	---
	Hoplitis		3	---	---	---
	Osmia		31	---	---	---
Colletidae	Hylaeus		2	---	---	---
Andrenidae	Adrena		100	---	---	1
	Panurginus		5	---	---	1
Halictidae	Sphecodes		1	---	---	---
	Dialictus		25	---	---	---
	Augochloropsis		2	---	---	---
	Halictus		15	---	1	---
	Lasioglossum		1	---	---	---
Total Large Bees			760	0	18	0
Total Small Bees			200	0	1	2
Total Primary Pollinators			960	0	19	2
Syrphidae	Volucella		12	---	---	---
	Leucozona		6	---	---	---
	Xanthogramma		1	---	---	---
	Didea		1	---	2	---
	Syrphus		13	---	20	---
	Metasyrphus		1	---	1	---
	Epistrophe		2	---	---	---
	Platychirus		---	---	1	---
	Sericomyia		2	---	---	---
	Eristalis		35	---	---	---
	Other		1	---	---	---
Bombyliidae	Bombylius		8	---	---	---
	Anastoechus		6	---	---	---
	Phthiria		1	---	---	---
	Villa		9	---	13	---
	Other		---	---	1	---
Sphingidae	Hemaris		8	---	---	---
	Other		3	---	---	1
Pericopidae	Gnophaela		130	---	---	---
Satyridae	Cercyonis		5	---	---	---
	Erebia		3	---	---	---
	Coenonympha		9	---	1	---
	Oenus		3	---	---	---
	Other		1	---	---	---
Papilionidae	Papilo		---	---	---	16
	Parnassius		3	---	---	---
Nymphalidae	Polygonia		1	---	---	---
	Argynnis		22	---	---	---
	Phyciodes		9	---	---	---
Lycaenidae	Lycaea		31	---	---	---
	Other		7	---	---	---
Pieridae	Pieris		6	---	---	1
	Other		5	---	---	---
Total Secondary Pollinators			344	0	39	18
Total Other Invertebrates			356	202	977	501

* Man hours
** Trap days

APPENDIX C. SPECIES LIST

Scientific Name	Code
Acer glabrum	ACGL
Achillea millefolium	ACMI
Actaea spp.	ACSPP
Agoseris glauca	AGGL
Agoseris spp.	AGOSPP
Agropyron caninum	AGCA
Agropyron spicatum	AGSP
Agropyron spp.	AGSPP
Agrostis spp.	AGRSPP
Allium brevistylum	ALBR
Allium cernuum	ALCE
Allium spp.	ALSPP
Allium textile	ALTE
Alyssum alyssoides	ALAL
Amelanchier alnifolia	AMAL
Anaphalis margaritacea	ANMA
Anemone multifida	ANMU
Anemone nuttaliana	ANNU
Anemone spp.	ANSPP
Antennaria microphylla	ANMI
Antennaria parvifolia	ANPA
Antennaria racemosa	ANRA
Antennaria spp.	ANTSPP
Aquilegia coerulea	AQCO
Arabis glabra	ARGL
Arabis nuttallii	ARNU
Arabis spp.	ARSPP
Arctostaphylos uva-ursi	ARUV
Arenaria congesta	ARCO
Arenaria macrophylla	ARMA
Arenaria obtusiloba	AROB
Arenaria spp.	ARESPP
Arnica cordifolia	ARCOR
Arnica sororia	ARSO
Arnica spp.	ARNSPP
Artemisia dracunculus	ARDR
Artemisia ludoviciana	ARLU
Artemisia tridentata	ARTR
Aster conspicuus	ASCO
Aster laevis	ASLA
Aster spp. #1	ASSPP-1
Aster spp. #2	ASSPP-2
Aster spp. #3	ASSPP-3
Astragalus miser	ASMI
Astragalus spp.	ASTSPP
Balsamorhiza sagittata	BASA
Berberis repens	BERE
Besseya rubra	BERU
Besseya wyomingensis	BEWY
Borago spp.	BOSPP
Bromus anomalus	BRAN
Bromus spp.	BRSPP
Calamagrostis rubescens	CARU
Campanula rotundifolia	CARO
Carex geyeri	CAGE
Carex rossii	CAROS
Carex spp. #1	CASPP-1
Carex spp. #2	CASPP-2
Cerastium arvense	CEAR
Chenopodium album	CHAL
Cirsium spp.	CISPP
Claytonia lanceolata	CLLA
Clematis hirsutissima	CLHI
Clematis columbiana	CLCO
Collinsia parviflora	COPA
Collomia linearis	COLI
Comandra umbellata	COUM
COMPOSITAE	COMPOS
Conimitella williamsii	COWI
Crepis acuminata	CRAC
Crepis atrabarba	CRAT
CRUCIFERAE	CRUCIF
Cymopterus spp.	CYSPP
Danthonia spp.	DASPP
Delphinium bicolor	DEBI
Delphinium spp.	DESPP
Disporum trachycarpum	DITR
Dodecatheon conjugens	DOCO
Draba verna	DRVE
Elymus glaucus	ELGL
Elymus canadensis	ELCA
Epilobium paniculatum	EPPA
Erigeron speciosus	ERSP
Erigeron spp.	ERSPP
Eriogonum umbellatum	ERUM
Eriogonum spp.	ERISPP
Erythronium grandiflorum	ERGR
Festuca idahoensis	FEID
Fragaria vesca	FRVE
Fragaria virginiana	FRVI
Frasera speciosa	FRSP
Fritillaria atropurpurea	FRAT
Fritillaria pudica	FRPU
Gaillardia aristata	GAAR
Galium aparine	GAAP
Galium boreale	GABO
Geranium richardsonii	GERI
Geranium viscosissimum	GEVI
Geum macrophyllum	GEMA
Geum spp.	GESPP
Geum triflorum	GETR
Gnaphalium viscosum	GNVI
Goodyera oblongifolia	GOOB
GRAMINEAE	GRAMIN
Gutierrezia sarothrae	GUSA
Helianthella uniflora	HEUN
Heuchera cylindrica	HECY
Hieracium cynoglossoides	HICY
Hymenoxys grandiflora	HYGR
Iris missouriensis	IRMI
Juniperus communis	JUCO
Koeleria cristata	KOCR
Linum perenne	LIPE
Lithophragma bulbifera	LIBU
Lithophragma parviflora	LIPA
Lithophragma spp.	LISPP
Lithospermum ruderale	LIRU
Lomatium cous	LOCO
Lomatium triternatum	LOTR
Lomatium spp.	LOSPP
Lonicera utahensis	LOUT
Lupinus spp.	LUSPP
Melica spectabilis	MESP
Mentha citrata	MECI
Mertensia oblongifolia	MEOB
Microseris nutans	MINU
Mitella stauropetala	MIST
Myosotis sylvatica	MYSY
Nemophila breviflora	NEBR
Osmorhiza chilensis	OSCH
Oxytropis sericea	OXSE
Pachistima myrsinites	PAMY
Penstemon spp.	PESPP
Perideridia gairdneri	PEGA
Phacelia spp.	PHSPP
Phleum pratense	PHPR
Phlox hoodii	PHHO
Phlox longifolia	PHLO
Phlox multiflora	PHMU
Poa pratensis	POPR
Poa spp.	POSPP
Polygonum bistortoides	POBI

Scientific Name	Code
Polygonum douglasii	PODO
Polygonum spp.	POLSPP
Populus tremuloides	POTR
Potentilla arguta	POAR
Potentilla diversifolia	PODI
Potentilla glandulosa	POGL
Potentilla gracilis	POGR
Potentilla ovina	POOV
Potentilla spp.	POTSPP
Potentilla recta	PORE
Pseudotsuga menziesii	PSME
Ranunculus acris	RAAC
Ranunculus glaberrimus	RAGL
Ribes cereum	RICE
Rosa acicularis	ROAC
Rosa spp.	ROSPP
Rumex spp.	RUSPP
Saxifraga rhomboidea	SARH
Sedum stenopetalum	SEST
Senecio pseudaureus	SEPS
Senecio spp.	SESPP
Shepherdia canadensis	SHCA
Smilacina racemosa	SMRA
Smilacina stellata[a]	SMST
Spirea betulifolia	SPBE
Stipa comata	STCO
Stipa spp.	STSPP
Stipa viridula	STVI
Symphoricarpos oreophilus	SYOR
Taraxacum officinale	TAOF
Thalictrum occidentale	THOC
Tragopogon dubius	TRDU
Trifolium longipes	TRLO
Trifolium spp.	TRSPP
UMBELLIFERAE	UMBELL
Unknown - fleshy leaf	UNK-1
Unknown - opposite leaf	UNK-2
Valeriana dioica	VADI
Valeriana sitchensis	VASI
Viola adunca	VIAD
Viola nuttallii	VINU
Viola orbiculata	VIOR
Zygadenus venenosus	ZYVE
Heuchera parvifolia	HEPA
Heuchera spp.	HESPP

	Site Number 1A				Site Number 1B			
	Early		Late		Early		Late	
Species Code	A.C.* Coverage	A.F.C.** Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage
ACMI	8.3	---	8.3	1.6	9.0	---	7.3	1.6
AGCA	---	---	<1.0	---	---	---	---	---
AGSP	---	---	---	---	1.5	---	---	---
ALAL	2.3	1.8	4.3	---	---	---	---	---
ANMI	---	---	---	---	<1.0	---	3.5	---
ANMU	---	---	<1.0	---	---	---	---	---
ANSPP	---	---	1.5	---	---	---	---	---
ARCO	---	---	<1.0	0.5	<1.0	---	---	---
ARDR	---	---	---	---	2.5	---	3.0	0.9
ARGL	---	---	---	---	<1.0	0.3	---	---
ARLU	---	---	---	---	1.8	---	2.3	0.3
ARSO	1.5	---	---	---	5.5	---	---	---
ARTR	---	---	<1.0	---	---	---	---	---
ASSPP	---	---	---	---	3.8	---	---	---
BASA	---	---	---	---	<1.0	---	<1.0	---
BERE	<1.0	---	<1.0	---	---	---	---	---
BRSPP	---	---	<1.0	---	---	---	2.3	1.2
CARO	---	---	---	---	---	---	<1.0	0.5
CEAR	<1.0	---	1.3	---	5.0	2.5	3.3	0.2
CHAL	---	---	<1.0	0.5	---	---	<1.0	0.5
COLI	10.3	10.3	10.0	1.1	2.8	2.2	<1.0	0.2
COPA	13.0	12.1	---	---	1.3	0.7	---	---
CRAC	---	---	---	---	1.8	---	---	---
CRUCIF	---	---	1.0	0.5	---	---	---	---
DEBI	3.3	0.8	---	---	9.3	6.1	---	---
DRVE	9.0	6.0	---	---	---	---	---	---
EPPA	---	---	<1.0	0.4	---	---	---	---
ERISPP	---	---	<1.0	---	---	---	---	---
ERSP	---	---	---	---	---	---	3.0	1.4
FEID	5.0	---	<1.0	---	5.0	---	2.0	---
GETR	<1.0	0.5	<1.0	0.5	---	---	---	---
GEVI	5.0	---	7.0	---	8.8	---	5.5	1.4
GRAMIN	<1.0	---	---	---	---	---	---	---
HECY	---	---	---	---	3.0	---	<1.0	---
HEUN	---	---	---	---	11.3	---	4.5	---
LIPA	22.5	7.0	---	---	17.8	12.3	---	---
LIRU	<1.0	---	<1.0	---	---	---	---	---
LOTR	6.3	2.3	---	---	1.8	0.6	---	---
LUSPP	25.3	---	39.3	21.7	5.3	---	3.0	---
MECI	---	---	---	---	6.0	---	5.8	2.0
MESP	---	---	---	---	1.5	---	---	---
NESPP	---	---	---	---	3.0	---	---	---
PHLO	1.5	0.3	2.3	---	1.0	0.7	<1.0	---
PHPR	---	---	---	---	<1.0	---	---	---
POAR	<1.0	---	---	---	2.5	---	---	---
PODO	2.8	---	11.3	10.5	<1.0	---	1.5	1.5
POGL	---	---	---	---	5.3	---	---	---
PORE	---	---	<1.0	0.5	---	---	2.5	0.2
POPR	31.0	---	33.8	---	29.0	---	44.3	---
ROSPP	---	---	---	---	<1.0	---	---	---
STCO	---	---	20.5	---	---	---	1.3	---
STSPP	5.5	---	---	---	6.3	---	---	---
STVI	---	---	2.0	---	---	---	1.3	---
SYOR	<1.0	---	---	---	---	---	---	---
TAOF	3.3	---	4.3	---	<1.0	---	---	---
TRDU	1.0	---	2.0	1.3	---	---	<1.0	---
RAGL	---	---	---	---	<1.0	---	---	---
VIOR	---	---	<1.0	---	---	---	---	---
VINU	---	---	1.0	---	---	---	---	---
ZYVE	---	---	---	---	<1.0	0.5	---	---

*Average Canopy
**Average Flowering Canopy

Species Code	Site Number 2A Early A.C. Coverage	Site Number 2A Early A.F.C. Coverage	Site Number 2A Late A.C. Coverage	Site Number 2A Late A.F.C. Coverage	Site Number 2B Early A.C. Coverage	Site Number 2B Early A.F.C. Coverage	Site Number 2B Late A.C. Coverage	Site Number 2B Late A.F.C. Coverage
ACMI	5.3	---	8.3	---	5.5	---	6.0	---
ACGL	---	---	---	---	< 1.0	---	< 1.0	---
AGSP	4.0	---	---	---	---	---	---	---
AGSPP	---	---	< 1.0	---	---	---	---	---
ANMI	---	---	2.8	---	2.0	---	---	---
ANPA	3.8	---	---	------	---	---	---	---
ANRA	---	---	---	---	---	---	2.5	---
ARCO	---	---	---	---	8.0	---	4.0	---
ARSPP	1.0	---	---	---	---	---	---	---
ARSO	5.8	---	1.0	---	---	---	---	---
ASCO	---	---	---	---	< 1.0	---	< 1.0	---
ASSPP	1.5	---	---	---	---	---	---	---
ARTR	---	---	3.5	0.3	---	---	---	---
BASA	10.0	4.0	8.5	---	---	---	---	---
BERE	---	---	---	---	1.3	---	1.3	---
BOSPPP	< 1.0	---	---	---	---	---	---	---
BRSPP	3.0	---	3.3	---	< 1.0	---	< 1.0	---
CAGE	---	---	---	---	10.3	---	8.8	---
CARU	---	---	---	---	50.3	---	66.0	---
CASPP	8.0	---	3.4	---	---	---	---	---
CEAR	---	---	2.0	0	---	---	---	---
CLLA	---	---	---	---	< 1.0	0.3	---	---
COLI	< 1.0	0	< 1.0	0.3	---	---	---	---
COPA	2.0	1.0	---	---	< 1.0	0.3	---	---
COUM	< 1.0	0	---	---	---	---	---	---
CRAC	---	---	---	---	< 1.0	0	---	---
ELGL	---	---	---	---	< 1.0	0	---	---
ERGR	---	---	---	---	12.5	1.0	1.0	0
ERSPP	---	---	1.8	1.5	---	---	---	---
ERUM	10.8	0	15.5	3.0	---	---	---	---
DITR	---	---	---	---	< 1.0	0	---	---
FEID	5.0	0	4.5	0	---	---	---	---
FRVE	---	---	----	---	2.5	0	2.5	0
FRVI	---	---	---	---	4.3	0	6.5	0
GAAP	2.0	1.0	---	---	---	---	---	---
GABO	---	---	1.3	0	---	---	---	---
GERI	---	---	---	---	< 1.0	0	< 1.0	0.3
GEVI	9.5	0	5.3	1.0	< 1.0	0	< 1.0	0
GOOB	---	---	---	---	< 1.0	0	< 1.0	0
HEUN	---	---	1.0	0	---	---	---	---
LIPA	10.8	4.7	---	---	---	---	---	---
LIRU	2.8	1.9	< 1.0	0	1.0	1.0	2.5	0
LOTR	---	---	---	---	2.3	0	1.3	0.6
LOUT	---	---	---	---	< 1.0	0	---	---
LUSPP	1.8	0	< 1.0	0	12.8	0	9.5	0
MESP	18.0	0	2.3	0	---	---	---	----
MIST	---	---	---	---	< 1.0	0.3	2.0	0
NESPP	---	---	---	---	< 1.0	0.5	---	---
OSCH	---	---	---	---	2.5	0	1.5	0
PEGA	< 1.0	0	---	---	< 1.0	0	---	---
PHPR	---	---	---	---	---	---	< 1.0	0
PHSPP	< 1.0	0	---	---	---	---	---	---
PODO	2.8	0	3.0	1.4	---	---	< 1.0	0.5
POGL	---	---	---	---	1.5	0	---	---
POGR	---	---	---	---	---	---	2.0	0.5
POPR	---	---	36.3	0	---	----	---	---
PORE	---	---	2.0	0	---	---	---	---
POSPP	6.0	0	----	---	---	---	---	---
RAAC	---	---	---	---	< 1.0	0	---	---
ROSPP	< 1.0	0	---	---	---	---	---	---
SMRA	---	---	---	---	---	---	< 1.0	0
SPBE	---	---	---	---	3.0	0	7.3	0
STSPP	---	---	3.8	0	---	---	---	---
SYOR	---	---	---	---	7.5	0	7.3	0
TAOF	< 1.0	0	---	---	1.8	0	3.5	0
THOC	---	---	---	---	13.0	0.8	3.7	0
TRSPP	---	---	---	---	< 1.0	0	< 1.0	0
UMBELL	---	---	---	---	< 1.0	0	---	---
VADI	---	---	---	---	< 1.0	0.3	---	---
VASI	---	---	---	---	---	---	1.3	0
VIAD	---	---	---	---	---	---	< 1.0	0
VINU	2.0	0.1	2.0	0	---	---	---	---
VIOR	---	---	---	---	< 1.0	0	---	---
ZYVE	1.0	0.3	< 1.0	0	---	---	---	---

Species Code	Site Number 3A Early A.C. Coverage	Site Number 3A Early A.F.C. Coverage	Site Number 3A Late A.C. Coverage	Site Number 3A Late A.F.C. Coverage	Site Number 3B Early A.C. Coverage	Site Number 3B Early A.F.C. Coverage	Site Number 3B Late A.C. Coverage	Site Number 3B Late A.F.C. Coverage
ACMI	No data		4.0	0	No data		1.5	0
AGCA	"		---	---	"		2.3	0
AGSP	"		7.8	0	"		---	---
ANMI	"		6.0	0	"		---	---
ANTSP	"		---	---	"		9.0	6.0
ARCO	"		9.0	5.1	"		<1.0	0.5
ARCOR	"		---	---	"		6.8	0
ASLA	"		---	---	"		10.0	1.2
ASMI	"		5.3	2.4	"		22.0	5.2
ASSPP	"		<1.0	0	"		---	---
BEWY	"		1.8	0	"		---	---
BRSPP	"		29.3	0	"		3.0	0
CARO	"		2.8	0.7	"		---	---
CAROS	"		---	---	"		1.3	0
CASPP	"		23.5	0	"		---	---
CEAR	"		3.3	0	"		---	---
CLHI	"		6.3	0	"		---	---
COMPOS	"		<1.0	0.3	"		---	---
COUM	"		<1.0	0	"		---	---
DOCO	"		<1.0	0	"		---	---
ERSPP	"		3.5	1.8	"		---	---
FEID	"		12.5	0	"		1.0	0
FRSP	"		<1.0	0	"		---	---
GABO	"		---	---	"		<1.0	0
GETR	"		4.3	1.4	"		<1.0	0
GRAMIN	"		4.0	0	"		---	---
HEUN	"		---	---	"		<1.0	0.5
LIPE	"		<1.0	0.5	"		---	---
LOCO	"		2.0	0	"		---	---
LUSPP	"		<1.0	0.1	"		---	---
MYSY	"		---	---	"		<1.0	0
NEBR	"		<1.0	0.3	"		---	---
OXSE	"		<1.0	0	"		---	---
PHHO	"		10.5	0	"		---	---
PHLO	"		---	---	"		<1.0	0
POBI	"		5.5	0.2	"		<1.0	0
POPR	"		---	---	"		52.0	0
SARH	"		<1.0	0	"		---	---
STSPP	"		1.8	0	"		5.3	0
TAOF	"		---	---	"		1.0	0
VASI	"		---	---	"		13.0	0
VIAD	"		---	---	"		1.3	0
VIOR	"		2.0	0	"		---	---
ZYVE	"		1.3	0	"		---	---

Species Code	Site Number 4A Early A.C. Coverage	Site Number 4A Early A.F.C. Coverage	Site Number 4A Late A.C. Coverage	Site Number 4A Late A.F.C. Coverage	Site Number 4B Early A.C. Coverage	Site Number 4B Early A.F.C. Coverage	Site Number 4B Late A.C. Coverage	Site Number 4B Late A.F.C. Coverage
ACMI	11.5	0	15.8	0.9	3.8	0	4.5	0.7
AGCA	2.8	0	<1.0	0	2.0	0	4.0	0
AGGL	<1.0	0	---	---	<1.0	0	---	---
AGSP	---	---	1.3	0	---	---	---	---
ALCE	<1.0	0	<1.0	0.3	---	---	---	---
ANMA	1.0	0	---	---	---	---	---	---
ANMI	1.8	0	3.0	0.6	---	---	---	---
ARCO	1.0	0	1.5	0.8	---	---	---	---
ARSO	<1.0	0	1.0	0.3	---	---	---	---
ASMI	---	---	---	---	1.0	0	1.3	0.6
ASSPP-1	---	---	---	---	<1.0	0	<1.0	0
ASSPP-2	---	---	<1.0	0.3	2.5	0	5.3	3.3
ASTSPP	---	---	<1.0	0	----	---	---	---
BRSPP	13.0	0	9.0	0	3.0	0	6.8	0
CEAR	---	---	---	---	---	---	<1.0	0
CLLA	<1.0	0.4	---	---	---	---	---	---
COLI	---	---	8.8	6.4	---	---	28.8	21.6
CRAC	<1.0	0	1.3	0	---	---	---	---
DEBI	1.3	0.3	<1.0	0	<1.0	0.3	<1.0	0
DOCO	1.0	0.3	<1.0	0	---	---	---	---
ERGR	<1.0	0	---	---	---	---	---	---
FEID	1.8	0	1.8	0	---	---	---	---
FRPU	---	---	---	---	1.8	0.4	---	---
FRVI	4.5	0	8.0	0	<1.0	0	1.8	0
GAAP	---	---	---	---	<1.0	0.3	---	---
GABO	---	---	---	---	2.0	0	2.5	2.5
GEVI	<1.0	0	---	---	9.5	0	14.5	10.0
GRAMIN	---	---	2.0	0	---	---	---	---
HICY	---	---	---	---	6.0	0	---	---
HYGR	---	---	---	---	---	---	5.8	1.6
LIPA	<1.0	0	---	---	6.5	0	---	---
LOTR	---	---	2.5	1.1	---	---	3.8	1.9
LUSPP	2.0	0	3.3	1.3	---	---	---	---
MESP	---	---	---	---	5.3	0	2.0	0
MYSY	3.8	1.3	1.5	0	---	---	---	---
NEBR	16.0	9.6	8.0	0.5	39.8	28.2	3.0	0
PEGA	3.5	0	---	---	4.0	0	---	---
PHLO	1.8	0.9	2.0	0	---	---	---	---
PHPR	30.8	0	41.5	0	10.8	0	13.0	1.3
POBI	2.0	0	<1.0	0	---	---	---	---
PODO	---	---	12.3	8.5	---	---	9.8	7.5
POGL	1.5	0	5.0	0.8	7.3	0	10.5	8.2
POPR	3.8	0	---	---	---	---	---	---
POSPP	---	---	---	---	1.8	0	5.5	0
RAGL	<1.0	0	---	---	---	---	---	---
ROSPP	<1.0	0	---	---	4.0	0	4.5	4.5
SYOR	---	---	---	---	<1.0	0	---	---
TAOF	<1.0	0	1.8	0	<1.0	0.3	1.5	0
TRLO	1.8	0.6	4.3	0.7	3.0	0.4	2.0	0
UMBELL	---	---	1.0	0.5	---	---	---	---
UNK-2	5.0	0	---	---	8.5	0	---	---
VINU	1.5	0.5	<1.0	0	<1.0	0	1.0	0
ZYGE	<1.0	0	<1.0	0	---	---	---	---

	Site Number 5A				Site Number 5B			
	Early		Late		Early		Late	
Species Code	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage
ACMI	1.8	0	2.3	0	1.8	0	3.5	0
AGCA	<1.0	0	1.3	0	---	---	---	---
AGGL	4.5	0.8	---	---	1.8	0	---	---
AGOSPP	---	---	1.3	0	---	---	1.3	0
AGSP	---	---	<1.0	0	---	---	---	---
ALCE	---	---	---	---	---	---	<1.0	0
ALTE	1.0	0	1.0	0.3	---	---	---	---
ANMI	6.0	0	6.8	0	4.5	0	4.3	0
ANMU	---	---	1.0	0	---	---	---	---
ANNU	1.0	0.1	---	---	4.5	0.3	---	---
ARCO	2.5	0	2.8	0.8	<1.0	0	<1.0	0
ARCOR	---	---	---	---	<1.0	0	<1.0	0
ARMA	---	---	---	---	---	---	<1.0	0
ARNSPP	---	---	4.5	0	---	---	---	---
ARNU	1.0	1.0	---	---	---	---	---	---
ARSO	---	---	---	---	---	---	<1.0	0
ARUV	---	---	---	---	1.3	0.3	2.3	0
ASMI	---	---	11.0	6.1	7.8	0	9.5	2.0
ASSPP-1	<1.0	0	6.5	2.3	<1.0	0	4.0	0.3
ASSPP-2	1.8	0	---	---	---	---	---	---
ASTSPP	8.8	0	6.0	0.3	---	---	---	---
BERE	---	---	---	---	<1.0	0	<1.0	0
BRSPP	---	---	---	---	---	---	2.5	0
CARO	---	---	1.0	0.3	<1.0	0	<1.0	0
CASPP	10.8	0	3.8	0	---	---	---	---
CEAR	<1.0	0	2.5	0	---	---	<1.0	0
CLHI	1.5	0.3	1.3	0	---	---	5.8	0
CLLA	<1.0	0	---	---	---	---	---	---
COLI	---	---	4.5	0.6	---	---	---	---
COMPOS	1.3	0	---	---	2.3	0	---	---
COPA	1.5	1.0	---	---	---	---	---	---
COUM	<1.0	0	---	---	---	---	---	---
DASPP	---	---	12.3	0	---	---	---	---
DEBI	3.8	1.0	---	---	---	---	---	---
DOCO	<1.0	0.4	---	---	---	---	---	---
ERGR	---	---	---	---	1.0	0	---	---
ERSP	---	---	4.5	3.2	---	---	---	---
FEID	28.3	0	29.8	0	20.3	0	26.3	0
FRSP	1.5	0	1.3	0	---	---	---	---
FRVE	---	---	---	---	1.3	0	3.5	0
GAAR	---	---	3.5	0	---	---	---	---
GABO	1.8	0	1.3	1.1	---	---	2.8	0.3
GETR	---	---	---	---	3.0	0	4.0	0
HEUN	<1.0	0	<1.0	0.5	12.5	0	17.0	9.6
LIBU	1.8	0.9	---	---	---	---	---	---
LOCO	2.8	0.4	---	---	<1.0	0.4	---	---
LOTR	1.3	0	<1.0	0.3	---	---	---	---
LUSPP	2.5	0	2.3	0	---	---	---	---
PAMY	---	---	---	---	<1.0	0	<1.0	0
PESPP	2.3	0	4.5	1.5	---	---	---	---
PHHO	4.8	0.9	3.8	0	---	---	---	---
PHLO	2.0	0	<1.0	0	14.5	0	10.8	2.4
POBI	2.3	0.3	---	---	1.5	0	<1.0	0
PODO	---	---	1.8	0	---	---	---	---
POGR	---	---	---	---	---	---	<1.0	0.4
POPR	---	---	---	---	---	---	4.3	0
POSPP	<1.0	0	1.3	0	2.5	0	---	---
POTSPP	---	---	---	---	<1.0	0	---	---
ROAC	---	---	---	---	<1.0	0	1.5	0
SARH	<1.0	0	---	---	---	---	---	---
STSPP	8.0	0	---	---	3.5	0	---	---
STVI	---	---	4.8	0	---	---	2.5	0
TAOF	<1.0	0	<1.0	0	---	---	---	---
UMBELL	---	---	---	---	<1.0	0	---	---
UNK-2	---	---	---	---	<1.0	0	---	---
VASI	---	---	---	---	<1.0	0	1.0	0
VINU	7.3	2.4	<1.0	0	---	---	---	---
VIOR	---	---	---	---	<1.0	0	---	---
ZYVE	4.8	0	1.5	0	<1.0	0	1.3	0

Species Code	Site Number 6A Early A.C. Coverage	Site Number 6A Early A.F.C. Coverage	Site Number 6A Late A.C. Coverage	Site Number 6A Late A.F.C. Coverage	Site Number 6B Early A.C. Coverage	Site Number 6B Early A.F.C. Coverage	Site Number 6B Late A.C. Coverage	Site Number 6B Late A.F.C. Coverage
ACMI	2.0	0	2.3	0	2.5	0	1.5	0
AGGL	11.3	1.6	4.5	0	---	---	---	---
AGRSPP	---	---	---	---	---	---	<1.0	0
AGSP	<1.0	0	---	---	<1.0	0	---	---
ANMI	13.0	0	15.8	0.9	2.3	0	3.5	0
ARCO	4.0	0	6.3	1.5	1.5	0	---	---
ARNU	---	---	---	---	1.3	0.4	<1.0	0
ARSO	2.3	0	2.0	0	---	---	---	---
ARTR	4.0	0	3.0	1.5	---	---	---	---
ASLA	---	---	---	---	3.0	0	2.3	0
ASSPP	<1.0	0	3.3	0	---	---	---	---
ASTSPP	3.3	0	3.3	0.1	---	---	---	---
BERU	---	---	<1.0	0	---	---	---	---
BRSPP	---	---	---	---	2.0	0	---	---
CAROS	---	---	---	---	<1.0	0	1.0	0
CARU	---	---	---	---	41.3	0	46.8	0
CEAR	---	---	<1.0	0	---	---	---	---
CLLA	1.8	0.4	---	---	2.8	1.0	---	---
COLI	---	---	---	---	1.5	0	2.0	0.5
COMPOS	---	---	<1.0	0	---	---	---	---
COPA	---	---	---	---	1.0	1.0	<1.0	0
DEBI	2.3	0	<1.0	0	1.0	0	---	---
ERGR	---	---	---	---	4.3	0	2.5	0
FEID	12.3	0	5.5	0	1.0	0	1.0	0
FRVE	---	---	---	---	---	---	1.0	0
GABO	---	---	---	---	1.3	0	1.8	0.2
GETR	1.0	0	<1.0	0	<1.0	0	---	---
GEVI	---	---	---	---	2.3	0	2.8	0.5
GRAMIN	40.5	0	51.8	0	---	---	---	---
HESPP	---	---	---	---	<1.0	0	---	---
LIPA	---	---	---	---	6.8	0	1.3	0
LUSPP	<1.0	0	1.8	0	---	---	<1.0	0
MYSY	---	---	---	---	5.0	0.6	5.0	0.4
OSCH	---	---	---	---	---	---	<1.0	0
PEGA	---	---	---	---	2.3	0	---	---
PHLO	3.5	0	6.0	0	---	---	---	---
POAR	---	---	---	---	---	---	<1.0	0
POBI	4.0	0	2.8	0	---	---	---	---
POGL	---	---	---	---	1.3	0	<1.0	0
POOV	3.3	0.3	3.5	0.2	---	---	---	---
POPR	---	---	---	---	---	---	1.5	0
PSME	---	---	---	---	---	---	<1.0	0
RAGL	1.3	0.4	---	---	---	---	---	---
ROSPP	<1.0	0	<1.0	0	---	---	---	---
RUSPP	<1.0	0	---	---	---	---	---	---
SARH	6.0	0.4	3.3	0	<1.0	0	<1.0	0
SEST	<1.0	0	<1.0	0	---	---	---	---
TAOF	<1.0	0	<1.0	0	6.0	0	7.3	0
UNK-1	3.0	0	<1.0	0	---	---	---	---
VINU	---	---	---	---	7.8	1.2	3.3	0
ZYVE	4.5	0	2.3	0	---	---	---	---

Species Code	Site Number 7A Early A.C. Coverage	Site Number 7A Early A.F.C. Coverage	Site Number 7A Late A.C. Coverage	Site Number 7A Late A.F.C. Coverage	Site Number 7B Early A.C. Coverage	Site Number 7B Early A.F.C. Coverage	Site Number 7B Late A.C. Coverage	Site Number 7B Late A.F.C. Coverage
ACMI	2.8	0	2.5	0	1.0	0	1.3	0
AGOSPP	---	---	< 1.0	0	---	---	---	---
AGRSPP	12.5	0	2.3	0	---	---	---	---
AGSP	---	---	---	---	3.0	0	3.8	0
ALBR	---	---	1.0	1.0	---	---	---	---
ALCE	1.8	0	---	---	< 1.0	0	< 1.0	0
AMAL	< 1.0	0	1.5	0	1.5	0	1.8	0
ANMI	< 1.0	0	< 1.0	0	2.0	0	1.8	0
ANSPP	---	---	---	---	< 1.0	0	---	---
ARCOR	---	---	---	---	8.0	0	5.3	0
ARESPP	< 1.0	0	1.5	0	---	---	---	---
ARGL	< 1.0	0.3	< 1.0	0	---	---	---	---
ARNU	< 1.0	0	< 1.0	0	---	---	---	---
ARUV	1.5	0	1.5	0	---	---	---	---
ASLA	2.0	0	1.3	0	1.5	0	2.5	0
ASMI	---	---	---	---	7.5	0	9.5	0.8
ASTSPP	---	---	< 1.0	0	---	---	---	---
BERE	7.3	0	3.5	0	< 1.0	0	1.0	0
BRSPP	---	---	< 1.0	0	---	---	---	---
CASPP	---	---	< 1.0	0	---	---	---	---
CISPP	---	---	---	---	< 1.0	0	1.0	0
CLCO	1.8	0	1.5	0	---	---	---	---
CLHI	---	---	---	---	---	---	1.0	0
COLI	---	---	< 1.0	0.3	---	---	< 1.0	0
COPA	< 1.0	0	---	---	< 1.0	0.4	< 1.0	0.3
COWI	< 1.0	0	< 1.0	0	---	---	---	---
CRAT	---	---	---	---	< 1.0	0	< 1.0	0
FEID	1.3	0	< 1.0	0	< 1.0	0	< 1.0	0
FRAT	---	---	---	---	< 1.0	0	---	---
FRVI	9.0	0.7	5.5	0	4.3	0	5.5	0
GABO	5.0	0	6.8	0.5	3.5	0	3.8	0.3
GEMA	1.3	0	< 1.0	0	---	---	---	---
GEVI	17.5	0	16.5	1.0	---	---	---	---
HESPP	---	---	---	---	< 1.0	0	< 1.0	0
IRMI	2.0	0	2.5	0.4	---	---	---	---
JUCO	< 1.0	0	< 1.0	0	---	---	---	---
LIRU	< 1.0	0	1.5	0	---	---	---	---
LUSPP	2.0	0	4.5	3.2	3.3	0	1.0	0.2
MEOB	< 1.0	0.1	---	---	1.0	0	< 1.0	0
MYSY	< 1.0	0.2	< 1.0	0	< 1.0	0.3	1.8	0
NESPP	---	---	< 1.0	0	---	---	---	---
OSCH	< 1.0	0	< 1.0	0	---	---	---	---
PEGA	< 1.0	0	---	---	---	---	---	---
PESPP	< 1.0	0	---	---	---	---	---	---
PHLO	---	---	---	---	1.3	0	1.8	0
PHPR	2.3	0	1.3	0	---	---	---	---
POGL	3.3	0	4.0	0	---	---	---	---
POSPP	15.8	0	25.3	0	9.5	0	14.0	0
POTR	1.3	0	3.3	0	---	---	---	---
RAGL	< 1.0	0.3	---	---	---	---	---	---
ROSPP	< 1.0	0	< 1.0	0	1.0	0	3.3	0
SEPS	---	---	< 1.0	0	1.0	0	1.3	0
SEST	< 1.0	0	---	---	---	---	---	---
SHCA	---	---	< 1.0	0	---	---	---	---
SMRA	---	---	1.0	0	15.3	12.2	3.5	0
SMST	1.0	0.5	< 1.0	0	---	---	---	---
STSPP	---	---	---	---	---	---	< 1.0	0
SYOR	19.5	0	16.8	2.6	< 1.0	0	1.8	0
TAOF	28.0	0	25.5	0	1.0	0	1.8	0
THOC	20.0	4.0	19.8	0.4	< 1.0	0	< 1.0	0
TRDU	< 1.0	0	---	---	---	---	---	---
VASI	---	---	---	---	4.0	2.0	6.0	0.6
VINU	---	---	---	---	< 1.0	0	---	---

Species Code	Site Number 8A				Site Number 8B			
	Early		Late		Early		Late	
	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage	A.C. Coverage	A.F.C. Coverage
ACMI	3.8	0	6.0	1.3	2.8	0	2.5	0
AGGL	1.8	0.4	---	---	---	---	---	---
AGSP	15.8	0	15.3	0	---	---	---	---
ANMI	< 1.0	0	< 1.0	0	< 1.0	0	< 1.0	0
ANNU	---	---	---	---	< 1.0	0	---	---
ANRA	---	---	---	---	---	---	< 1.0	0
ARCO	---	---	---	---	< 1.0	0	< 1.0	0.5
ARCOR	---	---	---	---	2.0	0	1.3	0
ARMA	---	---	---	---	---	---	1.8	0
ARTR	6.0	0	7.0	1.8	---	---	---	---
ASMI	3.3	0.5	3.3	0.6	17.8	0	20.3	0
ASSPP	< 1.0	0	---	---	---	---	1.0	0.5
ASSPP-1	---	---	---	---	---	---	< 1.0	0
ASTSPP	< 1.0	0.3	< 1.0	0	---	---	---	---
BASA	2.8	0	1.5	0	---	---	---	---
BERE	---	---	---	---	1.8	0	2.0	0
BRAN	---	---	1.0	0	---	---	---	---
BRSPP	< 1.0	0	---	---	< 1.0	0	1.5	0
CAGE	---	---	---	---	10.3	0	9.5	0
CARU	---	---	---	---	17.5	0	20.8	0
CEAR	1.5	0.8	1.0	0	---	---	---	---
CLHI	---	---	---	---	---	---	1.0	0
COLI	3.0	1.9	2.0	0	---	---	---	---
COPA	< 1.0	0.2	---	---	< 1.0	0	---	---
COUM	2.8	0.2	2.5	0	---	---	---	---
COWI	---	---	---	---	1.0	0	< 1.0	0
CRAC	---	---	4.0	0.9	---	---	---	---
CRAT	3.3	0	< 1.0	0	---	---	---	---
CYSPP	---	---	< 1.0	0	---	---	---	---
DEBI	2.0	0.3	---	---	---	---	---	---
DOCO	---	---	---	---	< 1.0	0.5	---	---
ERGR	---	---	---	---	12.5	2.9	< 1.0	0
ERSP	---	---	< 1.0	0	---	---	---	---
ERUM	1.5	0	1.3	0.8	---	---	---	---
FEID	27.5	0	28.3	0	< 1.0	0	1.3	0
FRVE	---	---	---	---	30.5	1.7	38.3	2.9
FRVI	---	---	---	---	6.0	0	5.5	0.9
GAAR	---	---	1.5	0.9-	---	---		
GABO	---	---	---	---	2.8	0	3.0	0.3
GEMA	---	---	---	---	3.3	0	---	---
GETR	---	---	---	---	< 1.0	0	---	---
GEVI	---	---	---	---	1.3	0	7.5	1.4
HEUN	9.5	0	10.0	1.3	---	---	---	---
KOCR	---	---	1.0	0	---	---	---	---
LIPE	1.0	1.0	1.5	0	---	---	---	---
LOSPP	< 1.0	0	---	---	---	---	---	---
LUSPP	3.0	0	4.5	0.5	---	---	---	---
MEOB	---	---	---	---	1.8	0.3	---	---
MYSY	---	---	---	---	< 1.0	0	1.3	0
NESPP	---	---	---	---	< 1.0	0	---	---
OSCH	---	---	---	---	6.5	0	5.3	0
PEGA	---	---	---	---	< 1.0	0	---	---
PHHO	---	---	< 1.0	0	---	---	---	---
PHMU	< 1.0	0	---	---	---	---	---	---
PODO	< 1.0	0	1.8	0	---	---	---	---
POGI	---	---	---	---	< 1.0	0	---	---
POGR	---	---	---	---	---	---	1.0	0
POPR	---	---	---	---	1.0	0	11.5	0
POSPP	< 1.0	0	---	---	---	---	---	---
ROAC	---	---	---	---	---	---	2.0	0
ROSPP	---	---	---	---	< 1.0	0	---	---
SESPP	1.3	0	---	---	---	---	---	---
SEST	---	---	< 1.0	0.3	1.0	0	< 1.0	0
STCO	---	---	2.5	0	---	---	---	---
STVI	---	---	---	---	---	---	2.3	0
SYOR	2.0	0	2.0	0	11.8	0	12.0	4.0
TAOF	---	---	---	---	7.5	0	12.8	0
THOC	---	---	---	---	< 1.0	0	< 1.0	0
VASI	---	---	---	---	7.0	1.6	5.5	0
VIAD	---	---	---	---	< 1.0	0	1.0	0
VINU	4.3	0	< 1.0	0	---	---	---	---
ZYVE	< 1.0	0	---	---	---	---	---	---

Species Code	Site Number 9A Early A.C. Coverage	Site Number 9A Early A.F.C. Coverage	Site Number 9A Late A.C. Coverage	Site Number 9A Late A.F.C. Coverage	Site Number 9B Early A.C. Coverage	Site Number 9B Early A.F.C. Coverage	Site Number 9B Late A.C. Coverage	Site Number 9B Late A.F.C. Coverage
ACMI	2.5	0	4.0	0	3.0	0	5.5	0.6
ACSPP	1.3	0	---	---	---	---	---	---
AGCA	---	---	---	---	2.8	0	---	---
AGSP	---	---	---	---	---	---	<1.0	0
ALBR	---	---	<1.0	0	---	---	---	---
ALCE	<1.0	0	---	---	---	---	---	---
AMAL	---	---	<1.0	0	---	---	---	---
ANMA	---	---	---	---	4.0	0	1.5	0.8
ANMI	---	---	---	---	<1.0	0	2.8	0.5
AQCO	---	---	4.3	0	---	---	---	---
ARCO	---	---	---	---	<1.0	0	2.0	0.8
ARCOR	23.3	0	29.5	4.3	---	---	---	---
AROB	2.5	0	1.5	0.7	---	---	---	---
ARSO	---	---	---	---	---	---	2.8	2.1
ARSPP	---	---	---	---	1.5	0	<1.0	0
ARTR	---	---	---	---	---	---	<1.0	0
ASCO	---	---	3.0	0.2	---	---	---	---
ASLA	<1.0	0	1.3	0.3	---	---	---	---
ASMI	6.5	0	12.5	0.6	---	---	---	---
ASSPP	---	---	---	---	<1.0	0	1.5	0
ASTSPP	---	---	---	---	3.5	0	6.5	1.2
BERU	---	---	---	---	<1.0	0	1.0	0
BRSPP	<1.0	0	1.3	0	11.3	0	29.0	0
CAROS	<1.0	0	---	---	---	---	---	---
CASPP-1	---	---	---	---	1.3	0	4.0	0
CASPP-2	---	---	---	---	<1.0	0	---	---
CLLA	<1.0	0	---	---	9.3	1.4	<1.0	0
COLI	---	---	---	---	---	---	4.3	2.4
COMPOS	<1.0	0	---	---	---	---	1.3	0.2
COPA	---	---	---	---	---	---	<1.0	0
CRAC	---	---	---	---	<1.0	0	1.5	0
DEVI	---	---	---	---	1.3	0	<1.0	0
DESPP	<1.0	0	---	---	---	---	---	---
DOCO	---	---	---	---	2.3	1.6	1.3	0
ELCA	---	---	1.3	0	---	---	---	---
ERISPP	---	---	---	---	<1.0	0	<1.0	0.5
ERGR	<1.0	0	---	---	---	---	---	---
FEID	---	---	---	---	34.0	0	34.0	0
FRPU	---	---	---	---	1.0	0.6	---	---
FRVI	10.8	0	12.8	1.1	---	---	---	---
GABO	4.0	0	5.0	0	---	---	---	---
GEMA	---	---	2.0	0	---	---	---	---
GESPP	1.3	0	---	---	---	---	---	---
GETR	<1.0	0	---	---	4.8	0	5.0	0.5
GEVI	---	---	<1.0	0	---	---	---	---
GNVI	---	---	---	---	<1.0	0	<1.0	0.5
GRAMIN	---	---	---	---	<1.0	0	1.5	0
GUSA	---	---	---	---	---	---	<1.0	0.3
HEPA	<1.0	0	---	---	---	---	---	---
LISPP	<1.0	0	---	---	---	---	---	---
LOCO	---	---	---	---	<1.0	0.5	<1.0	0
LOSPP	---	---	---	---	2.5	0	---	---
LOTR	---	---	<1.0	0.3	---	---	---	---
LUSPP	---	---	---	---	1.3	0	5.0	2.1
MECI	<1.0	0	---	---	---	---	---	---
MEOB	2.3	0	---	---	<1.0	0	1.0	0
MINU	---	---	---	---	1.0	0	---	---
MYSY	1.3	0	---	---	1.8	0.4	2.3	0.2
OSCH	---	---	2.3	0	---	---	---	---
PESPP	<1.0	0	---	---	---	---	---	---
PHLO	---	---	---	---	<1.0	0	1.0	0.3
PHPR	4.8	0	2.5	0	---	---	---	---
POBI	---	---	---	---	---	---	<1.0	0
PODI	1.3	0	2.3	0.6	---	---	---	---
PODO	---	---	---	---	---	---	2.5	0.8
POGL	---	---	---	---	8.0	0	15.5	7.2
POLSPP	<1.0	0	1.3	0	1.0	0	---	---
POSPP	7.8	0	7.5	0	---	---	<1.0	0
RAGL	<1.0	0.3	---	---	4.3	3.1	---	---
RICE	<1.0	0	<1.0	0	---	---	---	---
ROSPP	<1.0	0	1.0	0	---	---	---	---
RUSPP	---	---	---	---	<1.0	0	---	---

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AQUATIC INSECT ANALYSIS
FOR THE
1975 SPRUCE BUDWORM PROJECT

by

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Northern Region

TABLE OF CONTENTS

INTRODUCTION

The number of drifting organisms passing a given point in a stream is subject to several sources of variation, such as: time of day, amount of light and heat, water velocity, bank cover, stream nutrient levels, disturbance, and life-history stage of the insects (Hynes 1970). Therefore, it is difficult to isolate a disturbance, in the form of insecticides as the single cause of increased drift. Experimental controls which were imposed during the 1975 spray project included matching pre- and post-spray samples with respect to time of day, sampling locations, and length of sampling period. Variables which were not, or could not be, controlled included: emergences and other growth changes, light and heat differences, fluctuations in water velocity due to evaporation or rain, and amount of backwash out of nets due to clogging of mesh.

Assuming the above variations were minor, there remain several factors yet to be considered in estimating the efforts of the insecticides upon aquatic fauna. Before the relative toxicities of Sevin and Dylox can be assessed, the concentration of spray entering the streams should be known. Unless one insecticide were much more toxic, the spray hitting a stream more directly would be expected to cause the greater disturbance. And does this disturbance result in the death of the aquatic insects? Hynes (1970) agrees in part by proposing, "Presumably, under normal circumstances, drifting invertebrates either find an empty niche in which to settle, or they are eaten by such predators as fish or net-spinning caddisworms. Great numbers must, however, be swept out of areas which are habitually suitable for them and must ultimately perish."

Kick samples were collected before and after spray application to help assess the lethality of the disturbance. Variables such as size of bottom area sampled and velocity of surrounding water are inherent in kick samples, precluding their use in quantitative comparisons. However, the persistance of insecticide caused damages can be demonstrated qualitatively by drastic changes in size and/or diversity of post-spray samples. If little change is observed, one might suspect that either the insecticide was not very toxic or that recruitment from upstream and/or downstream sources was sufficient to mask the temporary disturbance.

METHODS AND MATERIALS (LABORATORY)

Drift and kick samples, initially preserved in 10% formalin, were emptied into a #40 sieve and washed with water to remove the formalin and finer particulate matter. The sieve contents were transferred to 70% alcohol. Aquatic insects were separated from detritus using a standard binocular microscope at 7x magnification. Insects were keyed most often to genus, except dipterans, which were identified to family. Volumes of drift samples were estimated by water displacement and presented in histograms. Rankings were given only to taxa represented by at least five organisms in a given drift sample.

RESULTS - BLOCK 2 (SEVIN)

Daisy Creek - The volume of drifting organisms increased very slightly over pre-spray levels during the application of Sevin. Most of the increase could be attributed to an influx of springtails (Collembola) which are semi-aquatic, inhabiting the shoreline areas. Otherwise, pre-spray and spray drift samples were taxonomically similar.

Analysis of the kick samples revealed that spray impact was short-lived. The few genera found only in pre-spray samples were present in such small quantities that sampling variation could explain their disappearance. In fact, the total number of aquatic insects collected increased in post-spray samples.

South Fork Meadow Creek, Stations B-1 and B-2 - During spraying, drift in the South Fork of Meadow Creek increased to seven times the pre-spray levels at Station B-1. A change in the principal drifting organisms was also noted. Before spraying, members of Chironomidae, *Baetis*, and *Alloperla* contributed most to the drift. Simuliidae, *Siphlonurus*, and *Cinygmula*, minor constituents before, predominated during spraying. Drift increased less at Station B-2 during spraying, but its composition changed noticeably. An influx of Simuliidae, *Siphlonurus*, and *Cinygmula*, none of which were found in pre-spray samples, accounted for most of the increase.

Again kick samples showed that spray effects were not lasting. Only *Rhithrogena* exhibited a steady decline. This may have been due to emergence. Selective sensitivity to Sevin seems an unlikely explanation, because other fragile mayfly genera present either persisted through sampling or appeared in post-spray samples.

Leonard Creek - A very dramatic increase from less than one millilitter per hour (pre-spray) to about 100 millilitters per hour (spray) was noted in Leonard Creek. Many more species were found in the latter sample. Except for *Baetis*, those insects most abundant in the spray sample were an insignificant part of or absent from the pre-spray drift sample.

By July 16, all but one genus of may flies found in pre-spray kick samples, i.e., Peltoperla, were absent. The relative abundance of stoneflies (especially Diura) had increased, but this was of little importance since the total number of insects had decreased from 44 to only 9. By October 31, the number and diversity of insects exceeded pre-spray levels, suggesting that Leonard Creek had been recolonized.

RESULTS - BLOCK 8 (SEVIN)

Ruby Creek, Station C - Peak drift (30 milliliters per hour) during spraying was substantially higher than pre-spray levels (less than one milliliter). This increase was caused primarily by an influx of many *Alloperla* and *Nemoura*. Spray drift had already decreased nearly to pre-spray volume before sampling was completed.

Both volume and diversity of kick samples increased after spraying, suggesting that spray effects were transitory.

Ruby Creek, Station B - From 0800 to 0900 during spray application, drift reached a peak of approximately 200 milliliters, as compared to less than one milliliter during the same time before spraying. The change in drift composition was also dramatic with six taxa appearing in pre-spray drift and 18 taxa in spray drift.

Although the diversity of the kick samples changed little, the total number of organisms in post-spray samples was only half that of pre-spray samples. However, a sample taken on November 14 indicated that most of the pre-spray organisms were still represented within the stream community. Again Sevin appeared to have a noteable but temporary effect.

Ruby Creek, Station A - Drift increase was again very pronounced, jumping from less than one milliliter per hour to a range from 50 milliliters per hour to 150 milliliters per hour. Nine taxa were found in pre-spray drift while 26 taxa comprised the spray drift.

The taxonomic composition of kick samples changed from pre- to post-spray, but total numbers of organisms and total diversity changed little. Selective emergence or variation in sampling sites (e.g., with different water velocities) could explain these minor differences.

RESULTS - BLOCK 6 (SEVIN)

Middle Fork Warm Springs Creek, Station A - The volume of drifting insects increased from almost none each hour before spraying to 200 milliliters per hour at peak spray drift. This marked change decreased to only 10 milliliters, five hours after spray effects first appeared.

Relative abundances of organisms was not estimated for pre-spray kick samples. However, observed rankings indicate that several mayfly genera present earlier were absent from post-spray samples. An overall decrease in diversity was counteracted, though, by the appearance of additional stoneflies, caddisflies, and true flies.

RESULTS - BLOCK 4 (DYLOX)

Warm Springs Creek - Spray drift was significantly larger than pre-spray drift. The same insect taxa were principle constituents to both the pre-spray and spray samples. The latter sample also contained small numbers of new organisms, many not normally found drifting.

Kick samples were very similar before and after spraying, suggesting that impact was light.

RESULTS - BLOCK 7 (DYLOX)

South Fork Warm Springs Creek - Drift of insects during spray application increased very little over pre-spray levels. Perhaps a minor impact was reflected in the addition of several new organisms to the drift.

An increase in diversity of post-spray kick samples indicates that sampling variation was probably more significant than spray effects.

Smith Creek and French Creek - Again, as in the South Fork of Warm Springs Creek, a change in diversity, but not volume, was the only indication of possible spray impact.

No post-spray kick samples were available to confirm the supposition of negligible impact.

Squaw Creek - No drift samples were collected. Only one pre-spray kick sample was collected and analyzed.

SUMMARY

The application of spruce budworm insecticides upon streams resulted in a significant increase in the number of drifting organisms. Impact was greatest in those streams sprayed with Sevin. For example, in Leonard Creek, Ruby Creek, and the Middle Fork of Warm Springs Creek, drift volumes per hour rose from less than one milliliter to peaks of 100 milliliters, 200 milliliters, and 200 milliliters respectively during spraying. Dylox had little effect on any stream except Warm Springs where spray drift increased 30 milliliters over pre-spray levels.

Examination of kick samples taken before and after spray application revealed that the fauna in all the streams was capable of recovery. Volume and diversity of post-spray samples was comparable, within experimental error, to pre-spray collections.

HOURLY DRIFT

(Volume in Milliliters)

BLOCK 2

Daisy Creek, Station A

0615	0715	0815	0915	1015	
	< 1	< 1	< 1	1	(pre-spray)
1	2	2	1	3	(spray)

South Fork Meadow Creek, Station B-1

0700	0800	0900	1000	
1	< 1	< 1	< 1	(pre-spray)
1	7	5	4	(spray)

South Fork Meadow Creek, Station B-2

0650	0750	0850	0950	
< 1	< 1	< 1		(pre-spray)
< 1	1	4	< 1	(spray)

Leonard Creek, Station C

0710	0810	0910	1010	
< 1	< 1	< 1	1	(pre-spray)
< 1	100	50 (½ hr.)		(spray)

BLOCK 8

Ruby Creek, Station A

0710	0810	0910	1010	1110	
< 1	< 1	< 1	< 1		(pre-spray)
< 1	150	50	100	75	(spray)

Ruby Creek, Station B

0725	0825	0925	1025	1125	
< 1	< 1	< 1	< 1		(pre-spray)
15	50	250	180	50	(spray)

HOURLY DRIFT Cont'd

(Volume in Milliliters)

BLOCK 8

Ruby Creek, Station C

0735	0835	0935	1035	1135	
< 1	< 1	< 1	< 1		(pre-spray)
30	30	10	1	2	(spray)

BLOCK 6

Middle Fork Warm Springs Creek, Station A

0655	0755	0855	0955 ---	1255	1355	
	< 1	0				(pre-spray)
1	< 1	100	200	150	10	(spray)

BLOCK 4

Warm Springs Creek

0730	0830	0930	1030	
1	< 1	1		(pre-spray)
2	15	25	15	(spray)

BLOCK 7

South Fork Warm Springs Creek

0700	0800	0900	1000	
	1	< 1		(pre-spray)
1	2	2	2	(spray)

Smith Creek

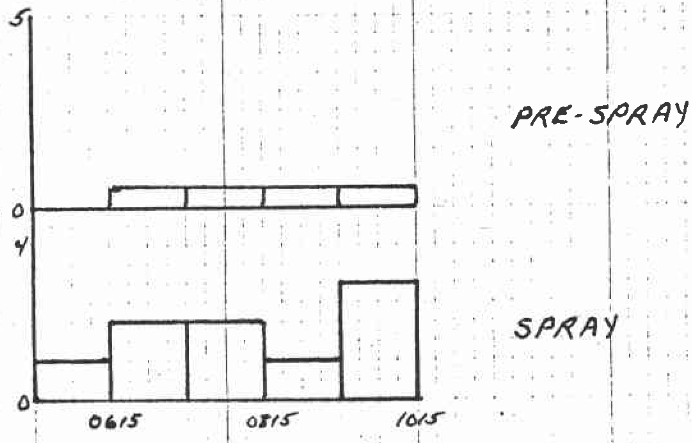
(pre-spray)		(spray)	
0545	0700	0800	0900
< 1	< 1	< 1	< 1

French Creek

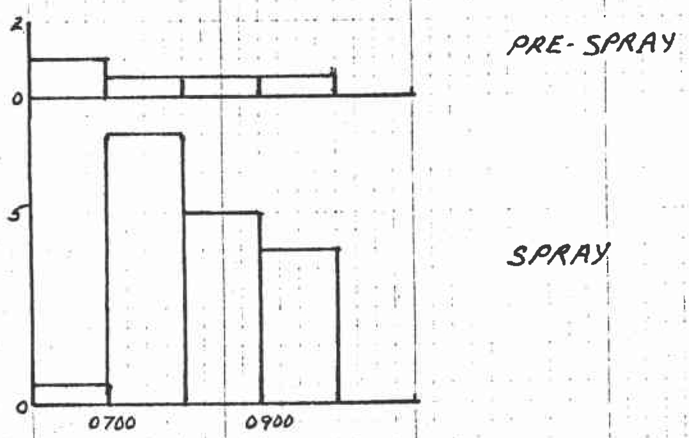
(pre-spray)		(spray)	
0555	0700	0800	0900
< 1	< 1	< 1	1

BLOCK 2, HOURLY DRIFT SAMPLES BY VOLUME (ml)

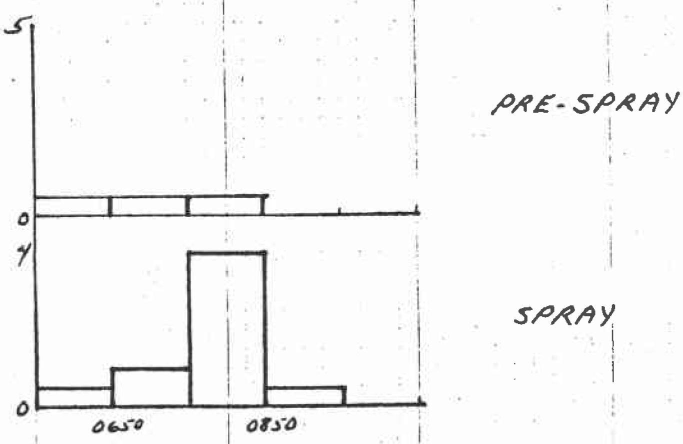
DAISY CREEK, STATION A



S.F. MEADOW CK., STATION B-1

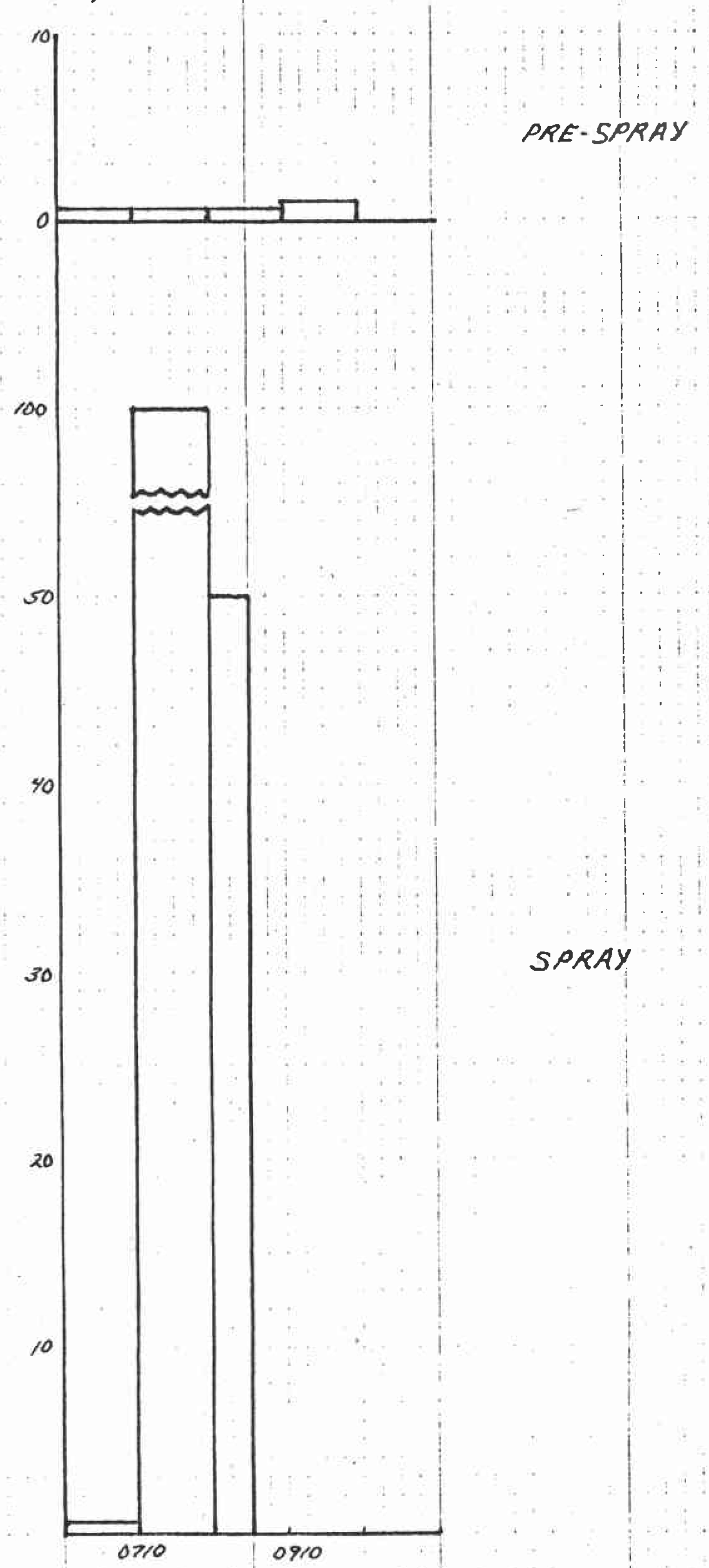


S.F. MEADOW CK., STATION B-2



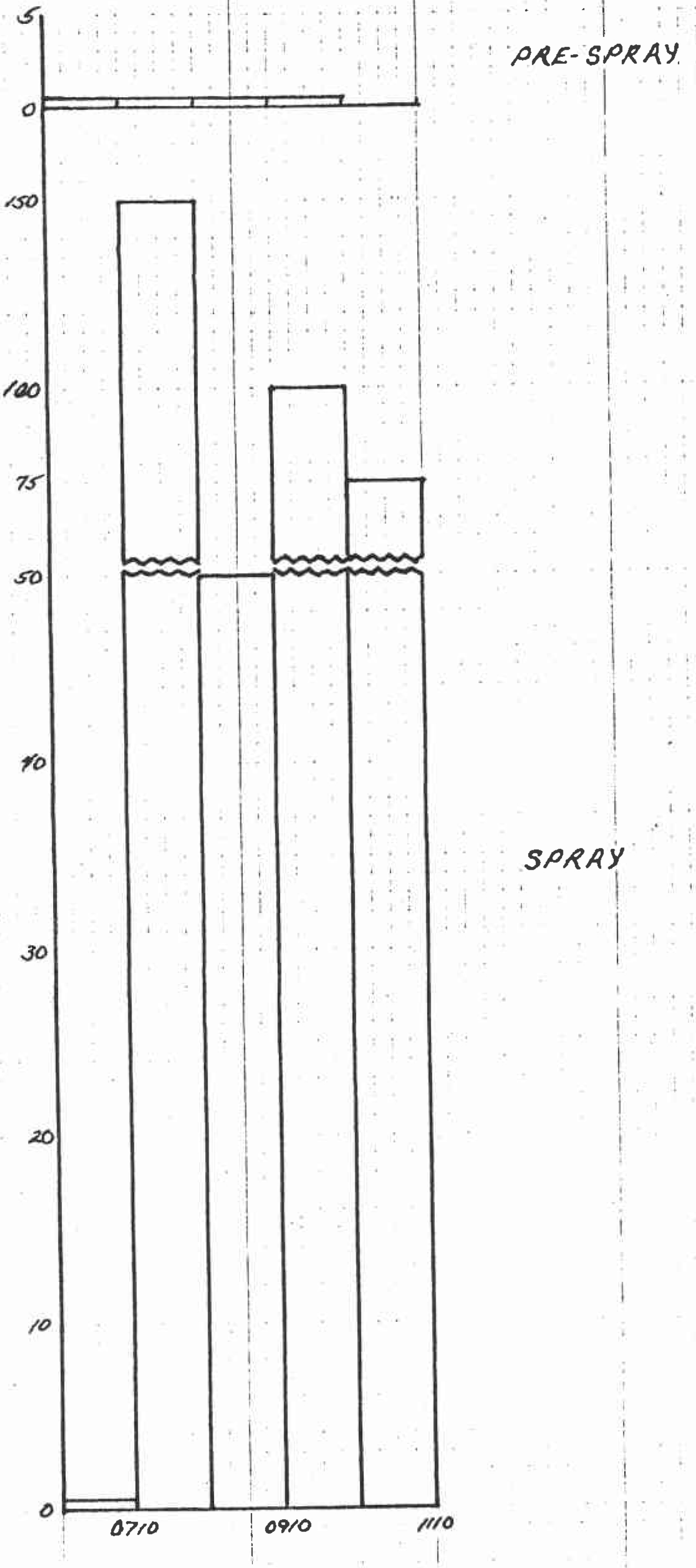
BLOCK 2 (CONT'D)

LEONARD CK., STATION C



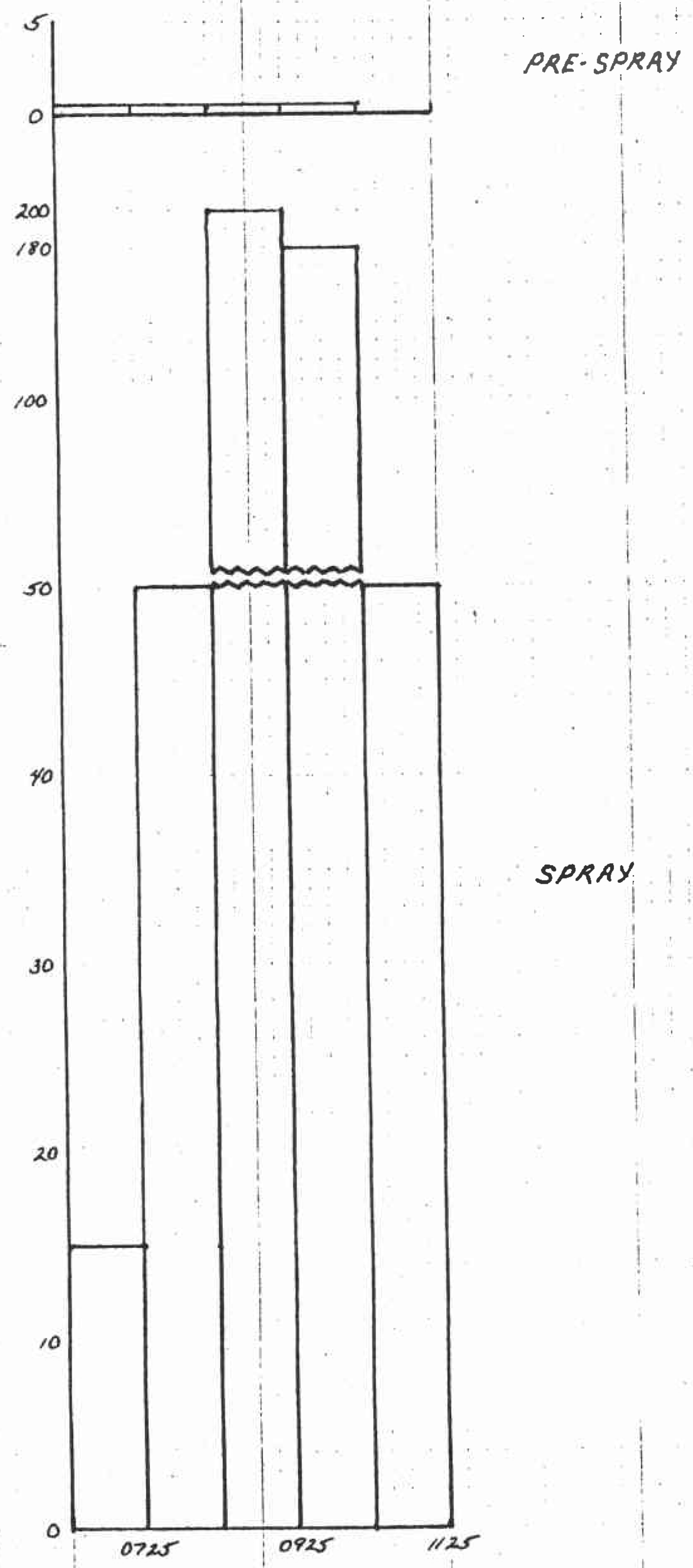
BLOCK 8, HOURLY DRIFT SAMPLES BY VOLUME (ml)

RUBY CREEK, STATION A



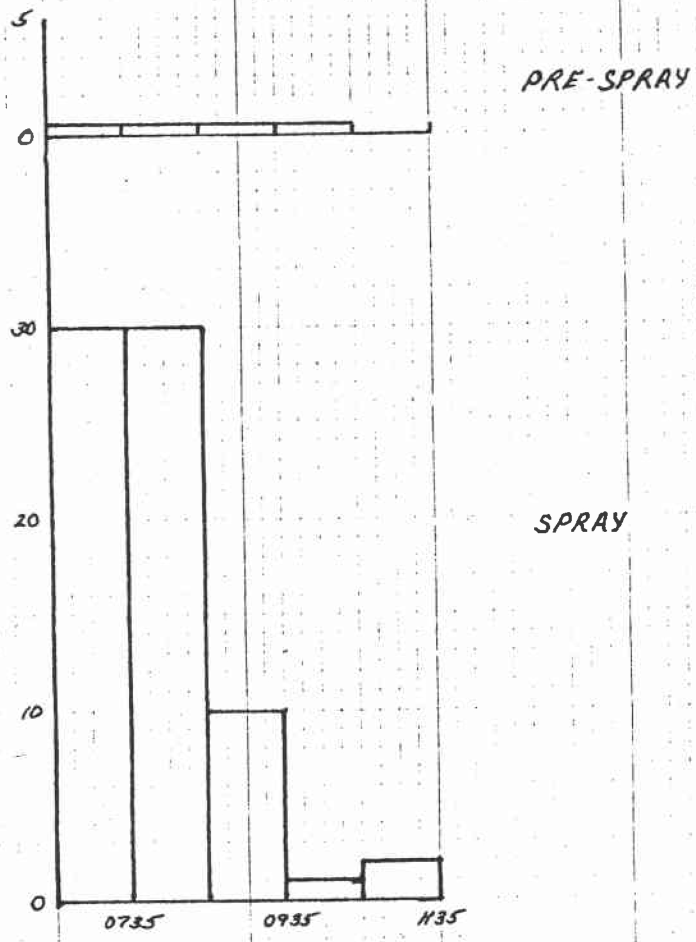
BLOCK 8 (CONT'D.)

RUBY CREEK, STATION B



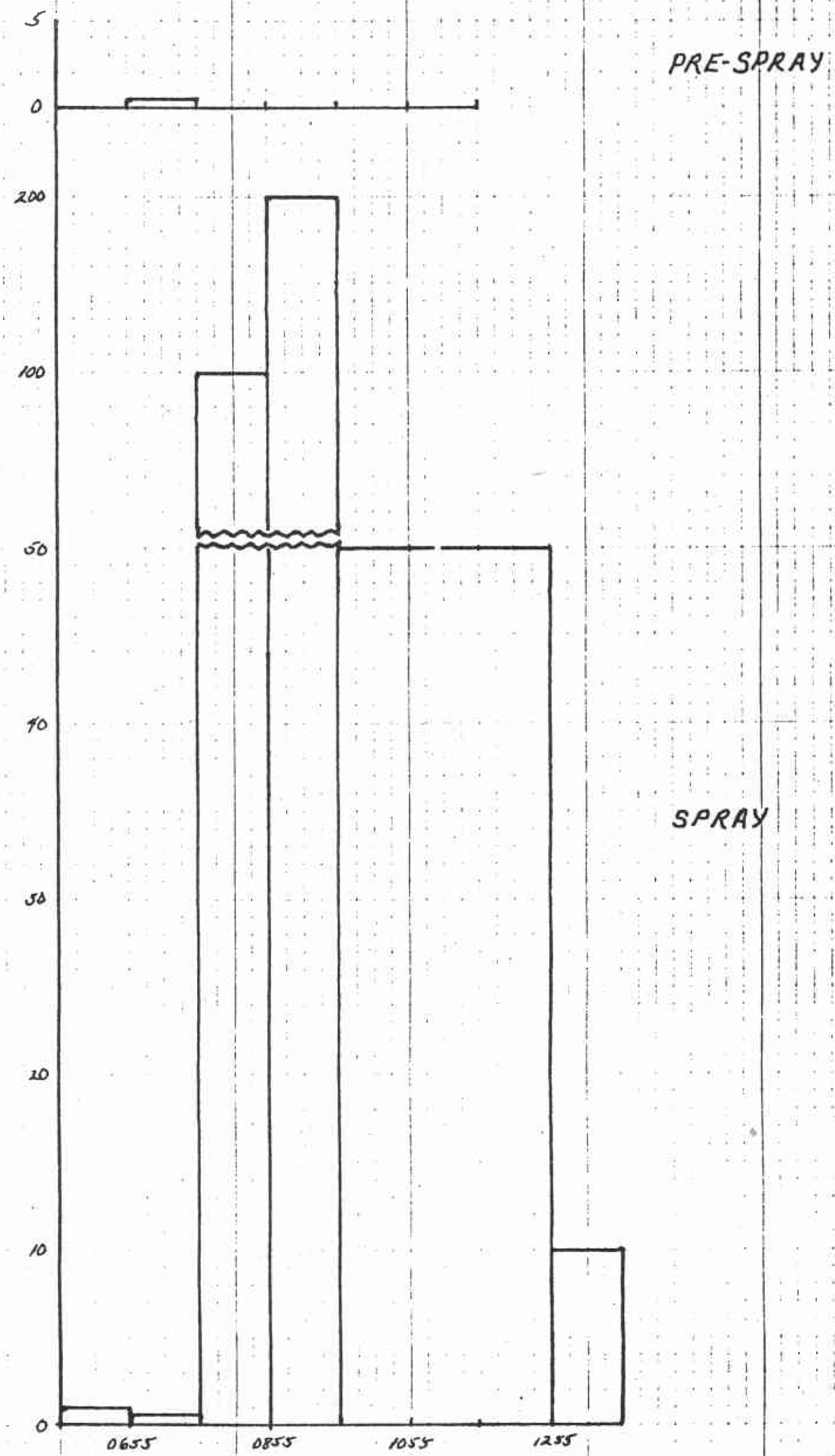
BLOCK 8 (CONT'D)

RUBY CREEK, STATION C



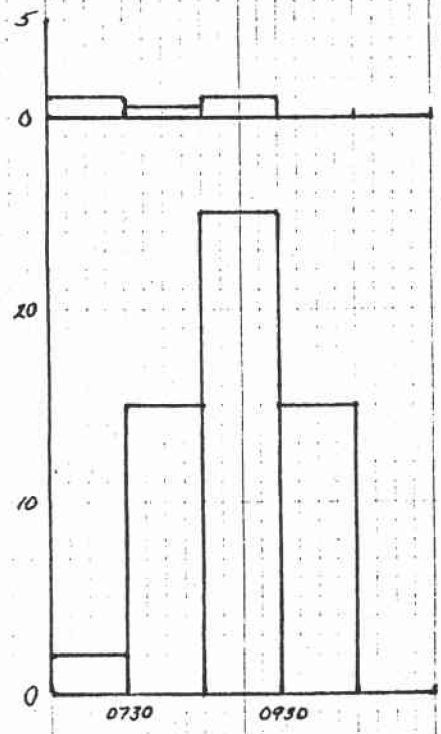
BLOCK 6, HOURLY DRIFT SAMPLES BY VOLUME (ml)

M.F. Wm. SPRINGS CREEK, STATION A



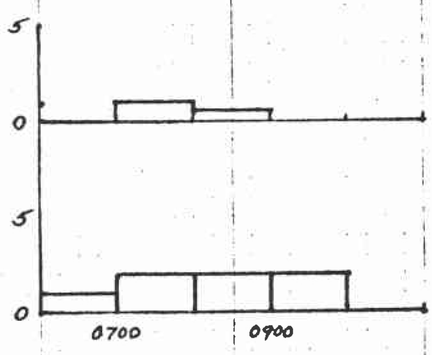
BLOCK 4, HOURLY DRIFT SAMPLES BY VOLUME (ml).

WARM SPRINGS CREEK



BLOCK 7

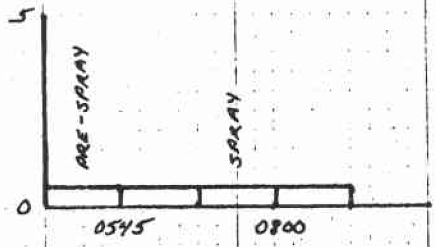
S.F. WARM SPRINGS CREEK



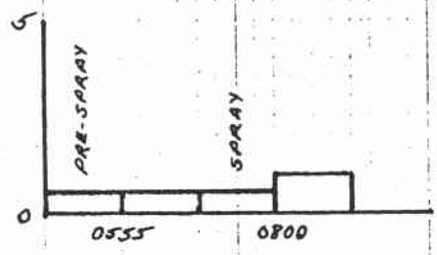
HOURLY DRIFT SAMPLES BY VOLUME (ml)

BLOCK 7 (CONT'D)

SMITH CREEK



FRENCH CREEK



BLOCK 2, DAISY CREEK, STATION A

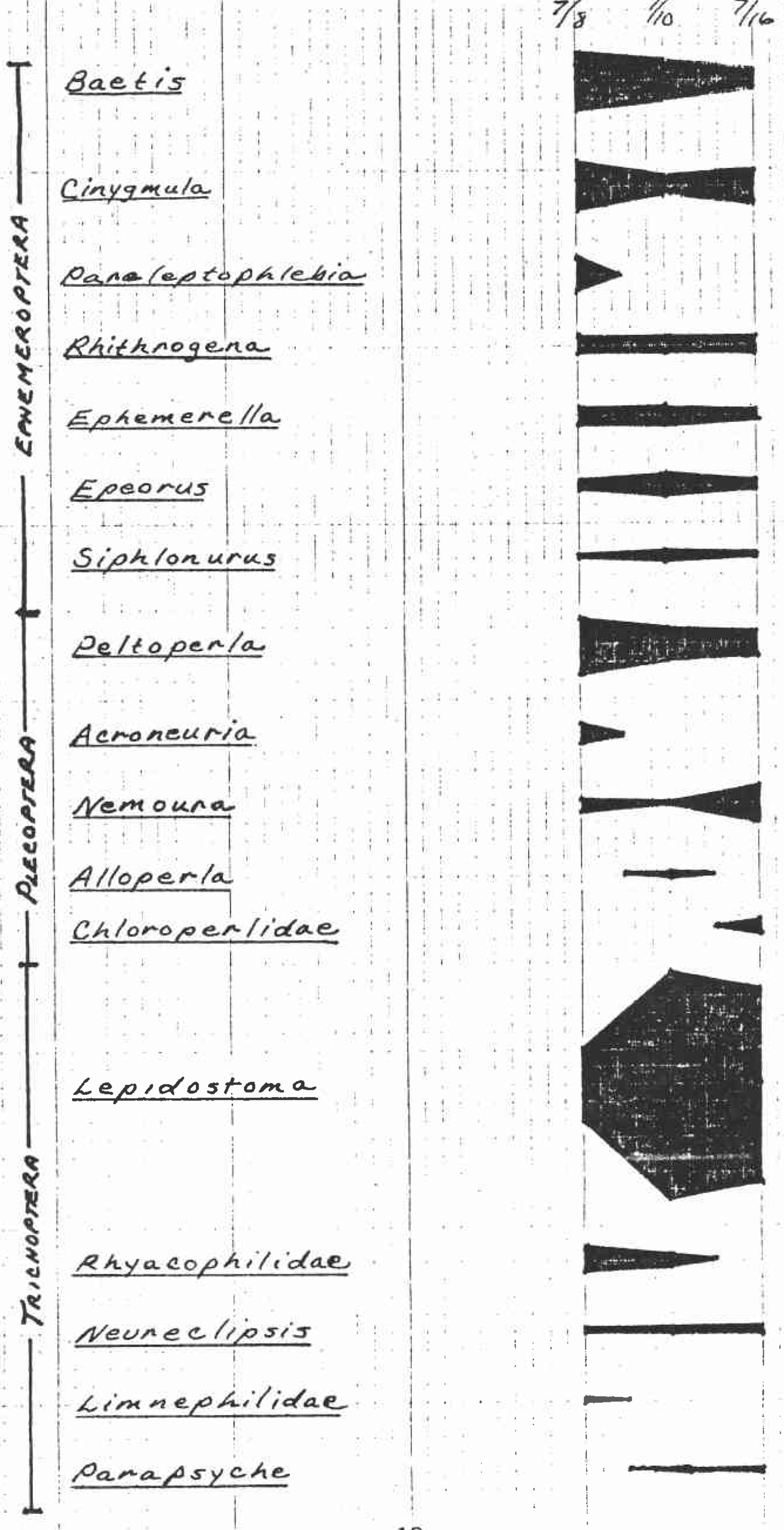
Rank	Pre-Spray Drift	Rank	Spray Drift	(%)	Pre-Kick (7-8)
1	Lepidostoma	1	Collembola	18	Lepidostoma
2	Baetis	2	Lepidostoma	13.5	Peltoperla
3	Chironomidae	3	Baetis	13.5	Baetis
4	Peltoperla	4	Chironomidae	12	Cinygmula
5	Nemoura	5	Peltoperla	9	Paraleptophlebia
6	Neureclipsis	6	Alloperla	6	Rhyacophilidae
7	Ephemerella	7	Siphlonurus	4.5	Rhithrogena
8	Cinygmula	8	Nemoura	4.5	Ephemerella
	Epeorus	9	Cinygmula	4.5	Acroneuria
	Isoperla	9	Ephemerella	3	Epeorus
	Chloroperlidae	9	Epeorus	1	Siphlonurus
	Elmidae	9	Elmidae	3	Nemoura
	Ephydridae	10	Neureclipsis	1	Neureclipsis
	Paraleptophlebia	10	Diptera (other)	1	Limnephilidae
	Simuliidae	11	Rhithrogena	1	Elmidae
			Chloroperlidae	3	Chironomidae
			Rhyacophilidae		Total 111
			Ephydridae		
			Paraleptophlebia		
			Empididae		

(%)	Post-Kick (7-10)	(%)	Post-Kick (7-16)	(%)	Post-Kick (10-30)
52	Lepidostoma	43.5	Lepidostoma	48.5	Lepidostoma
10	Baetis	9	Cinygmula	14.5	Peltoperla
7	Peltoperla	9	Nemoura	13	Epeorus
5	Epeorus	6	Peltoperla	5	Nemoura
5	Cinygmula	5	Baetis	0.5	Rhithrogena
5	Ephemerella	5	Elmidae	0.5	Cinygmula
4	Rhithrogena	4	Rhithrogena	1.5	Baetis
2	Siphlonurus	3	Ephemerella	2	Ephemerella
1	Nemoura	3	Chloroperlidae	1.5	Paraleptophlebia
1	Alloperla	3	Chironomidae	2	Acroneuria
1.5	Elmidae	2	Epeorus	1.5	Alloperla
3	Rhyacophilidae	1	Siphlonurus	1	Elmidae
1.5	Neureclipsis	2	Neureclipsis	2	Parapsyche
1	Parapsyche	1	Parapsyche	2	Neureclipsis
1.5	Psychodidae	2	Simuliidae	0.5	Rhyacophilidae
		1	Empididae	2	Psychodidae
	Total 135		TERREST.	2	Chironomidae
			Total 161	0.5	Tipulidae
					Total 206+

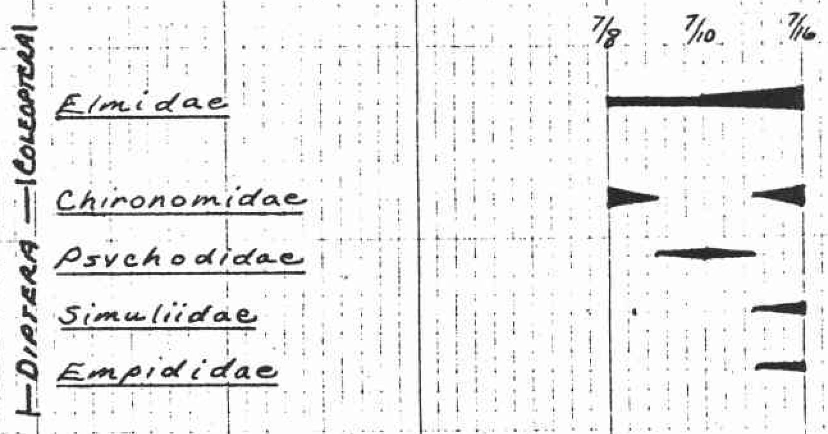
DAISY CREEK BLOCK 2

Kick Samples	Relative Abundance (Percent Total Numbers, N)		
	7/8	7/10	7/16
Baetis	13.5	10	5
Cinygmula	12	5	9
Paraleptophlebia	9		
Rhithrogena	4.5	4	4
Ephemerella	4.5	5	3
Epeorus	3	5	2
Siphlonurus	1	2	1
Peltoperla	13.5	7	6
Acroneuria	4.5		
Nemoura	3	1	9
Alloperla		1	
Chloroperlidae			3
Lepidostoma	18	52	43.5
Rhyacophilidae	6	3	
Neureclipsis	1	1.5	2
Limnephilidae	1		
Parapsyche		1	1
Elmidae	1	1.5	5
Chironomidae	3		3
Psychodidae		1.5	
Simuliidae			2
Empididae			1
N	111	135	161

DAISY CREEK
KICK SAMPLES
RELATIVE ABUNDANCES



DAISY CREEK (CONT'D)



BLOCK 2, SOUTH FORK MEADOW CREEK, STATION B-1

Rank	Pre-Spray Drift	Rank	Spray Drift	(%)	Pre-Kick (B-1/B-2) (7-8)
1	Chironomidae	1	Simuliidae	50	Rhithrogena
2	Baetis	2	Siphlonurus	12.5	Cinygmula
3	Alloperla	3	Cinygmula	12.5	Baetis
	Ephemerella	4	Chironomidae	6	Nemoura
	Cinygmula	5	Baetis	6	Chironomidae
	Epeorus	6	Alloperla	6	Diptera (other)
	Lepidostoma	7	Epeorus	6	Trichoptera
	Parapsyche	8	Nemoura		
	Diptera (other)	9	Diptera (other)		Total 16
	Siphlonurus	10	Rhithrogena		
	Nemoura	11	Paraleptophlebia		
	Neureclipsis	12	Neureclipsis		
	Collembola		Blephariceridae		
	Tipulidae		Ephemerella		
	Nematoda		Dixidae		
	TERREST.		Arcynopteryx		
			Parapsyche		
			Tipulidae		
			Rhyacophilidae		
			TERREST.		

(%)	Post-Kick (7-10) (B-1/B-2)	(%)	Post-Kick (7-16) (B-1/B-2)	(%)	Post-Kick (10-30) (B-1/B-2)
27	Cinygmula	20	Epeorus	38	Nemoura
23	Baetis	15	Cinygmula	19	Arcynopteryx
23	Rhithrogena	15	Acroneuria	14	Epeorus
7	Epeorus	15	Baetis	8	Rhithrogena
3	Paraleptophlebia	10	Alloperla	6	Neureclipsis
3	Ephemerella	7	Chironomidae	5	Parapsyche
3	Acroneuria	7	Ephemerella	2	Ephemerella
3	Nemoura	5	Neureclipsis	1	Baetis
3	Neureclipsis	2	Rhithrogena	0.5	Alloperla
3	Psychodidae	1	Arcynopteryx	0.5	Elmidae
		3	Parapsyche	2	Rhyacophilidae
	Total 30	2	Psychodidae	0.5	Trichoptera case
				2	Chironomidae
			Total 102	0.5	Tipulidae
					Total 209

BLOCK 2, SOUTH FORK MEADOW CREEK, STATION B-2

No Rank	Pre-Spray Drift	Rank	Spray Drift
All	Baetis	1	Simuliidae
<5	Epeorus	2	Siphlonurus
	Arcynopteryx	3	Cinygmula
	Chironomidae	4	Baetis
	Diptera (other)	4	Epeorus
	TERREST.	5	Chironomidae
		6	Nemoura
			Paraleptophlebia
			Rhithrogena
			Trichoptera cases
			Tipulidae
			Ephemerella
			Alloperla
			Psychomiidae
			Diptera (other)

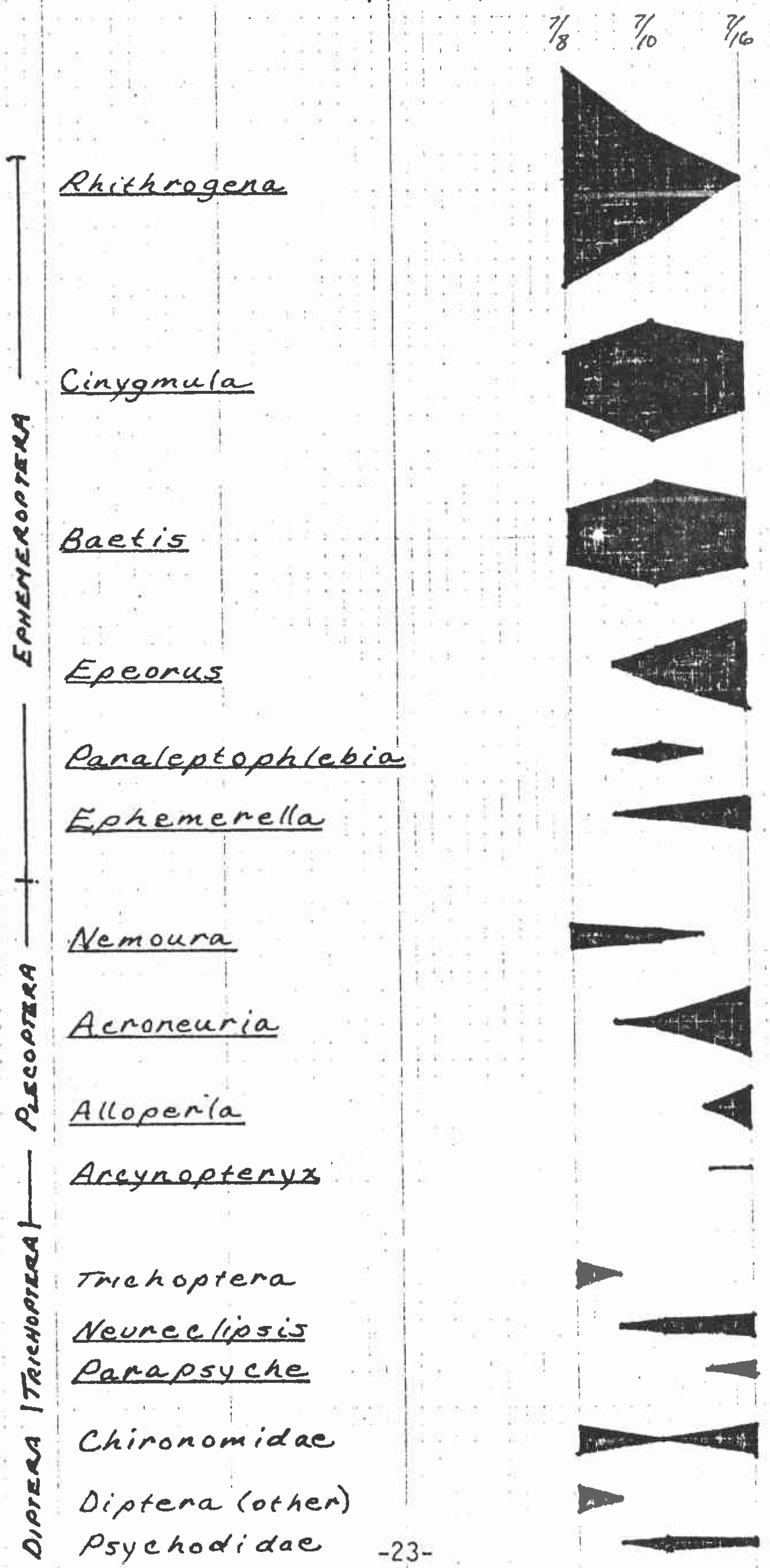
Pre-Kick and Post-Kick rankings listed under:

Block 2, South Fork Meadow Creek, Station B-1

SOUTH FORK MEADOW CREEK — BLOCK 2

Kick Samples	Relative Abundance (Percent Total Numbers, N)		
	7/8	7/10	7/16
Rhithrogena	50	23	2
Cinygmula	12.5	27	15
Baetis	12.5	23	15
Epeorus		7	20
Paraleptophlebia		3	
Ephemerella		3	7
Nemoura	6	3	
Acroneuria		3	15
Alloperla			10
Arcynopteryx			1
Trichoptera	6		
Neureclipsis		3	5
Parapsyche			3
Chironomidae	6		7
Diptera (other)	6		
Psychodidae		3	2
N	16	30	102

S.F. MEADOW CREEK
KICK SAMPLES
RELATIVE ABUNDANCES



BLOCK 2, LEONARD CREEK, STATION C

Rank	Pre-Spray Drift
1	Collembola
2	Chironomidae
3	Baetis
4	Nemoura
	Ephemerella
	Plecoptera(early instar)
	Diptera (other)
	Peltoperla
	Neureclipsis
	Siphlonurus
	Chloroperlidae
	Cinygmula
	TERREST.

Rank	Spray Drift
1	Baetis
2	Alloperla
3	Isogenus
4	Cinygmula
5	Simuliidae
6	Peltoperla
7	Blephariceridae
8	Siphlonurus
9	Rhyacophilidae
	Paraleptophlebia
	Psychomiidae
	Limnephilidae
	Dixidae
	Epeorus
	Arcynopteryx
	Trichoptera (other)
	Chironomidae
	Neureclipsis
	Nemouridae
	Collembola
	Rhithrogena
	TERREST.

(%)	Pre-Kick (7-8)
23	Cinygmula
23	Baetis
16	Peltoperla
11	Diura
11	Chironomidae
2	Epeorus
2	Ephemerella
2	Alloperla
4.5	Neureclipsis
2	Trichoptera (other)
2	Blephariceridae
2	Empididae
	Total 44

(%)	Post-Kick (7-10)
25	Cinygmula
17	Baetis
8	Peltoperla
8	Alloperla
17	Limnephilidae
8	Neureclipsis
8	Donacia
8	Chironomidae
	TERREST.
	Total 12

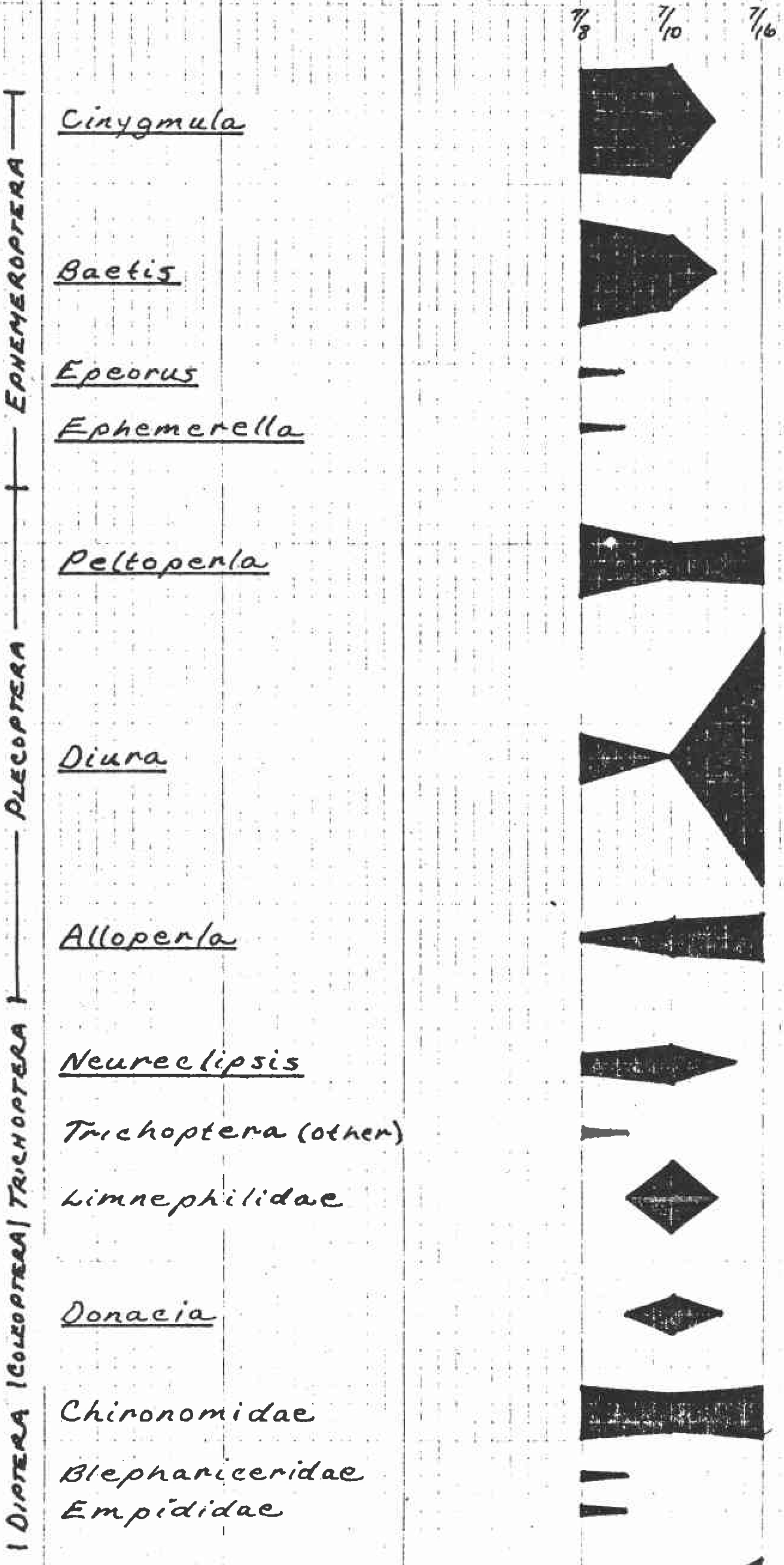
(%)	Post-Kick (7-16)
56	Diura
11	Alloperla
11	Peltoperla
11	Chironomidae
11	Nematoda
	TERREST.
	Total 9

(%)	Post-Kick (10-31)
28	Baetis
20	Peltoperla
17	Arcynepteryx
14	Nemoura
4	Neureclipsis
4	Ephemerella
3	Alloperla
0.5	Epeorus
2	Rhithrogena
0.5	Paraleptophlebia
2	Paraperla
2	Lepidostoma
1	Glossosomatidae
1	Elmidae
2	Simuliidae

LEONARD CREEK BLOCK 2

Kick Samples	Relative Abundance (Percent Total Numbers, N)		
	7/8	7/10	7/16
Cinygmula	23	25	
Baetis	23	17	
Epeorus	2		
Ephemerella	2		
Peltoperla	16	8	11
Diura	11		56
Alloperla	2	8	11
Neureclipsis	4.5	8	
Trichoptera (other)	2		
Limnephilidae		17	
Donacia		8	
Chironomidae	11	8	11
Blephariceridae	2		
Empididae	2		
Nematoda			11
N	44	12	9

LEONARD CREEK
KICK SAMPLES
RELATIVE ABUNDANCES



BLOCK 8, RUBY CREEK, STATION A

Rank	Pre-Spray Drift
1	Baetis
2	Chironomidae
	Epeorus
	Cinygmula
	Chloroperlidae
	Tipulidae
	Trichoptera (cases)
	Ephemerella
	Perlodidae
	Mollusca
	TERREST.

Rank	Spray Drift
1	Baetis
2	Alloperla
3	Chironomidae
4	Rhithrogena
5	Cinygmula
5	Simuliidae
6	Epeorus
7	Diura
8	Tipulidae
9	Siphlonurus
	Chloroperlidae
	Psychomiidae
	Lepidostoma
	Rhyachophilidae
	Heleidae
	Diptera (other)
	Ephemerella
	Isogenus
	Isoperla
	Peltoperla
	Limnephilidae
	Paraleptophlebia
	Neureclipsis
	Dytiscidae
	Brachyptera
	Pteronarcys
	TERREST.

(%)	Pre-Kick (7-9)
29	Neureclipsis
23.5	Epeorus
23.5	Rhithrogena
8	Ephemerella
2	Isoperla
2	Acroneuria
2	Diura
8	Alloperla
2	Chironomidae
	Total 51

Rank	Hand-Picked (7-9)
1	Neureclipsis
2	Ephemerella
3	Hydropsyche
4	Epeorus
5	Rhithrogena

(%)	Post-Kick (7-15)
22	Cinygmula
14.5	Alloperla
14.5	Neureclipsis
12	Ephemerella
7	Limnephilidae
7	Epeorus
7	Diura
7	Baetis
1	Lepidostoma
1	Elmidae
3	Tipulidae
1	Chironomidae
	Total 69

Rank	Post-Kick (11-14)
1	Nemoura
2	Neureclipsis
3	Psychodidae
3	Chironomidae
4	Cinygmula
4	Rhithrogena
5	Baetis
6	Parapsyche
7	Arcynopteryx
	Ephemerella
	Acroneuria
	Isoperla
	Limnephilidae
	Trichoptera cases
	Glossosomatidae

Rank	Post-Kick (A above, 11-14)
1	Isoperla
2	Acroneuria
3	Chironomidae
4	Neureclipsis
5	Nemoura
6	Cinygmula
7	Baetis
	Ephemerella
	Arctopsyche
	Glossosomatidae
	Trichoptera cases
	Tipulidae
	Psychodidae

BLOCK 8, RUBY CREEK, STATION B

Rank	Pre-Spray Drift
1	Baetis
2	Lepidostoma
	Cinygmula
	Chironomidae
	Ephemerella
	Diptera (other)
	TERREST.

Rank	Spray Drift
1	Baetis
2	Alloperla
3	Cinygmula
4	Simuliidae
5	Ameletus
6	Rhithrogena
7	Ephemerella
8	Isoperla
9	Nemoura
10	Diura
	Peltoperla
	Psychodidae
	Glossosomatidae
	Lepidostoma
	Amphizoa
	Tipulidae
	Epeorus
	Nematoda
	TERREST.

(%)	Pre-Kick (7-9)
30	Ephemerella
20	Baetis
20	Rhithrogena
8	Neureclipsis
7	Glossosomatidae
3	Epeorus
3	Alloperla
1	Arcynopteryx
2	Diura
1	Peltoperla
1	Limnephilidae
3	Chironomidae
1	Simuliidae
	Total 300

(%)	Post-Kick (7-15)
31	Ephemerella
14	Baetis
14	Glossosomatidae
10.5	Neureclipsis
7	Limnephilidae
7	Alloperla
3.5	Chironomidae
1	Cinygmula
1	Peltoperla
1	Nemouridae
3	Hydropsychidae
3	Elmidae
3	Diptera (other)
	TERREST.
	Total 143

Rank	Post-Kick (11-14)
1	Arcynopteryx
2	Rhithrogena
3	Baetis
4	Nemoura
5	Neureclipsis
	Siphlonurus
	Ephemerella
	Peltoperla
	Alloperla
	Limnephilidae
	Glossosomatidae

BLOCK 8, RUBY CREEK, STATION C

Rank	Pre-Spray Drift
1	Lepidostoma
2	Cinygmula
2	Chironomidae
3	Ephemerella
4	Baetis
4	Alloperla
5	Epeorus
5	Diptera (other)
	Rithrogena
	Plecoptera (other)
	Neureclipsis
	Diura
	Elmidae
	Paraleptophlebia
	Heleidae
	Mollusca
	TEREST.

Rank	Spray Drift
1	Alloperla
2	Cinygmula
3	Nemoura
4	Rithrogena
5	Chironomidae
6	Ephemerella
7	Baetis
8	Epeorus
9	Simuliidae
	Paraleptophlebia
	Lepidostoma
	Psychomiidae
	Amphizoa
	Tipulidae
	Diura
	Siphlonurus
	Glossosomatidae
	Limnephilidae
	Acroneuria
	Rhyacophilidae
	Nematoda
	TERREST.

(%)	Pre-Kick (7-9)
33	Rhitrogena
11	Ephemerella
44	Epeorus
11	Alloperla
	Total 9

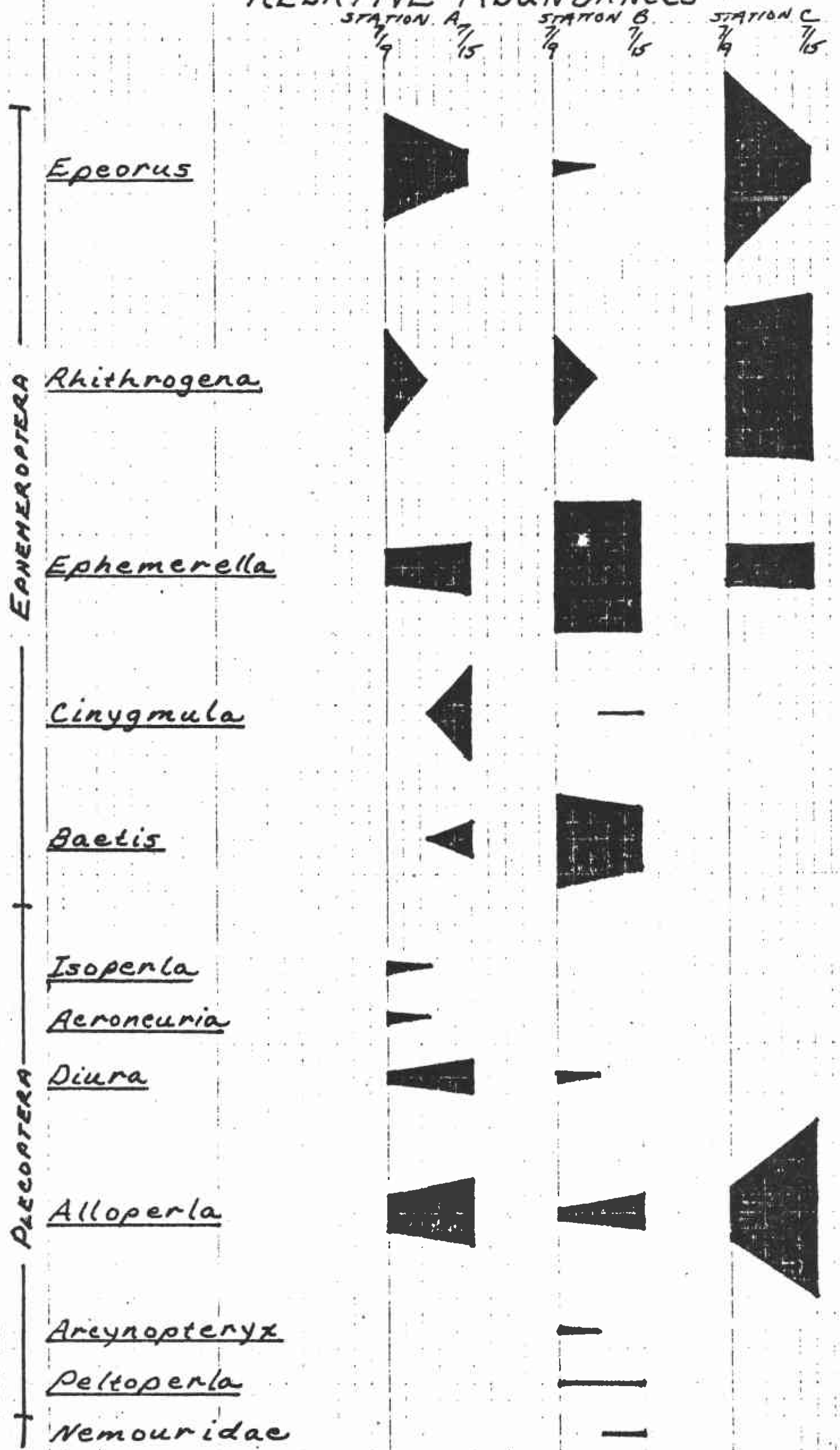
(%)	Post-Kick (9-15)
41	Alloperla
38	Rhithrogena
10	Ephemerella
7	Epeorus
3.5	Chironomidae
	TERREST.
	Total 29

Rank	Post-Kick (11-14)
1	Cinygmula
2	Nemoura
3	Ephemerella
4	Psychodidae
5	Trichoptera cases
	Baetis
	Acroneuria
	Isoperla
	Neureclipsis
	Glossosomatidae
	Arctopsyche
	Elmidae
	Simuliidae
	Tipulidae
	Chironomidae

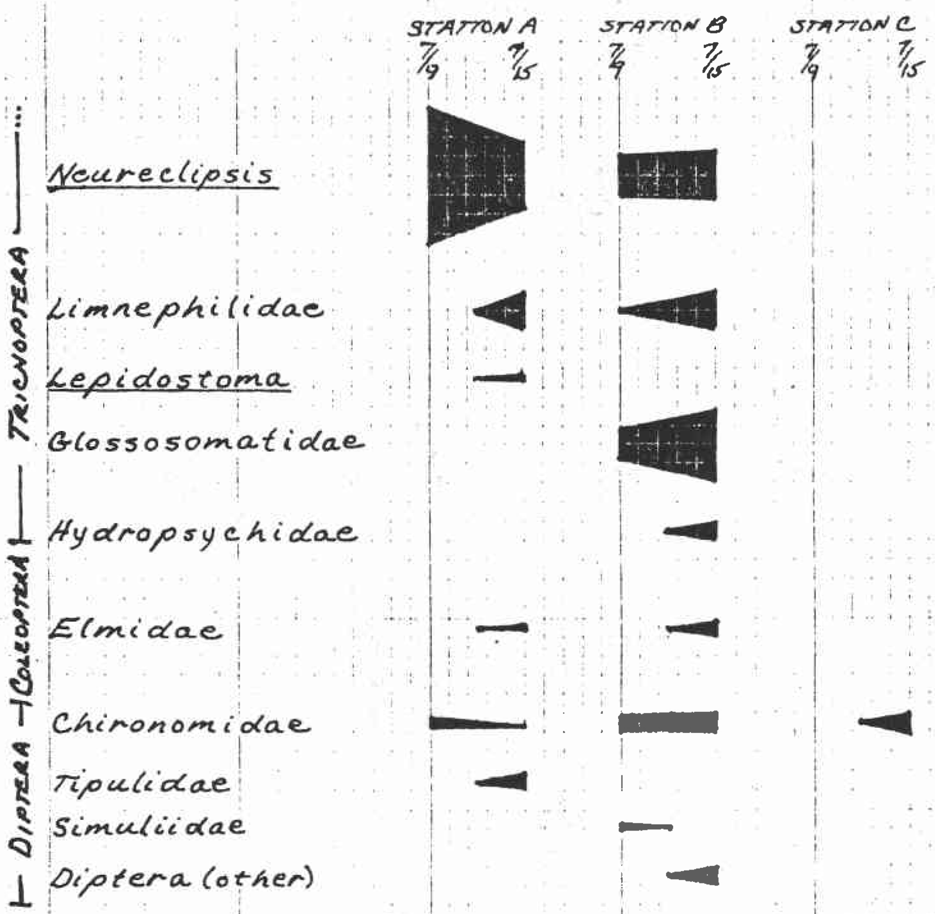
RUBY CREEK (STATIONS A, B, AND C) BLOCK 8

	Station A		Station B		Station C	
	7/9	7/15	7/9	7/15	7/9	7/15
Epeorus	23.5	7	3		44	7
Rhithrogena	23.5		20		33	38
Ephemerella	8	12	30	31	11	10
Cinygmula		22		1		
Baetis		7	20	14		
Isoperla	2					
Acroneuria	2					
Diura	2	7	2			
Alloperla	8	14.5	3	7	11	41
Arcynopteryx			1			
Peltoperla			1	1		
Nemouridae				1		
Neureclipsis	29	14.5	8	10.5		
Limnephilidae		7	1	7		
Lepidostoma		1				
Glossosomatidae			7	14		
Hydropsychidae				3		
Elmidae		1		3		
Chironomidae	2	1	3	3.5		3.5
Tipulidae		3				
Simuliidae			1			
Diptera (other)				3		
N	51	69	~300	143	9	29

RUBY CREEK
KICK SAMPLES
RELATIVE ABUNDANCES



RUBY CREEK (CONT'D.)



BLOCK 6, MIDDLE FORK WARM SPRINGS CREEK

Rank	Pre-Spray Drift	Rank	Spray Drift	Rank	Pre-Kick (7-9)
1	Chironomidae	1	Chironomidae	1	Ephemerella
	Baetis	2	Baetis	2	Epeorus
	Cinygmula	3	Alloperla	3	Baetis
	Epeorus	4	Neureclipsis		Siphlonurus
	Stratiomyidae	5	Ephemerella		Diura
	Tipulidae	6	Nemoura		Neureclipsis
	Corixidae	7	Siphlonurus		Parapsyche
		8	Diura		Chironomidae
		9	Cinygmula		Tipulidae
		10	Epeorus		Hirudinea
		10	Tipulidae		
			Cinygmula		
			Trichoptera case		
			Lepidostoma		
			Stratiomyidae		
			Simuliidae		
			TERREST.		

(%)	Post-Kick (7-11)	(%)	Post-Kick (7-13)	Post-Kick (10-30)
57.5	Ephemerella	73	Ephemerella	*Baetis
16	Neureclipsis	11	Neureclipsis	Limnephilidae
9	Chironomidae	2	Parapsyche	Psychodidae
6	Parapsyche	2	Trichoptera case	Stratiomyidae
1	Nemoura	2	Tipulidae	Chironomidae
1	Diura	7	Chironomidae	Tipulidae
1	Brachycentrus	4	Hirudinea	Hirudinea
3.5	Stratiomyidae		TERREST	
1	Tipulidae			
1	Mollusca		Total 45	
1	Hirudinea			
	Total 87			

* Not ranked because leaves prevented accurate estimate.

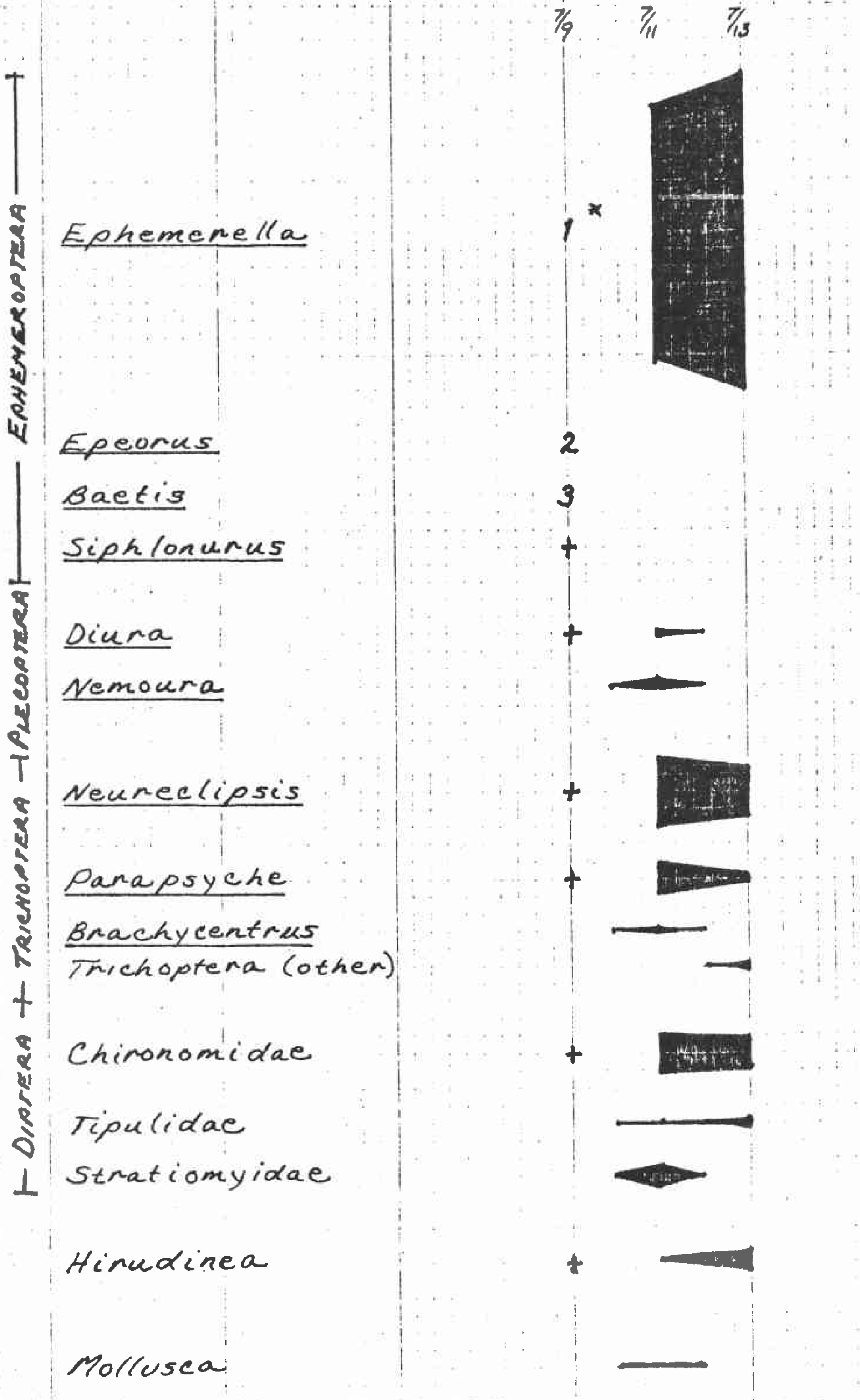
MIDDLE FORK WARM SPRINGS CREEK BLOCK 6

Kick Samples	Relative Abundance (Percent Total Numbers, N)		
	7/9	7/11	7/13
Ephemerella	1*	57.5	73
Epeorus	2		
Baetis	3		
Siphlonurus			
Diura	+	1	
Nemoura		1	
Neureclipsis	+	16	11
Parapsyche	+	6	2
Brachycentrus		1	
Trichoptera (other)			2
Chironomidae	+	9	7
Tipulidae	+	1	2
Stratiomyidae		3.5	
Hirudinea	+	1	4
Mollusca		1	
N	?*	87	45

* Insects were not counted. Only rankings were noted.

+ Present in small quantities.

M.F. Wm. Springs Creek
Kick Samples
Relative Abundances



* Insects were not counted. Only rankings were noted.

BLOCK 4, WARM SPRINGS CREEK

Rank	Pre-Spray Drift
1	Chironomidae
2	Baetis
3	Simuliidae
4	Lepidostoma
5	Diptera (other)
	Epeorus
	Glossosomatidae
	Amphizoa
	Neureclipsis
	TERREST.

Rank	Spray Drift
1	Chironomidae
2	Baetis
3	Simuliidae
4	Diptera (other)
5	Alloperla
6	Elmidae
7	Lepidostoma
7	Limnephilidae
	Siphlonurus
	Cinygmula
	Diura
	Amphizoa
	Neureclipsis
	Tipulidae
	Ephemerella
	Nemoura
	Corixidae
	Psychodidae
	TERREST.

(%)	Pre-Kick (7-9)
48.5	Baetis
10	Epeorus
6.5	Ephemerella
6.5	Cinygmula
6.5	Diura
5	Neureclipsis
5	Siphlonurus
3	Chironomidae
3	Simuliidae
0.5	Acroneuria
0.5	Alloperla
0.5	Brachycentrus
1	Glossosomatidae
1	Lepidostoma
0.5	Limnephilidae
1	Elmidae
0.5	Tipulidae
	Total 309

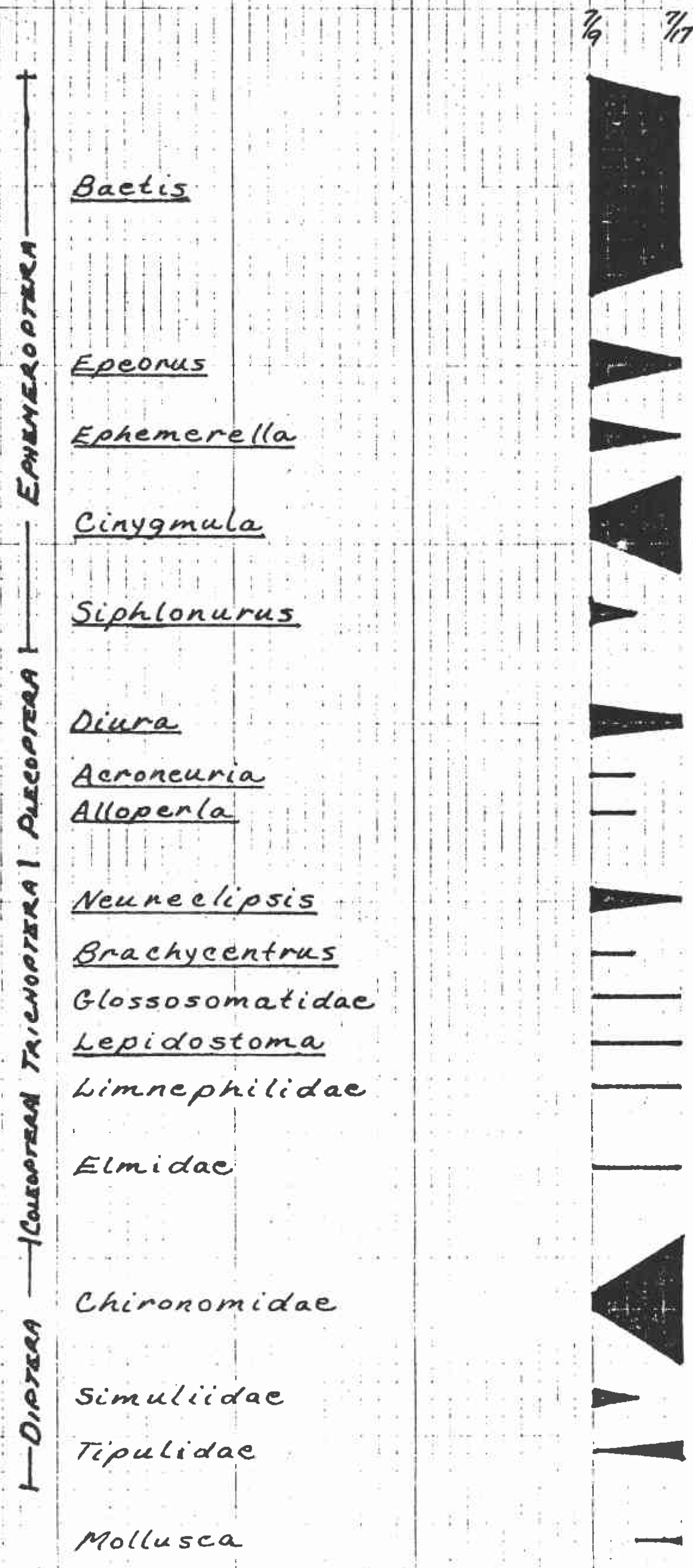
(%)	Post-Kick (7-17)
37	Baetis
27	Chironomidae
20	Cinygmula
3	Epeorus
1	Ephemerella
3	Diura
1	Neureclipsis
1	Lepidostoma
1	Limnephilidae
1	Glossosomatidae
3	Tipulidae
1	Elmidae
1	Mollusca
	Total 149

Rank	Post-Kick (10-30)
1	Arcynopteryx
2	Baetis
3	Pteronarcys
4	Ephemerella
5	Nemoura
	Cinygmula
	Acroneuria
	Alloperla
	Arctopsyche
	Neureclipsis
	Lepidostoma
	Tipulidae
	Rhithrogena

WARM SPRINGS CREEK BLOCK 4

Kick Samples	Relative Abundance (Percent Total Numbers, N)	
	7/9	7/17
Baetis	48.5	37
Epeorus	10	3
Ephemerella	6.5	1
Cinygmula	6.5	20
Siphlonurus	5	
Diura	6.5	3
Acroneuria	0.5	
Alloperla	0.5	
Neureclipsis	5	1
Brachycentrus	0.5	
Glossosomatidae	1	1
Lepidostoma	1	1
Limnephilidae	0.5	1
Elmidae	1	1
Chironomidae	3	27
Simuliidae	3	
Tipulidae	0.5	3
Mollusca		1
N	309	149

WARM SPRINGS CREEK
KICK SAMPLES
RELATIVE ABUNDANCES



BLOCK 7, SOUTH FORK WARM SPRINGS CREEK

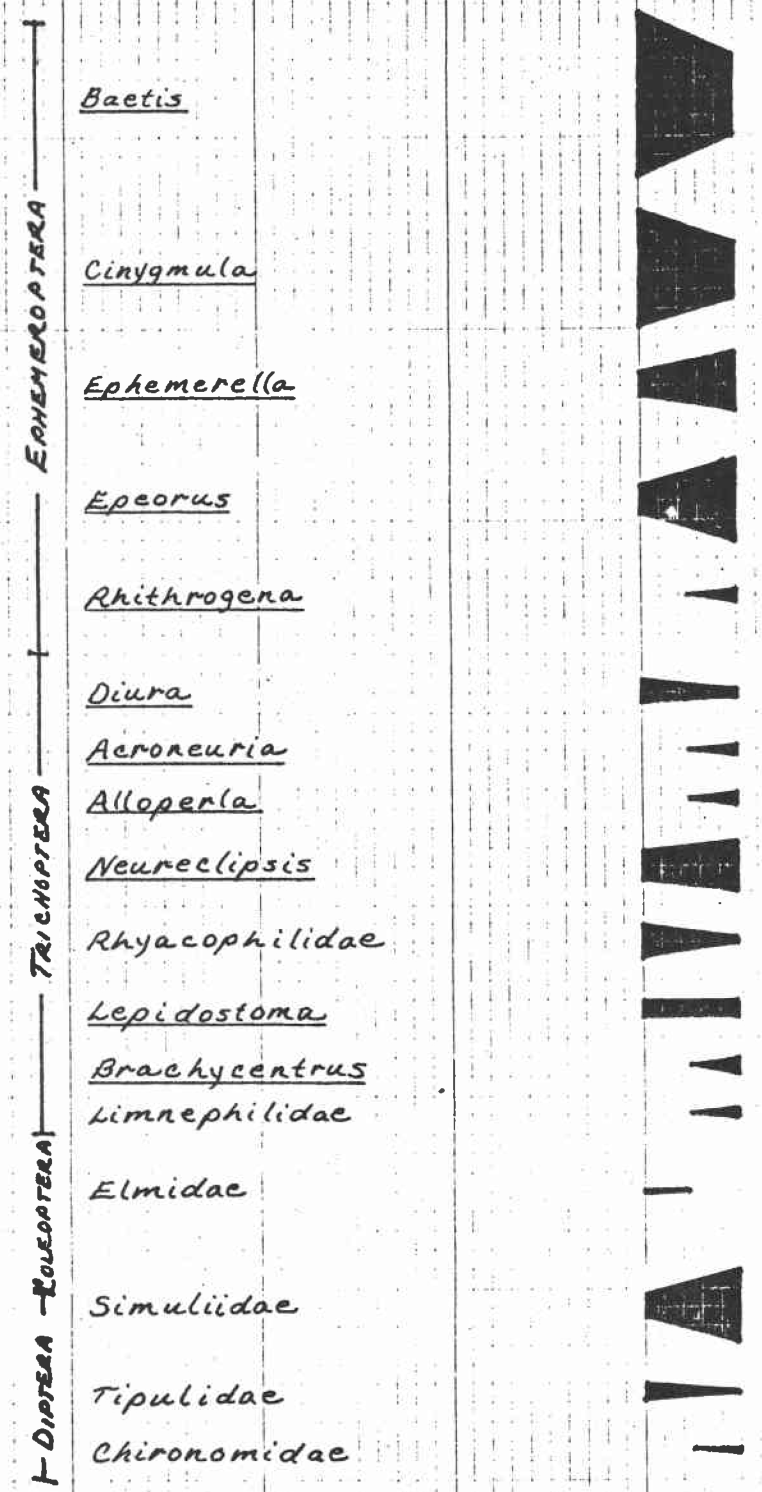
Rank	Pre-Spray Drift	Rank	Spray Drift	(%)	Pre-Kick (7-9)
1	Lepidostoma	1	Simuliidae	34	Baetis
2	Simuliidae	2	Limnephilidae	24	Cinygmula
3	Baetis	3	Baetis	6	Neureclipsis
4	Chironomidae	4	Stratiomyidae	6	Rhyacophilidae
5	Cinygmula	4	Acroneuria	5	Simuliidae
	Acroneuria	4	Chironomidae	5	Ephemerella
	Alloperla	5	Lepidostoma	5	Epeorus
	Neureclipsis	6	Ephemerella	4	Diura
	Rhyacophilidae	6	Brachycentrus	3	Lepidostoma
	Brachycentrus	6	Diptera (other)	3	Tipulidae
	Stratiomyidae	7	Neureclipsis	0.5	Elmidae
	Psychodidae	8	Epeorus		
	Ephemerella		Alloperla		Total 205
	TERREST.		Amphizoa		
			Tipulidae		
			Cinygmula		
			Siphlonurus		
			Elmidae		
			TERREST.		

(%)	Post-Kick (7-18)	Rank	Post-Kick (10-29)
18	Epeorus	1	Baetis
18	Baetis	1	Psychodidae
15	Simuliidae	2	Neureclipsis
13	Cinygmula	3	Ephemerella
11	Ephemerella	3	Rhithrogena
10	Neureclipsis	4	Brachycentrus
3.5	Lepidostoma	4	Elmidae
3	Brachycentrus	4	Chironomidae
2	Rhithrogena	5	Alloperla
1	Acroneuria	6	Acroneuria
1	Diura	7	Nemoura
1.5	Alloperla	8	Tipulidae
1	Limnephilidae		Lepidostoma
1	Rhyacophilidae		Glossosomatidae
0.5	Chironomidae		
0.5	Tipulidae		
	Total 197		

SOUTH FORK WARM SPRINGS CREEK BLOCK 7

Kick Samples	Relative Abundance (Percent Total Numbers, N) 7/9	7/18
Baetis	34	18
Cinygmula	24	13
Ephemerella	5	11
Epeorus	5	18
Rhithrogena		2
Diura	4	1
Acroneuria		1
Alloperla		1.5
Neureclipsis	6	10
Rhyacophilidae	6	1
Lepidostoma	3	3.5
Brachycentrus		3
Limnephilidae		1
Elmidae	0.5	
Simuliidae	5	15
Tipulidae	3	0.5
Chironomidae		0.5

S.F. Wm. Springs Creek
Kick Samples
Relative Abundances



BLOCK 7, SMITH CREEK, FRENCH CREEK, SQUAW CREEK

Smith Creek, Station 1

Rank	Pre-Spray Drift	Rank	Spray Drift	(%)	Pre-Kick
1	Baetis	1	Baetis	24	Cinygmula
2	Cinygmula	2	Trichoptera cases	18.5	Baetis
	Ephemerella	3	Chironomidae	13	Ephemerella
	Siphlonurus		Alloperla	13	Rhithrogena
	Peltoperla		Peltoperla	9	Neureclipsis
	Nemoura		Nemoura	7	Acroneuria
	Elmidae		Neureclipsis	4	Arcynopteryx
	Leptoceridae		Simuliidae	4	Nemoura
	Chironomidae		Tipulidae	2	Epeorus
	TERREST.		Ephemerella	2	Tipulidae
			Rhithrogena	4	Leptoceridae
			Cinygmula		
			Collembola		Total 54
			TERREST.		

French Creek, Station 2

Rank	Pre-Spray Drift	Rank	Spray Drift	(%)	Pre-Kick
1	Baetis	1	Baetis	34	Baetis
2	Ephemerella	2	Limnephilidae	14	Cinygmula
	Siphlonurus	2	Chironomidae	15	Ephemerella
	Paraleptophlebia	3	Simuliidae	6	Neureclipsis
	Alloperla	4	Peltoperla	5	Rhyacophilidae
	Rhyacophilidae	4	Heptageniidae	4	Rhithrogena
	Trichoptera case		Ephemerella	1	Epeorus
	Chironomidae		Cinygmula	4	Peltoperla
	Simuliidae		Alloperla	1	Arcynopteryx
	TERREST.		Trichoptera cases	4	Alloperla
			Diptera (other)	2	Acroneuria
			Arcynopteryx	7	Trichoptera cases
			Neureclipsis	1	Tipulidae
			Psychomiidae	2	Simuliidae
			Tipulidae	1	Chironomidae
			Siphlonurus		
			Nemoura		Total 104
			Rhyacophilidae		
			TERREST.		

Squaw Creek

(%)	Kick
37	Cinygmula
28	Baetis
12	Rhithrogena
6.5	Ephemerella
6	Limnephilidae
1	Arcynopteryx
2	Nemoura
2	Psychomiidae
3	Parapsyche
2	Simuliidae
1	Epeorus

Total 107

Rankings were given only to taxa represented by at least five organisms in a given sample.

SPRUCE BUDWORM PILOT TEST
OF TRICHLORFON (DYLOX) AND CARBARYL (SEVIN 4-OIL)

A. The Impact on Breeding Bird Numbers and Nesting Success

B. The Impact on Brain Cholinesterase Activity in Birds

TABLE OF CONTENTS

A. The impact on breeding bird numbers and nesting success[1]

Lawrence R. DeWeese[2] and Charles J. Henny[3]

INTRODUCTION

The Beaverhead National Forest in southwestern Montana was chosen as the 1975 site to pilot test trichlorfon (Dylox)[4] and carbaryl (Sevin-4-oil)[4] for Western spruce budworm control at 1 lb/acre (active ingredient). The Section of Pesticide-Wildlife Ecology of the Denver Wildlife Research Center was contracted by the U.S. Forest Service, Region 1 Office to evaluate the impact of the spray program on bird populations. This report briefly presents the objectives, methods, and some preliminary results from the bird studies.

To minimize the exclusion of significant phenomena, several methods were used to detect and quantify direct and indirect effects of the

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[1]Results incomplete and not for publication or use without authority of the Director, Denver Wildlife Research Center.

[2]U.S. Fish and Wildlife Service, Denver Wildlife Research Center, P. O. Box C, Davis, California 95616.

[3]U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Bldg. 16, Federal Center, Denver, Colorado 80225.

[4]Reference to trade names does not imply U.S. Government endorsement of commercial products.

aerial applications of the two insecticides on resident birds. Stickel (1974) pointed out that there are two primary techniques for studying field applications of phosphates and carbamates: (1) a careful search for sick or dead birds and (2) the analysis of brain or blood for cholinesterase inhibition. Stickel did not suggest counts of living birds because of a possible temporary exodus, simply as a result of reduction in food supply. Our study utilizes the two approaches recommended by Stickel but also includes (3) the study of live birds using two census techniques, (4) the determination of nesting success (an index) at as many nests as possible, and (5) the exploration of the food habits of resident birds as they relate to the spruce budworm and other important insects. We realize that birds may leave an area due to temporary loss of food supply, but we wanted to evaluate the magnitude of such a temporary loss if it occurred. Furthermore, the live bird census information could possibly aid in interpreting reduced nesting success if it occurred in the treatment plots. Preliminary results regarding the density and species composition of breeding pairs before and after spray and the determination of reproductive performance are presented in this interim report. Brain cholinesterase information is included in part II of this study. Other data are not yet analyzed, but will be included in a final report to be submitted to a proper journal for publication.

METHODS

Details of the major plot locations, dates sprayed, application rates, formulation of the insecticides and operational summaries are not given here. These data will be prepared by the USFS. Briefly, among nine 1-2,000-acre plots three were sprayed by helicopter with Sevin-4-oil formulation, three with a Dylox formulation and three were untreated. Each was a single application made in early morning at a calculated rate of 1 lb/acre (active ingredient).

An important aspect of our study was to locate, map, and revisit all nests that we could find. Visits to nest sites were minimized to reduce effects of human intrusion and disturbance; however, important events, such as nest building, egg laying, number of eggs laid, number of young hatched and fledged were recorded. A cavity viewing device (DeWeese et al. 1975) and dental inspection mirror were used for viewing into cavity nests. An end-mounted mirror on a telescoping pole was used for observation of open-type nests.

For breeding pair censuses, we established a 20-acre rectangular subplot within each of nine major plots that the USFS had chosen for the test. The dominant criterion for these subplots was to have similar habitats which would likely yield similar bird communities. Each subplot was oriented such that the 1,320-foot side generally crossed a major drainage at nearly a right angle and the 660-foot side paralleled the drainage. All subplots contained a drainage. Forested habitat available for bird studies in the original major plots was dominated by Douglas-fir (Pseudotsuga menziesii) habitat types as described in Pfister et al. (1974). Overall treatment boundaries were then modified somewhat for our subplots to include additional bottom lands in the major drainages associated with each major plot. Boundaries were marked so that untreated areas were not less than one-quarter mile from our subplots. All subplots included a variable percentage of the three common habitats found in the 6-8,000-foot elevational range in this area. These habitats as labelled by their dominant overstory were: (1) Douglas-fir, (2) aspen (*Populus tremuloides*), and (3) big sagebrush (*Artemisia tridentata*). Other occurring habitats included open grassy meadows and willows associated with the stream-bottom complex, as well as understory complexes in association with habitats described here.

An internal, lettered-numbered grid of stakes was surveyed into the subplots as described in Pillmore (1973:145). We assigned plots and data collection routines to three people experienced in field ornithology and made some duplicate counts ourselves to evaluate their coverage. Each person was assigned to three plots, each with different treatments, for the entire study, mornings were spent censusing, and other data were collected during afternoons. Trial censuses were made to familiarize personnel with procedures and the birds and we began collecting data by mid-June and continued through July. All data were logged daily into a separate notebook for each plot.

Five estimates of breeding pairs were made during 3-week periods before and after the insecticide application. Each breeding bird census began at official sunrise and extended for two hours. Breeding pairs were mapped by species as presented by Svensson et al. (1970). In addition, other information, such as weather, bird behavior, nest locations and occurrence of dead birds on the plots was also recorded. Effort and results of searching for dead or sick birds were specifically quantified on all plots throughout the study.

We will briefly mention the methods used for fixed-station counts, however, results are not available at this time. Three to five round-shaped, fixed-stations were flag-marked at their periphery and central spot in each of the major habitats. Size of the stations varied from one-third of an acre to three acres, depending upon availability of habitat, but their adjacent boundaries were never less than 100 yards apart. A route of stations was established apart from the 20-acre subplots in each major plot. Station counts for 5 minutes were made at the central spot after a 1-minute initial pause at each successive station. This count routine was performed after the breeding bird censuses each day from two hours after sunrise until completion. This fixed-station method of counting forest breeding birds is not a standard practice; the method described here is a synthesis of our own design with comments and assistance from Chandler S. Robbins (personal communication). Time at completion varied from 11:00 a.m. to 11:45 a.m., depending on the plot, but was fairly consistent among counts on the same plot. Bird species were segregated by their occurrence inside and outside the fixed-station boundary and by sex, when known. These data represent an index to changes in bird numbers and species composition after treatments by acreage and time for each habitat.

Food items were excised from stomachs of 150 birds shot for brain samples. These plant and animal food materials will be sorted out, identified and tabulated for each bird. The stomach contents are now in a preservative and awaiting more refined identification.

RESULTS AND DISCUSSION

Nesting Success

Nests that were active at spray time are presented in Table 1. Species that nested in cavities comprised 56% and those not in cavities comprised 44% of the nests. Thrushes (22%), the woodpecker group (17%), flycatchers and swallows (17%), the house wren (14%), sparrows and juncos (11%) and the warbling vireo (7%) comprised the majority of the nests. An additional 73 nests were initially observed but the adults had terminated their nesting activities before the plots were sprayed. Species are also classed by their general feeding strategy. In this way, species with similar food-gathering habits and with similar potentials for insecticide exposure are grouped to increase the sensitivity of our comparisons. Inspection of stomach contents from several species perhaps will necessitate a more meaningful species grouping.

Outcome of nests that were active at treatment time is an important indication of the overall success of breeding birds in treatment and nontreatment areas. Nest results within treatment groups, by nest type and also by feeding strategies are shown in Table 2. We must emphasize that our nesting success data are indices. Nests active at spray time were well on their way to a successful outcome since the pressures of desertion and nest loss during early nesting had already been exerted, thus, the success indices are quite high. The percentage of nests active at spray time which were ultimately successful held consistent during the postspray period regardless of treatment. In the control plots, 74% of nests with eggs and 97% of nests with young at spray time were successful, in the Dylox plots 90% and 100% were successful, and in the Sevin-4-oil plots 86% and 100% were successful. These data suggest that the nesting process of species for which we found nests was not generally disrupted by the insecticide treatments.

We attempted to determine the outcome of all known active nests but could not do so in many cases. A weekly summary of the final visits made after spraying to the nests that were active at spray time is shown in Table 3. Those data indicate that we made a similar effort to recheck nests in all plots.

Breeding Pair Estimates

A schedule of breeding bird censuses that permitted daily bird counts on plots with different treatments was followed as shown in Table 4. Given the spray schedule of 1 plot/day, we patterned postspray counts so that all plots were censused nearly the same number of times, and on days with equal time elapsed since treatment. Census data from the control plots were divided into two periods similar to the pre- and post-treatment periods for the sprayed plots.

Many different species of birds inhabited our 20-acre subplots. Although some observed differences in occurrence and abundance of a few species were apparent among plots, the more abundant species occurred on all plots (Table 5). Twenty of the 34 common species that were abundant enough and met the requirements of our census are shown. An additional two species (evening grosbeak and pine siskin) were obviously abundant but their behavior and territorial traits prevented a meaningful census of their breeding pairs. Also, 16 other species occurred either uncommonly or their breeding status was unknown in the subplots; 20 more species were uncommon and registered on treatment plots only, 5 on control plots only, and 5 on control or treatment plots. In all, 66 species were encountered during the breeding pair censuses.

When grouped by feeding strategies (Table 6), breeding pair estimates showed no decrease or increase after treatments unique to the sprayed plots. Species were grouped into the five feeding strategies that were also used for nesting outcomes. Total breeding pairs changed by more than 20% after treatment in those groups with greater than 20 prespray pairs for (1) aerial feeders in control, (2) aerial and tree-canopy feeders in Dylox, and (3) no groups in Sevin-4-oil-treated areas. The total breeding pair estimate for the postspray period was 91% of the prespray estimate in the control plots, 88% of the prespray estimate in the Dylox plots, and 92% of the prespray estimate in the Sevin-4-oil plots.

Our breeding pair estimates as presented here may be influenced by many factors including insecticide exposure. Great concern must be voiced when large differences in the breeding pair density occur or a species becomes completely absent after treatment. This was not noted in our study.

Casualty Searches

Two search efforts were made for dead or sick birds in all plots throughout the study. The first, and most important, was specifically to look for dead or sick birds while doing nothing else. Results of these searches (Table 7) clearly indicate that mortalities did not increase after treatment on treated plots. Also, in support of this finding, is a secondary effort that each observer made while walking many hours on constant routes to, from, and during routine bird censuses. We found a few dead birds on the census routes in about equal frequencies on all plots. No sick birds were found during any search efforts which further suggests that mortalities that we encountered were likely not insecticide induced.

SUMMARY

Objectives, methods and preliminary results of effects of aerial applications of Sevin-4-oil and Dylox (both 1 lb/acre [active ingredient]) on birds in a pilot test for controlling Western spruce budworm are presented. Results from nest monitoring and breeding pair estimates are given; results of cholinesterase studies are presented as a separate report. Two additional sets of information will be included in a final report for publication.

Outcome of observed nests and estimates of breeding bird density and diversity showed similar patterns on control and treated plots after treatment. Searches for sick or dead birds showed no increase in mortalities on treated plots. Mortalities encountered during specific searches were likely not insecticide induced. The results support a conclusion that immediate adverse effects on birds, if any, were not obvious from the standpoint of the described approaches. Statistical comparisons of the data are not given in this preliminary report, pending further review of these and additional data. Literature from previous studies will also be included in the final report.

ACKNOWLEDGMENTS

Three summer employees deserve special recognition for their outstanding efforts in collecting much of the basic information used in this report. Kathie A. Bobal, Randy L. Floyd, and Albert W. Shultz were in the field at sunrise most of the summer to observe the birds during their peak activity period--their efforts are most appreciated.

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Table 1. Number and type of nests and general feeding strategies of breeding bird species found active on the study areas at the time of spray.

Species	Nest Type[a]	General Feeding Strategy[b]	Nests Active at Spray: Control	Dylox	Sevin-4-oil
Goshawk[c]	Non-cavity	Raptorial	0	1	0
Sharp-shinned Hawk	Non-cavity	Raptorial	1	0	0
Red-tailed Hawk	Non-cavity	Raptorial	1	1	1
Common Flicker	Cavity	Ground	3	4	6
Yellow-bellied Sapsucker	Cavity	Tree-trunk	7	6	4
Williamson's Sapsucker	Cavity	Tree-trunk	0	1	0
Hairy Woodpecker	Cavity	Tree-trunk	2	2	2
Downy Woodpecker	Cavity	Tree-trunk	1	2	1
Northern Three-toed Woodpecker	Cavity	Tree-trunk	0	0	1
Empidonax spp. Flycatcher	Non-cavity	Aerial	4	7	3
Tree Swallow	Cavity	Aerial	6	18	3
Mountain Chickadee	Cavity	Tree-canopy	3	7	5
Black-capped Chickadee	Cavity	Tree-canopy	1	0	0
House Wren	Cavity	Understory	10	14	11
American Robin	Non-cavity	Ground	14	8	13
Swainson's Thrush	Non-cavity	Ground	0	0	2
Mountain Bluebird	Cavity	Air-ground	6	7	3
Warbling Vireo	Non-cavity	Tree-canopy	7	4	5
Yellow Warbler	Non-cavity	Understory	0	1	0
Yellow-rumped Warbler	Non-cavity	Tree-canopy	0	1	0
Pine Siskin	Non-cavity	Tree-canopy	0	2	0
Western Tanager	Non-cavity	Tree-canopy	0	0	2
Green-tailed Towhee	Non-cavity	Understory	2	0	0
Dark-eyed Junco	Non-cavity	Ground	3	7	3
Chipping Sparrow	Non-cavity	Ground	5	5	3
White-crowned Sparrow	Non-cavity	Ground	1	1	0
		Totals	77	99	68

[a]Based on nest sites utilized in the study area.

[b]Based on personal experience and observations during this study; also from Smithsonian Institution U.S. Natl. Mus. Bulletins on Life Histories of Birds of North America by Arthur C. Bent.

[c]Scientific names of birds are found in Table 8.

Table 2. Results of nesting as determined at the last postspray visit to nests that were active at the time of spray[a].

Treatment	No. Species	Nests With Eggs at Spray Time[b]: No. Nests	Nests With Eggs at Spray Time[b]: Percentage of Nests With Known Outcome: Active or Fledged[c]	Nests With Eggs at Spray Time[b]: Percentage of Nests With Known Outcome: Failed[d]	Nests With Eggs at Spray Time[b]: Total Unknown	Nests With Young at Spray Time[b]: No. Nests	Nests With Young at Spray Time[b]: Percentage of Nests With Known Outcome: Active or Fledged[c]	Nests With Young at Spray Time[b]: Percentage of Nests With Known Outcome: Failed[d]	Nests With Young at Spray Time[b]: Total Unknown
CONTROL									
Nest Type									
Cavity	9	16	73	27	1	19	100	0	1
Non-cavity	13	13	75	25	1	14	92	8	2
Total	22	29	74[g]	26[g]	2	33	97[g]	3[g]	3
Feeding Strategy[e]									
Raptorial	2	1	100	0	0	1	0	0	1
Aerial	2	7	29	71	0	3	100	0	0
Tree-canopy	3	0	0	0	0	3	100	0	0
Tree-trunk	3	2	100	0	0	7	100	0	0
Ground	7	8	86	14	1	14	100	0	2
Understory	4	8	100	0	0	3	67	33	0
Air-ground	1	3	50	50	1	2	100	0	0
Total	22	29	74[g]	26[g]	2	33	97[g]	3[g]	3

Table 2 (cont'd)

DYLOX									
Nest Type									
Cavity	9	19	100	0	4	33	100	0	6
Non-cavity	14	19	78	22	5	10	100	0	1
Total	23	38	90[g]	10[g]	9	43	100[g]	0	7
Feeding Strategy[e,f]									
Raptorial	3	0	0	0	0	3	100	0	0
Aerial	2	18	100	0	4	1	100	0	0
Tree-canopy	3	0	0	0	0	9	100	0	2
Tree-trunk	4	0	0	0	0	10	100	0	2
Ground	7	11	67	33	2	7	100	0	0
Understory	3	7	100	0	1	9	100	0	2
Air-ground	1	2	0	0	2	4	100	0	1
Total	23	38	90[g]	10[g]	9	43	100[g]	0	7
SEVIN-4-OIL									
Nest Type									
Cavity	9	13	91	9	2	18	100	0	3
Non-cavity	10	12	80	20	2	7	100	0	1
Total	19	25	86[g]	14[g]	4	25	100[g]	0	4

Table 2 (cont'd)

Feeding Strategy[e]									
Raptorial	1	0	0	0	0	1	100	0	0
Aerial	2	4	100	0	0	1	100	0	0
Tree-canopy	3	2	100	0	0	4	100	0	0
Tree-trunk	4	0	0	0	0	7	100	0	1
Ground	5	10	75	25	2	9	100	0	2
Understory	3	7	100	0	2	2	100	0	0
Air-ground	1	2	50	50	0	1	0	0	1
Total	19	25	86[g]	14[g]	4	25	100[g]	0	4

[a]See Table 3 for the frequency of final visits made to nests active at spray time.

[b]An additional 8 nests of 4 species in control plots that built nests at spraying or thereafter had 1 failure, 4 active or fledged and 3 unknown outcomes at the last postspray check; 9 similar nests of 4 species in Dylox plots had 3, 5, and 1, respectively, at last check, and 6 nests of 4 species had 0, 5, and 1, respectively, in Sevin-4-oil-treated plots.

[c]Active nests include those with eggs or young or with adults tending the unseen contents; "fledged" nests produced at least 1 young to the age of leaving the nests; young were detected by visual and auditory techniques.

[d]Causes of failures included disturbances from predators, weather, livestock, humans, and unknown factors.

[e]The majority of Warbling Vireo nests that were active at spray time are not included because we could not see into the nests; of 8 additional nests on control plots, 7 were active and 1 had unknown status; 1 nest on Dylox was active, and of 3 nests in Sevin-4-oil-treated plots, 2 were active and 1 had unknown status at the last postspray check.

[f]Stellar's Jay (1 nest), not included in table, had unknown outcome postspray.

[g]Weighted mean percentage.

Table 3. Weekly summary of final postspray visits to nests that were active at spray time.

	Numbers of Nests at Weekly Intervals Postspray									
	Nesting Not Terminated[a]				Nesting Terminated[b]				Result	Total
Treatment	1	2	3	4	1	2	3	4	Unknown	Nests
Control	6	13	10	2	6	15	5	7	13	77
Dylox	2	13	19	0	20[c]	11	13	0	21	99
Sevin-4-oil	6	10	1	5	9	16	3	4	14	68

[a]Nests not terminated at final visit were treated as active in nest studies.

[b]All terminated nests were categorized by their results; see Table 2.

[c]Proportionally, more early nesters were found in the Dylox plots; see Table 2 for percentage nesting successfully.

Table 4. Schedule of breeding-bird, fixed-station counts and treatments on the nine study plots.[a]

	Plots Pre-Spray										Plots Post-Spray								
Date	1	2	3	4	5	6	7	8	9	Date	1	2	3	4	5	6	7	8	9
June 15		C[b]			C				C	July 8									
16	C					C	C			9									
17			C	C				C		10		T							
18		C								11		C			C	T			C
19	End Trial Counts--Begin Counts									12	C					C	C	T	
20		C			C				C	13		C	C					C	
21	C					C	C			14				T		C			C
22			C	C				C		15				C				C	
23		C			C				C	16	C		C		T				
24	C									17		C			C		T		C
25						C	C			18				C		C	C		
26			C	C				C		19	C				C			C	
27		C			C				C	20		C	C				C		
28	C					C	C			21				C		C			C
29			C	C				C		22	C				C			C	
30										23		C	C				C		
July 1		C			C				C	24						C			C
2	C					C	C			25				C	C			C	
3			C	C				C		26	C								
4		C			C				C	27		C	C				C		
5	C					C	C			28				C		C			
6			C	C				C		29					C			C	
7										30			C				C		

a Plots 1, 4 and 2 were assigned to first observer, plots 3, 5 and 6 to a second, and 9, 7 and 8 to a third observer; treatments within each set of plots were control, Dylox and Sevin-4-Oil respectively.

b C=date breeding-bird and fixed-station counts were made; T=date a plot was treated.

Table 5. Estimated pairs of selected breeding birds in the nine plots with respective treatments during the pre- and post-spray periods.[a]

Species[b]	Overall Rank[c] Pre-Spray	Control Plots Pre-Spray 1	3	9	Control Plots Post-Spray 1	3	9	Dylox Plots Pre-Spray 4	5	7	Dylox Plots Post-Spray 4	5	7	Sevin-4 Oil Plots Pre-Spray 2	6	8	Sevin-4 Oil Plots Post-Spray 2	6	8
Common Flicker	14	0	1	1	0	1	1	1	1+	1	1	0	2	P	1+	P	P	2	0
Yellow-bellied Sapsucker	12	2	P	1	2	1	1	1	1	1	0	0	1	1	0	1	1	1+	0
Empidonax Spp.[d]	2	7	5	6	4	4	4	7	4	3	4	3	2	7	6	5	9	4	6
Tree Swallow	10	2	1	1	2	1	1	2	1+	4	2	0	5	1	3	P	0	2	0
Mountain Chickadee	5	2	4	4	2	4	3	4	3	3	3	2	4	3	4	5	2	4	2
House Wren	8	2	2	3	3	2	3	3	2	2	3	1+	2	3	4	0	2	3	0
American Robin	3	8	3	3	5	3	6	6	2	3	8	1+	4	6	8	3	4	6	5
Hermit Thrush	14	0	2	1	0	1	0	P	1	0	0	1	+	1	0	3	1	1	3
Swainson's Thrush	10	4	1	1	3	0	1	1	0	1	1	0	1	2	0	3	2	0	3
Mountain Bluebird	15	1	0	0	1	P	0	1	P	1	0	0	1	0	1+	0	0	0	0
Ruby-crowned Kinglet	7	1	4	4	0	2	3	3	2	P	2	2	P	3	4	3	3	2	2
Warbling Vireo	1	7	3	7	4	3	6	8	5	6	9	3	3	9	6	4	10	6	3
Yellow-rumped Warbler	4	4	4	5	4	4	5	6	3	1	5	1+	P	5	3	4	5	3	3
Macgillivray's Warbler	10	0	0	2	1	1	2	2	2	2	3	2	0	2	0	3	1	0	4
Western Tanager	9	1	3	3	2	3	3	2	2	0	0	2	0	5	2	3	5	3	3
Lazuli Bunting	10	3	0	1	5	0	3	1	2	0	3	3	0	4	2	2	4	2	3
Cassin's Finch	13	P	P	1	0	0	0	2	P	P	1	0	2	2	2	0	1	2	0
Dark-eyed Junco	5	4	4	4	4	6	2	6	2	5	6	2	5	3	6	3	3	6	2
Chipping Sparrow	6	3	6	5	4	6	4	6	5	3	4	4	4	5	6	5	5	6	4
White-crowned Sparrow	11	1	1	0	0	P	0	2	0	3	3	0	3	2	0	0	2	P	0
Subtotals		52	44	53	46	42	48	64	38	39	58	27	39	64	58	47	60	53	43
Totals		149			136			141			124			169			156		

a P = species that occurred on a plot in insufficient numbers for pair determination; 0 = species that did not occur on a plot; + = at least one observation suggested an additional pair, but not enough to call it a full breeding pair.

b of 180 possible instances of occurrance (9 plots x 20 species), 10 species (none ranked lower than 8th) were absent from 1-3 plots in 16 instances.

c rank in decreasing order of abundance from total pair estimates in all plots before treatment.

d likely includes *E. traillii* (Willow Flycatcher), *E. hammondii* (Hammond's Flycatcher), and *E. oberholseri* (Dusky Flycatcher); the latter was the most common.

Table 6. Estimated numbers of selected resident breeding pairs in each group of three plots with differing treatments and grouped by feeding strategy[a].

Feeding Strategy	No. Species	Control		Dylox		Sevin-4-oil	
		Pre	Post	Pre	Post	Pre	Post
Aerial	2	22	16	21	16	22	21
Tree-canopy	6	57	48	50	39	67	59
Tree-trunk	1	3	4	3	1	2	2
Ground	6	51	47	44	44	55	53
Understory	4	15	20	21	23	22	21
Air-ground	1	1	1	2	1	1	0
Total	20	149	136	141	124	169	156

[a]All species included from Table 5; see Table 1 for feeding strategies; species and their feeding strategies not included on Table 1 but used here are: Hermit Thrush - ground, Ruby-crowned Kinglet - tree-canopy, Lazuli Bunting - understory, and Cassins's Finch - tree-canopy feeders.

Table 7. Results of searching for sick or dead birds in untreated and treated major plots.

	Prespray			Postspray		
Treatment	Search Days[a]	Search Hours	No. Birds Found Dead	Search Days[a]	Search Hours	No. Birds Found Dead
Control	10	11.0	0	8	7.5	0
Dylox	10	13.0	1[b]	8	8.5	2[c]
Sevin-4-oil	12	13.5	4[d]	7	9.0	0

[a]Each search day represents one person searching in one plot for one day, for 0.5 to 2.5 hours.

[b]Blue Grouse.

[c]Newly hatched young found partly ingested by garter snakes.

[d]One each of adult Yellow-rumped Warbler, Blue Grouse, Common Flicker, and Western Tanager.

Table 8. Scientific names of birds mentioned in this paper (A.O.U. 1957, 1973).

Common Name	Scientific Name
Goshawk	*Accipiter gentilis*
Sharp-shinned Hawk	*Accipiter striatus*
Red-tailed Hawk	*Buteo jamaicensis*
Common Flicker	*Colaptes auratus*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Williamson's Sapsucker	*Sphyrapicus thyoideus*
Hairy Woodpecker	*Dendrocopos villosus*
Downy Woodpecker	*Dendrocopos pubescens*
Northern Three-toed Woodpecker	*Picoides tridactylus*
Flycatcher	*Empidonax* spp.
Tree Swallow	*Iridoprocne bicolor*
Mountain Chickadee	*Parus gambeli*
Black-capped Chickadee	*Parus atricapillus*
House Wren	*Troglodytes aedon*
American Robin	*Turdus migratorius*
Hermit Thrush	*Catharus guttatus*
Swainson's Thrush	*Catharus ustulatus*
Mountain Bluebird	*Sialia currucoides*
Ruby-crowned Kinglet	*Regulus calendula*
Warbling Vireo	*Vireo gilvus*
Yellow Warbler	*Dendroica petechia*
Yellow-rumped Warbler	*Dendroica coronata*
MacGillivray's Warbler	*Oporornis tolmiei*
Pine Siskin	*Spinus pinus*
Western Tanager	*Piranga ludoviciana*
Lazuli Bunting	*Passerina amoena*
Green-tailed Towhee	*Chlorura chlorura*
Cassin's Finch	*Carpodacus cassinii*
Dark-eyed Junco	*Junco hyemalis*
Chipping Sparrow	*Spizella passerina*
White-crowned Sparrow	*Zonotrichia leucophrys*

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B. The Impact on Brain Cholinesterase Activity in Birds

B. The impact on brain cholinesterase activity in birds[1]

Joseph G. Zinkl,[2] Charles J. Henny,[2] and Lawrence R. DeWeese[3]

INTRODUCTION

Our study in the Beaverhead National Forest of southwestern Montana of the impact of trichlorfon (Dylox)[4] and carbaryl (Sevin-4-oil)[4] on resident breeding bird populations was outlined in the first report of this series (DeWeese and Henny 1976). The study plan included: (1) an evaluation of reproductive performance (nesting success), (2) the estimation of breeding pair density before and after spray within major habitats, (3) estimation of total birds at fixed stations in each major habitat, an approach distinct from the breeding pair estimates, (4) exploration into the food habits of the resident birds as they related to the spruce budworm and other important insect groups, and (5) determination

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[1]Results incomplete and not for publication or use without authority of the Director, Denver Wildlife Research Center.

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[4]Reference to trade names does not imply U.S. Government endorsement of commercial products.

of brain cholinesterase activities from abundant and diverse avian species. The latter is the topic of this report.

Details of the plot locations, dates sprayed, application rates, formulation of the insecticides and operational summaries are not given here. Briefly, among nine 1-2,000-acre plots, three were sprayed by helicopter with a Sevin-4-oil formulation, three with Dylox and three were untreated. Each was a single application made early in the morning at a calculated rate of 1 lb/acre (active ingredient).

Since Dylox and Sevin-4-oil are organophosphate and carbamate insecticides, respectively, they inhibit cholinesterase enzymes. By specifically inhibiting acetylcholinesterase, they interfere with cholinergic nerve transmissions. Signs of cholinesterase inhibitor poisoning include myosis, salivation, and lacrimation (muscurinic effects) and muscle twitching, paralysis and clonic convulsions (nicotinic effects). Death is due to asphyxiation from paralysis of respiratory muscles and/or inhibition of the central respiratory center (O'Brien 1967:56).

Since cholinesterase activity is easily measured, its measurement can be used to determine if an animal has been poisoned with organophosphate or carbamate insecticides (Stickel 1974). However, certain precautions must be taken in order to assure that the results are valid. The first is that the cholinesterase activity of birds suspected to have been poisoned with cholinesterase inhibitors must be compared with that of unpoisoned birds of the same species because of the great variation of activity between species (Stickel 1974). The second is that storage of the enzyme-containing tissue should be such as not to cause any deterioration of enzyme between the time of death and the time of analysis (Stickel 1974, Ludke et al. 1975). With these precautions in mind, brain cholinesterase activities were determined in birds collected from Montana forest areas sprayed with either Dylox or Sevin-4-oil.

MATERIALS AND METHODS

Birds were collected using mist nets or by shooting with shotguns. The birds collected with mist nets were killed by asphyxiation in CO_2. Either whole birds or heads were frozen on dry ice until the brains were dissected for analysis. Occasionally, the brain of a shot bird was discarded because of excessive damage. This precaution was taken because different areas of the brain have different cholinesterase activities (Knittle and Tucker 1974).

Control birds and treatment birds (spray area) were collected from similar habitats. Control birds were collected before spraying and during the time of spraying in order to determine if a short-term temporal change in cholinesterase activity occurred. Since both sexes were collected, it was also possible to determine if there were any differences due to sex.

The Ennis High School science laboratory was kindly donated for laboratory space. All analyses were carried out at this location within 12 hours after collection.

After removal from the calvarium, brains were homogenized in cold 0.1 M phosphate buffer (pH 7.4) at a 1-5 dilution. They were then diluted to either 1-50 or 1-100 with the phosphate buffer just prior to analysis.

The Ellman (Ellman et al. 1961) method was adapted to determine brain cholinesterase activity (Dieter and Ludke 1975). The reagents for this technique were obtained in kit form from BMC Corporation, Dallas, Texas. A Spectronic 88 (Bausch & Lomb) fitted with a flow-through, water-jacketed curvette was used for determining the activity. Optical density readings were taken every 30 seconds for 3 minutes in order to assure that the reaction was linear. All analyses were carried out at 25°C.

RESULTS

Cholinesterase activities of 27 species of the orders Passiformes (24 species) and Piciformes (3 species) were determined. However, for several species insufficient data were obtained to be useful in evaluating the effects of the spray. No short-term temporal effects or sex differences were found. The species with the highest activities were the yellow-bellied sapsucker (Sphyrapicus varius) and the hairy woodpecker (Dendrocopos villosus) (47.2 and 42.5 mU/mg brain, respectively).

Sufficient data were obtained from 10 species of birds to evaluate the effect of Dylox on brain cholinesterase activity. One dark-eyed junco (Junco hyemalis), one evening grosbeak (Hesperiphona vespertina), two mountain chickadees (Parus gambeli) and two western tanagers (Piranga ludoviciana) had values which were at least 2 standard deviations (S.D.) below the mean (Table 1). Both western tanagers' activities were more than 20% below the mean (26.5% and 20.5%) while the evening grosbeak's activity was depressed nearly to that level (19.8%). These western tanagers were collected on the day of spray, while the evening grosbeak was collected 3 days after the spraying.

Of the 12 species of birds evaluated from the Sevin-4-oil spray areas, 3 individuals representing 3 species had values depressed greater than 2 S.D. below the mean (Table 2). They were a mountain chickadee, an evening grosbeak and a Lincoln's sparrow (Melospiza lincolnii). Only the evening grosbeak's brain cholinesterase activity was more than 20% below the mean (21.3%). This evening grosbeak was collected on the day of spray.

DISCUSSION

Previous work in our laboratory with starling (Sturnus vulgaris) brains and sera showed that storage in dry ice preserves cholinesterase enzyme activity for up to 5 weeks (Zinkl and Hudson 1975). Knittle and Tucker (1974) have shown that storage at -40°C and -68°C preserves the enzyme. However, deterioration does occur at -18°C (Knittle and Tucker 1974) or -22°C (Ludke et al. 1975). In this study it is unlikely that there was any loss of activity from the time of collection until analysis because the brains were stored in dry ice and the analyses were carried out soon after collection (within 12 hours).

A considerable difference of opinion exists among authors regarding how great the brain cholinesterase depression must be for diagnosing cause of death. Ludke et al. (1975) showed that 50% inhibition occurred in Japanese quail (Coturnix c. japonica) that died after being fed up to 1,400 ppm parathion for up to 5 days. Bunyan et al. (1968) found that pheasants dying from a single dose of a variety of organophosphates had at least 90% brain cholinesterase depression. In our laboratory, ring doves given a single dose of 21.2 mg Dylox/kg B.W. had 83% brain cholinesterase depression when sacrificed 2 hours after dosing. Others given this amount survived. Ring doves that died after being given 42.4 mg Dylox/kg B.W. had 95% depression. Homing pigeons given 195 mg Dylox/kg B.W. died within 45 minutes after dosing. Their brain cholinesterase activities were 83% inhibited. Others given 78.1 mg Dylox/kg B.W. survived for 18 hours before being sacrificed. Their activities were depressed 68% at that time even though they were showing few signs of organophosphate toxicity. Ring doves given 1,000 mg Sevin-4-oil/kg B.W. had brain cholinesterase activities that were decreased 56% when sacrificed 2 hours after dosing. Other birds given the same dose survived (Zinkl and Hudson 1975).

Therefore, even using the most stringent criteria (50% depression), no birds were in immediate danger of dying from either Dylox or Sevin-4-oil poisoning. However, at least 4 of the birds had activities depressed about 20% below the mean of the species. This indicates exposure had occurred (Ludke et al. 1975). Five more birds had activities depressed greater than 2 S.D. below the mean. Of the 5 species having depressed activities ($\bar{x}$ - 2 S.D.) 3 are canopy dwellers (mountain chickadee, evening grosbeak, and western tanager). These birds represented 7 of the 9 depressed values, and they were the most depressed values, probably reflecting greater exposure of these species rather than increased susceptibility to the chemicals.

Most of the depressed values occurred on the day of spray (day 0), probably due to the transient environmental nature of the compounds (especially Dylox) (Kaemmerer and Buntenkotter 1973:201, Paris and Lewis 1973).

There is no experimental work concerning the effects of sublethal cholinesterase inhibition on birds. Perhaps these levels might increase a bird's susceptibility to predation or decrease its ability to obtain food (e.g., fly-catching). Nevertheless, they represent a small number of birds compared to the total evaluated.

In conclusion, spraying with Dylox or Sevin-4-oil at 1 lb/acre (active ingredient) had little effect on brain cholinesterase activities. Thus, only minimal exposure occurred, a finding similar to that of Kurtz and Studholme (1974) who determined residues in birds from eastern forests sprayed with Dylox and Sevin.

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Table 1. Brain Cholinesterase Activities[1] of Birds Taken From Areas Sprayed With Dylox

Species	Control[2]	Normal Range ($\bar{x} \pm 2$ S.D.)	Day 0[3]	Day 1	Day 2	Day 3	Day 5	Abnormally Low Values
Empidonax spp.[4]	22.2±2.6	17.0 - 27.4	24.6±0.5	-	-	-	-	
	(8)		(2)					
Evening Grosbeak	31.9±2.1	27.7 - 36.1	33.1	30.9	30.3	28.1±3.5	30.4±2.8	25.6
(*Hesperiphona vespertina*)	(6)		(1)	(1)	(1)	(2)	(3)	(day 3)
Pine Siskin	22.2±2.4	17.4 - 27.0	25.8±1.1	-	-	22.0	25.5±1.5	
(*Spinus pinus*)	(10)		(2)			(1)	(3)	
Chipping Sparrow	23.5±1.8	19.9 - 27.1	24.5±1.3	24.4±3.5	23.4±1.1	24.7±1.9	24.2±1.4	
(*Spizella passerina*)	(7)		(4)	(2)	(3)	(3)	(5)	
Dark-eyed Junco	33.2±1.1	31.0 - 35.4	35.6±1.8	36.7±1.4	32.3±1.0	35.6±1.7	35.6±2.5	30.9
(*Junco hyemalis*)	(9)		(8)	(3)	(4)	(6)	(3)	(day 2)
Lazuli Bunting	31.6±2.7	26.2 - 37.0	31.0	-	-	32.0	-	
(*Passerina amoena*)	(5)		(1)			(1)		
Western Tanager	28.3±2.9	22.5 - 34.1	21.7±1.2	30.0±2.3	30.1±1.6	30.2±1.3	29.7	22.5 20.8
(*Piranga ludoviciana*)	(8)		(2)	(3)	(4)	(3)	(1)	(day 0) (day 0)

Table 1 (cont'd)

Warbling Vireo	33.8±3.9	26.0 - 41.6	35.0±1.5	-	29.3	31.6	-		
(*Vireo gilvus*)	(10)		(3)		(1)	(1)			
Mountain Chickadee	33.8±1.3	31.2 - 36.4	30.9±3.2	34.6±2.9	32.3±2.0	31.4	33.2±0.6	28.6	30.9
(*Parus gambeli*)	(3)		(2)	(4)	(2)	(1)	(3)	(day 0)	(day 2)
American Robin	26.6±3.9	18.8 - 34.4	29.6±3.4	28.1±2.2	28.0	29.7±0.3	31.5±2.6		
(*Turdus migratorius*)	(10)		(3)	(3)	(1)	(3)	(4)		

[1] Activities expressed as mU/mg brain.

[2] Mean and standard deviation.

[3] Days after spraying.

[4] *Empidonax* spp. were primarily dusky flycatchers (*Empidonax oberholseri*).

Table 2. Brain Cholinesterase Activities[1] of Birds Taken From Areas Sprayed With Sevin-4-oil

Species	Control[2]	Normal Range ($\bar{x} \pm 2$ S.D.)	Day 0[3]	Day 1	Day 2	Day 5	Abnormally Low Values
Yellow-bellied Sapsucker	47.2±4.3	38.6 - 55.8	50.7±2.6	-	-	-	
(*Sphyrapicus varius*)	(4)		(2)				
Common Flicker	24.8±1.2	22.4 - 27.2	25.7±0.5	-	-	-	
(*Colaptes auratus*)	(3)		(2)				
Empidonax spp.[4]	22.2±2.6	17.0 - 27.4	24.2±1.0	-	-	28.4	
	(8)		(4)			(1)	
Evening Grosbeak	31.9±2.1	27.7 - 36.1	27.7±2.3	31.2±2.3	-	32.4±2.4	25.1
(*Hesperiphona vespertina*)	(6)		(3)	(2)		(4)	(day 0)
Pine Siskin	22.2±2.4	17.4 - 27.0	22.6±1.3	23.0	-	22.1±0.9	
(*Spinus pinus*)	(10)		(7)	(1)		(3)	
Chipping Sparrow	23.5±1.8	19.9 - 27.1	24.2±1.6	-	-	26.4±0.5	
(*Spizella passerina*)	(7)		(5)			(3)	
Dark-eyed Junco	33.2±1.1	31.0 - 35.4	33.5±1.1	-	31.9	36.2±0.8	
(*Junco hyemalis*)	(9)		(6)		(1)	(4)	
Lincoln's Sparrow	25.2±1.4	22.4 - 28.0	24.1±2.5	24.9	-	24.8±0.7	21.6
(*Melospiza lincolnii*)	(5)		(4)	(1)		(2)	(day 0)

Table 2 (cont'd)

Western Tanager	28.3±2.9	22.5 - 34.1	29.8±2.5	-	-	-	
(*Piranga ludoviciana*)	(8)		(6)				
Warbling Vireo	33.8±3.9	26.0 - 41.6	32.7±2.6	-	-	33.0	
(*Vireo gilvus*)	(10)		(4)			(1)	
Mountain Chickadee	33.8±1.3	31.2 - 36.4	32.6±0.8	-	30.9±1.2	-	29.5
(*Parus gambeli*)	(3)		(3)		(3)		(day 2)
American Robin	26.6±3.9	18.8 - 34.4	28.9±2.9	29.0±0.4	28.8±1.5	30.5±1.9	
(*Turdus migratorius*)	(10)		(6)	(4)	(3)	(5)	

[1]Activities expressed as mU/mg brain.

[2]Mean and standard deviation.

[3]Days after spraying.

[4]*Empidonax* spp. were primarily dusky flycatchers (*Empidonax oberholseri*).

SPRAY DROPLET IMPACTION ON CONIFEROUS FOLIAGE GALLATIN AND BEAVERHEAD NATIONAL FORESTS, MONTANA 1975

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This paper reports work involving chemical insecticides. It does not imply that uses discussed here are registered. All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended. Mention of commercial products is for convenience only and does not imply endorsement by USDA. A version of this paper under the same title and authorship was prepared for presentation to the 1977 Annual Meeting of American Society of Agricultural Engineering, Raleigh, North Carolina, June 26-29, 1977.

ABSTRACT

Insecticide drops were counted and sized on coniferous foliage following application of a microbial and two chemical insecticides to forested areas in Montana for control of western spruce budworm, *Choristoneura occidentalis* Free. The study was conducted in conjunction with two pilot control projects conducted in Montana by the U.S. Forest Service during July 1975. Majority (86 to 94%) of drops observed on coniferous foliage was $<$ 61 µm diameter.

INTRODUCTION

Aerial spray projects provide excellent opportunities for studies under actual field conditions to investigate methods of improving application of pesticides. Results of studies by investigators such as Himel and Moore (1967) and Barry et al. (1977) have shown by the use of fluorescent tracer particles that a high percentage of particles impacting on forest defoliators and coniferous foliage is $\leq$ 50 µm diameter. Most sprays applied to western forests for insect control have volume median diameters (vmd) in the range of 200 to 350 µm. Therefore, most of the volume is in drops larger than 50 µm diameter droplets which have been observed on coniferous foliage and insects by the referenced researchers. This indicates that aerial application of pesticides directed at insect defoliators and coniferous foliage is an extremely wasteful process. For sprays generated by conventional spray systems with vmd's in the 200 to 350 µm range, approximately 1.0% of the volume, disregarding mass loss due to evaporation, is represented in droplets with diameters $\leq$ 50 µm. If these droplet distribution and droplet impaction data are typical of forest spray operations, it becomes obvious that only a fraction of a percent of spray volume has a chance of impacting and deposition on the intended targets.

To improve the efficiency of spraying pesticides both by increasing target contact and by reducing total volume sprayed, it seems reasonable to generate droplets which have a higher probability of impacting on the target, assuming that the smaller drops are effective in causing mortality. It is generally known that one 400 µm droplet contains a volume equal to that of 8,000 droplets 20 µm in diameter as the relationship is a cube function of the diameter. One gallon of liquid distributed on a horizontal surface and consisting entirely of 20 µm droplets would yield a concentration of 22,200 drops per square centimeter and only 2.8 drops per square centimeters of 400 µm droplets. Therefore, there is a very low probability of a 400-μm droplet coming into contact with an insect or coniferous needle due to the relatively low volume application rates, generally in the range of 9.35 liters/hectare used in forests.

One approach in improving efficiency of spraying, therefore, is to determine droplet sizes which are actually impacting and depositing on the target and to increase the availability of these sizes to the target. Once this and the rate of droplet evaporation are determined, the next step would be to design and develop spray systems which are capable of generating sprays of a droplet range which have a higher probability of impacting on the intended target and eliminate those which have a low probability of impaction.

OBJECTIVE

The objective of this evaluation was to determine the size of *Bacillus thuringiensis* (B.t.)1/, trichlorfon 2/, and carbaryl3/ droplets observed on coniferous foliage.

This study was conducted in conjunction with two pilot control projects designed to evaluate efficacy of a microbial insecticide, B.t., and two chemicals, trichlorfon and carbaryl, against spruce budworm, *Choristoneura occidentalis* Free. The projects were conducted by the Northern Region, U.S. Forest Service, during July 1975 in the Beaverhead and Gallatin National Forests.

MATERIALS AND METHODS

Pesticides were applied to blocks, about 405 hectares in size, with a Bell 205 helicopter equipped with conventional spray booms and Spraying System Co. T-Jet flat fan 80 series nozzles. Application rate was 18.70 liters per hectare (2 gallons/acre) for B.t., 9.35 liters per hectare (1 gallon per acre) for trichlorfon, and 4.675 liters per hectare (1/2 gallon/acre) for carbaryl.

B.t. was mixed at the rate of 0.436 kg of B.t. in 7.75 liters of water. Carbaryl was mixed at a ratio of one to one with No. 2 fuel oil and 1.12 kg of trichlorfon was added to sufficient Panasol AN3 to make 9.35 liters. One half of 1% of Rhodamine B extra S dye was added to the B.t. tank mix and 2% by volume of Automate red dye was added to carbaryl and trichlorfon tank mixes. The dye tracers were essential to the detection and measurement of stains on foliage. All helicopter spraying was planned to be conducted at a ground speed of 144.81 km/hr (90 mph) and a release height above the

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1/ *Bacillus thuringiensis* Berliner (Dipel). Dipel is a product of Abbott Laboratories.

2/ Trichlorfon (Dylox). Dylox is a product of Chemagro Agricultural Division, Mobay Chemical Corporation.

3/ Carbaryl (Sevin). Sevin is a product of Union Carbide Chemical Co.

forest of 15.24 meters. B.t. was applied on blocks referred to as Smith and Doe, carbaryl on Block 8, and trichlorfon on Block 4. Spraying was completed by 1000 hours each morning to minimize loss of spray due to evaporation, drift, and thermal uplifting.

Twig samples, 2 inches in length, were obtained from Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) and Engelmann spruce *Picea engelmannii* Parry) trees distributed throughout the spray block. Samples were collected several hours after spraying from the periphery of the tree 1.8 meters above ground.

Care was taken to insure that the sample foliage was not touched to prevent smearing. Each sample was placed in a glass tube, labeled, and kept in cold storage until examined and assessed.

Assessment consisted of selecting 10 needles at random from each twig sample. The 10 needles consisted of both current and previous year's growth. Both upper and lower needle surfaces were examined under a binocular dissecting microscope at 25x magnification using artificial lighting. All stains observed were counted and noted relative to position on the needle (upper or lower surface). A measurable stain was defined as a stain whose longest axis did not exceed, by a factor of 2, its shortest axis. For stains which were not spherical the stain diameter was determined by averaging length of the long axis and short axis. Stain diameters were measured to the nearest 10 µm and corrected to drop diameter.

Droplets will spread after impacting upon a surface. Drop or aerodynamic drop are terms used to describe both airborne drops and drops which have been converted for spreading on an impacting media such as deposit cards or foliage. Stains are defined as drops which have spread on an impacting media, coniferous foliage in the case of this study. Stain measurements were converted to drop diameters simply by applying a correction factor or spread factor. The amount of spreading is dependent upon factors such as physical properties of the collecting surface and the tank mix. Spread factors were determined for each tank mix.

Meteorological conditions were monitored in an opening within each spray block during conduct of spraying. Measurements included temperature, relative humidity, and wind speed. Temperature was measured near the surface and above the canopy. Meteorological data are presented in Table 1.

The volume median diameter (vmd) which also was determined by assessment of stains on Printflex cards was 350 µm for B.t., 279 µm for carbaryl, and 288 µm for trichlorfon.

RESULTS

The majority, 86 to 94%, of the aerodynamic drops deposited on needles were $\leq$61 µm in diameter and 50% or more of the drops were $\leq$21 µm diameter (Tables 2 and 3).

These results are significant in view of the fact that the droplet distribution of the spray for droplets 70 µm were as follows: B.t. 32%, carbaryl 30%, and trichlorfon 30%.

Table 1.--Meteorological conditions during conduct of spraying, USDA Forest Service, Pilot Project, Montana, 1975.

Spray block	Wind speed range (m/sec.)		Wind speed range above canopy (m/sec.)	Temperature range level 2-m (°C)	Stability 6-m to 61-m	Relative humidity range (%)
	Open	Forest				
Smith	0.22 to 2.10	0.09 to 0.58	0.04 to 2.95	9-18	Inversion	70-96
Doe	.18 to 2.46	.31 to 1.60	.09 to 3.35	8-13	Neutral	86-93
8	.13 to 1.56	.31 to 1.56	.04 to 2.15	8-16	Inversion	71-91
4	.36 to 2.82	.27 to 2.63	.09 to 3.62	7-12	Neutral	80-89

Table 2.--Number of drops observed on needles by size categories for spray blocks Smith, Doe, 8, and 4, USDA Forest Service, Pilot Project, Montana, 1975

Size category	Spray blocks							
	Smith		Doe		8		4	
	No. drops	Cum. %	No. drops	Cum. %	No. drops	Cum. %	No. drops	Cum. %
≤ 4	96	12.15	108	15.86	137	11.40	353	18.85
> 4-10	226	40.76	239	50.96	236	31.03	323	36.10
> 10-15	172	62.53	139	71.37	106	39.85	200	46.78
> 15-21	43	67.97	28	75.48	139	51.41	228	58.95
> 21-31	114	82.40	90	88.70	254	72.54	338	77.00
> 31-41	31	86.32	10	90.17	76	78.86	116	83.19
> 41-61	45	92.02	24	93.69	88	86.18	57	86.23
> 61-81	27	95.44	25	97.36	73	92.25	108	92.00
> 81-121	16	97.47	7	98.39	45	95.99	87	96.64
>121-151	8	98.48	8	99.56	26	98.15	21	97.76
>151-200	9	99.62	1	99.71	17	99.56	24	99.04
>200	3	100.00	2	100.00	5	99.98	18	100.00
Total	790		681		1,202		1,873	

Table 3.--Summary of drop size distribution for spray blocks Smith, Doe, 8, and 4 by percent of drops on coniferous needles for drop size categories 4 to 21 μm and 4 to 61 μm, USDA Forest Service, Pilot Project, Montana, 1975.

Size category (um)	Spray blocks Smith	Doe	8	4
< 4 to 21	68	75	51	59
< 4 to 61	92	94	86	86

Table 4.--Number of spray droplet stains for spray blocks Smith, Doe, 8, and 4 by observation category, USDA Forest Service, Pilot Project, Montana, 1975

Observation	Spray blocks Smith	Doe	8	4	Total
Measurable stain	790	681	1,202	1,873	4,546
Stain observed					
Upper surface	266	181	463	854	1,764
Lower surface	607	291	945	1,213	3,056
Unmeasurable stain	119	61	208	257	645
Needles examined	307	400	660	910	2,340

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Himel, C. M., and A. D. Moore. 1967. Spruce budworm mortality as a function of aerial spray droplet size. Science, Vol. 156: 1250-1.

ACKNOWLEDGMENTS

We would like to acknowledge the following persons of U.S. Forest Service Northern Region who supported this project by providing counters, laboratory equipment, and space: Scott Tunnock, Hubert Meyer, Tom Flavell, Bill Ciesla, and Carma Gilligan.

CANOPY PENETRATION STUDY

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INTRODUCTION

The amount of aerial spray, both in terms of mass and drops, which penetrate the forest canopy and is deposited on the forest floor is related to insect mortality, droplet spectrum of the spray, atmospheric conditions, spray geometry (release height, aircraft type, swath width, etc.), and other unknown or undefined factors.

Pilot projects provide an opportunity to study spray behavior with the immediate purpose of improving spray projects of similar nature. The field approach to studying spray behavior has provided opportunities for improving application techniques on subsequent projects of a similar nature at relatively low costs. Canopy penetration studies are suited to and compatible with pilot projects.

METHODS

The objective of this study was to investigate penetration of spray material through the canopy. This was accomplished on each spray block by positioning deposit cards under the sample trees. These cards collect the droplets which pass through the canopy and adjacent trees, having avoided interception by the foliage.

Approximately 50 deposition cards were placed in open areas within the spray block. Ideally, the recovery on open cards represents the amount of material presented to the top of the canopy.

To each of 16 droplet size categories a ratio of mass under the trees to mass in open areas was computed and plotted on log paper by drop size category (Figures 1-5). This ratio represents the proportion of spray penetrating to the ground. A ratio of 1 would indicate that no drops in that size were intercepted by the trees. A ratio of 0.5 would indicate that half of the droplets were intercepted. In practice, the ratios are observed to occasionally exceed 1. This is probably due to a partial miss of the open cards by the spray aircraft. Even in this case the shape of the curve indicates the relative collection efficiency of various size droplets.

RESULTS

Canopy penetration plots are shown for each spray plot for which open card data was available.

The slope of the curve shows that a higher percentage of the smaller droplets penetrate through the canopy and deposit on the ground as compared to the larger drops. The practical application of this information becomes apparent. Where complete tree coverage of the spray is desired to accomplish this, a wide range of droplet size may be required, although not as wide a range as is usually encountered in forest spraying. More thorough study of these and other canopy penetration studies will provide insight into the optimum drop size range for effective coverage of various tree types and foliage densities.

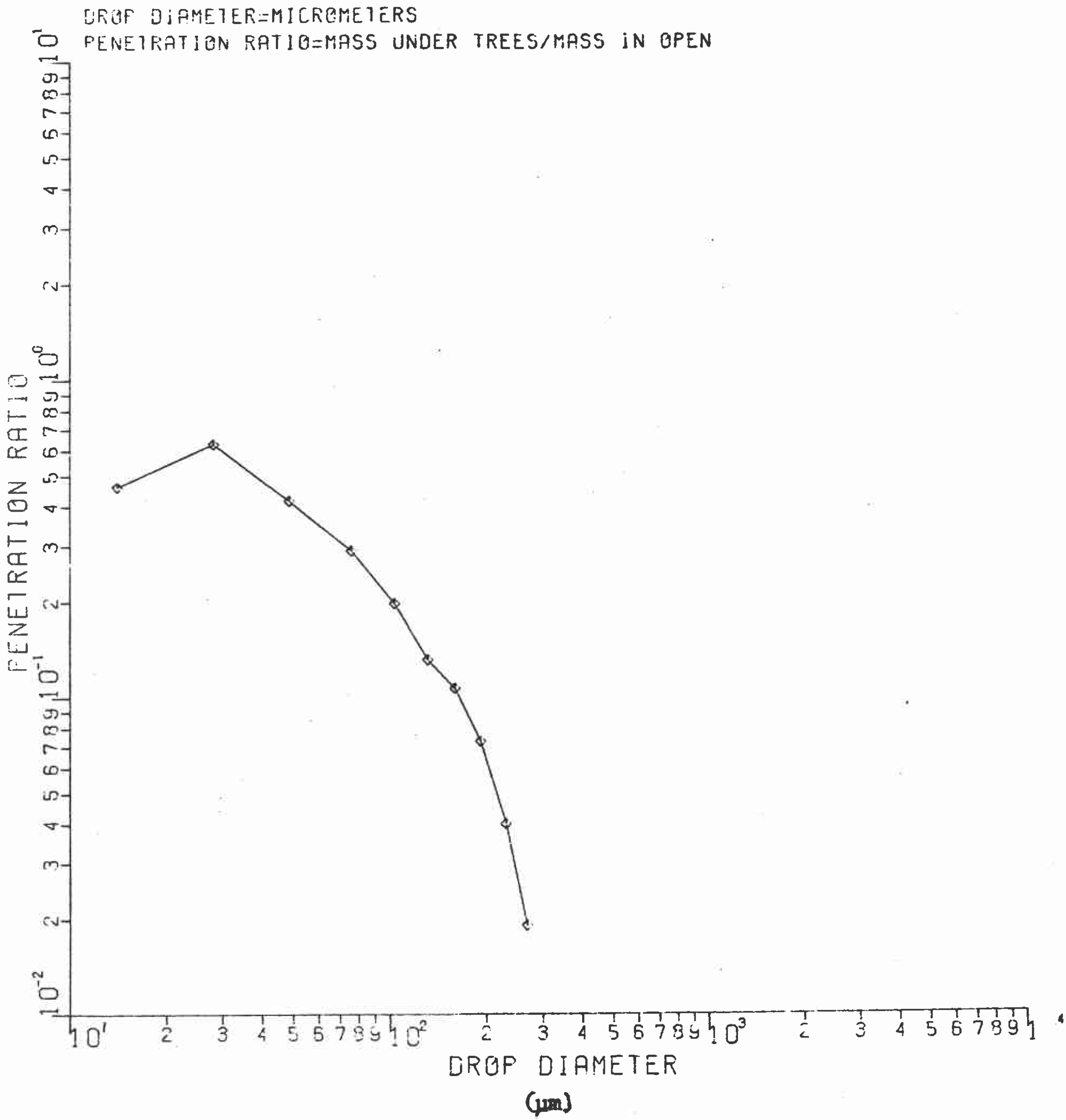


Figure 1.--Block 2, carbaryl aerial spray penetration through a Douglas-fir canopy, Beaverhead National Forest, Montana, 1975.

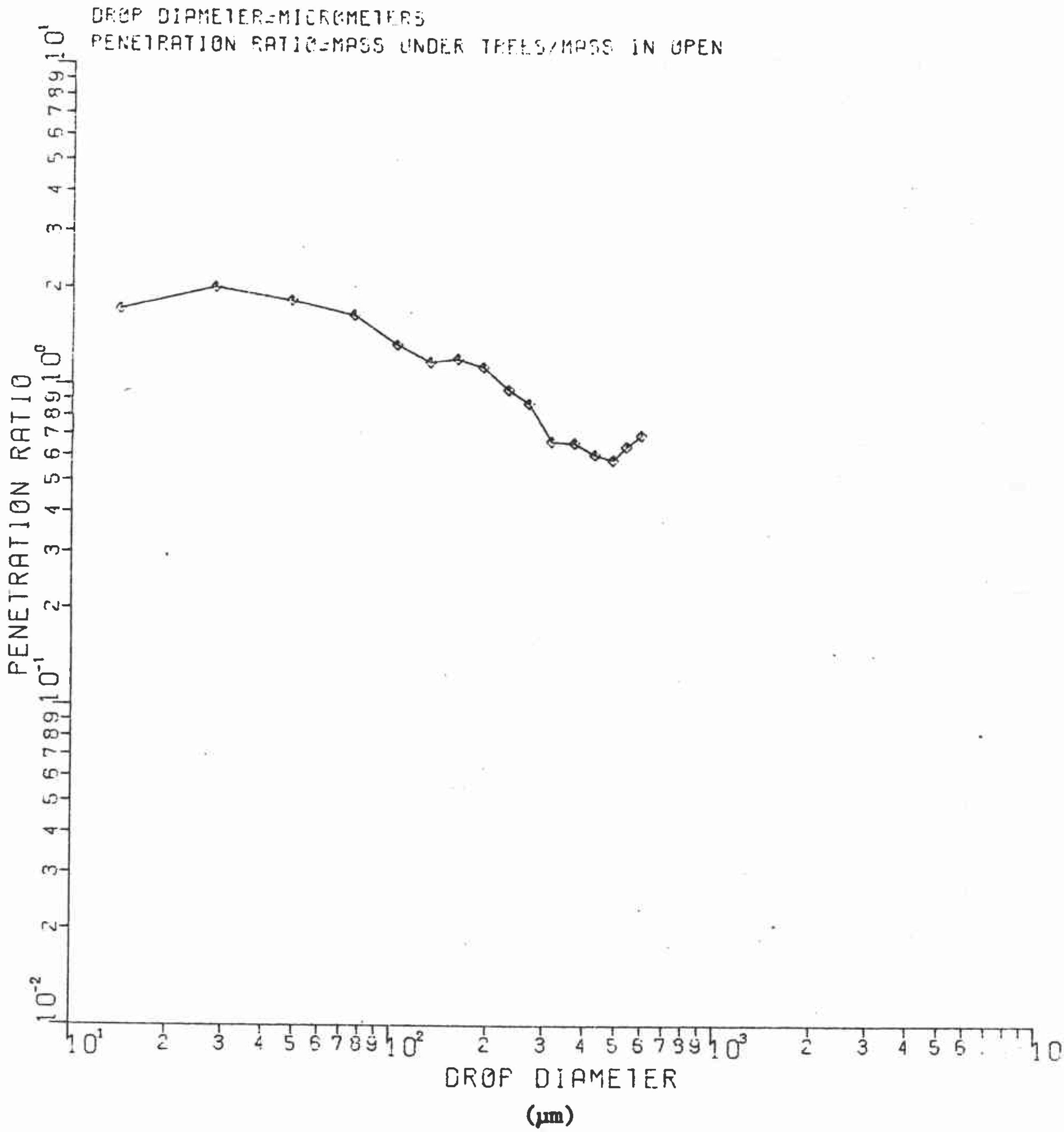


Figure 2.--Block 6, carbaryl aerial spray penetration through a Douglas-fir canopy, Beaverhead National Forest, Montana, 1975.

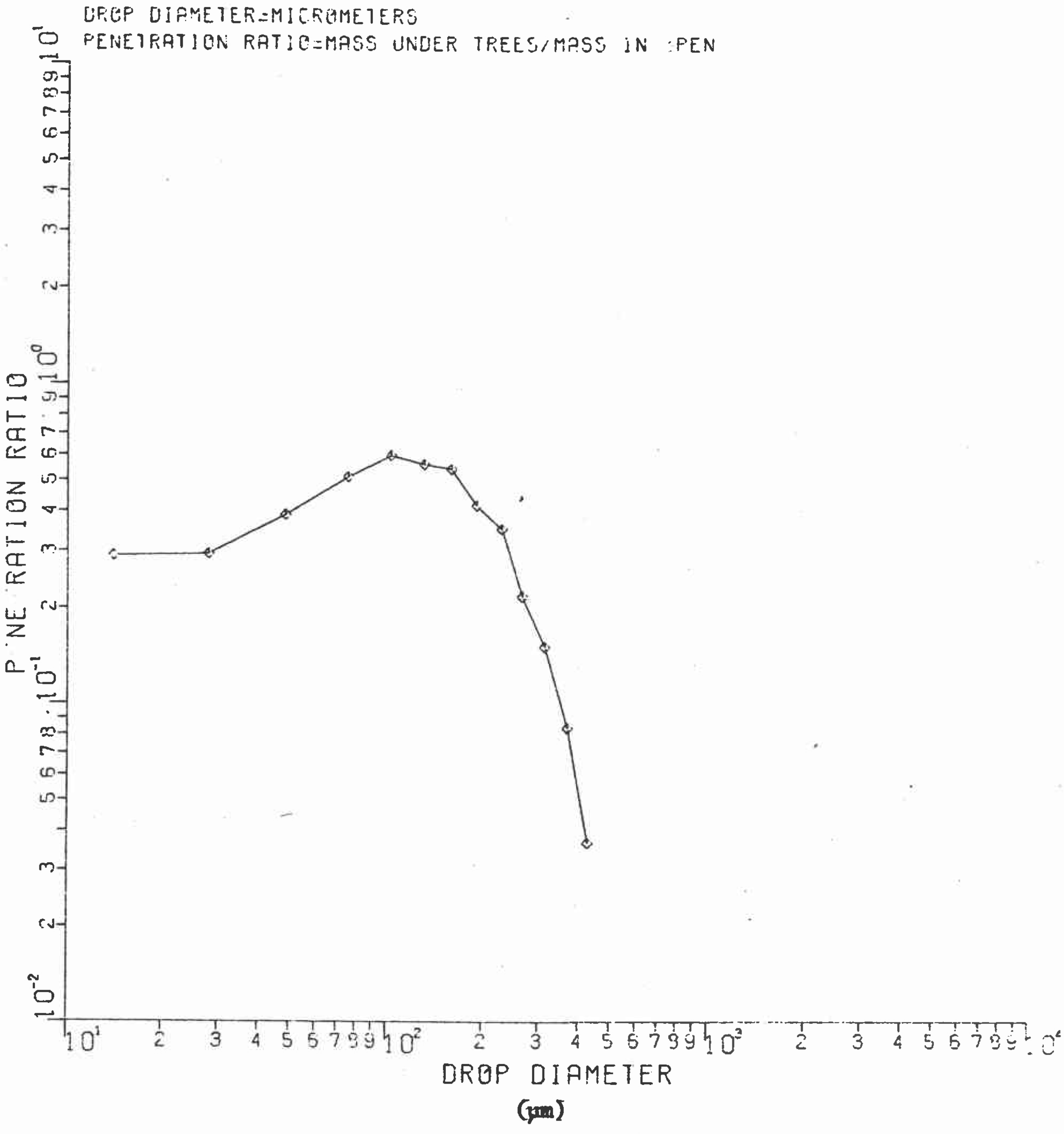
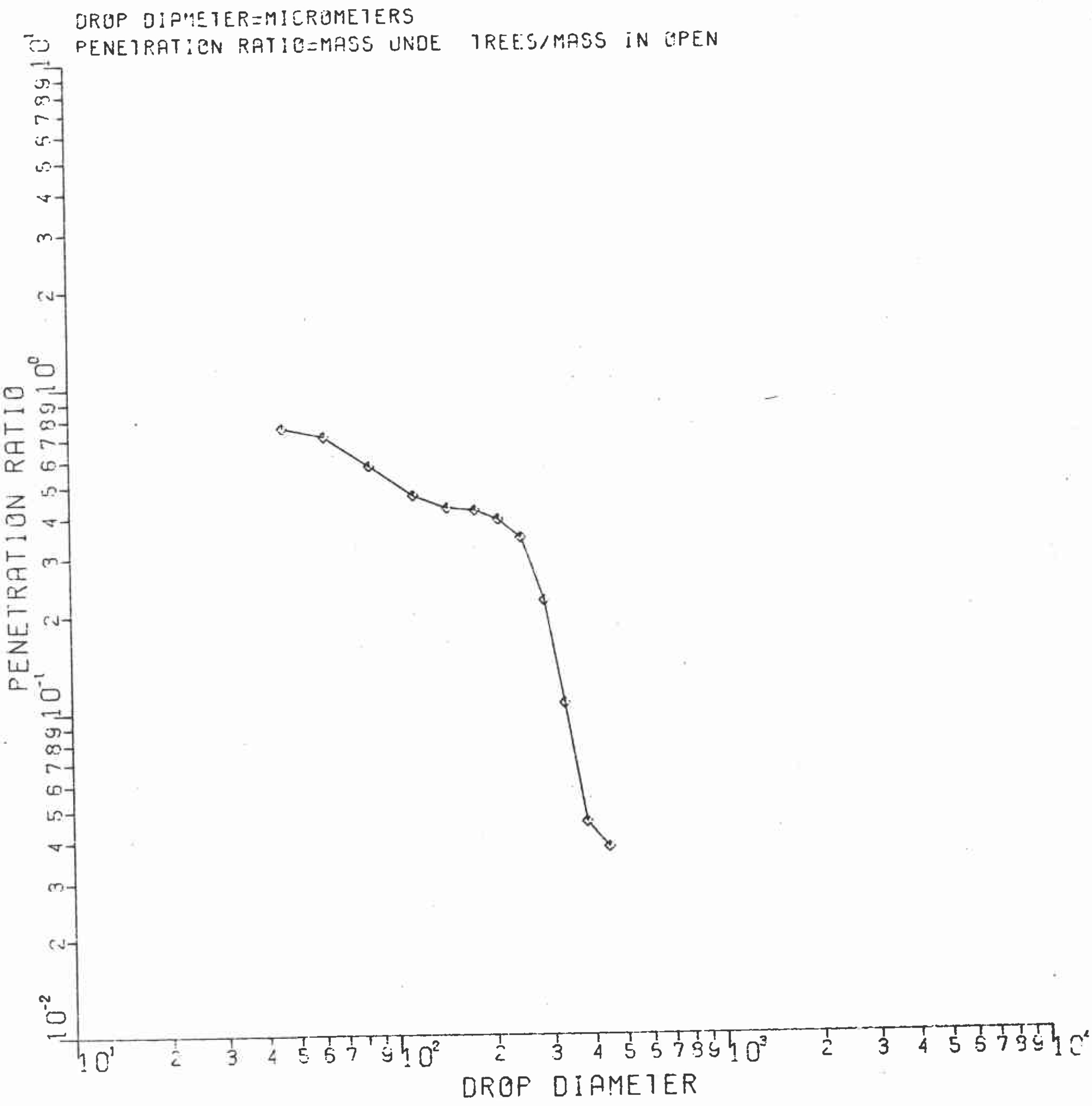


Figure 3.--Block 8, carbaryl aerial spray penetration through a Douglas-fir canopy, Beaverhead National Forest, Montana, 1975.



(µm)

Figure 4.--Block 4, trichlorfon aerial spray penetration through a Douglas-fir canopy, Beaverhead National Forest, Montana, 1975.

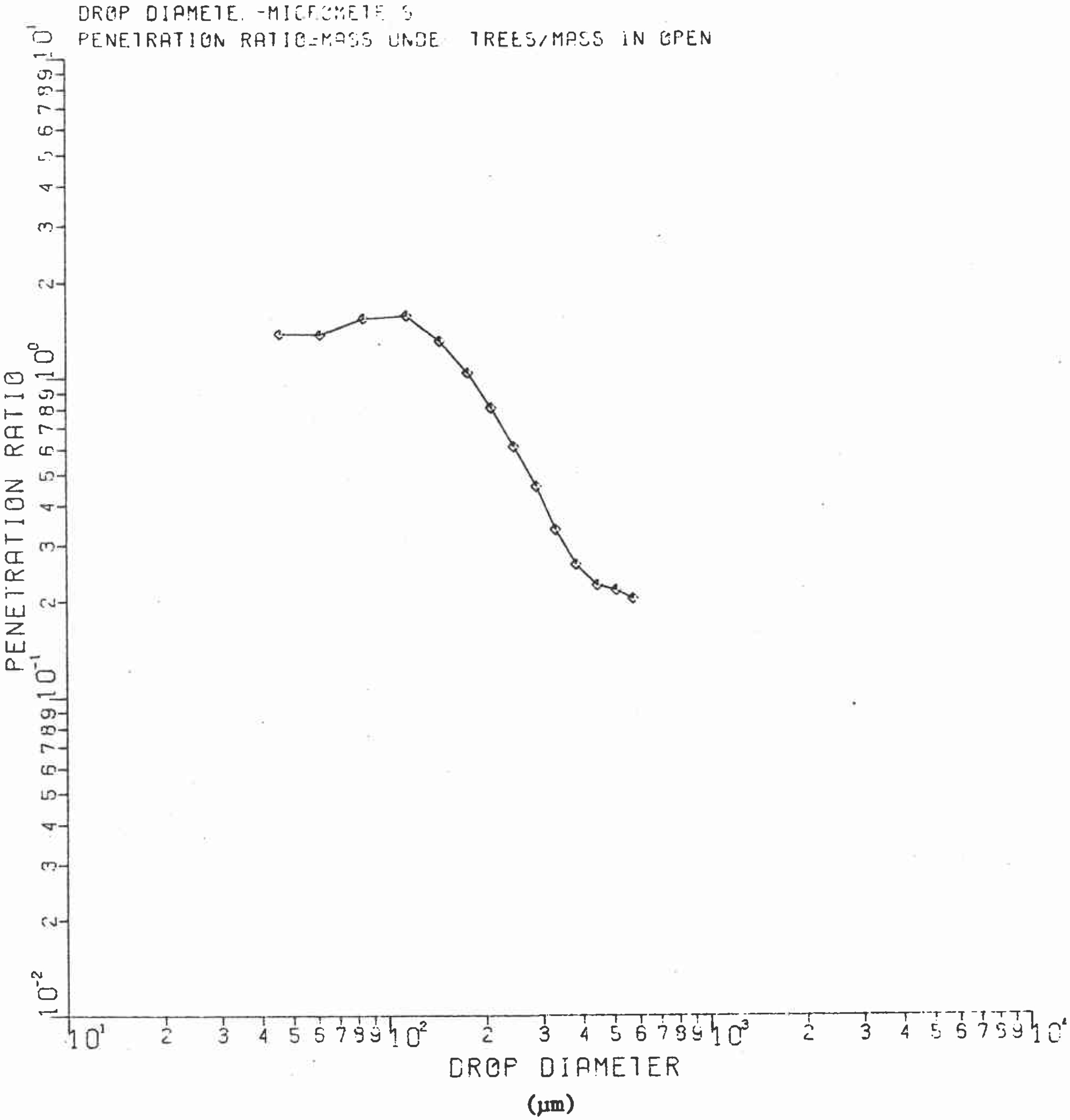


Figure 5.--Block 7, trichlorofon aerial spray penetration through a Douglas-fir canopy, Beaverhead National Forest, Montana, 1975.

USATECOM PROJECT NO. 5-CO-153-UFS-002
DPG DOCUMENT NO. DPG-DR-C630A
USFS MEDC PROJECT NO. 2425

METEOROLOGICAL DATA SUPPLEMENT

1975 SPRUCE BUDWORM PILOT TEST

GALLATIN AND BEAVERHEAD NATIONAL FORESTS

DATA REPORT

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SEPTEMBER 1975

U.S. ARMY DUGWAY PROVING GROUND
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U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE, REGION ONE
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VIII

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Spruce Budworm
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Sevin - 4 - oil
Bacillus thuringiensis
Forest Spraying

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This data report provides meteorological data collected during conducted of 12 pilot control tests in the Gallatin and Beaverhead National Forests during July 1975. The U.S. Army Dugway Proving Ground supported the U.S. Forest Service by providing meteorological personnel, instrumentation, and weather forecasts. These data are provided for use by all cognizant organizations having a need for meteorological data in analyzing test data.

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FOREWORD

Data presented in this test date supplement were obtained in support of a pilot control project conducted by the U.S. Department of Agriculture, Forest Service, Region 1 Center, Missoula, MT, as outlined in reference 1.

These data cover three pilot test trials in the Gallatin National Forest and six pilot test trials in the Beaverhead National Forest which were conducted during July 1975.

Meteorological personnel consisting of two professional meteorologists (civilian) and two meteorological specialists (military), were provided by U.S. Army Dugway Proving Ground, Dugway, UT.

This test was supported under Supplemental Agreement No. 3, dated April 1975, to Memorandum of Understanding between U.S. Army Materiel Command and U.S. Forest Service dated April 1973, (Reference 2).

This report may be used in part or in its entirety with the main project report as the customer may elect. There are no restrictions upon the use or publication of these data.

INTRODUCTION

The purpose of this data supplement is to provide all cognizant organizations with project meteorological data for their respective use and application. However, the user should be cautious in applying these data to specific problems. The meteorology was monitored only in a relatively small area of the spray plot which may or may not be representative of the entire plot. The terrain and forest type of each of the spray sites also should be taken into consideration when applying these data.

This report is organized into six sections. Each section contains similar data collected on each trial. As an example Section 4 contains the temperature profile data for all 12 trials while Section 5 contains ground temperature data for each trial.

These data will be used extensively to analyze the spray drop behavior, area coverage, mathematicla prediction model verification, spray drift and insect mortality.

The types of equipment used to obtain these data and the analyses of data will be discussed and illustrated in the main report of which this is a supplement.

SECTION 1. LOCATIONS OF SPRAY SITES

FIGURES 1 AND 2 ILLUSTRATE LOCATION OF SPRAY SITES IN THE GALLATIN AND BEAVERHEAD NATIONAL FORESTS.

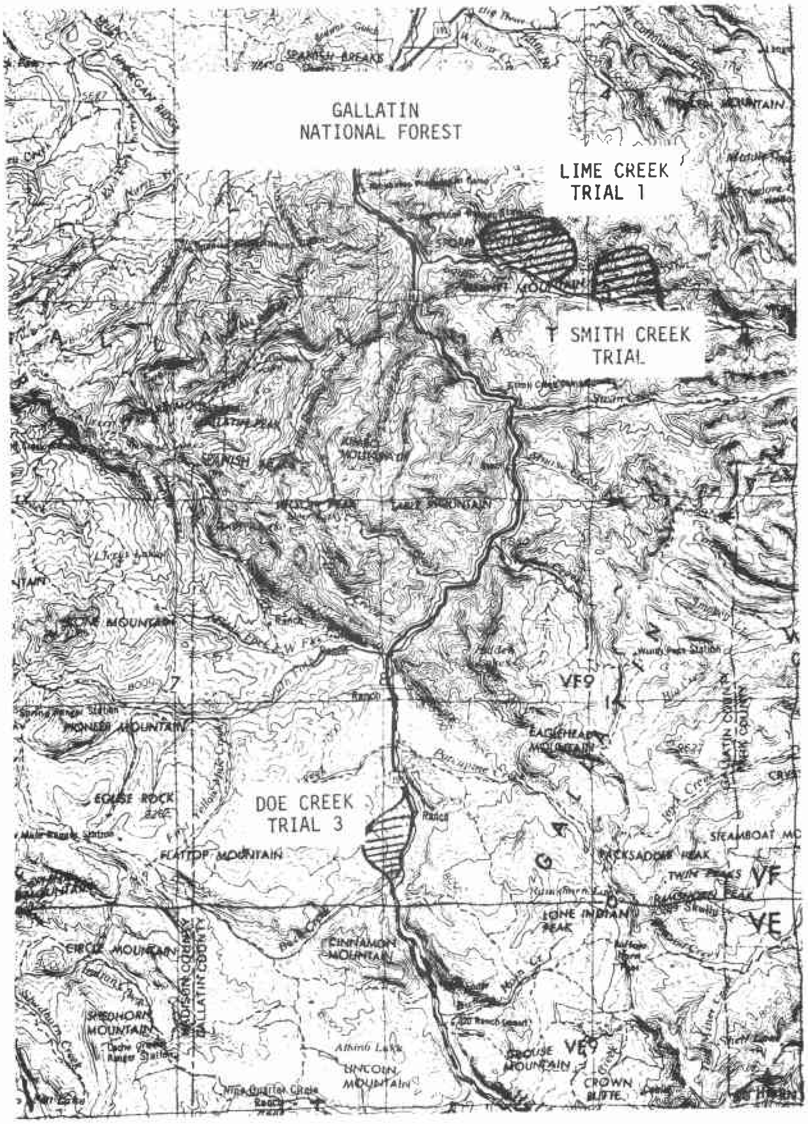


Figure 1 Spray Sites - Lime, Smith, and Doe, Gallatin National Forest.

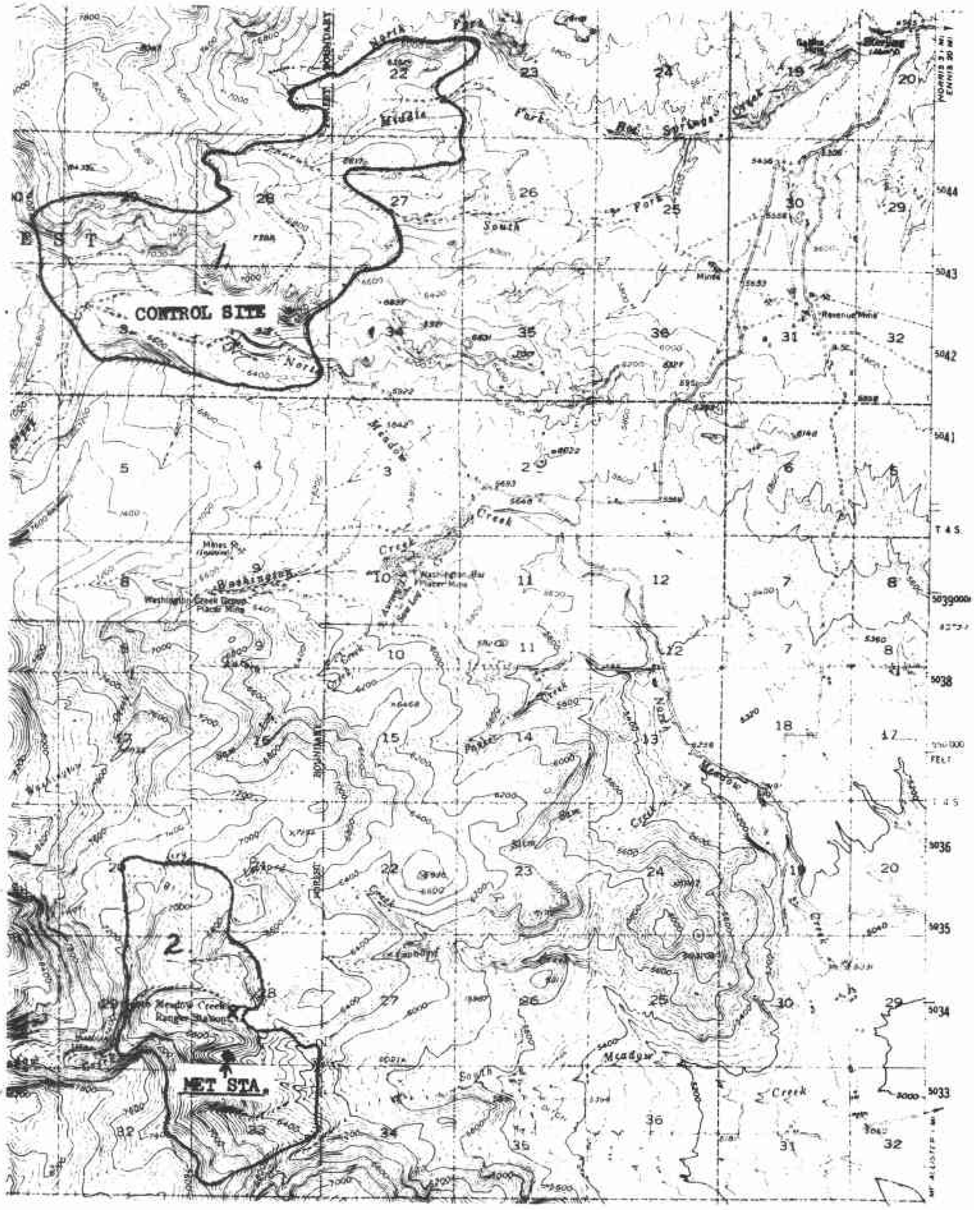


Figure 2. Control Site Number 1 and Spray Site Number 2, Beaverhead National Forest, Montana.

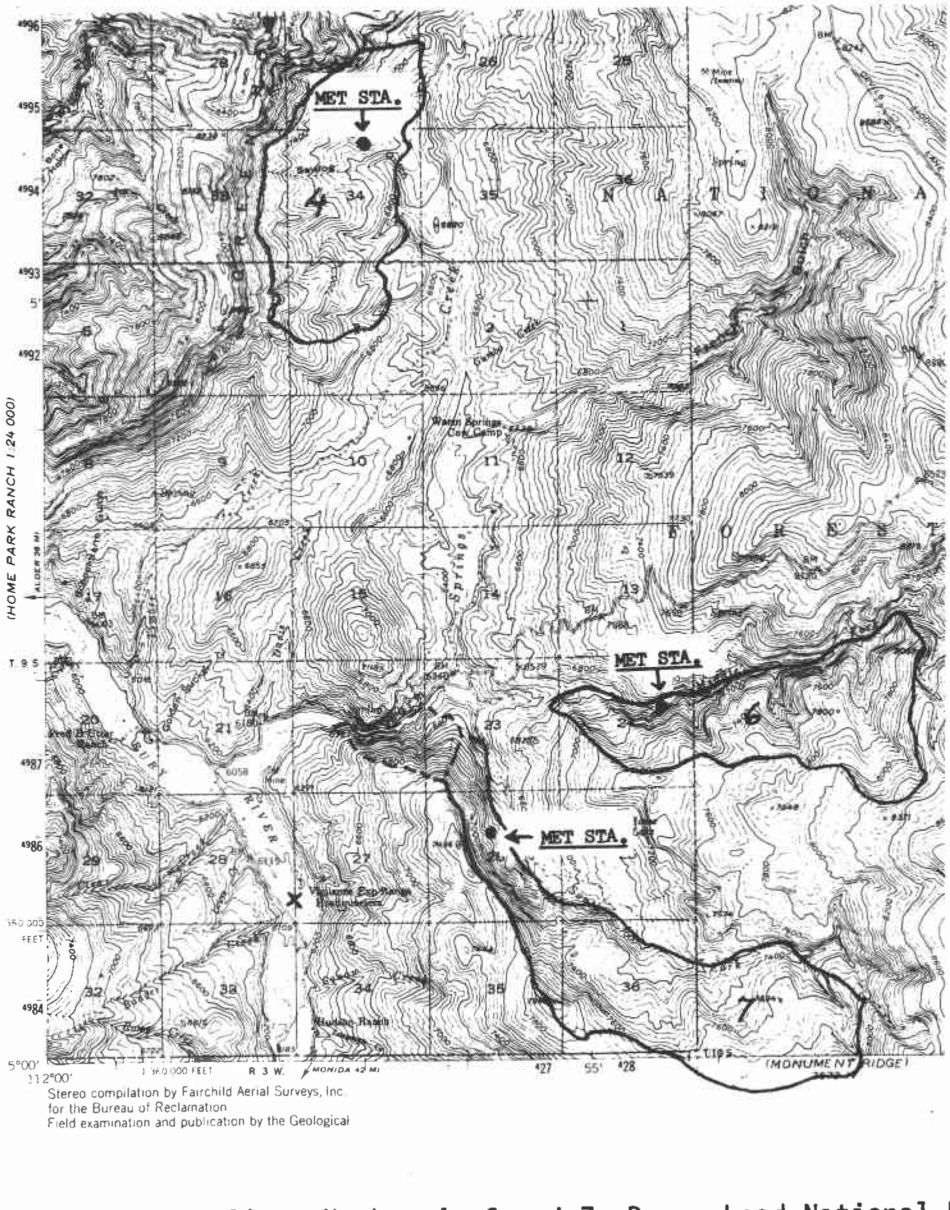


Figure 2a. Spray Sites Number 4, 6 and 7, Beaverhead National Forest, Montana.

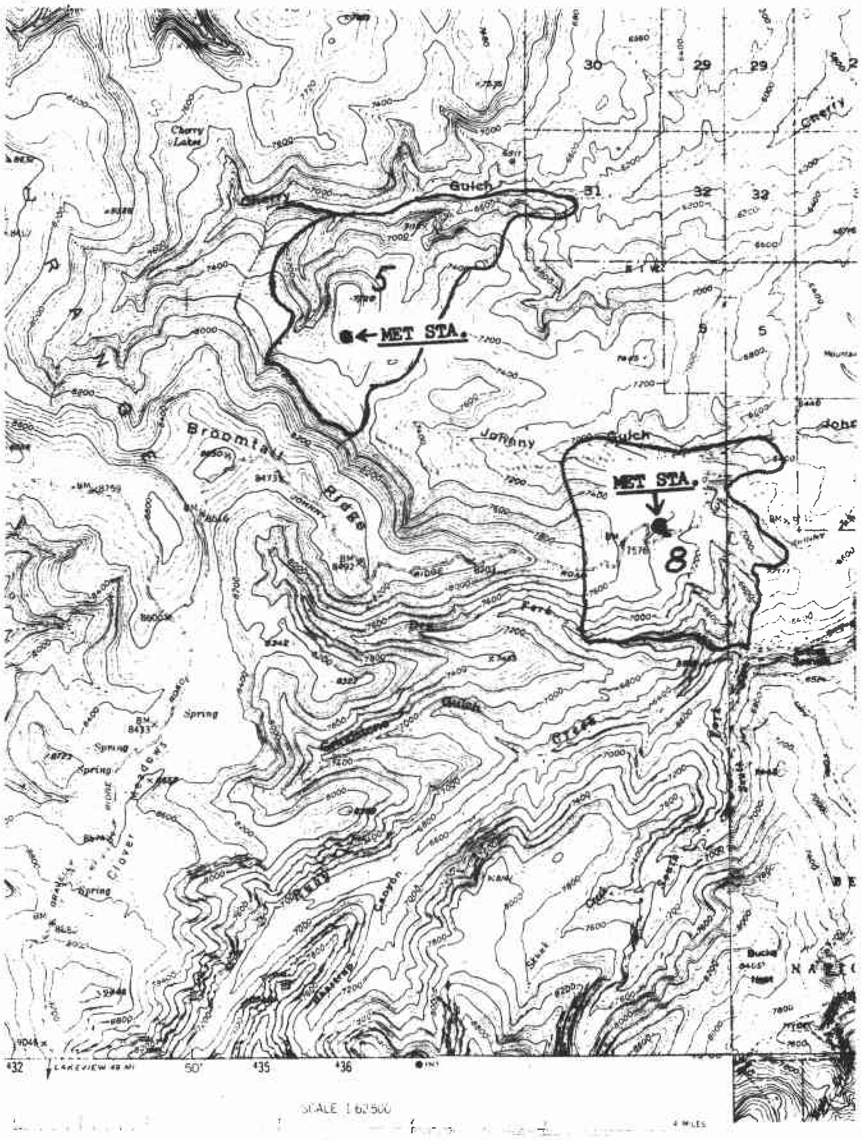


Figure 2b. Spray Sites Number 5 and 8. Beaverhead National Forest, Montana.

SECTION 2. SYNOPTIC SURFACE CHARTS

FIGURES 3 THROUGH 17 DEPICT SYNOPTIC SURFACE CHARTS WHICH WERE USED IN DAILY WEATHER BRIEFINGS IN SUPPORT OF SPRAY OPERATIONS IN THE GALLATIN AND BEAVERHEAD NATIONAL FORESTS, MONTANA. THE METEOROLOGISTS BEGAN TO MONITOR THE WEATHER STARTING ON 2 JULY AND TERMINATED 16 JULY 75. TARGET SPRAY DATES WERE ESTABLISHED BY THE PROJECT LEADER AND FORECASTS WERE DEVELOPED FOR THOSE SCHEDULED DAYS.

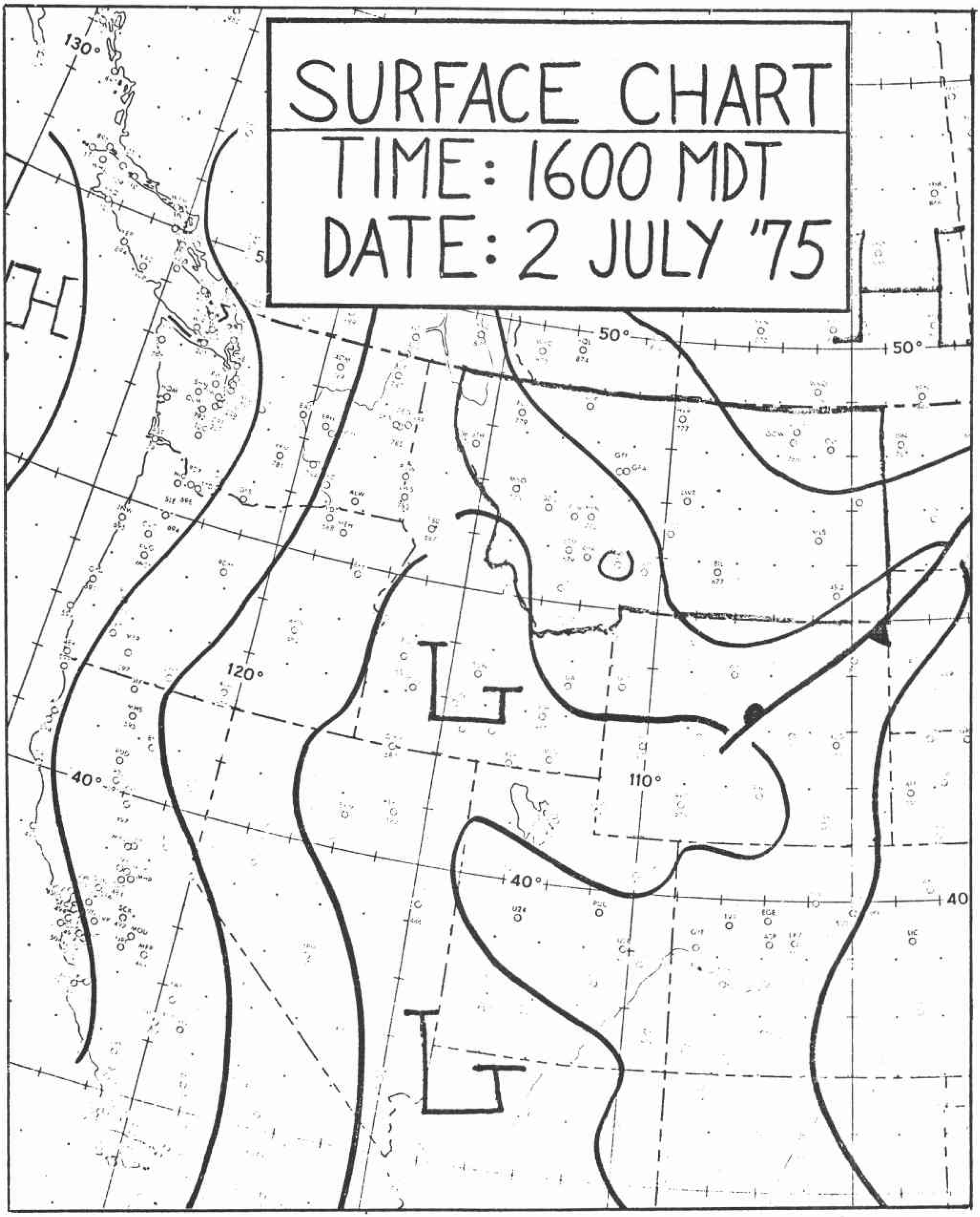
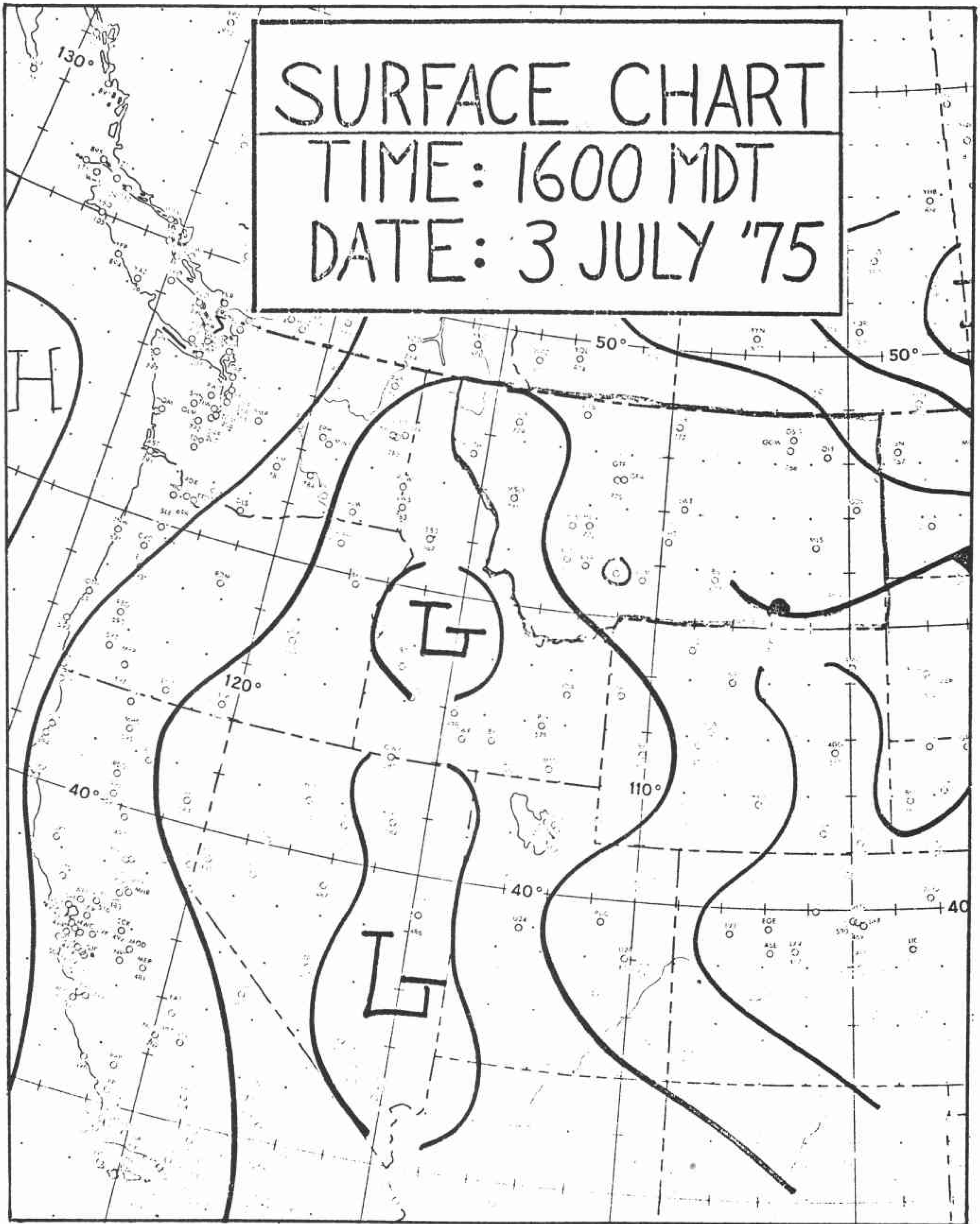


Figure 3. Synoptic Surface Chart Used in Briefing for Spray Operations conducted on 7 July 1975. Gallatin National Forest



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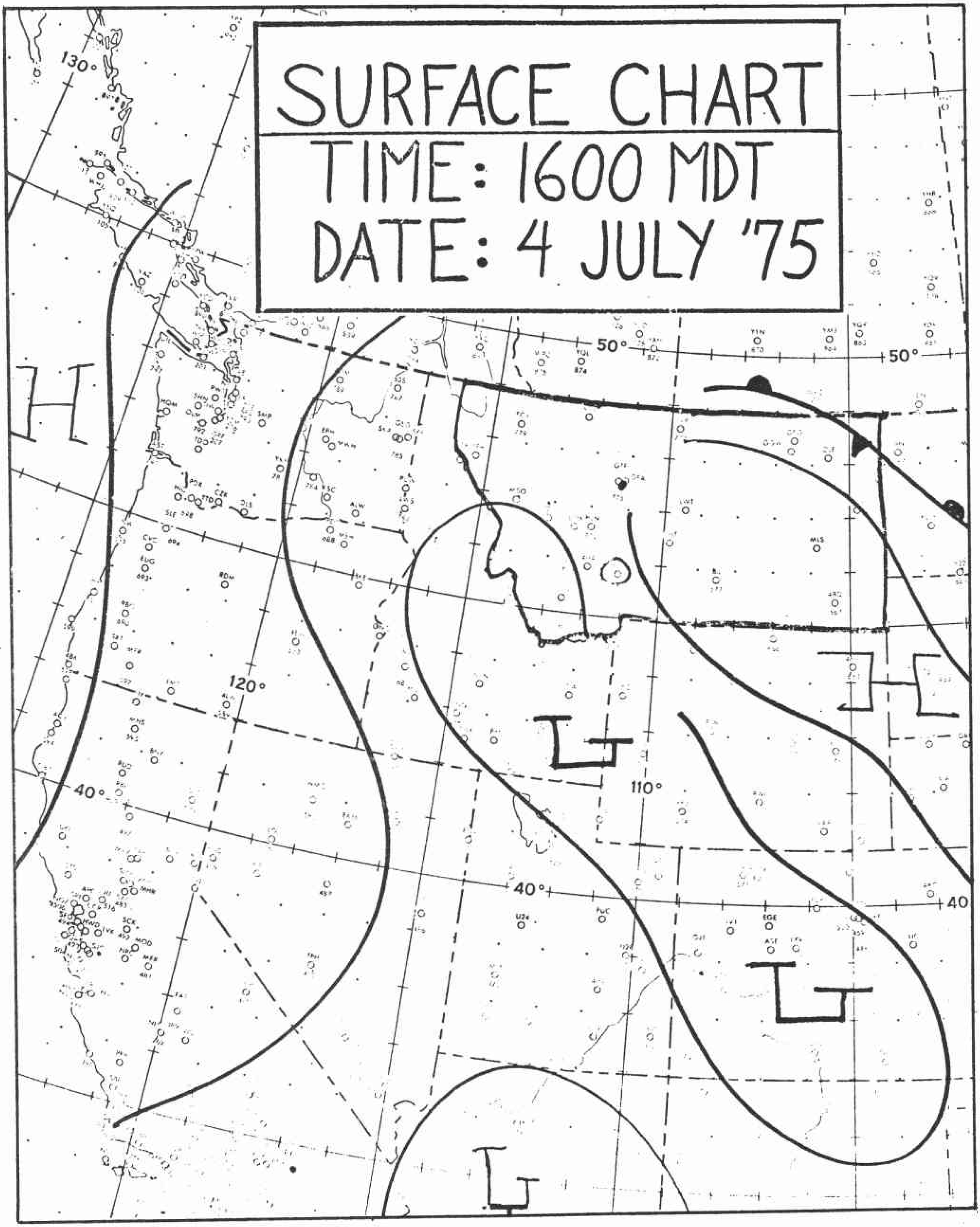

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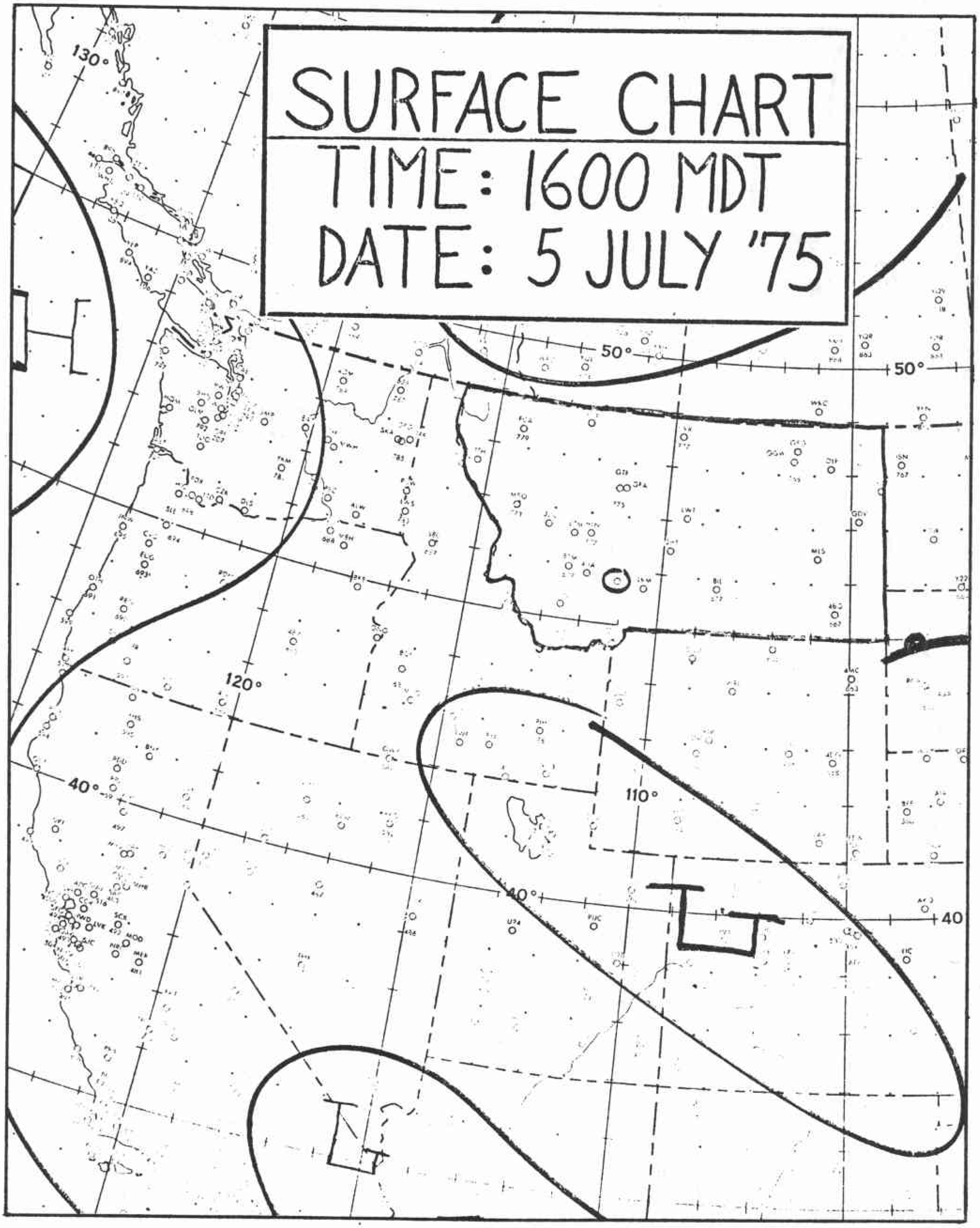

Figure 6. Synoptic Surface Chart Used in Briefing for Spray Operations conducted on 7 July 1975. Gallatin National Forest.

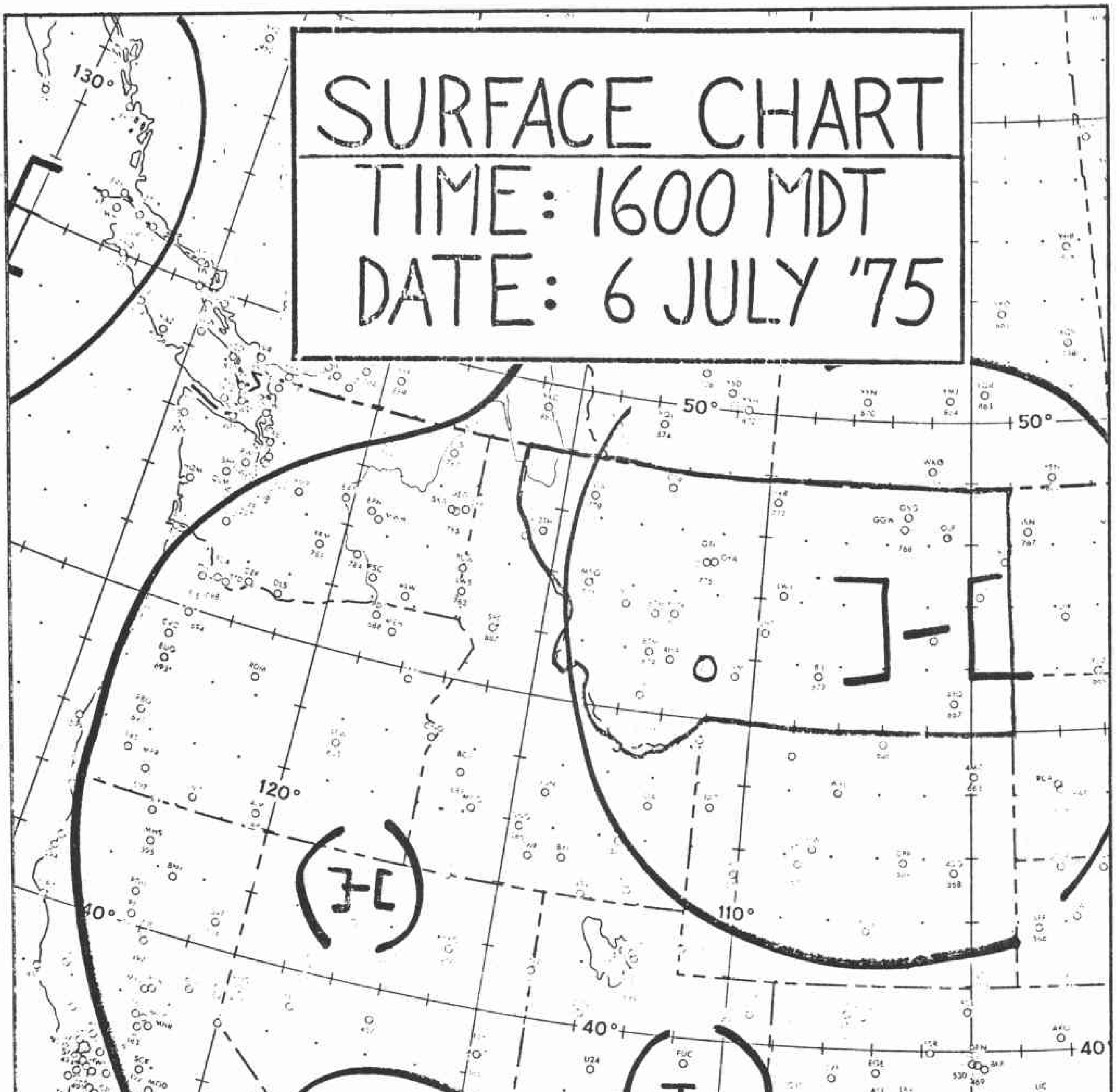

Figure 7. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 1 (Lime) conducted on 7 July 1975. Gallatin National **Forest.**

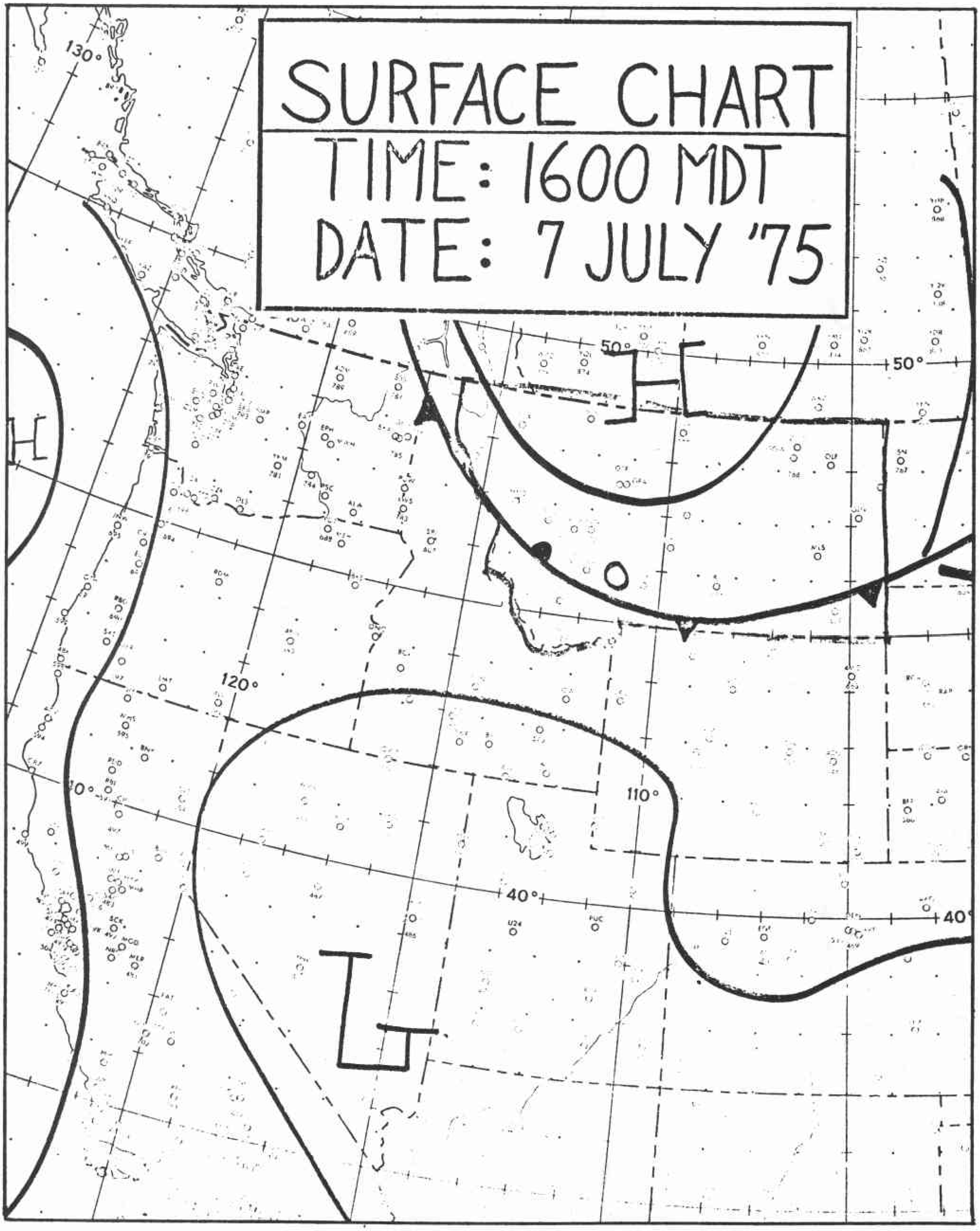

Figure 8. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 2 (Smith) conducted on 8 July 1975. Gallatin National **Forest.**

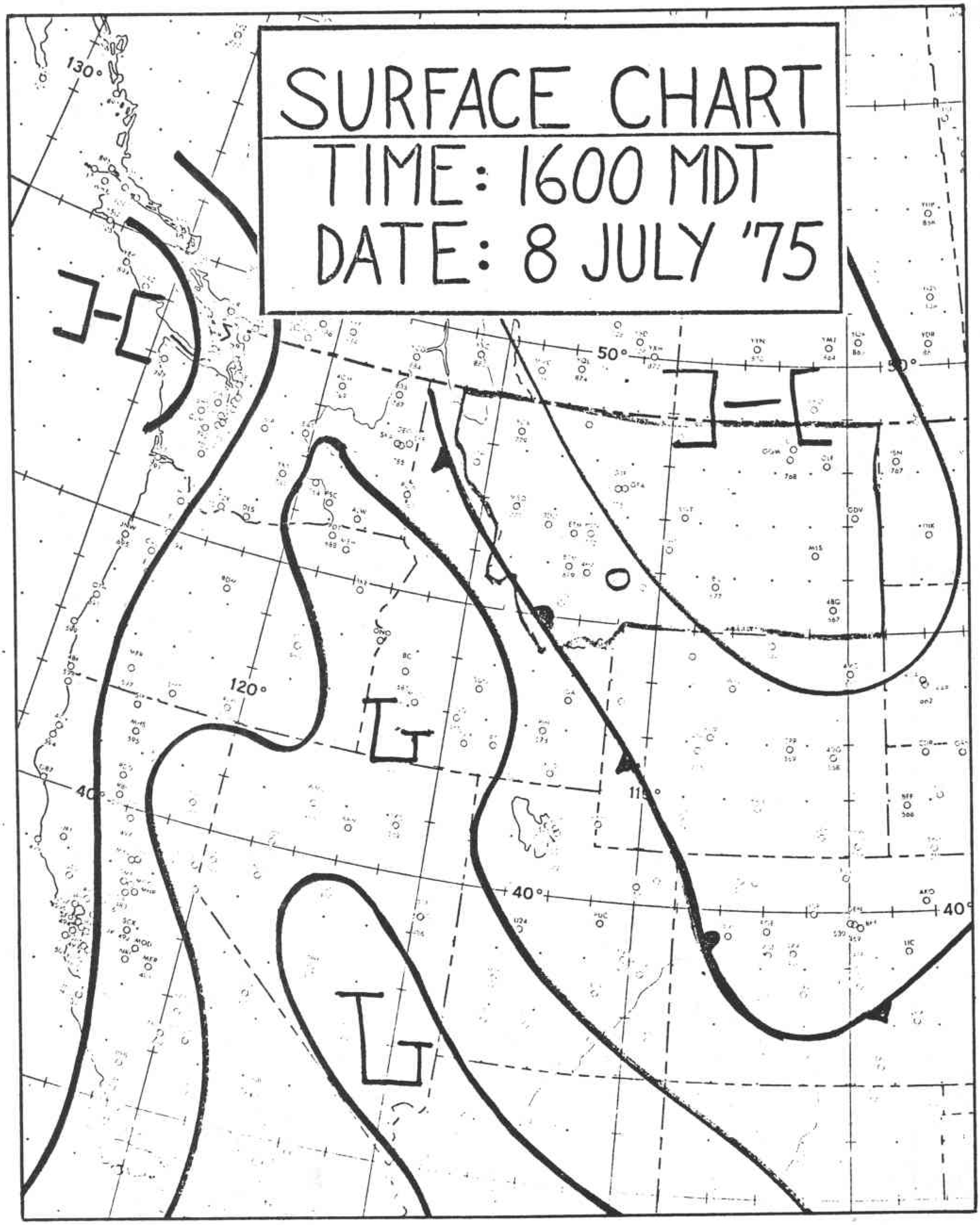

Figure 9. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 3 (Doe) conducted on 9 July 1975. Gallatin National **Forest.**

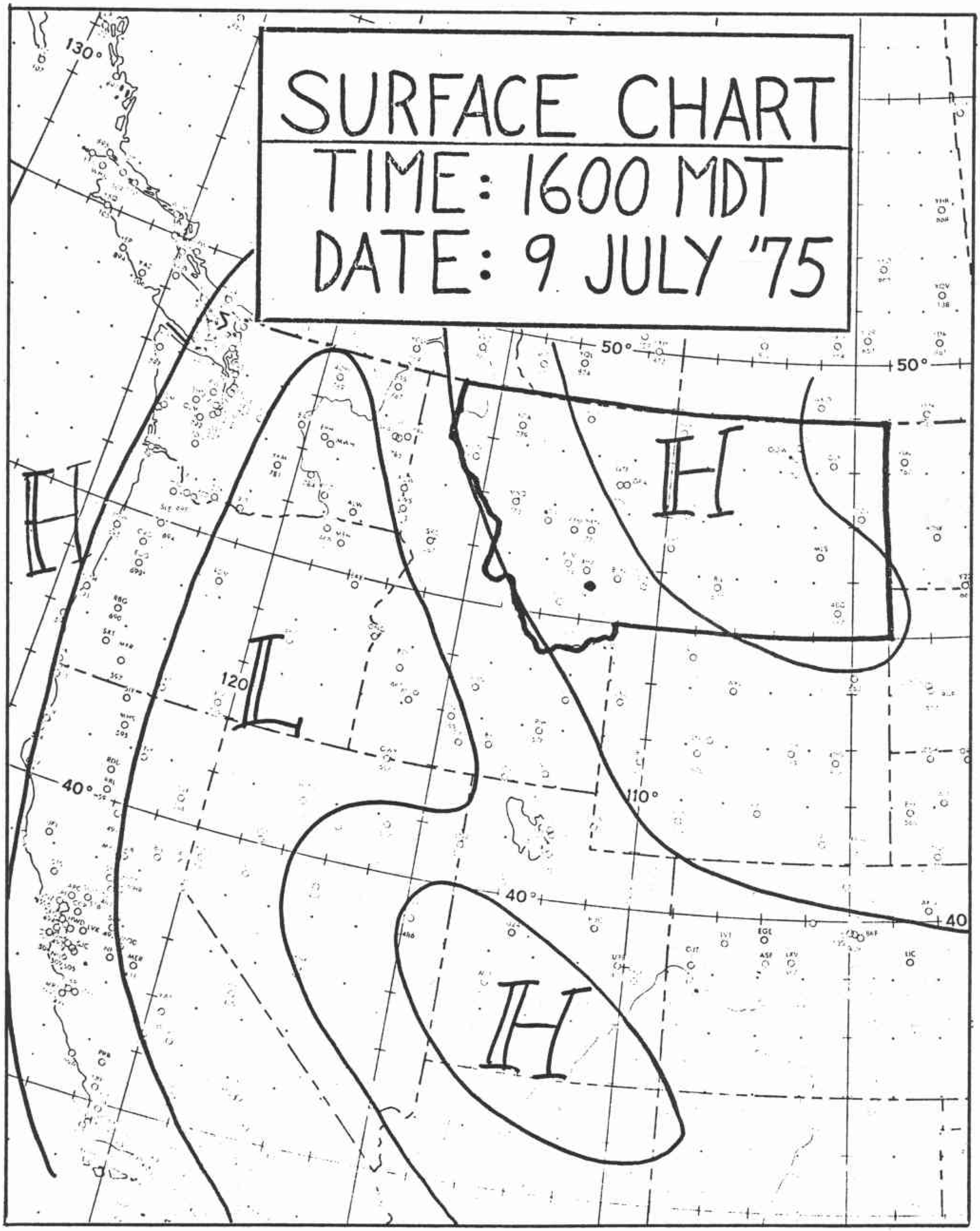

Figure 10. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 2 Scheduled for 10 July 1975. Beaverhead National Forest.

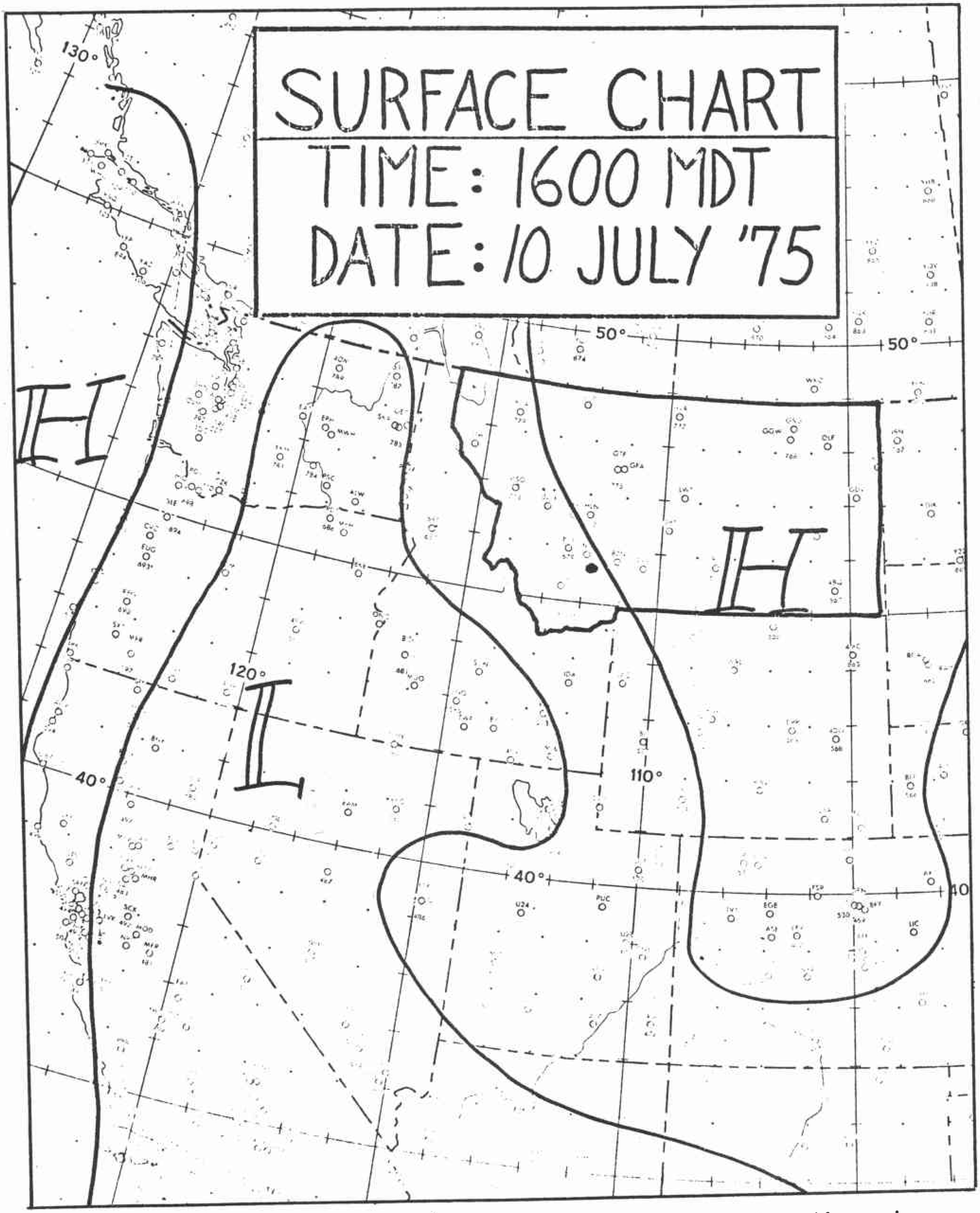

Figure 11. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 6 Scheduled for 11 July 1975. Beaverhead National Forest.

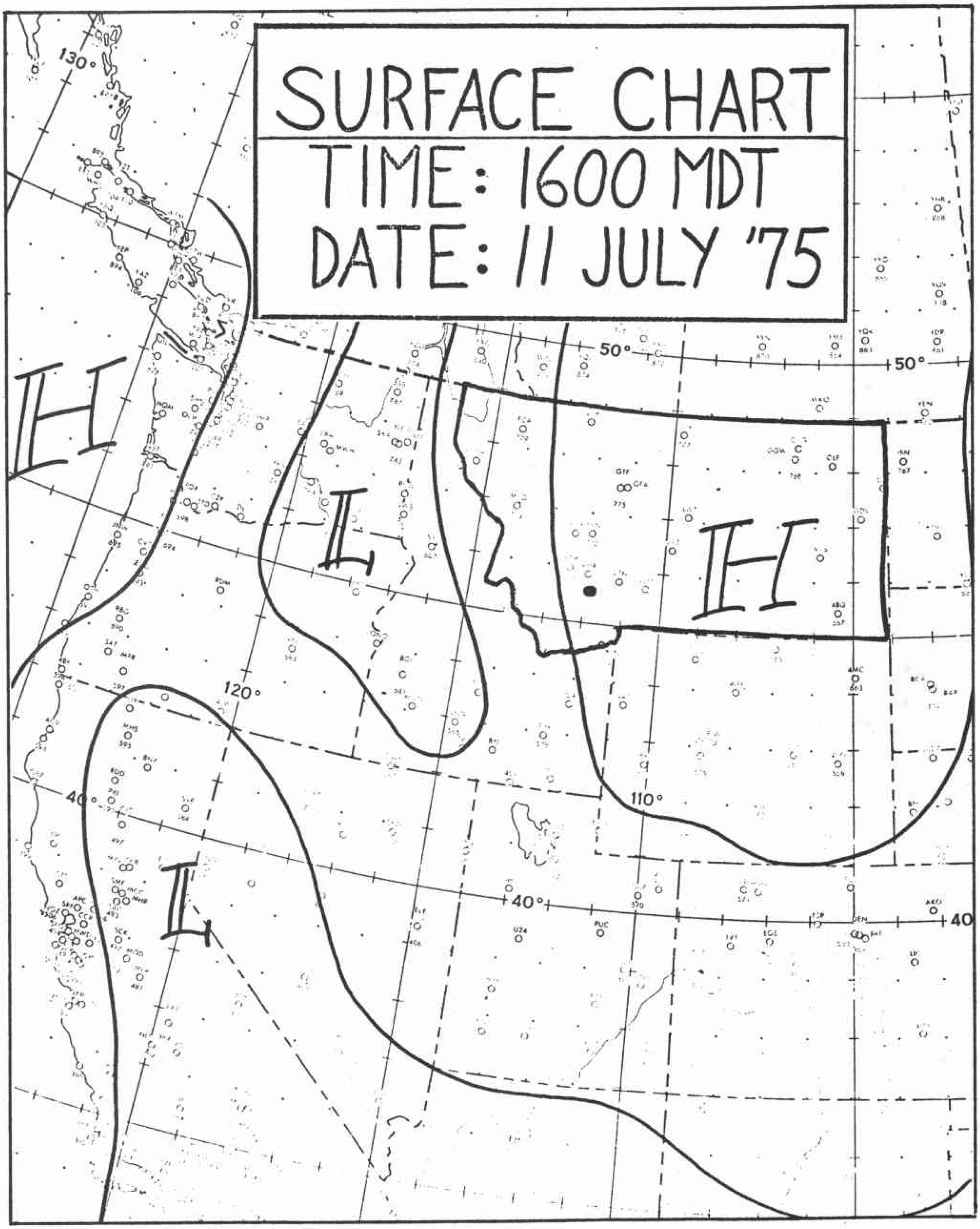

Figure 12. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 8 Scheduled for 12 July 1975. Beaverhead National Forest.

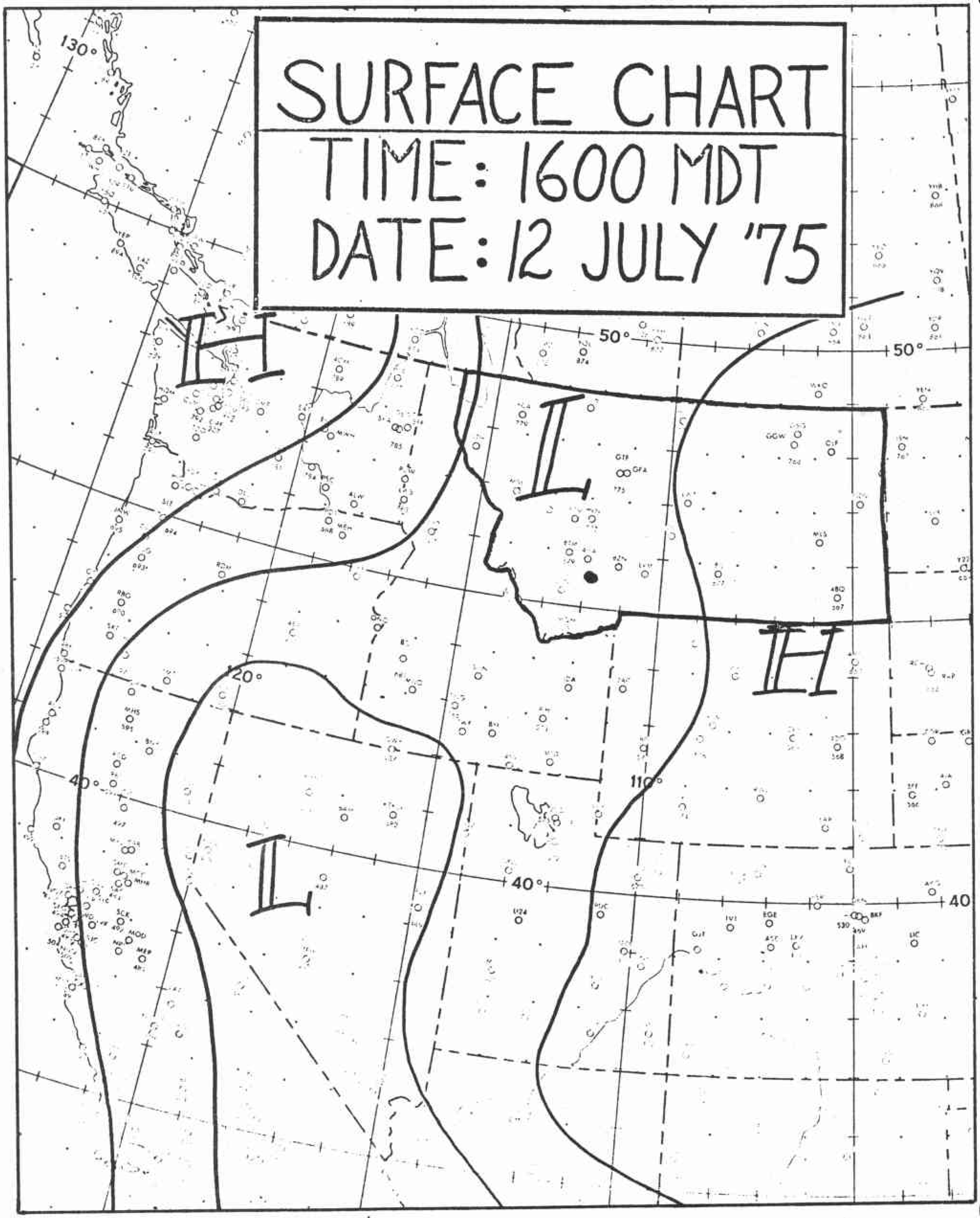

Figure 13. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 4 Scheduled for 13 July 1975 (Spraying Postponed for Weather). Beaverhead National Forest.

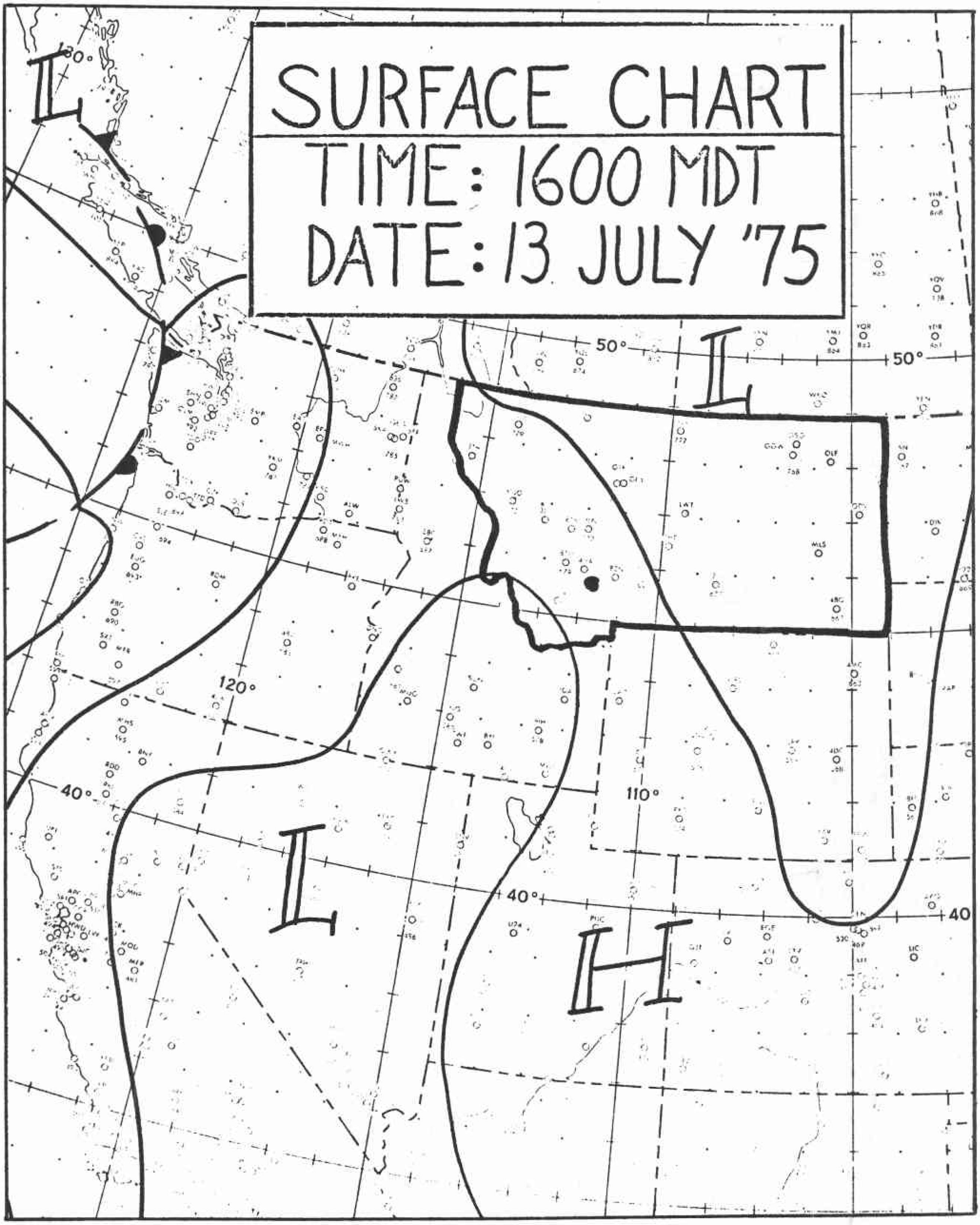

Figure 14. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 4 Rescheduled for 14 July 1975. Beaverhead National Forest.

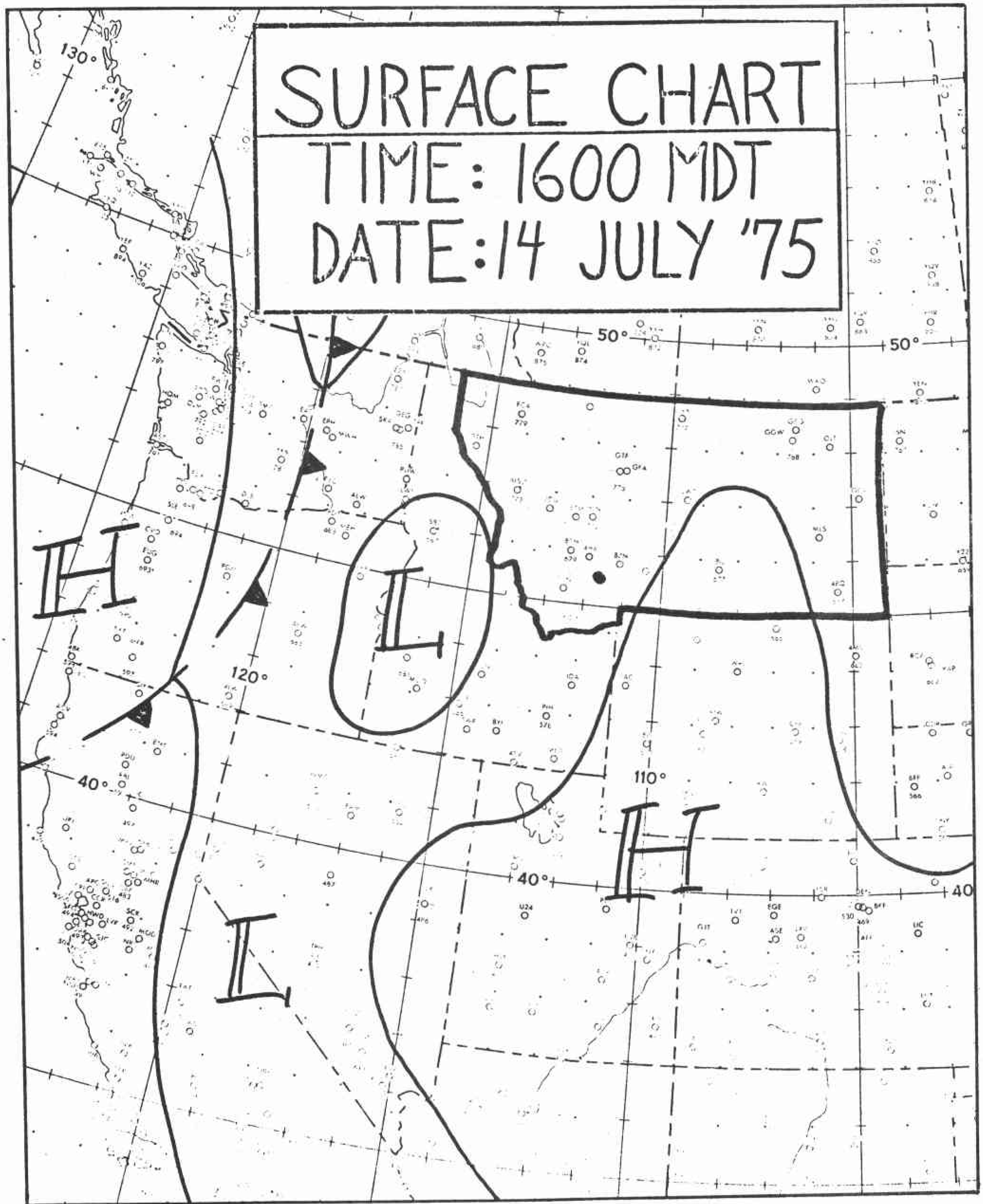

Figure 15. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 5 Scheduled for 15 July 1975 (Spraying Postponed for Weather). Beaverhead National Forest.

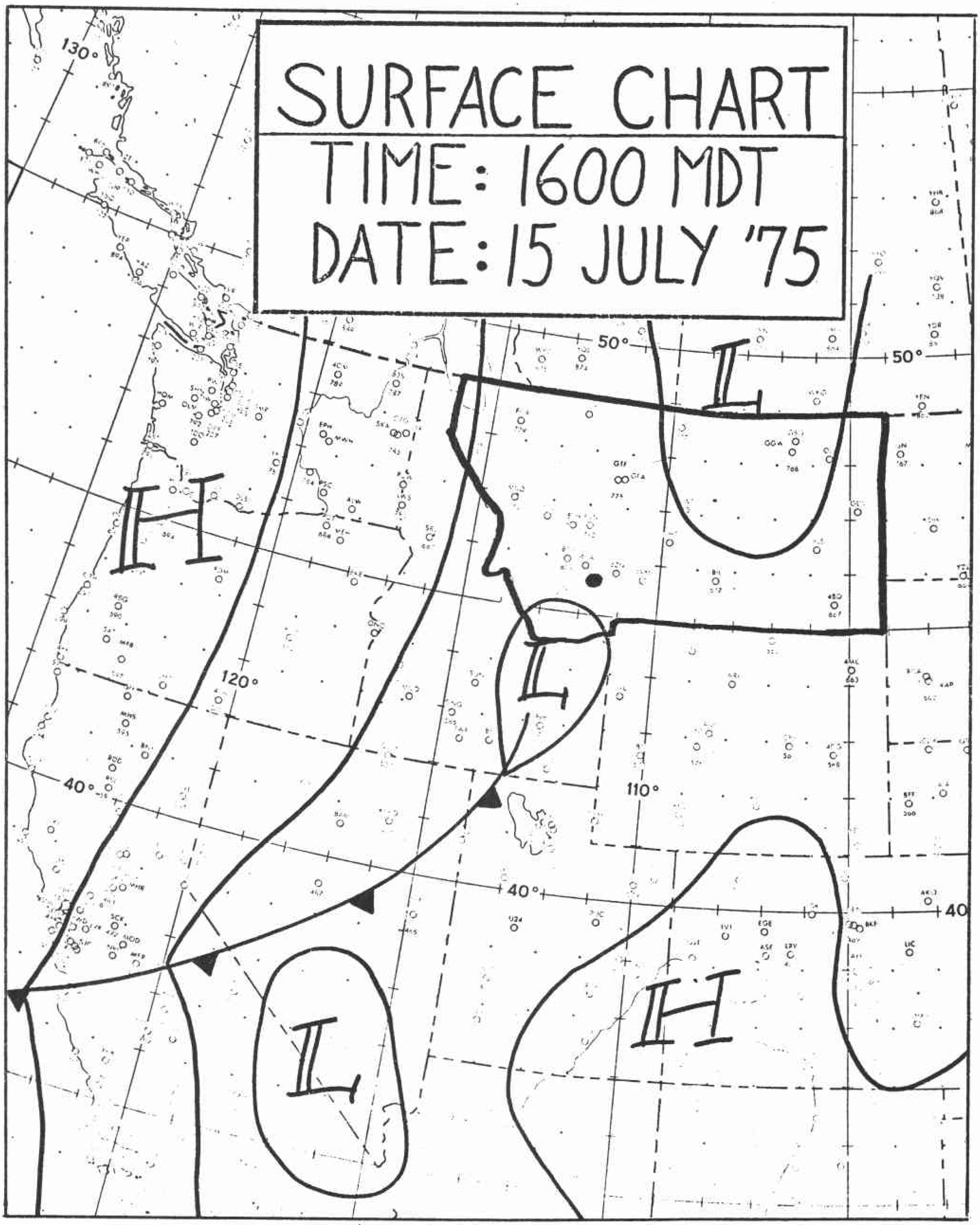

Figure 16. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 5 Rescheduled for 16 July 1975. Beaverhead National Forest.

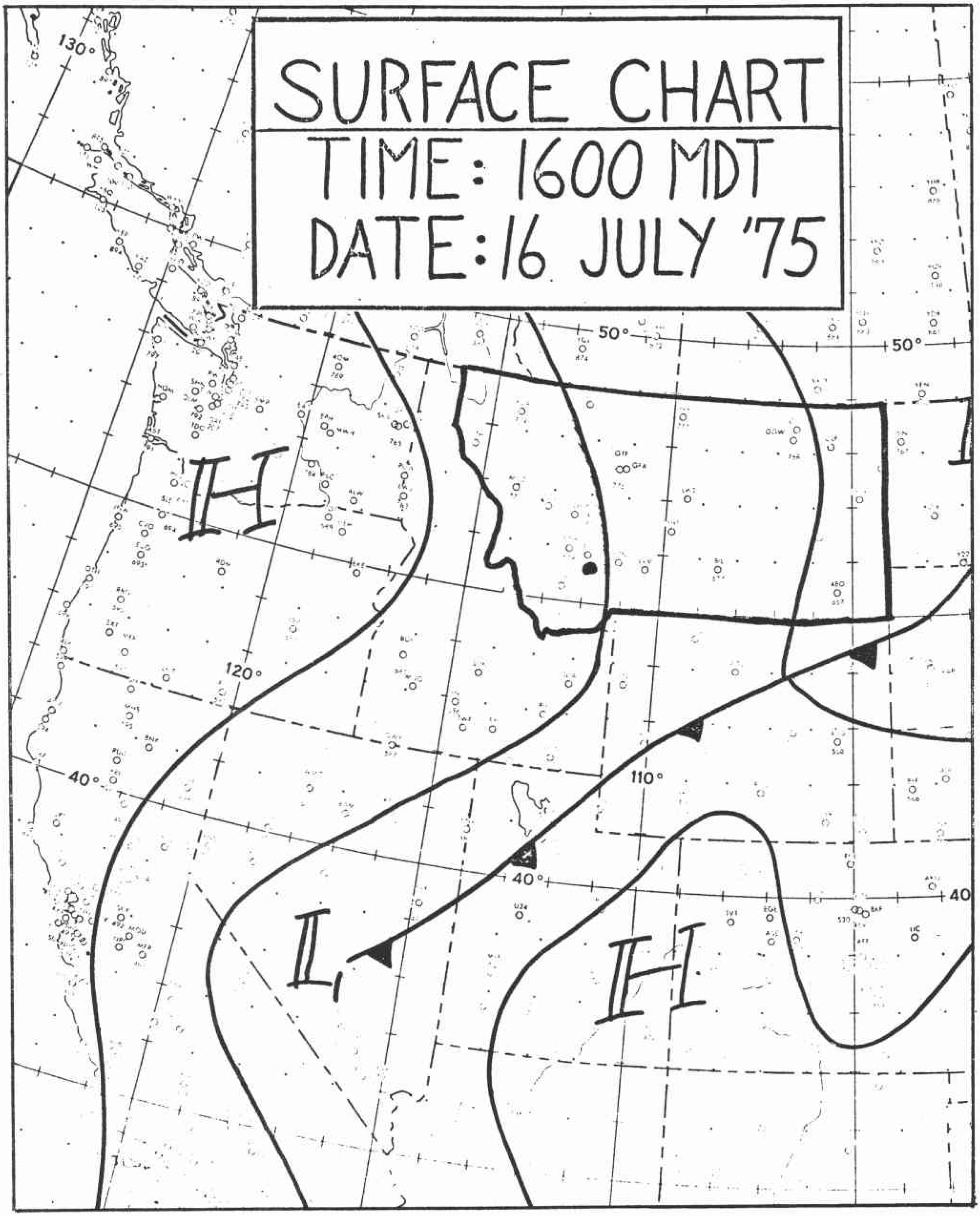

Figure 17. Synoptic Surface Chart Used in Briefing for Spray Operations at Site Number 7 Scheduled for 17 July 1975. Beaverhead National Forest.

SECTION 3. SPRAY DAY WEATHER FORECAST

FORECASTS FOR EACH SCHEDULED SPRAY DAY, PERIOD 2 THROUGH 16 JULY 1975.

WEATHER FORECAST

DATE: 2 July 1975 TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 1 (Lime)

WEATHER DISCUSSION: Low pressure along coast and warm ridge of high pressure over Montana.

GENERAL AREA FORECAST: Partly cloudy to mostly cloudy tonight with isolated thunderstorms.

SPRAY PLOT FORECAST: VALID: DATE: 3 July 75 TIME: 0530 End of Spray

TEMPERATURE: 48° - 55° F

RELATIVE HUMIDITY: 50% - 60%

WIND SPEED: RIDGE TOP: 5-8 MPH

SLOPE: Lt. downslope thru 0900 become variable upslope by noon. 2-3 MPH inc. to 7-8 MPH by afternoon.

WIND DIRECTION: ESE TO S

PRECIPITATION: NONE

CLOUD COVER: 2/10 TO 4/10 ths

SUNRISE TIME: 0528

FURTHER OUTLOOK: Continued warm and humid. Scattered thunderstorms afternoon and evening. Little change expected thru 5 July.

WEATHER FORECAST

DATE: 3 July 1975 TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 1 (Lime)

WEATHER DISCUSSION: Low pressure west of Montana centered over Boise moving ENE. High pressure over NE Montana with moist SW flow.

GENERAL AREA FORECAST: Good chance of afternoon and evening thunderstorms. Also, 1" hail in thunderstorms. Warm and Humid.

SPRAY PLOT FORECAST: VALID: DATE: 4 July 75 TIME: 0530 End of Spray

TEMPERATURE: 40° - 55° F

RELATIVE HUMIDITY: 40% - 60%

WIND SPEED: RIDGE TOP: 4-7 MPH SLOPE: Lt. downslope thru 0900 become variable upslope by noon. 2-3 MPH inc. to 8-10 MPH by afternoon

WIND DIRECTION: E TO ESE

PRECIPITATION: None

CLOUD COVER: 4/10ths

SUNRISE TIME: 0528

FURTHER OUTLOOK: Continued warm and humid. Scattered thunderstorms afternoon and evening. Little change expected thru 6 July.

WEATHER FORECAST

DATE: 4 July 1975

TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 1 (Lime)

WEATHER DISCUSSION: Low pressure moving into Montana from the west-southwest. Very moist low level flow continues into Montana east of the divide.

GENERAL AREA FORECAST: Widely scattered thunderstorms until late tonight. Temperatures up 5°. Humidity down. Slightly stronger surface winds.

SPRAY PLOT FORECAST:

VALID: DATE: 5 July 75 TIME: 0530 End of Spray

TEMPERATURE: 45° - 60° F

RELATIVE HUMIDITY: 35% - 55%

WIND SPEED: RIDGE TOP: 8-10 MPH

SLOPE: Downslope thru 0830 become upslope by noon.
4-6 MPH inc. to 8-12 MPH by aft.

WIND DIRECTION: SW

PRECIPITATION: None

CLOUD COVER: 3/10ths

SUNRISE TIME: 0529

FURTHER OUTLOOK: Continued warm and humid. Scattered thunderstorms afternoon and evening. Little change expected.

WEATHER FORECAST

DATE: 5 July 1975 TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 1 (Lime)

WEATHER DISCUSSION: Ridge of high pressure over Montana. Slow drying of airmass taking place but still plenty of moisture available for scattered afternoon and evening thunderstorms.

GENERAL AREA FORECAST: Widely scattered thunderstorms afternoon and evening.

SPRAY PLOT FORECAST: VALID: DATE: 6 July 75 TIME: 0530 End of Spray

TEMPERATURE: 45° - 62° F

RELATIVE HUMIDITY: 40% - 55%

WIND SPEED: RIDGE TOP: 7-9 MPH SLOPE: Downslope thru early morn. become upslope by noon. 5-7 MPH inc. to 8-11 MPH by aft.

WIND DIRECTION: S to SW

PRECIPITATION: None

CLOUD COVER: 4/10ths

SUNRISE TIME: 0529

FURTHER OUTLOOK: Continued warm and humid. Scattered thunderstorms afternoon and evening.

WEATHER FORECAST

DATE: 6 July 1975 TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 1 (Lime)

WEATHER DISCUSSION: High pressure centered over east Montana. Low pressure west and southwest. High pressure off west coast. Weak Canadian front approaching area.

GENERAL AREA FORECAST: Continued warm and humid. widely scattered thunderstorms late afternoon

SPRAY PLOT FORECAST: VALID: DATE: 7 July 75 TIME: 0530 End of Spray

TEMPERATURE: 55° - 65° F

RELATIVE HUMIDITY: 60% - 80%

WIND SPEED: RIDGE TOP: 3-5 MPH SLOPE: Downslope thru 0830 becom lt. upslope to variable upslope by noon. 2-3 MPH becom 6-8MPH by noon.

WIND DIRECTION: S to W

PRECIPITATION: None

CLOUD COVER: 1/10th

SUNRISE TIME: 0530

FURTHER OUTLOOK: Continued warm and humid. Scattered thunderstorms afternoon and evening.

WEATHER FORECAST

DATE: 7 July 1975 TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
SQUAW CREEK STATION, SITE NO. 2 (Smith)

WEATHER DISCUSSION: Cold front moving into Northern Wyoming. Front will stall along Cont. Div. Cool air coming into Montana (10° to 15°)

GENERAL AREA FORECAST: Showers and thunderstorms will be isolated.

SPRAY PLOT FORECAST: VALID: DATE: 8 July 75 TIME: 0530 End of Spray

TEMPERATURE: 50° - 65° F

RELATIVE HUMIDITY: 60% - 80%

WIND SPEED: RIDGE TOP: 5-10 MPH SLOPE: Downslope thru 0830 become upslope. 2-3 MPH becom 4-5 MPH

WIND DIRECTION: Variable

PRECIPITATION: None

CLOUD COVER: None

SUNRISE TIME: 0530

FURTHER OUTLOOK: Isolated thunderstorms

WEATHER FORECAST

DATE: 8 July 1975

TIME: 1600 Local

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 11
GALLATIN NATIONAL FOREST, MONTANA.
PORCUPINE STATION, SITE NO. 3 (Doe)

WEATHER DISCUSSION: Canadian high pressure over most of area. Airmass slightly unstable along forward edge of thermal low pressure system which extends from Nevada into Pacific Northwest.

GENERAL AREA FORECAST: Isolated thunderstorms.

SPRAY PLOT FORECAST:

VALID: DATE: 9 July 75 TIME: 0530 End of Spray

TEMPERATURE: 45° - 50° F

RELATIVE HUMIDITY: 65% - 85%

WIND SPEED: RIDGE TOP: 3-4 MPH

SLOPE: Lt. downslope thru 0900 become upslope thru afternoon. 2-3 MPH becom 4-5 MPH

WIND DIRECTION: Variable

PRECIPITATION: None

CLOUD COVER: 3 to 4/10 ths

SUNRISE TIME: 0530

FURTHER OUTLOOK: Very Little change

WEATHER FORECAST

DATE: 9 Jul 1975 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 2.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Surface thermal trough will dominate the Rocky Mtn Basin from Washington to Mexico.

GENERAL AREA FORECAST: Isolated Thunderstorms will occur over the area prior to valid period. Skies will be clear over the site during the valid period.

SPRAY PLOT FORECAST: VALID: DATE: 10 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 52-55^{0} F

RELATIVE HUMIDITY: 80%

WIND SPEED: RIDGE TOP: 3-4 MPH SLOPE: 3-4 MPH downslope becoming upslope after 0800 MDT.

WIND DIRECTION: Southwest

PRECIPITATION: None

CLOUD COVER: Clear

SUNRISE TIME: 0531 MDT

FURTHER OUTLOOK: Thunderstorms will develop by afternoon and prevail into the evening.

WEATHER FORECAST

DATE: 10 Jul 1975 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 6.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Thermal low pressure system will prevail over most of the Rocky Mtn Basin with a high pressure system extending from Canada into Eastern Montana.

GENERAL AREA FORECAST: Isolated thunderstorms will prevail over the area, but they will dissipate prior to valid period.

SPRAY PLOT FORECAST: VALID: DATE: 11 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 49-57° F

RELATIVE HUMIDITY: 80%

WIND SPEED: RIDGE TOP: 5-6 MPH SLOPE: 2-3 MPH downslope then upslope after 0730 MDT.

WIND DIRECTION: South

PRECIPITATION: None

CLOUD COVER: Clear

SUNRISE TIME: 0531 MDT

FURTHER OUTLOOK: Increasing cloudiness by afternoon with showers or thunderstorms developing by evening.

WEATHER FORECAST

DATE: 11 Jul 1975 **TIME:** 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 8.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Thermal trough will continue to dominate the western Rockies from Oregon to Western Arizona. A high pressure system will prevail over Montana.

GENERAL AREA FORECAST: Isolated thunderstorms will prevail over the area, but will dissipate by 0200 MDT.

SPRAY PLOT FORECAST: VALID: DATE: 12 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 46-57° F

RELATIVE HUMIDITY: 85%

WIND SPEED: RIDGE TOP: 2 MPH SLOPE: 1-2 MPH downslope becoming upslope after 0730 MDT

WIND DIRECTION: West

PRECIPITATION: None

CLOUD COVER: Clear

SUNRISE TIME: 0531 MDT

FURTHER OUTLOOK: Thunderstorm activity will develop by afternoon and into the evening.

WEATHER FORECAST

DATE: 12 July 75 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 4.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Weak low pressure systems will dominate the western portion of the US. A Pacific high pressure system will remain off-shore.

GENERAL AREA FORECAST: Widely scattered thunderstorms will prevail over extreme western Montana, Idaho, Nevada, and Northwest Utah.

SPRAY PLOT FORECAST: VALID: DATE: 13 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 46-58° F

RELATIVE HUMIDITY: 85%

WIND SPEED: RIDGE TOP: 2 MPH SLOPE: Downslope 2 MPH becoming upslope 1-2 MPH by 0730 MDT.

WIND DIRECTION: west

PRECIPITATION: Rainshowers in area.

CLOUD COVER: Scattered to broken

SUNRISE TIME: 0532 MDT

FURTHER OUTLOOK: Occasional showers during afternoon and evening.

WEATHER FORECAST

DATE: 13 Jul 75 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 4.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: A high pressure ridge will prevail over most of Montana with thermal low extending from Idaho southward into Arizona.

GENERAL AREA FORECAST: Widespread thunderstorms will occur over southwestern Montana and into Idaho and will dissipate prior to valid period of test.

SPRAY PLOT FORECAST: VALID: DATE: 14 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 46-54° F

RELATIVE HUMIDITY: 85%

WIND SPEED: RIDGE TOP: 2-4 MPH SLOPE: 2-4 MPH downslope becoming upslope after 0830 MDT

WIND DIRECTION: West

PRECIPITATION: None

CLOUD COVER: 3-5 Tenths

SUNRISE TIME: 0532 MDT

FURTHER OUTLOOK: Increasing cloudiness with afternoon thunderstorms or showers.

WEATHER FORECAST

DATE: 14 July 75 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 5.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Occluded front will be over central Washington and southward into western oregon. Thermal low pressure system will continue to prevail over Nevada, Utah, and southward into Mexico.

GENERAL AREA FORECAST: Thunderstorms will diminish in activity west of front but they will occur over western Montana and Northern Idaho.

SPRAY PLOT FORECAST: VALID: DATE: 15 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 49-57° F

RELATIVE HUMIDITY: 85%

WIND SPEED: RIDGE TOP: 5 MPH SLOPE: Downslope 5 MPH except gusting to 10 MPH in showers.

WIND DIRECTION: west-southwest

PRECIPITATION: Occasional showers.

CLOUD COVER: 8-10 tenths

SUNRISE TIME: 0532 MDT

FURTHER OUTLOOK: Showers will continue until front moves through the area by evening. Cooler temperatures will follow frontal passage.

WEATHER FORECAST

DATE: 15 Jul 75 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 5.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: A cold front will be positioned east of Site 5 over Eastern Montana through Wyoming and southwestward into Nevada. The thermal low will remain over Nevada southward onto Mexico.

GENERAL AREA FORECAST: Clear skies to scattered clouds will prevail over the area.

SPRAY PLOT FORECAST: VALID: DATE: 16 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 45-53° F

RELATIVE HUMIDITY: 80%

WIND SPEED: RIDGE TOP: 3-4 MPH SLOPE: 2-3 MPH downslope becoming 2-4 MPH upslope after 0730 MDT.

WIND DIRECTION: West-Southwest

PRECIPITATION: None

CLOUD COVER: Clear to 1 tenth

SUNRISE TIME: 0532 MDT

FURTHER OUTLOOK: Clear to scattered clouds for remainder of the day.

WEATHER FORECAST

DATE: 16 Jul 75 TIME: 1900 MDT

PROJECT: PILOT CONTROL - WESTERN SPRUCE BUDWORM

AGENCY: USFS

LOCATION: ZONE 7, SITE 7.
BEAVERHEAD NATIONAL FOREST, MONTANA

WEATHER DISCUSSION: Cold front over eastern Montana and Central Wyoming will continue to move eastward. A high pressure system will move into the area behind cold front.

GENERAL AREA FORECAST: Clear to scattered clouds

SPRAY PLOT FORECAST: VALID: DATE: 17 Jul 75 TIME: 05-12 MDT

TEMPERATURE: 50-57° F

RELATIVE HUMIDITY: 75%

WIND SPEED: RIDGE TOP: 2-4 MPH SLOPE: 3-5 MPH downslope becoming upslope after 0800 MDT.

WIND DIRECTION: East

PRECIPITATION: None

CLOUD COVER: Clear to 2 tenths

SUNRISE TIME: 0532 MDT

FURTHER OUTLOOK: Partly cloudy for remainder of the day with possible showers in the afternoon.

SECTION 4. TEMPERATURE PROFILES

OBSERVED TEMPERATURE PROFILE FOR EACH SPRAY TRIAL ACTUALLY CONDUCTED.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 7 July 1975

TRIAL NUMBER: 1

SITE: 1 (LIME), Gallatin National Forest, Montana

	TIME OF OBSERVATION (MDT)			
HEIGHT (FT)	0500	0700	0730	1005
20	14.3	14.2	15.2	18.7
40	14.3	14.9	15.2	18.5
60	15.7	14.2	15.0	18.7
80	15.8	14.7	15.0	18.7
100	15.8	14.5	15.6	18.7
120	15.8	-	16.0	18.5
140	16.4	-	16.4	18.5
160	15.7	-	15.4	18.5
180	15.7	-	15.4	18.3
200	16.4	-	16.0	18.3

NOTE: Temperatures are in °C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 8 July 1975

TRIAL NUMBER: 2

SITE: 2 (SMITH), Gallatin National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0525	1000
20	9.9	12.7
40	9.8	12.8
60	10.2	12.8
80	9.9	13.6
100	9.9	14.5
120	10.5	13.6
140	10.5	14.3
160	-	14.5
180	-	14.5
200	-	13.6

NOTE: Temperatures are in ^{o}C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 9 July 1975

TRIAL NUMBER: 3

SITE: 3 (DOE), Gallatin National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0600	0630	1010
20	7.9	8.5	14.2
40	7.7	8.5	14.2
60	7.9	8.5	14.0
80	7.7	8.2	13.4
100	7.7	8.2	14.9
120	7.7	8.2	13.4
140	7.7	8.2	13.5
160	7.7	8.0	14.2
180	7.7	8.0	14.2
200	7.7	8.2	13.8

NOTE: Temperatures are in $^{\circ}C$.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 10 July 1975

TRIAL NUMBER: 4

SITE: 2, **Beaverhead National Forest, Montana**

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0530	0610	0755
20	11.7	11.1	15.6
40	11.7	11.6	15.9
60	12.0	11.7	15.9
80	12.8	12.3	15.6
100	12.9	13.6	15.6
120	12.9	13.6	15.5
140	13.5	14.0	15.5
160	13.9	14.3	15.5
180	13.9	14.5	15.4
200	13.9	14.6	15.4

NOTE: Temperatures are in °C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 11 July 1975

TRIAL NUMBER: 5

SITE: 6, Beaverhead National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0625	0800
20	8.5	11.9
40	9.5	12.0
60	8.5	12.8
80	8.8	13.0
100	8.8	13.0
120	9.5	12.5
140	9.8	12.8
160	9.9	13.0
180	10.4	12.5
200	10.3	13.0

NOTE: Temperatures are in °C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 12 July 1975

TRIAL NUMBER: 6

SITE: 8, Beaverhead National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0530
20	11.6
40	13.5
60	14.7
80	15.1
100	15.1
120	14.9
140	14.7
160	14.9
180	14.7
200	14.7

NOTE: Temperatures are in ^{o}C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 14 July 1975

TRIAL NUMBER: 7

SITE: 4, Beaverhead National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT)		
20			
40	NO DATA AVAILABLE.		
60			
80			
100			
120			
140			
160			
180			
200			

NOTE: Temperatures are in °C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 16 July 1975

TRIAL NUMBER: 8

SITE: 5, Beaverhead National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0740	0900
20	11.1	13.1
40	11.0	13.6
60	11.0	13.1
80	10.9	13.1
100	10.9	12.9
120	10.9	12.9
140	10.9	13.0
160	10.8	13.0
180	10.9	13.0
200	10.8	12.9

NOTE: Temperatures are in °C.

TEMPERATURE PROFILE IN FORESTED AREA

DATE: 17 July 1975

TRIAL NUMBER: 9

SITE: 7, Beaverhead National Forest, Montana

HEIGHT (FT)	TIME OF OBSERVATION (MDT) 0600
20	12.1
40	12.5
60	12.2
80	12.6
100	12.5
120	12.2
140	12.4
160	12.2
180	12.1
200	12.2

NOTE: Temperatures are in °C.

SECTION 5. SURFACE OBSERVATIONS

SURFACE OBSERVATIONS TAKEN DURING THE OPERATION OF EACH SPRAY TRIAL. ALL MEASUREMENTS WERE TAKEN IN AN OPEN AREA WITHIN THE SPRAY SITE.

SURFACE OBSERVATIONS

GALLATIN NAT. FOREST, MONT.

TEST NO. 1 DATE 7 July 1975 SITE # 1 (Lime)

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0500	55.0	51.6	81	350/02	54.2	10	none	814.2
0530	52.9	51.2	90	080/03	54.5	10	none	814.6
0600	56.8	53.3	81	155/03	54.0	8	none	814.3
0630	55.2	52.7	85	100/02	54.0	8	none	814.2
0700	55.1	52.3	88	035/02	54.0	7	none	814.2
0730	58.3	52.7	71	calm	56.8	6	none	814.6
0800	56.4	53.8	85	calm	55.9	3	none	814.8
0830	60.3	55.7	76	calm	58.8	2	none	815.1
0900	64.0	57.0	67	310/02	61.0	3	none	815.2
0930	66.0	58.0	64	290/02	63.0	2	none	815.2
1000	68.0	58.5	59	270/02	65.7	2	none	815.2

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0802 MDT.

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SURFACE OBSERVATIONS

GALLATIN NAT. FOREST, MONT.

TEST NO. 2

DATE 8 July 1975

SITE # 2 (Smith)

DRY BULB MEASUREMENT TAKEN AT 1 METER

GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0500	49.5	48.0	91	045/02	48.8	0	none	797.8
0530	48.5	47.9	90	040/02	47.0	0	none	797.9
0600	49.1	48.5	96	calm	48.0	1	none	798.0
0630	50.7	49.8	96	calm	50.5	2	none	797.9
0700	50.4	49.6	95	345/03	50.4	2	none	797.9
0730	52.0	50.9	95	calm	52.7	2	none	797.8
0800	55.7	53.9	95	155/02	54.2	1	none	797.5
0830	56.0	53.7	90	190/02	52.2	1	none	797.7
0900	60.0	57.0	85	165/02	57.0	1	none	797.7
0930	64.0	58.8	76	150/02	61.4	0	none	797.7
1000	65.0	58.5	70	145/02	62.0	0	none	797.7

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0803 MDT

STEDP-MD Form 2. 12 Apr 63

SURFACE OBSERVATIONS

GALLATIN NAT. FOREST, MONT.

TEST NO. 3 DATE 9 July 1975 SITE # 3 (Doe)

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0500	47.1	45.9	93	180/02	46.7	1	Grd.Fog	791.0
0530	47.1	46.2	93	180/02	46.8	1	Grd.Fog	791.0
0600	47.1	46.3	93	180/02	46.9	0	Grd.Fog	791.1
0630	47.5	46.5	93	180/02	47.0	0	Grd.Fog	791.1
0700	47.5	46.7	93	160/02	47.0	0	Grd.Fog	791.1
0730	51.0	49.5	91	140/02	49.8	0	none	791.1
0800	52.0	50.5	91	220/02	50.0	0	none	791.1
0830	53.0	51.5	91	300/02	51.0	0	Grd.Fog	791.1
0900	54.1	52.6	91	330/02	52.0	0	Grd.Fog	791.2
0930	54.3	52.7	91	335/02	53.0	0	none	791.2
1000	56.4	54.0	86	344/02	55.2	0	none	791.2

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0834 MDT.

STEDP-MD Form 2. 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 4 DATE 10 July 1975 SITE # 2

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0500	51.0	49.9	94	230/04	50.2	1	none	812.2
0530	50.6	49.4	90	230/04	49.0	1	none	812.4
0600	50.5	49.7	96	230/03	49.0	3	none	812.6
0630	52.1	51.1	92	230/03	51.0	0	none	812.6
0700	55.9	53.8	88	calm	53.3	0	none	812.7
0840	61.2	58.0	83	135/02	57.7	0	none	812.8

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0730 MDT.

STEDP-MD Form 2, 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 5 DATE 11 July 1975 SITE # 6

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0630	42.0	40.8	92	calm	41.5	7	none	806.0
0700	42.9	41.6	92	calm	42.9	6	none	805.8
0730	48.1	46.8	89	calm	44.4	0	none	805.7
0810	55.0	52.5	86	340/03	45.8	0	none	805.7

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0802 MDT.

STEDP-MD Form 2. 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 6 DATE 12 July 1975 SITE # 8

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION very dry

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0530	46.1	42.1	86	290/02	38.1	3	none	781.0
0600	47.2	42.7	71	285/02	38.3	3	none	781.0
0630	48.7	44.2	71	290/03	46.3	6	none	780.0
0700	52.0	48.7	73	calm	50.1	4	none	780.4
0730	61.0	51.7	53	calm	53.2	3	none	780.5

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0712 MDT.

STEDP-MD Form 2, 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 7 DATE 14 July 1975 SITE # 4

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION wet

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0630	44.2	42.9	91	calm	43.1	0	none	788.0
0700	52.2	50.2	89	030/02	51.8	1	none	788.1
0730	55.0	52.7	86	030/02	54.0	1	none	788.2
0800	58.0	55.2	85	040/02	57.1	1	none	788.3
0830	60.0	54.2	71	010/03	57.3	1	none	788.4

REMARKS: THE WIND DIRECTION WAS GENERALLY DOWNSLOPE THROUGHOUT THE SPRAY PERIOD.

STEDP-MD Form 2, 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 8 DATE 16 July 1975 SITE # 5

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION moist

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0600	45.9	43.2	82	200/04	43.8	2	none	766.8
0630	45.0	43.7	89	265/03	44.7	1	none	766.8
0700	49.1	45.7	80	265/03	47.6	0	none	766.9
0730	50.0	47.3	85	350/02	48.0	0	none	766.8
0900	54.3	51.3	81	070/03	53.5	3	none	766.7

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0734 MDT.

STEDP-MD Form 2, 12 Apr 63

SURFACE OBSERVATIONS

BEAVERHEAD NAT. FOREST, MONT.

TEST NO. 9 DATE 17 July 1975 SITE # 7

DRY BULB MEASUREMENT TAKEN AT 1 METER GROUND CONDITION dry

TIME (MDT)	DRY BULB (°F)	WET BULB (°F)	RELATIVE HUMIDITY (%)	WIND DIR /SPEED (MPH)	GROUND TEMP (°F)	CLOUD COVER (10th)	WEATHER	SURFACE PRESSURE (MBS)
0600	53.5	47.7	67	170/06	53.0	6	none	794.6
0630	52.0	47.0	71	110/05+12	52.0	8	none	794.9
0700	53.0	47.6	68	110/06+12	53.0	9	none	795.1
0730	59.8	52.8	65	090/06	59.0	7	none	795.2

REMARKS: THE WIND DIRECTION SHIFTED FROM DOWNSLOPE TO UPSLOPE AT 0700 MDT.

STEDP-MD Form 2, 12 Apr 63

SECTION 6. WIND PROFILE DATA

THE WIND PROFILE DATA RECORDED IN THE OPEN, FOREST, AND ABOVE THE CANOPY DURING THE OPERATION OF EACH SPRAY TRIAL ARE SHOWN IN HALF HOURLY AVERAGES.

WIND PROFILE DATA

TRIAL NUMBER 1   SITE 1 (LIME), Gallatin National Forest, Montana   DATE: 7 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0500-0530	-	-	2.7	1.0-5.7	075	290-195	-	-	-	-
0530-0600	-	-	3.0	0.6-5.6	085	270-215	-	-	-	-
0600-0630	090	360-195	3.0	1.0-5.7	045	275-200	-	-	2.1	0.2-6.6
0630-0700	315	270-015	2.0	1.0-5.0	055	270-200	-	-	1.8	0.2-5.6
0700-0730	015	320-055	2.3	1.0-5.3	045	280-225	1.2	0.6-2.7	1.0	0.2-2.6
0730-0800	070	340-195	2.2	0.5-4.6	070	305-195	1.5	0.7-2.6	1.7	0.2-3.8
0800-0830	315	270-350	2.5	0.5-5.0	060	280-150	1.2	0.7-2.0	0.7	0.1-2.9
0830-0900	330	270-055	1.3	0.6-2.2	055	280-165	1.1	0.7-1.9	0.9	0.1-4.4
0900-0930	315	280-020	2.0	0.8-4.5	060	320-165	1.6	0.8-3.0	-	-
0930-1000	280	240-015	2.0	0.7-5.3	060	350-200	1.2	0.8-3.4	-	-

WIND PROFILE DATA

TRIAL NUMBER 2   SITE 2(SMITH), Gallatin National Forest, Montana   DATE: 8 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0500-0530	-	-	-	-	270	180-350	0.4	0.2-0.8	0.9	0.1-2.6
0530-0600	005	345-040	1.5	0.7-2.9	300	240-010	0.3	0.2-0.5	0.6	0.0-1.5
0600-0630	020	350-025	1.8	0.7-3.0	350	325-165	0.3	0.2-0.5	0.5	0.0-1.5
0630-0700	010	350-045	2.0	0.7-2.6	310	180-005	0.4	0.2-0.6	0.7	0.1-3.6
0700-0730	360	330-050	1.5	0.6-3.5	180	125-345	0.5	0.2-0.9	0.8	0.1-3.3
0730-0800	360	255-055	1.2	0.6-2.0	200	130-005	0.3	0.2-0.7	0.8	0.1-2.6
0800-0830	180	115-280	1.6	0.5-4.7	190	060-225	0.5	0.2-1.0	0.9	0.1-5.0
0830-0900	135	075-170	1.8	0.8-3.7	180	110-265	0.7	0.4-1.2	1.7	0.2-5.8
0900-0930	180	020-280	1.7	0.7-4.5	180	015-240	0.8	0.3-1.3	1.4	0.2-4.6
0930-1000	180	060-275	2.0	0.8-4.6	-	-	-	-	2.3	0.2-6.9

WIND PROFILE DATA

TRIAL NUMBER 3 SITE 3 (DOE), **Gallatin National Forest, Montana** DATE: **9 July 1975**

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0530-0600	180	020-300	2.7	0.7-5.5	-	-	1.6	0.7-2.6	-	-
0600-0630	135	010-320	1.9	0.5-5.4	145	115-165	1.3	0.7-2.6	2.9	0.3-7.5
0630-0700	120	040-190	2.0	0.6-3.3	140	110-155	1.6	0.7-3.0	2.6	0.6-6.3
0700-0730	135	020-230	1.9	0.6-5.2	145	110-165	-	-	2.6	0.2-6.1
0730-0800	110	005-225	1.8	0.5-5.4	135	105-170	-	-	2.5	0.6-6.3
0800-0830	075	005-210	1.5	0.5-4.3	135	105-150	-	-	1.5	0.4-4.3
0830-0900	320	285-080	2.7	0.6-5.1	295	225-350	-	-	1.2	0.3-3.5
0900-0930	325	275-030	1.7	0.4-5.3	-	-	-	-	1.4	0.2-4.0
0930-1000	315	245-040	3.1	0.6-5.3	-	-	1.8	0.8-3.6	-	-

WIND PROFILE DATA

TRIAL NUMBER 4 SITE 2, Beaverhead National Forest, Montana DATE: 10 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0500-0530	240	195-280	3.9	2.4-5.9	-	-	-	-	NO	DATA
0530-0600	245	180-280	3.8	2.2-4.9	265	225-285	2.0	1.2-3.0		
0600-0630	240	220-250	3.6	2.1-4.8	270	235-285	2.1	1.2-3.8		
0630-0700	245	230-250	3.0	0.7-5.2	275	205-090	1.7	0.9-3.2		
0700-0730	245	240-260	1.5	0.7-2.8	315	290-005	1.2	0.9-1.8		
0730-0800	015	270-115	1.5	0.7-3.9	045	330-150	1.4	1.0-2.3		
0800-0830	045	270-145	-	-	-	-	-	-		

WIND PROFILE DATA

TRIAL NUMBER 5 SITE 6, Beaverhead National Forest, Montana DATE: 11 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0630-0700	080	360-150	1.4	1.8-2.2	-	-	-	-	0.6	0.0-2.6
0700-0730	045	345-115	1.1	0.7-2.0	-	-	-	-	0.9	0.0-3.1
0730-0800	030	005-100	1.6	0.8-2.6	-	-	-	-	0.6	0.0-2.9

WIND PROFILE DATA

TRIAL NUMBER 6 SITE 8, Beaverhead National Forest, Montana DATE: 12 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0530-0600	285	280-290	2.0	1.1-3.1	280	278-283	1.9	1.4-2.4	1.3	0.2-4.3
0600-0630	287	285-290	2.0	1.3-2.9	280	278-285	2.0	1.4-2.7	1.4	0.2-3.9
0630-0700	292	290-295	1.6	1.1-2.8	280	278-285	1.9	1.3-2.6	0.9	0.1-2.5
0700-0730	045	225-105	0.9	0.3-2.8	285	282-286	1.0	0.7-2.4	0.7	0.1-2.1
0730-0800	120	205-155	1.5	0.3-3.5	125	120-135	1.7	0.7-3.5	1.4	0.2-4.8

WIND PROFILE DATA

TRIAL NUMBER 7 SITE 4, Beaverhead National Forest, Montana DATE: 14 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0600-0630	182	035-260	1.5	1.1-2.3	290	260-325	1.1	0.8-1.5	-	-
0630-0700	360	215-035	1.9	1.2-3.1	335	260-345	1.0	0.7-1.3	1.4	0.2-4.6
0700-0730	015	340-085	1.9	1.4-3.0	040	210-090	0.9	0.7-1.4	2.0	0.2-4.6
0730-0800	350	300-035	2.3	1.6-3.9	360	345-025	0.9	0.8-1.0	1.2	0.1-5.1
0800-0830	350	290-035	2.8	2.1-3.8	090	075-100	1.3	0.9-2.1	0.6	0.1-1.8

WIND PROFILE DATA

TRIAL NUMBER 8 SITE 5, Beaverhead National Forest, Montana DATE: 16 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0600-0630	225	195-265	2.9	1.7-5.9	225	220-235	1.7	0.6-2.8	-	-
0630-0700	275	195-315	3.5	1.6-6.2	330	240-355	1.3	0.6-4.1	2.9	0.5-8.1
0700-0730	285	265-310	2.8	1.6-4.2	300	225-015	1.2	0.6-4.0	2.1	0.2-5.9
0730-0800	040	295-070	2.3	1.4-6.2	035	350-085	1.7	1.0-3.2	1.2	0.2-4.4
0800-0830	075	025-125	2.3	1.4-3.7	110	350-175	1.1	0.6-2.6	1.3	0.2-4.0
0830-0900	090	335-125	2.2	1.4-4.2	105	225-135	1.4	0.6-3.0	1.3	0.2-4.0
0900-0930	020	290-130	2.7	1.4-5.9	080	345-130	1.9	0.7-4.5	2.5	0.3-7.3
0930-1000	035	320-085	3.7	0.8-6.3	055	025-095	2.2	0.7-4.7	2.6	0.3-6.9
1000-1030	-	-	-	-	080	225-175	2.2	0.8-5.9	-	-

WIND PROFILE DATA

TRIAL NUMBER 9 SITE 7, Beaverhead National Forest, Montana DATE: 17 July 1975

TIME INTERVAL (MDT)	OPEN AREA (6-FT LEVEL)				FORESTED AREA (6-FT LEVEL)				FORESTED AREA 50 FT ABV CANOPY	
	DIRECTION (°)		SPEED (MPH)		DIRECTION (°)		SPEED (MPH)		SPEED (MPH)	
	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE	AVG	RANGE
0600-0630	155	105-225	3.0	0.6-6.2	160	035-360	1.8	0.7-6.2	NO	DATA
0630-0700	160	110-190	2.9	1.0-5.6	135	050-350	1.2	0.4-3.0		
0700-0730	100	065-115	3.1	0.4-6.0	140	085-335	1.0	0.4-3.2		
0730-0800	085	045-125	3.5	0.5-5.8	080	035-115	1.3	0.4-3.8		
0800-0830	065	040-110	3.5	0.4-5.6	090	040-130	1.3	0.4-2.4		

APPENDIX A. REFERENCES

1. U.S. Army Dugway Proving Ground, Dugway, UT 84022, Action Plan for Meteorological and Spray Assessment Support of Pilot Control Project of Carbaryl, Trichlorfom, and Bacillus thuringiensis Against Western Spruce Budworm Beaverhead and Gallatin National Forest, Montana, by John W. Barry and Robert Ekblad, U.S. Forest Service, June 1975.

2. U.S. Army Dugway Proving Ground, Dugway, UT 84022 and U.S. Forest Service, Washington, DC 20250 Supplemental Agreement No. 3 dated April 1975 to Memorandum of Understanding between U.S. Army Materiel Command and U.S. Forest Service dated April 1973.

APPENDIX B. DISTRIBUTION LIST

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RESIDUE ANALYSIS

1. Residue analysis of carbaryl on forest foliage and in creek water.
2. Residue analysis on fish and aquatic organisms.
3. Brain cholinesterase activities in rainbow trout exposed to Sevin 4-Oil or Dylox.

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Residue Analysis of Carbaryl on
Forest Foliage and in Creek Water

Principal investigator: G. R. Pieper, U.S.F.S./IEP

Other cooperator: R. B. Roberts

June 1976

1. Summary

Methods are described for the residue analysis of carbaryl on forest foliage and in creek water and residue data are reported from a field test with carbaryl, conducted in Montana in 1975. Residues of carbaryl are extracted from foliage with chloroform. Subsequent clean-up is by Florisil open column chromatography and liquid-liquid partition. Carbaryl is extracted from creek water with dichloromethane and is further cleaned up by Florisil column chromatography. For the final determination of carbaryl an HPLC system is used operating in reverse phase. The instrument is equipped with a Bondapak C_{18}/Corasil column and a UV detector absorbing at 280nm. The method is sensitive to 0.1 ppm in foliage and 1 ppb in water for carbaryl.

2. Methods

2.1 Materials

2.1.1 Equipment

Rotary flask evaporator

High pressure liquid chromatograph equipped with a 1/8 inch O.D. x 2 ft (2 mm ID x 61 cm) Bondapak C_{18}/Corasil column (Waters Assoc., or equivalent) and a UV detector (280 nm)

Chromatographic column 9 mm ID x 15 cm (Made with 9 mm glass tubing.)

Chromatographic column 10.5 mm ID x 25 cm, 200 ml reservoir

Sample clarification kit, Waters Assoc. #26865 with Fluoropore filters FHLPO 1300 and pre-filters

2.1.2 Reagents:

carbaryl analytical standard, Union Carbide Corp.

chloroform: analytical grade, Mallinckrodt

hexane: analytical grade, Mallinckrodt, redistilled

acetonitrile: nanograde, Mallinckrodt

dichloromethane: analytical grade, Mallinckrodt

Florisil (activated magnesium silicate) 60/100 mesh, J. T. Baker Chem. Co. Differences occur between batches. Each batch must first be tested. If necessary, the amounts of solvents used must be adjusted.

2.2 Carbaryl residues in forest foliage.

2.2.1 Extraction of foliage samples*

Place 20 g of foliage in a wide mouth pint jar with a Teflon-lined lid.

*Extraction of carbaryl from foliage by "wash-off rather than by homogenization of the substrate was adopted from procedures developed by the manufacturer, Union Carbide Corp. Their experience with a large variety of plant materials, and with residue periods of up to 3 months, indicates that carbaryl does not penetrate the plant tissue (Romine, personal communication, 1975, 1976.)

Add 40 ml of chloroform and swirl gently for 3 minutes. Pass the extract through anhydrous sodium sulfate. Collect a 24 ml aliquot (representing 12 g of foliage) and store in a vial with a Teflon-lined cap at -20° C.

2.2.2 Clean-up of foliage samples

2.2.2.1 Grass and Geranium sp.

Transfer the sample to a 100 ml round bottom flask and add 1 ml acetonitrile. Evaporate the extract in a rotary flask evaporator at 37° C to about 2 ml. Complete the evaporation of the chloroform in a stream of air or nitrogen. Transfer the residue to a 60 ml separatory funnel with 5 ml hexane followed by 5 ml acetonitrile. Rinse the flask with additional 5 ml hexane and 5 ml acetonitrile and add the rinses to the separatory funnel. After shaking and allowing the phases to separate, collect the acetonitrile in a 100 ml round bottom flask. The hexane is back extracted with 5 ml and 2 ml of acetonitrile. Combine all acetonitrile fractions and evaporate as before.

Prepare "solvent A" by mixing 65% chloroform and 35% hexane (v/v) and saturating it with water by shaking with excess water in a separatory funnel.

Deactivate Florisil with 10% H_2O (w/w) and allow to stand for 3 days.

Pack a 10.5 mm ID chromatographic column with 5.2 g of deactivated (10% H_2O) Florisil. Use glass wool plugs at both ends of the column. Tap the column lightly so that the Florisil packing will have a length of 10 cm. Wet the column with 10 ml of solvent A.

The residue is dissolved in 2 ml of solvent A and transferred to the Florisil column. Repeat with additional 2 ml and 30 ml portions of solvent A and elute drop-wise. Allow the solvent to sink into the column bed between additions. Discard the eluate. Add 90 ml of solvent A and evaporate the eluate in a 250 ml round bottom flask as described before.

Add 3 ml of acetonitrile. Cap the flask with aluminum foil and warm gently and briefly to dissolve any film of plant waxes. Cool the flask at 3° C for about 1/2 hour and filter (Fluoropore and pre-filter).

2.2.2.2 Aspen and Douglas-fir

Waxes and resins present in aspen and Douglas-fir extracts cause the formation of bothersome emulsions during the liquid-liquid partition step. An extra step is required to remove these substances: Pack a 9 mm ID column with 1.6 g of dry Florisil. Tap the column lightly so that the length of the packing is 5 cm. Pass the initial extract (24 ml) through this column followed by 10 ml chloroform. Collect all the eluate and proceed as described before for the initial extracts of grass and geranium foliage.

2.2.3 Controls and fortified foliage samples

Process untreated foliage samples as described before to check for background response. Fortify untreated samples with known amounts of carbaryl. For a fortification at the 5 ppm level add 100 µg of carbaryl in 1 ml of dichloromethane to 20 g of foliage in a pint jar and proceed as described before to determine the percent of recovery.

2.3 Carbaryl residues in water

2.3.1 Extraction of water samples

In a 1000 ml separatory funnel shake 400 ml water sample twice with 70 ml and once with 60 ml of dichloromethane. Pass the dichloromethane extract through anhydrous sodium sulfate, collect a 150 ml aliquot and store at -20° C.

2.3.2 Clean-up of water samples

Evaporate the extract (150 ml) in a 500 ml round bottom flask and re-dissolve the residue in 2 ml of solvent A. Pack a chromatographic column, 10.5 mm ID with 7.8 g of deactivated Florisil (10% H_2O) (15 cm packing length after tapping the column).

Transfer the sample to the column and rinse the flask with 15 ml of solvent A in small rinses. Add the rinses to the column, elute drop wise, and discard the eluate. Pass 55 ml of solvent A through the column and evaporate the eluate in a 250 ml round bottom flask as described before. Re-dissolve the residue in 3 ml acetonitrile, filter (Fluoropore and pre-filter) and store at -20° C.

2.3.3 Controls and fortified samples

Process untreated (control) water samples as described before to check for background response. Fortify untreated samples with known amounts of carbaryl. For a fortification at the 0.1 ppm level add 40 µg of carbaryl in 0.4 ml dichloromethane to 400 ml water. Process the fortified sample as described before to determine the percent recovery.

2.4 HPLC:

The following conditions apply:

column: Bondapak C_{18}/Corasil, particle size 37-50 microns
1/8 inch OD x 2 ft (2 mm ID x 61 cm)

solvent: 40% acetonitrile/60% water (degassed)

flowrate: 0.3-0.6 ml/minute

sensitivity: 0.005 AUFS

recorder: 10 mV

chart speed: 0.25 inches/minute

Construct a standard curve based on peak height with 1 µl injections of standard solutions containing 5, 10, 15, 20, and 30 µg of carbaryl per ml acetonitrile.

After proper dilution of the sample inject 1 to 10 µl and find the amount of carbaryl by comparison of the peak height with the standard curve.

2.5 Calculations

The residue in parts per million (ppm) is calculated as follows:

$$ppm = \frac{A}{B} \div R \text{ where}$$

A = amount of injected carbaryl found in ng.

$$B = \text{aliquot in mg used for analysis} \times \frac{\mu l \text{ injected}}{\mu l \text{ final volume}}$$

C = recovery factor expressed as decimal (i.e. 100% = 1.0, 90% = .9, etc.)

After 3 to 5 sample injections check for any change in sensitivity of the HPLC system.

2.6 Results

2.6.1 Foliage

2.6.1.1 Controls

Chromatograms of control samples of grass, Geranium sp., Douglas-fir and aspen were free of interferences at the retention time of carbaryl. Interfering peaks did occur with snowberry foliage.

2.6.1.2 Recoveries

At the 5 ppm fortification level the following percent recoveries were obtained.

Grass: 90.0, 89.0

Geranium: 86.5, 86.5

Douglas-fir: 47.0, 48.5, 54.0

Aspen: 74.0, 76.0

Recoveries of carbaryl from Douglas-fir foliage were poor. Degradation of carbaryl may have occurred during the 7 month's storage period. Recoveries from freshly fortified Douglas-fir extract were about 100%.

2.6.2 Water

2.6.2.1 Controls

No interfering peaks occurred at the retention time of carbaryl. However, certain materials still present in the final preparation often lead to a drop in sensitivity of the HPLC system.

2.6.2.2 Recoveries from creek water samples fortified at the 0.1 ppm were 100, 102, and 97%.

2.7 Conclusions and recommendations

The described methods are relatively short and solvent requirements are modest. Some modifications could improve the methods. An extra clean-up step for water samples, perhaps liquid-liquid partition, could remove substances affecting the HPLC system. Recoveries from foliage could be improved by shortening the storage period or perhaps by slightly acidifying the samples in storage.

3. Residues of carbaryl in field samples

3.1 Foliage

Two analyses were performed on each field sample. The results corrected for percent recovery are listed in table 1.

3.2 Creek Water

Each sample was analyzed once. The results are listed in table 2.

3.3 Discussion

Since an extraction technique of the foliage by "wash-off" was adopted, the substrate could not be homogenized before division into subsamples. This may explain some of the large differences in residues found between replicate analyses.

Table 1. Residues of carbaryl in forest foliage (ppm).

Time after spray	Grass			Geranium			Douglas-fir			Aspen		
	1	2	Ave.	1	2	Ave.	1	2	Ave.	1	2	Ave.
1-2 hrs.	89.4	51.1	70.3	226.6	107.5	167.1	103.4	173.1	138.3	30.8	28.7	29.4
1 day	50.8	60.9	55.9	92.8	104.0	98.4	133.5	113.4	123.5	39.7	19.7	29.7
3 days	76.0	54.2	65.1	109.8	97.2	103.5	48.7	39.4	44.1	16.7	16.3	16.5
7 days	51.7	39.9	45.8	72.8	44.8	58.8	66.2	68.2	67.2	5.4	17.2	11.3
14 days	16.8	24.9	20.9	35.8	11.7	23.8	18.1	38.5	28.3	10.7	21.7	16.2
28 days	0.3	0.3	0.3	3.6	2.0	2.8	3.5	4.4	4.0	3.4	9.9	6.7
47 days	0	0.1	0.1	0.2	0.2	0.2	5.4	3.6	4.5	2.5	2.2	2.4
67 days	0	0	0	0.1	< 0.1	< 0.1	0.6	7.6	3.8	0.5	0.4	0.5

Table 2. Residues of carbaryl in creek water.

Daisy Creek Sample ID		ppm
1	6:10	.004
2	6:25	.003
3	6:45	.003
4	7:05	.004
5	7:25	.006
6	7:45	.004

Lenard Creek Sample ID		ppm
1	6:55	.003
2	7:15	.006
3	7:39	.160
4	7:55	.175
5	8:15	.085
6	8:35	.003

Middle Fork Warm Springs		
1	6:45	.002
2	7:25	.003
3	7:45	.007
4	8:05	.006
5	8:25	.011
6	9:00	.240
7	9:30	.260

Ruby Creek		
1	7:05	.108
2	7:25	.062
3	7:45	.012
4	8:05	.007
5	8:25	.004

RESULTS OF RESIDUE ANALYSIS[1/] ON FISH AND AQUATIC ORGANISMS[2/]

Carbaryl

Aquatic insects	P.p.m. carbaryl
13 Stoneflies (10 hr., Daisy Creek)	0
29 Mayflies (10 hr., Daisy Creek)	0
29 Mayflies (10 hr., Leonard Creek)	0
29 Mayflies (10 hr., S. Meadow Fork Creek)	0
Drift sample, Ruby Creek A	0
Drift sample, Ruby Creek B	0
19 Mayflies, Ruby Creek D	0
20 Mayflies, Ruby Creek B	0
20 Mayflies, Ruby Creek C	0
18 Mayflies, Middle Fork Warm Springs Creek	0
11 Drift samples, 3 hr., Middle Fork Warm Springs Creek	0

Fish	
7 Fish, 11 hr., Block 2	0
7 Fish, 11 hr., Block 8	0
5 Fish, 52 hr., Block 6	0
6 Fish, 75 hr., Block 8	0
Fish food (from hatchery)	0.46

Trichlorfon

Aquatic insects	P.p.m. trichlorfon
4 Mayflies, 80 hr., Sawlog Creek	9.60
17 Mayflies, 25 hr., South Fork Warm Springs Creek	2.80
17 Stoneflies, 80 hr., Warm Springs Creek, Station C	6.00
4 Mayflies, ?, Warm Springs Creek	4.80
16 Mayflies, 80 hr., Warm Springs Creek, Station A	.50
16 Mayflies, ?, Warm Springs Creek, Station D	2.20

Fish	
7 Fish, 25 hr., Block 7	.03[3/]
Fish food (from hatchery)	.01[3/]

1/ Method: A.O.A.C. 24.188, p. 407, 11th Ed. (1971)
2/ Analysis done by Warf Institute, Inc., Madison, Wisconsin
3/ Limit of detection 0.01 p.p.m., other samples 0.50 p.p.m.

Table: Brain cholinesterase activities in rainbow trout exposed to Sevin-4-oil or Dylox

Treatment	Control	Sevin 4 hr exp.	Sevin 4 hr exp.	Sevin 11 hr exp.	Sevin 11 hr exp.	Dylox 3 hr exp.
Source	Ennis Fish Hatchery	Middle Fk Warm Spring Cr.	Ruby Cr. Station A Upper	South Fk Meadow Cr. Daisy Cr. Station A	South Fk Meadow Cr. Leonard Cr. Station C	South Fk Warm Spring Cr.
Block	-	6	8	2	2	7
$\bar{x}$	15.3	10.8	15.6	17.4	15.3	12.2
S.D.	1.4	0.8	1.6	1.6	3.0	0.7
N	5	4	4	5	8	5

United States Department of the Interior
FISH AND WILDLIFE SERVICE
DENVER WILDLIFE RESEARCH CENTER
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DENVER, COLORADO 80225

WRes-EP
March 16, 1976

Mr. Gordon Haugen
Gallatin National Forest
P. O. Box 130
Bozeman, Montana 59715

Dear Gordon:

I am sorry it has taken me so long to get the results of the rainbow trout cholinesterase activities to you. As you can see, there only seem to be two sprays that had any effect on the fish. There was the 4-hour exposure to Sevin in the Middle Fork of Warm Springs Creek * and the 3-hour exposure to Dylox on the South Fork of Warm Springs Creek. Perhaps the relatively slow movement and small volume of the water in these areas might have combined to give a greater exposure to the compounds for a longer period of time, thus causing the depression. These values should be considered significant depressions when final evaluations of the effects of the spray are undertaken.

Sincerely,

Joseph G. Zinkl
Physiologist

Attachment

* Stream Discharge < 5 CFS + Temp 47 - 56 °F during application

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