

SPRUCE BEETLE SUPPRESSION WITH
FELLED LETHAL TRAP TREES IN
CENTRAL BRITISH COLUMBIA IN 1981

by

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Abstract

MSMA (Glowon[®]) at a rate of 160 g/l (a.i.) was applied to basal frills on standing spruce, Picea engelmannii x glauca (Kirby) in May in British Columbia. Trees were felled 2 weeks later, and were subsequently lethal to attacking spruce beetle, Dendroctonus rufipennis (Kirby). When assessed 3 months after treatment, MSMA had reduced egg gallery lengths by 53% and caused a 98% failure of egg galleries. MSMA also killed at least 27% of parent adults that remained in treated trees, and there were over 98% fewer larvae found in treated trees. Treated trees repelled 28% of attacking beetles from excavating entrance holes. Chlorpyrifos (Dursban-4E[®] 2% a.i.) sprayed on untreated felled trap trees 5 months after beetle attack, fumigated 63-74% of parent adults and brood.

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SPRUCE BEETLE SUPPRESSION WITH FELLED LETHAL TRAP TREES IN CENTRAL BRITISH COLUMBIA IN 1981

I. INTRODUCTION

The spruce beetle, Dendroctonus rufipennis (Kirby) is the most destructive pest of spruce (Picea sp.) forests in western North America (Schmid and Frye 1977). In the Province of British Columbia in 1981 and 1982, 84 090 ha and 99 300 ha of spruce were infested to various degrees, respectively. Of these totals, 59 048 ha and 57 455 ha of damage occurred in the Prince George Forest Region, respectively (Fiddick and Van Sickle 1982, Wood and Van Sickle 1983).

Spruce beetle control methods have included removal of both freshly attacked timber and felled trap trees, and burning or insecticide treatment of standing or felled trees. Suppression activities have been difficult because of the large tree sizes infested, expensive equipment, transportation and labour costs, and critical timing (Frye and Wygant 1971).

During the past decade, use and refinement of spruce beetle trap tree methodology has received emphasis. Felled trap trees are living, large diameter spruce which are felled to attract spruce beetles (Nagel et al. 1957). Trap trees felled into the shade and left unbuckled and unlimbed can absorb up to 10 times the number of beetles a standing tree can absorb (Wygant 1960).

The lethal trap tree technique is a recent modification of the original felled trap tree method of Nagel et al. (1957). Lethal traps are created by applying the silvicide MSMA¹ (monosodium methane arsenate) into the axe-frilled xylem tissue of living, large diameter spruce. Injected trees are later felled, and when attacked by spruce beetles, the adults and any subsequent brood are killed by the toxicant (Lister et al. 1976).

Some advantages to this strategy are: (1) use in off-road or inaccessible areas where subsequent trap tree extraction is difficult or impossible, (2) ease of application, (3) inexpensive labour and equipment costs (compared to tree removal, bark peeling, burning or topically-applying insecticides), (4) relatively safe for both applicator and environment, and (5) lower hazard to non-target insects and other organisms than applying fumigant insecticides to the bark exterior (Chansler and Pierce 1966, Frye and Wygant 1971, Minnemeyer 1975).

Injection of tree-killing silvicides into the xylem tissue of trees to destroy attacking bark beetles is not a new idea. Bedard (1938) discovered that copper sulphate was 90% effective against mountain pine beetle, Dendroctonus ponderosae Hopkins in western white pine, Pinus monticola Doug. Craighead and St. George (1938), Mathers (1947), and Lekander (1952) tested other herbicides such as zinc chloride and sodium-based compounds with some positive results.

1. Commercially available product called Glowon[®] from Later's Chemical Ltd., Richmond, B.C. (see Table 1, footnote g)

Kinghorn (1955) injected two systemic insecticides, schraden² and demeton³ into freshly-attacked lodgepole pine, Pinus contorta Dougl. to kill mountain pine beetle. Unfortunately, the rapid penetration of the xylem by blue stain fungi impaired insecticide translocation.

Chansler and Pierce (1966) first achieved success in suppressing broods of spruce beetle, mountain pine beetle and other Dendroctonus species in standing trees by injecting full-strength cacodylic acid⁴ (dimethylarsinic acid). McGheley and Nagel (1967) found that Silvisar 510[®] injected into western hemlock, Tsuga heterophylla (Raf.) was highly effective in killing broods of the silver fir beetle, Pseudohylesinus sericeus (Mannerheim) (= P. grandis Swaine) and P. tsugae Swaine.

Further successful testing of cacodylic acid against mountain pine beetle has been conducted by Chansler et al. (1970), Stevens et al. (1974), and Dyer and Hall (1979). In addition, cacodylic acid has also proved lethal against the Arizona fivespined ips, Ips lecontei Swaine (Stelzer 1970), the roundheaded pine beetle, D. adjunctus Blandford (Buffam and Flake 1971), and the pine engraver, Ips pini (Say) (Newton and Holt 1971).

2. Systam[®] no longer commercially manufactured by Murphy Chemical Co.

3. Commercially available product called Systox[®] from Chemagro Ltd., Mississauga, Ontario.

4. Common name of the herbicide marketed as Silvisar 510[®] by the Ansul Co. containing 680 g/l a.i. (5.7 lbs./U.S. gal).

Since Chansler and Pierce's (1966) first experiment, arsenic-containing silvicides have had most use and success, however, against spruce beetle. Table 1 summarizes all the research to date on silvicide-injected trap trees for spruce beetle control.

Studies by Buffam (1971), Buffam et al. (1973), Minnemeyer (1975), Lister et al. (1976), and Frye et al. (1977) demonstrated that a dosage of 1/2-strength Silvisar 510[®] killed 90-99% of spruce beetle broods in felled trap trees. At this dosage, only Lister et al. (1976) recorded spruce beetle attack repellency (in 6 of 7 trap tree sample locations). Based on these findings and other unpublished Provincial reports, a study was undertaken to test the efficacy of Glowon[®] (Table 1, footnote g) - the MSMA product registered for use and available in British Columbia.

II. METHODS

The experiment was incorporated into an operational, felled lethal trap tree project in the Herrick Creek drainage, 115 km to the northeast of Prince George, British Columbia. A total spruce volume of 8 million m³ (64% of all mature species) in the 70 km-long drainage had become increasingly threatened by expanding pockets of spruce beetle since first noted in 1978. During the winter of 1980-81, ground reconnaissance indicated a substantial beetle population increase and potential epidemic.

By felling a series of lethal trap trees in the spring of 1981 (in the first year of a 2-3 year program), an attempt was made to decoy some of the attacking spruce beetle population into felled lethal trap trees.

A. MSMA Application

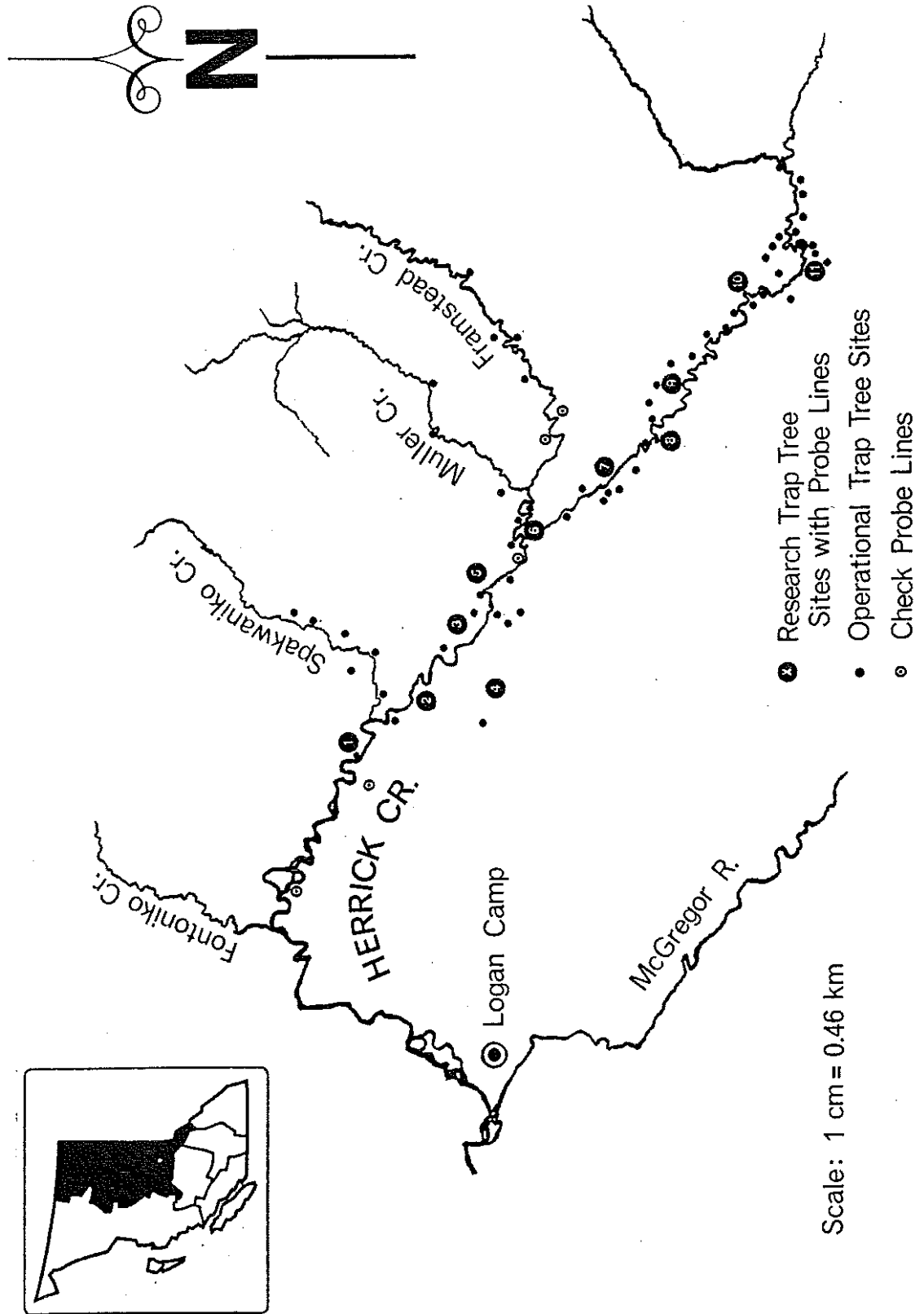
From May 11-14, 1981, a total of 670 standing Engelmann spruce, Picea engelmannii x glauca (Kirby) were numbered, axe-frilled and treated with 1/2-strength MSMA (160 g/l a.i.) in 72 locations along the Herrick Creek and its tributaries (Fig. 1). A total of 11 research sites were randomly chosen from the 72 locations. In each of the latter, 10 trees (5 pairs) were selected; 5 were axe-frilled and treated with 1/2-strength MSMA, the other 5 randomly-chosen trees were axe-frilled but left untreated (Table 2).

The MSMA formulation used was Glowon[®] diluted to 50% strength with water. For ease of storage in the helicopter, the pesticide was pre-mixed and transported in 22.7 l plastic fuel containers. The various project crews were accommodated at excellent facilities of the nearby Logan Camp⁵ - a 30 minute helicopter trip from the farthest plot.

A Bell-206 helicopter continually airlifted 4 2-person crews in and out of pre-designated helispots along the drainage. Within 0.3 km of the helispot, the crew selected and marked with spray paint 10 large diameter

⁵ Northwood Pulp and Timber Ltd., Prince George, B.C.

Fig.1 Location of Felled Lethal Trap Trees in Herrick Creek Drainage in 1981



spruce in a 0.10 ha area. One crew member then axed a shallow bark frill (just cutting the cambium) around the base of each tree. The second crewperson carefully applied MSMA into the frill with a 500 ml polyethylene squeeze bottle. A calibration label attached to the bottle ensured proper dosage delivery (Fig. 2). The solution was applied at the rate of approx. 1 ml/2.54 cm of tree circumference (1/2 ml a.i.).

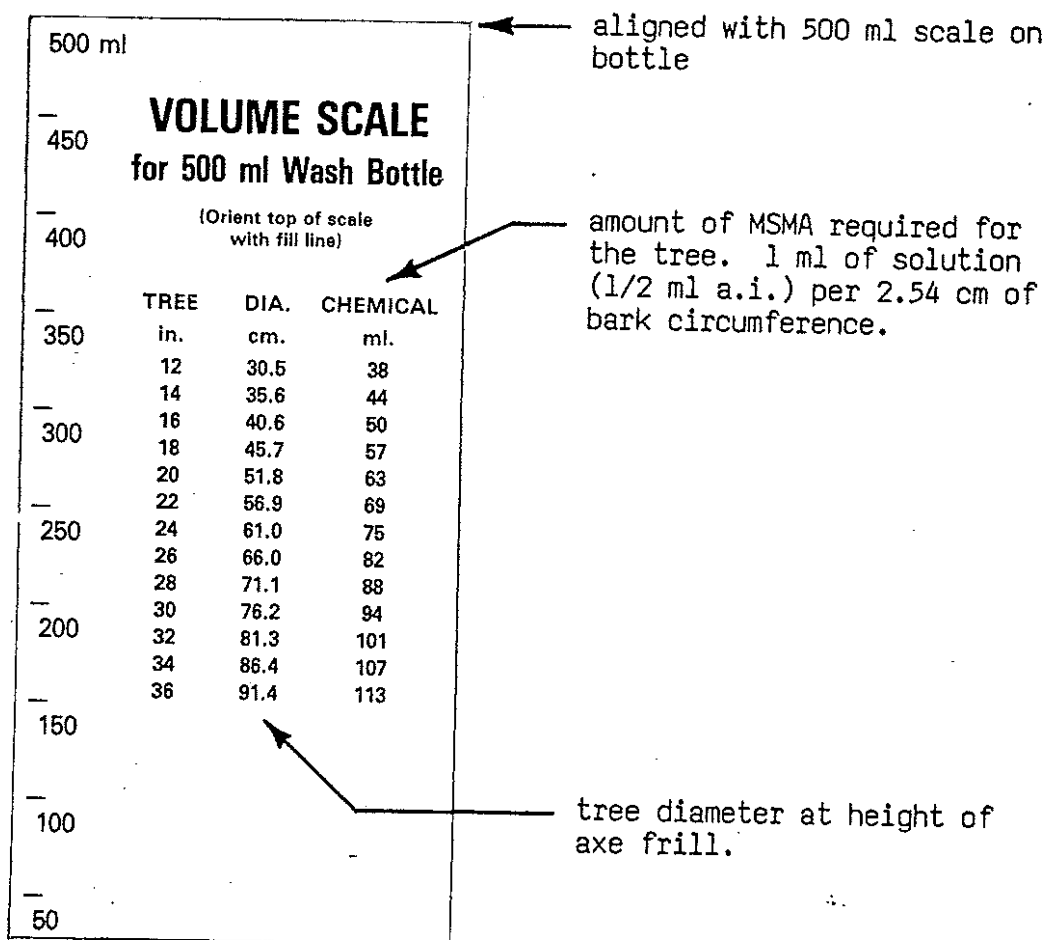
Injected standing spruce were left for 2 weeks to allow translocation of the MSMA (Buffam 1971), and then were felled during May 25-28. A portable hygrothermograph was set up on site 6 (Fig. 1) on May 26 to aid in determining the date of the spruce beetle flight.

B. MSMA Efficacy Sampling

Felled lethal and check trap trees on the 11 research sites were sampled for brood survival by a 2-person crew during Aug. 11-18. Four 20 cm x 20 cm bark samples were cut from each of the 10 trap trees per site. Samples were taken in pairs on opposite sides of the tree below the midline at: (1) 3 m from the butt end, and (2) at approx. 20 m from the butt end where the tree diameter equalled approx. 20 cm. Data recorded were: (1) trap tree dbh, (2) entrance holes, (3) successful egg galleries, (4) egg gallery lengths, (5) larval and adult survival, and (6) presence of secondary beetles and other insects.

Fig. 2

Calibration Label Attached to MSMA Application Bottle



C. Arsenic Sampling

A 2.5 cm x 7.5 cm phloem sample was cut at 20 m up from the butt end on 1 treated and 1 check trap tree in each of 9 sites between June 9-11, 1982 for an analysis of both translocated and natural levels of arsenic. These samples were wrapped in aluminum foil and frozen prior to X.E.S.⁶ analysis at the Faculty of Forestry, University of British Columbia in Vancouver, B.C.

D. Chlorpyrifos⁷ Application

On completion of the MSMA efficacy sampling, the surviving broods in the 5 check trap trees and stumps on each of the 11 sites had to be destroyed. A Research Pesticide Use Permit was obtained from the Provincial Pesticide Control Branch for experimental topical application of the organophosphate insecticide chlorpyrifos (Dursban-4E[®] 2% a.i. in type 3, winter grade diesel oil) to fumigate parent adults and brood under the bark.

From October 14-16, 1981, prior to application, 4 of 5 check trap trees in each site were delimbed and the lopped branches were pulled away from the trap trees and stumps to allow walking access along each side of the bole for the chlorpyrifos applicator. One of the 5 check trap trees in each site was left untreated to serve as a check for assessing chlorpyrifos efficacy.

⁶X-ray Energy Dispersive Spectroscopy

⁷Commerically available product called Dursban-4E[®] from Dow Chemical of Canada Ltd., Vancouver, B.C.

Boxes of chlorpyrifos (16 480 ml bottles/box, 48% a.i.) and several 205 l drums of diesel oil were trucked into the Logan Camp for mixing. The formulation was transported in the helicopter and carried into the sites in 22.73 l plastic fuel containers.

Chlorpyrifos was applied during October 20-21 and November 4-6, 1981 by one 3- and 4-person crew, respectively. The crew consisted of 2 applicators and 1-2 assistants. Before application, the assistant(s) used a corn broom to sweep away loose sawdust, debris (and in one instance a light dusting of snow) on the stumps and top edges of the trap trees. The formulation was applied to the drip point from 2 manually-pressurized backpack sprayers (13.6 l capacity) with a fan nozzlehead. Insecticide coverage of the beetle-infested portion of the boles was good, and it was not deemed cost-efficient to buck and roll sections of the traps in order to achieve additional coverage.

E. Chlorpyrifos Efficacy Sampling

From June 9-11, 1982, a portion of the chlorpyrifos-treated trap trees were sampled for determination of efficacy. In each of 10 sites, a chlorpyrifos-treated trap tree and a check trap tree were sampled. The trap tree sampling procedure was the same as outlined in II.B, except that these bark samples were removed 50 cm closer to the butt. This was done to avoid sampling potentially extra dry phloem adjacent to previously-cut efficacy samples.

F. Probe Lines

To assess the effectiveness of lethal trap trees in protecting adjacent standing timber from spruce beetle attack in 1981, a series of probe lines and prism plots (B.A.F. 5) were established around the 11 research sites. An additional 5 "check" probe sites were randomly established in helicopter-accessible locations in the drainage. Four of the 5 check sites were established at least 0.8 km away from any lethal trap trees. Fig. 3 depicts the probe line configuration for both the 11 "research" and 5 "check" sites, and Fig. 1 shows their locations.

Probe line data was collected on November 12-13, 1981 in timber adjacent to research plots, and on April 26-30, 1982 for the check plots.

III. RESULTS AND DISCUSSION

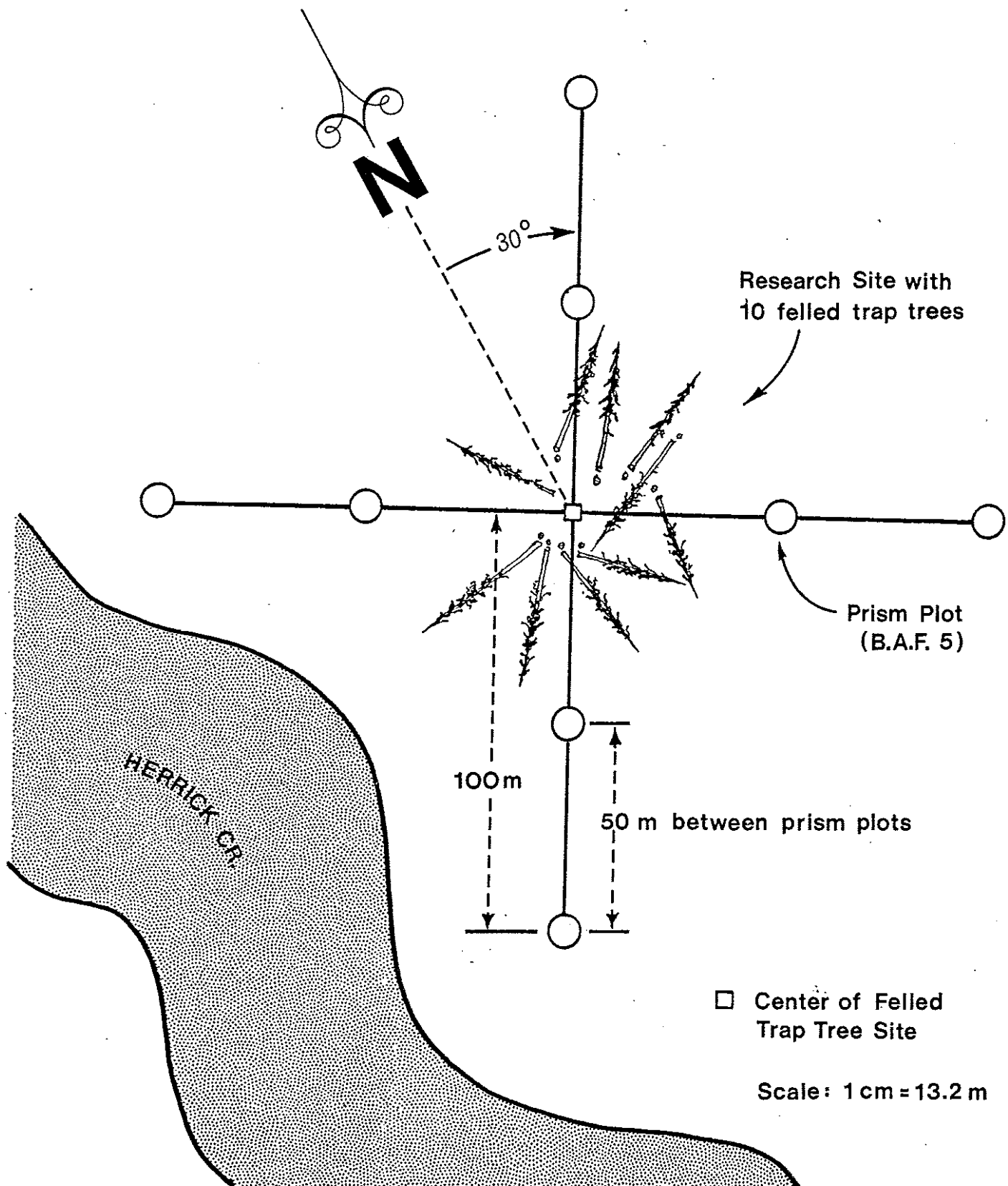
A. MSMA Application and Total Costs

The mean d.b.h. of felled trap trees⁸ was 42 ± 8 cm. The mean diameter of MSMA-injected spruce at the frill line was 47 cm (approximately 5 cm more diameter than at d.b.h.). A mean of 58 ml of MSMA formulation (160 g/l) was applied to the frill line of this average diameter tree. Cost of MSMA (alone) per tree averaged 23¢⁹.

⁸ Based on 110 trap trees from 11 sites

⁹ Glowon[®] (320 g/l) cost \$7.84/l in May 1981.

Fig. 3 Probe Line Prism Plot Configuration



Walking to and from the helicopter and selecting, marking, axe-frilling and injecting 10 large diameter spruce took approx. 1 hour for a 2-person crew (approx. 6 minutes/tree). With nearby helicopter refuelling sites available, maximum work efficiency was achieved with three 2-person field crews and a full-time air co-ordinator in the helicopter.

Two weeks after injection, the felling and remarking of the 10 lethal trap trees per site, and return to the helicopter, took approximately 30 minutes for a faller and his assistant.

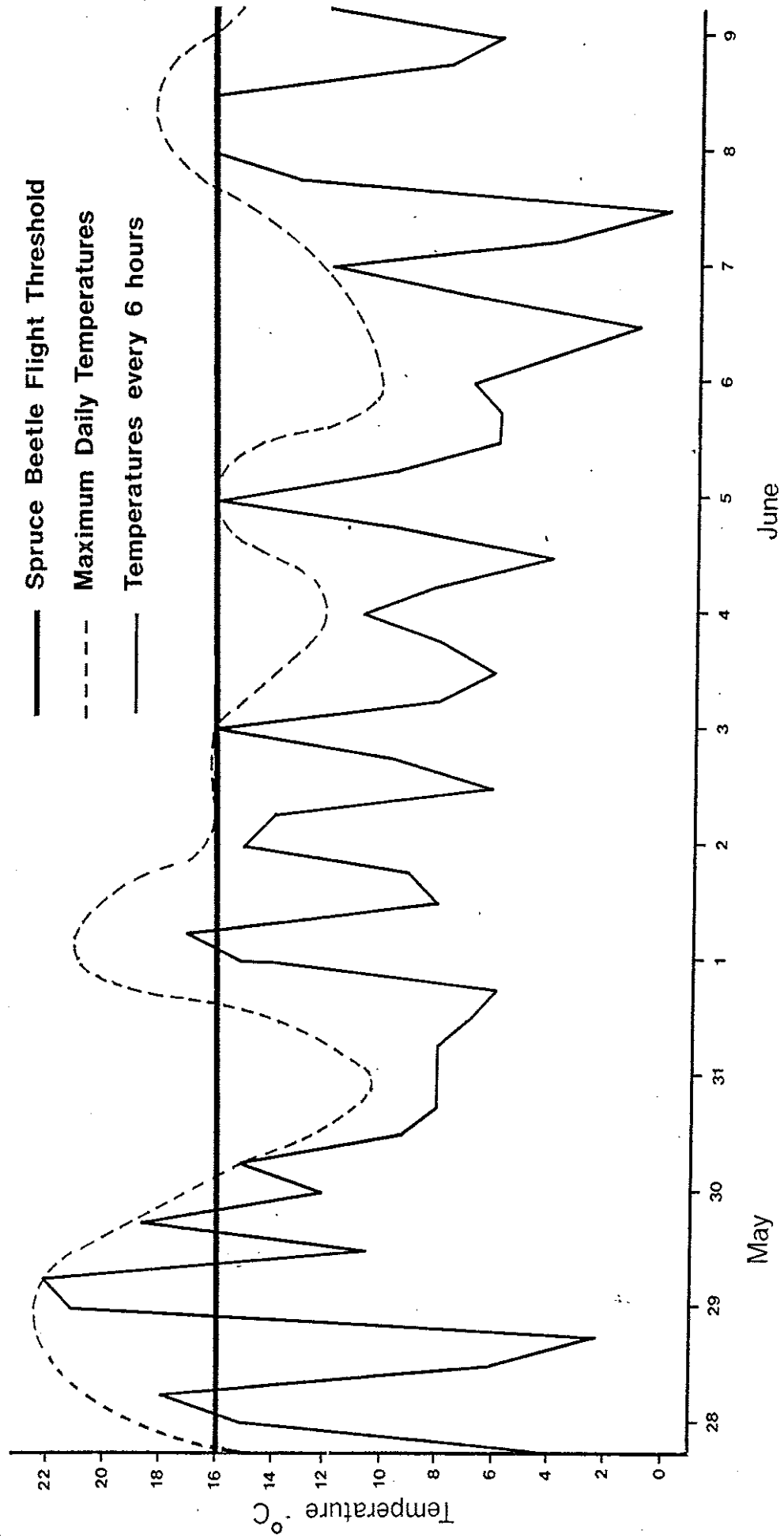
Total cost of the operational project (excluding chlorpyrifos application and all efficacy assessments) was \$46.15 per felled lethal trap tree (Table 3).

B. Spruce Beetle Emergence

The portable hygrothermograph recorded data from May 26 to June 19, 1981; Figure 4 illustrates the temperatures between May 28 (the date the last trap trees were felled), and June 8 (the date of an assessment field trip). The latter field trip to site 6 revealed fresh spruce beetle entrance holes and egg galleries of an average 2.5 cm in length in felled check trap trees.

Dyer (1973) reported that spruce beetle emergence can occur in May when the maximum temperatures in the shade exceed the approximate flight threshold temperature of 16⁰ C. Considering the daily temperatures above 16⁰ C (Fig. 4) and the 2.5 cm galleries observed on June 8, it is assumed that the spruce beetle flight commenced between May 28-June 3.

Fig. 4 Temperatures in Herrick Creek During Initiation of Spruce Beetle Flight in 1981



C. MSMA Efficacy

The mean of 2.39 spruce beetles attacking 400 cm² bark samples on MSMA-treated trap trees was significantly less than the mean of 3.34 beetles attacking check trap trees (Table 4). Table 4 suggests that 28% of the attacking beetle population was repelled from initiating attack on treated trap trees, or they simply found adjacent untreated trap trees more attractive.

Lister et al. (1976) found that 1/2-strength Silvisar-510[®] repelled 34% of attacking spruce beetles away from felled lethal trap trees. However, no repellency was observed when 1/2-strength Silvisar-510[®] was tested by Buffam (1971), Buffam et al. (1973), Minnemeyer (1975), or Frye et al. (1977) (Table 1). Repellency may depend in part on population densities of attacking beetles and/or arsenic concentrations in phloem. The latter is discussed in Sect. III D.

MSMA-treated trap trees had a significantly lower mean number of successful spruce beetle egg galleries¹⁰ (0.09 per 400 cm² bark surface) than those found in check trap trees (3.87) - a 98% difference (Table 5). Mean spruce beetle gallery lengths of 4.03 cm in treated trap trees were only 47% as long as those found in check trees.

A mean of 52.28 live larvae per bark sample were found in check trap trees compared to 0.79 larvae in treated trees - a 98.49% difference (Table 5). Percent natural mortality of larvae was 0.15% (Table 6).

¹⁰ A successful spruce beetle egg gallery is defined as one having laterally-branching larval galleries.

During efficacy sampling from August 11-18, spruce beetle development in check trap trees ranged from eggs to callow adults (depending on site, shading, date of initial parent attack, etc...). Mean stage of spruce beetle development was 3rd instar.

Although spruce beetle eggs were not counted per unit of bark sample, their presence per trap tree revealed that 25% of check trees contained what appeared to be viable eggs, while only 0.02% of treated trees contained viable eggs. Inviabile eggs were found in 0.07% of treated trees, and none were detectable in the heavily, larval-damaged phloem of check trees.

A mean of 3.32 living and dead parent adults per bark sample were found in check trap trees compared to 1.72 in treated trees - a 48.19% difference (Tables 5,6). Therefore, 48.19% of attacking beetles were repelled either before or during gallery construction (Table 6).

If 28% of beetles were repelled from treated trees before constructing galleries (Table 4), (then $48\% - 28\% = 20\%$). Therefore, 20% of beetles that excavated partial galleries, eventually left the tree. It is not known if MSMA toxicity prevented these latter beetles from successfully attacking other host material.

Percent natural mortality of parent adults that remained in trap trees was 4.82% (Table 6). Percent mortality of adults that remained in treated trees (from MSMA) was 26.74% at the time of efficacy sampling (Table 6).

A large unquantified percentage of the additional parent adults that remained in treated trees appeared moribund. Eventual percent mortality of the latter group from MSMA toxicity was probably very high.

D. Arsenic Analysis

The quantity of translocated arsenic (contained in silvicides) in felled lethal trap trees is one of the main factors influencing spruce beetle attack densities (Lister et al. 1976). The mean concentration of arsenic translocated to the 20 m level in treated trap tree phloem (24.7 ± 7.3 ppm) was significantly higher than the natural trace levels found in check tree phloem (1.4 ± 1.1 ppm). Table 7 compares arsenic levels and percent repellencies in this study to those of Buffam et al. (1973) and Lister et al. (1976).

The efficiency of translocation and subsequent repellency in this study were higher than those achieved with a similar dosage by Lister et al. 1976. It is interesting that Buffam et al. (1973) injected a higher dosage of silvicide (340 g/l of Silvisar-510[®]) than in our study, obtained a similar phloem arsenic concentration (26.15 ppm), yet observed no repellency.

The somewhat higher beetle attack densities on check trap trees in Buffam et al. (1973) (3.95 attacks/400 cm² bark surface) compared to those in this study (3.34 attacks/400 cm² bark surface) would not seem to adequately explain Buffam's complete lack of repellency. Other dosages and repellencies are depicted in Table 1.

E. Chlorpyrifos Efficacy

The total volume of chlorpyrifos formulation (2% a.i. in diesel oil) required to treat 1 felled trap tree and stump to the drip point was approx. 23-30 l (depending on tree d.b.h. and length). Treatment time per trap tree, including re-filling time, was approx. 30 minutes per applicator.

Efficacy sampling occurred during June 9-11, 1982, 8 months after the chlorpyrifos application. Over the winter of 1981/82, a maximum of approx. 2 m of snow covered these treated trees. Chlorpyrifos fumigated 63% of larvae, 74% of callow adults, and 64% of parent adults. Natural mortality of the overwintering larvae and callow adults was 26% (Tables 8,9).

McCambridge and Knight (1972) recorded a 17% natural mortality rate of spruce beetle brood overwintering in snow-covered trap trees. It is surmised that if the natural mortality had been less in our experiment, chlorpyrifos efficacy would have shown a higher percent toxicity against the various surviving life stages.

F. Probe Line Assessment

Table 10 shows data collected from probe line prism plots adjacent to the 11 lethal trap tree research sites in the Herrick Creek. Of the mean of 4.1 spruce per prism plot, only a mean of 0.01 spruce (or ^{0.002}0.24%) were strip-attacked by spruce beetle in areas adjacent to trap trees in 1981.

(1-1/4)

Table 11 depicts the same information collected from probe line prism plots in 5 "check" (untreated) locations of the Herrick Creek. Four of these 5 randomly selected locations were able to be chosen at least 0.8 km distant from any trap tree sites so as to minimize possible natural pheromone interference. Of the mean of 3.9 spruce trees per prism plot, a mean of 0.05 spruce (or 1.28%) were heavily attacked by spruce beetle in check areas.

Although overall beetle attack densities were low in the drainage in 1981, they were 5.3 times higher and more severe in check areas than in areas protected by felled trap trees. Unfortunately, this could not be verified statistically because of the low level of spruce beetle attack in the drainage in 1981.

IV. SUMMARY AND CONCLUSIONS

The silvicide MSMA (Glowon[®]) was applied at the rate of 160 g/l to basal frills on standing spruce in May in British Columbia. Trees were felled 2 weeks later after complete translocation of MSMA. When attacked by spruce beetles, MSMA-treated felled trap trees:

- (i) repelled as many as 28% of parent adults from initiating attack,
- (ii) repelled a further 20% of the parent adults that had excavated partial egg galleries,
- (iii) reduced egg gallery success by 98%,
- (iv) reduced egg gallery lengths by 53%,

- (v) reduced the presence of larvae by 98%, and
- (vi) killed at least 27% of parent adults which remained in treated trees.

Therefore, MSMA at 160 g/l a.i. (mean of 23.3 ppm translocated arsenic) had a very toxic impact on the survival, mating and fecundity of parent adults which attacked and remained in felled treated trap trees. Total deployment cost was \$46.15 per felled lethal trap tree.

Lower dosages of MSMA were tested in 1982 in the hope of achieving a similar or acceptable efficacy without repelling as many attacking adults. The latter results are in press.

Chlorpyrifos (2% a.i. in diesel oil) sprayed on untreated felled trap trees 5 months after spruce beetle attack, fumigated 63-74% of parent adults and brood. It is assumed that if the high natural mortality of 26-31% had been lower, the chlorpyrifos would have killed a higher percentage of the surviving adults and brood.

Spruce beetle attack densities in healthy standing spruce were 5.3 times higher and more severe in check areas of the drainage than in areas protected by felled lethal trap trees. Unfortunately, this could not be verified statistically because of the low level of spruce beetle attack in the drainage in 1981.

V. RECOMMENDATIONS

1. Based on the results of this study and others, it was recommended that MSMA receive a minor-use registration for control of spruce beetle in lethal trap trees in British Columbia as soon as possible. This was obtained in February 1983.
2. It was recommended that MSMA be re-tested in 1982 at 1/2-strength dosage and at lower dosages of 1/4- and 3/8- strength. It was hoped that the lower dosages would reduce spruce beetle attack-repellency without significantly compromising MSMA efficacy (Results of the 1982 study are in press).
3. It was recommended that chlorpyrifos (2% a.i. in diesel oil) be re-tested in 1982 to confirm its efficacy in fumigating spruce beetle broods in felled trap trees. Diesel oil alone was also recommended for re-testing.
4. To conclusively test the value of felled trap trees in protecting adjacent standing timber, it was suggested that probe lines (with prism plots) be extended to 400 meters around treated and check sites in 1982. It was hoped that the increased number of prism plots at farther distances would allow collection of significant comparative data - even if beetle attack density was low.

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Table 2

Number of Felled Trap Trees in Herrick Creek Drainage 1981

Purpose	Number of Trap Tree Sites	Number of Lethal Trap Trees	Number of Check Trap Trees
Operational	61	615 ^a	-
Research	11	55 ^b	55 ^b
Total	72 ^c	670	55

a approx. 10 trees/site

b 5 trees/site

c 70 helicopter landing locations; two locations had 2 trap trees sites each.

Table 3

Costs of Felled Lethal Trap Tree Deployment
in Herrick Creek in 1981*

1. MSMA Application Costs

- wages of 9 Forest Service Staff of various pay rates (370 man-hours)	\$3656.39
- 40 man-days of room and board @ \$25.00/day	1000.00
- MSMA cost at \$0.23/tree x 725 trees	166.75
- 5 vehicles @ \$15.00/day x 20 days	300.00
Total	= \$5123.14

Cost of MSMA application per lethal trap tree = \$7.07

2. Lethal Trap Tree Felling Costs

- 4 fallers @ \$17.32/hr. x 142.5 man-hours	\$2468.10
- saw rental	180.00
- chainsaw fuel and oil	100.00
- wages of 5 Forest Service staff of various pay rates (185 man-hours)	1879.19
- 40 man-days room and board @ 25.00/day	1000.00
- 3 vehicles @ 15.00/day x 12 days	180.00
Total	= \$5807.29

Cost of felling per lethal trap tree = \$8.01

3. Helicopter Transportation Costs

- 1 Bell 206B Jet Ranger III @ \$ 475.00/hr. x 47 hrs. (including fuel and oil)	\$22235.00
- 8 man-days room and board for pilot @ 25.00/day	200.00
Total	= \$22525.00

Cost of helicopter transportation per tree = \$31.07

Total cost of project per felled lethal trap tree = \$46.15

* Excludes chlorpyrifos application and all efficacy sampling

Table 4

Comparison of the Number of Spruce Beetle Attacks on MSMA-Treated
and Untreated Felled Trap Trees

Trap Tree Sampling Locations	Mean No. of Spruce Beetle Entrance Holes per 400 cm ² of Bark Surface		% Repellency ^e or Unattractiveness
	Treated	Check	
1. whole tree ^a comparison	2.39 ± 0.94 ^d	3.34 ± 0.96	28
2. upper bole ^b comparison	2.41 ± 1.32	3.42 ± 1.18	30
3. lower bole ^c comparison	2.40 ± 0.99	3.22 ± 1.12	26

- a Based on the $\bar{x}$ data from four 400 cm² bark samples per trap tree (53 trap tree pairs).
- b Based on the $\bar{x}$ data from two 400 cm² bark samples on the upper bole of each of 53 trap tree pairs.
- c Based on the $\bar{x}$ data from two 400 cm² bark samples on the lower bole of each of 53 trap tree pairs.
- d All paired means within comparisons are significantly different at $p < 0.001$ ($\pm$ Standard Errors) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972).
- e Percent repellency is defined as a significant difference between the mean number of beetle attacks in treated and untreated trap trees.

Table 5

Effects of MSMA on Spruce Beetle Egg Galleries, Larvae and Parent Adults

Data Collected	Means ($\bar{x}$) ^{a, b}		Percent Difference
	Treated	Check	
<u>Egg Galleries</u>			
No. of Successful	0.09 $\pm$ 0.52*	3.87 $\pm$ 1.22*	98%
Length in cm	4.03 $\pm$ 1.18*	8.62 $\pm$ 1.27*	53%
<u>Number of Larvae</u>			
Living	0.66 $\pm$ 4.59*	52.20 $\pm$ 26.11*	-
Dead	<u>0.13 $\pm$ 0.72</u>	<u>0.08 $\pm$ 0.33</u>	-
Total	0.79	52.28	98%
<u>Number of Adults</u>			
Living	1.18 $\pm$ 0.85*	3.16 $\pm$ 1.45*	-
Dead	<u>0.54 $\pm$ 0.62</u>	<u>0.16 $\pm$ 0.22</u>	-
Total	1.72	3.32	48% ^c

^a Based on the $\bar{x}$ data from four 400 cm² bark samples per trap tree on each of 53 trap trees pairs.

^b Means designated with astericks within rows are significantly different at $p < 0.001$ ($\pm$ Standard Errors)(Mann-Whitney non-parametric test, Snedecor and Cochran 1972).

^c Percent mortality (from MSMA) of those parent adults which remained in treated trees was 27% (Table 6).

Table 6

MSMA Efficacy Calculations

(refer to Table 5 for means used in calculations)

1a. Percent Difference in No. of Living Larvae in Treated and Check Samples

$\bar{x}$ = 52.20 live larvae in check

$\bar{x}$ = 0.66 live larvae in treated

$$(0.66 \div 52.20) \times 100 = 1.26\%$$

$$100 - 1.26 = \underline{98.74\% \text{ difference}}$$

b. Percent Natural Mortality of Larvae

$\bar{x}$ = 52.20 live larvae in check

$\bar{x}$ = 0.08 dead larvae in check

Total = 52.28 larvae in check

$$(0.08 \div 52.28) \times 100 = \underline{0.15\% \text{ natural mortality}}$$

- (con't) -

Table 6

- (con't) -

2a. Percent Difference in No. of Living Adults in Treated and Check Samples

$\bar{x} = 3.16$ live adults in check

$\bar{x} = 1.18$ live adults in treated

$$(1.18 \div 3.16) \times 100 = 37.34\%$$

$$100 - 37.34 = \underline{62.66\% \text{ difference}}$$

b. Percent Natural Mortality of Adults

$\bar{x} = 3.16$ live adults in check

$\bar{x} = 0.16$ dead adults in check

Total = 3.32 adults in check

$$(0.16 \div 3.32) \times 100 = \underline{4.82\% \text{ natural mortality}}$$

c. Percent Reduction in Presence of Adults caused from Treatment

1.72 total adults in treated

3.32 total adults in check

$$(1.72 \div 3.32) \times 100 = 51.81\%$$

$$100 - 51.81 = \underline{48.19\% \text{ reduction in presence of}} \\ \underline{\text{adults caused from MSMA}}$$

d. Percent Adult Mortality from Treatment

natural mortality = 4.82%

$$4.82\% \times 1.72 = 0.08 \text{ died naturally in treated}$$

$$0.54 - 0.08 = 0.46 \text{ died from MSMA}$$

$$(0.46 \div 1.72) \times 100 = \underline{26.74\% \text{ mortality from MSMA of}} \\ \underline{\text{those beetles that remained}} \\ \underline{\text{in treated trees}}$$

Table 7. Comparison of Arsenic Concentrations and Spruce Beetle Attack-Repellency in Felled Lethal Trap Trees

Author	Sampling Location(s) from Butt End in metres	Silvicide Dosage	Phloem Arsenic Concentrations in ppm		Spruce Beetle Attack Repellency ^a
			Treated	check	
Buffam et al. (1973)	4.6, 13.7	340 g/l Silvisar- 510 [®]	26.15 ^b	0.55 ^b	none
Lister et al. (1976)	1.5, 4.6, 7.6, 10.7, 13.7, 16.8 and 19.8	170 g/l Silvisar- 510 [®]	8.3 ^c + 1.1	1.1 ^c + 0.1	12%
Herrick Creek (1981)	20	160 g/l Glowon [®]	24.7 ^d + 7.3	1.37 ^d + 1.1	28%

^a A significantly higher number of spruce beetle attack holes in check trap trees than in adjacent MSMA-treated trap trees.

^b The mean ppm of arsenic based on 2 sampling locations on each of 5 trees per treatment.

^c The mean ppm of arsenic based on 7 sampling locations on each of 6 trees per treatment ($\pm$ Standard Errors).

^d The mean ppm of arsenic based on the 1 sampling location on each of 11 trees per treatment ($\pm$ Standard Errors). These paired values are significantly different at $p < 0.001$ (Paired t-test, Snedecor and Cochran 1972).

Table 8

Efficacy of Chlorpyrifos^a in Fumigating Spruce Beetle Larvae
Callow and Parent Adults in Felled Trap Trees

Data Collected	Means ($\bar{x}$) ^b		Percent Mortality* from Chlorpyrifos
	Treated	Check	
<u>No. of Larvae</u>			
Living	3.44 ± 5.9 ^c	26.33 ± 19.5 ^c	63%
Dead	26.92 ± 18.8	9.44 ± 14.2	
Total	30.36	35.77	
<u>No. Callow Adults</u>			
Living	0 ^d	0.72 ± 1.8 ^d	74%
Dead	1.69 ± 3.8	0.25 ± 0.6	
Total	1.69	0.97	
<u>No. Parent Adults</u>			
Living	0.17 ± 0.7 ^e	1.56 ± 2.1 ^e	64%
Dead	2.78 ± 2.5	0.69 ± 1.1	
Total	2.95	2.25	

^a 2% chlorpyrifos (a.i.) in diesel oil

^b Based on the $\bar{x}$ data from 36 (400 cm²) bark samples; 4 samples from each of 9 trap trees

^{c,d,e} Means designated with the same letters within rows are significantly different at $p < 0.01$ ($\pm$ Standard Errors) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

* Adjusted by Abbot's Formula for natural mortality (Abbot 1925)

Table 9

Chlorpyrifos Efficacy Calculations

(refer to Table 8 for means used in calculation)

A. Percent Larval Mortality from Treatment

$$(9.44 \div 35.77) \times 100 = 26.39\% \text{ natural mortality}$$

$$26.39\% \times 30.36 = 8.01 \text{ died naturally}$$

$$26.92 - 8.01 = 18.91 \text{ died from chlorpyrifos}$$

$$(18.91 \div 30.36) \times 100 = \underline{62.29\% \text{ larval mortality from chlorpyrifos}}$$

B. Percent Callow Adult Mortality from Treatment

$$(0.25 \div 0.97) \times 100 = 25.77\% \text{ natural mortality}$$

$$25.77\% \times 1.69 = 0.44 \text{ died naturally}$$

$$1.69 - 0.44 = 1.25 \text{ died from chlorpyrifos}$$

$$(1.25 \div 1.69) \times 100 = \underline{73.96\% \text{ callow adult mortality from chlorpyrifos}}$$

C. Percent Parent Adult Mortality from Treatment

$$(0.69 \div 2.25) \times 100 = 30.67\% \text{ natural mortality}$$

$$30.67\% \times 2.95 = 0.90 \text{ died naturally}$$

$$2.78 - 0.90 = 1.88 \text{ died from chlorpyrifos}$$

$$(1.88 \div 2.95) \times 100 = \underline{63.73\% \text{ parent adult mortality from chlorpyrifos}}$$

Table 10. Data from Prism Plots Adjacent to Lethal Trap Tree Sites in 1981

Site No.	Mean No. of Tallied Trees per Prism		Mean DBH in cm of Tallied Trees per Prism Plot				Mean No. of Grey-Attacked ^d Spruce per Prism Plot	Mean No. of Green (Alive) Strip-Attacked ^e Spruce per Prism Plot
	Plot ^a		Prism Plot					
	Hybrid	Subalpine	Hybrid	Subalpine				
	Spruce ^b	Fir ^c	Spruce ^b	Fir ^c				
1	4.2	2.2	43.15	29.44			0.40	-
2	6.3	0.6	48.75	31.25			0.71	-
3	3.8	1.3	43.26	32.50			-	-
4	2.9	2.6	37.50	33.88			0.29	-
5	5.3	0.9	40.00	33.00			-	-
6	5.0	1.8	40.80	32.77			0.80	-
7	3.4	7.0	44.58	33.93			-	-
8	2.6	4.3	40.83	33.50			-	-
9	2.6	2.9	41.11	25.50			0.11	0.11 ^f
10	3.5	3.3	38.57	34.00			0.17	-
11	5.3	1.7	31.22	45.42			-	-
Mean ($\bar{x}$)	4.1	2.6	40.90	33.20			0.23	0.01

^a Wedge Prism Basal Area Factor = 5

^b *Picea Engelmanni* x *glauca*

^c *Abies lasiocarpa*

^d Spruce attacked by spruce beetle in 1979 or before

^e Spruce with less than 50% of the circumference attacked by spruce beetle in 1981.

^f Based on 1 attacked spruce in a prism plot 50 m to the northeast of, and 30 m higher in elevation than the trap tree site.

Table 11. Data from Check Prism Plots^a in Herrick Creek in 1981

Site No.	Mean No. of Tallied Trees per Prism Plot ^b		Mean DBH in cm of Tallied Trees per Prism Plot			Mean No. of Grey-Attacked ^e Spruce per Prism Plot	Mean No. of Green (Dead) Full-Attacked ^f Spruce per Prism Plot
	Hybrid	Subalpine	Hybrid	Subalpine	Fir ^d		
	Spruce ^c	Fir ^d	Spruce ^c	Subalpine	Fir ^d		
1	4.1	0.4	38.79	26.67		0.13	-
2	5.5	0.8	39.09	25.00		-	-
3	4.5	2.3	36.53	26.39		0.25	0.13
4	3.1	1.8	49.40	36.43		-	0.13
5	2.3	0.3	39.29	32.50		-	-
Mean ($\bar{x}$)	3.9	1.1	40.62	29.40		0.08	0.05

^a Plots randomly chosen at least 0.8 km distant from any trap tree sites.

^b Wedge Prism Basal Area Factor = 5

^c *Picea Engelmannii* x *glauca*

^d *Abies lasiocarpa*

^e Spruce attacked by spruce beetle in 1979 or before

^f Spruce with less than 50% of the circumference attacked by spruce beetle in 1981.

NOTE

Errata

- All reference to Dursban-4E®

Should Read -

Dursban-4E® (4% a.i.)

diluted in 24% a.i. in
diesel oil