

SPRUCE BEETLE SUPPRESSION WITH
LETHAL TRAP TREES IN CENTRAL
BRITISH COLUMBIA IN 1982

by

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ABSTRACT

MSMA (Glowon[®]) at rates of 80, 120 or 160 g/L (a.i.) was applied to basal frills on standing spruce, Picea engelmannii x glauca (Kirby) in early June in British Columbia in 1982. Trees were felled 2 weeks later, and were subsequently lethal to attacking spruce beetle, Dendroctonus rufipennis (Kirby).

When assessed 3 months after treatment, the 80 g/L dosage, unlike the higher dosages, showed no significant repellency of attacking adults compared to untreated traps. The 80 g/L dosage reduced egg gallery lengths by 27%, caused a 61% failure of egg galleries, killed at least 14% of parent adults that remained in treated trees, and reduced larval success by 99%.

MSMA at 80 g/L (a.i.) is presently recommended for operational use but re-testing is required for efficacy confirmation.

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SPRUCE BEETLE SUPPRESSION WITH LETHAL
TRAP TREES IN CENTRAL BRITISH COLUMBIA IN 1982

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 1982 and 1983, 99 300 ha and 58 600 ha of spruce were infested to various degrees, respectively. Of these totals, 57 455 ha and 33 480 ha of damage occurred in the Prince George Forest Region, respectively (Wood and Van Sickle 1983, 1984¹).

During the past decade, use and refinement of spruce beetle trap tree methodology has received emphasis. Lethal trap trees are living, large diameter spruce which are injected with a tree-killing silvicide. After translocation of the silvicide, trees are felled into the shade and left unbucked and unlimbed. Spruce beetle adults attacking such trap trees are killed by the silvicide in the phloem (Lister et al. 1976). The success of the strategy has been reviewed by Hodgkinson (1983).

¹ Preliminary estimates

Operational research in 1981 revealed that 1/2-strength MSMA² (160 g/L a.i.) had a significant toxic impact on the success, survival and mating of parent adults which attacked and remained in lethal trap trees. Unfortunately, this dosage repelled up to 28% of attacking adults from initiating attack (Hodgkinson 1983).

Based on the above findings and other unpublished Provincial reports, a second year of operational research was undertaken to test lower dosages of MSMA in the hope of obtaining sufficient efficacy without any repellency.

II. METHODS

The experiment was incorporated into an operational, 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. A series of lethal trap trees was felled in the spring of 1982 (in the second year of a 2-3 year program), in an attempt to attract and kill a significant proportion of the attacking population, and thereby reduce subsequent damage. The major objective was to protect a commercially valuable stand until road access could be constructed to allow harvesting and other resource activity.

² Monsodium methanearsonate. Commercially available product called Glowon[®] from Later's Chemical Ltd., Richmond, B.C.

A. MSMA Application

Between May 31 and June 3, 1982, a total of 510 standing spruce, Picea englemannii x glauca (Kirby) were numbered, axe-frilled and treated with various dosages of MSMA in 44 locations along the Herrick Creek and its tributaries (Fig. 1). A total of 5 research sites were randomly chosen from the 44 locations. In each research site, a total of 8 spruce were selected in 2 groups of 4. Within each group, each of the 4 trees was axe-frilled and randomly treated with one of the following dosages of MSMA: 1/4-strength (80 g/L a.i.), 3/8-strength (120 g/L a.i.), 1/2-strength (160 g/L a.i.) or left untreated (checks) (Table 1).

MSMA was applied to basal axe-frills (just cutting the sapwood) with a 0.5 L polyethylene squeeze bottle. The MSMA-water solution was applied at the rate of 1 ml total volume/2.5 cm of tree circumference (MSMA dosages of 0.50 ml a.i., 0.38 ml a.i., or 0.25 ml a.i. per 2.5 cm circumference). A calibration label attached to the bottle ensured proper dosage delivery. Helicopter and manpower logistics were similar to the 1981 project (Hodgkinson 1983). Injected standing spruce were left for 2 weeks to allow translocation of the MSMA (Buffam 1971), and then felled during June 14-16, 1982.

In order to assess possible effects of moderate shading on felled trap trees, directional felling was undertaken on the research sites. Of the 2 groups of 4 trees mentioned above, one was felled in an east-west direction, the other in a north-south direction (Fig. 2).

Fig. 1 Location of Lethal Trap Trees in Herrick Creek Drainage in 1982

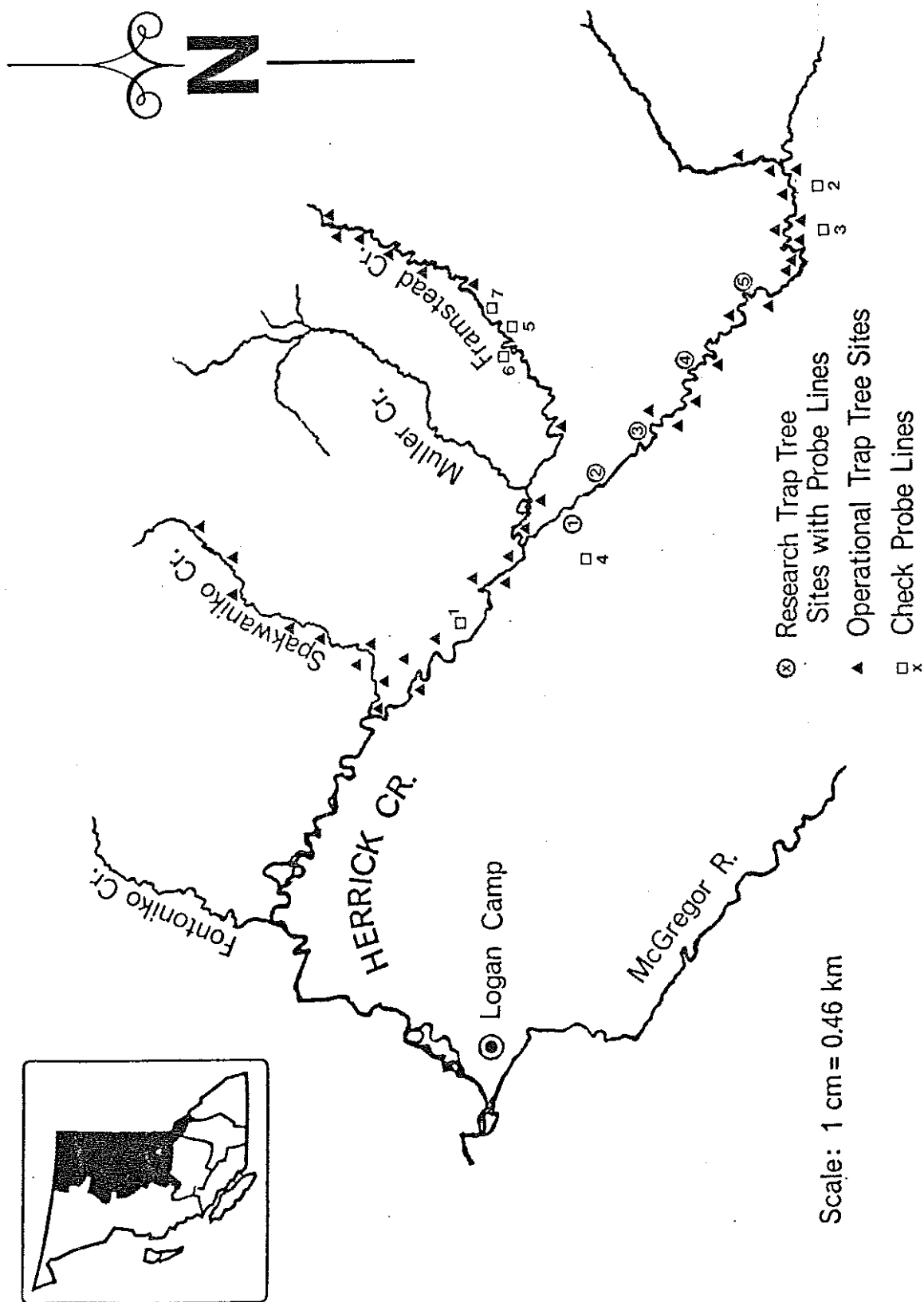


Table 1. Number of Trap Trees in Herrick Creek Drainage in 1982

Purpose	Number of Trap Tree Sites	Number of Lethal Trap Trees by Dosage			Number of Check Trap Trees
		80 g/L ^a	120 g/L ^b	160 g/L ^c	
Operational	39 [*]	---	---	480	---
Research	5	10	10	10	10
Total	44	10	10	490	10

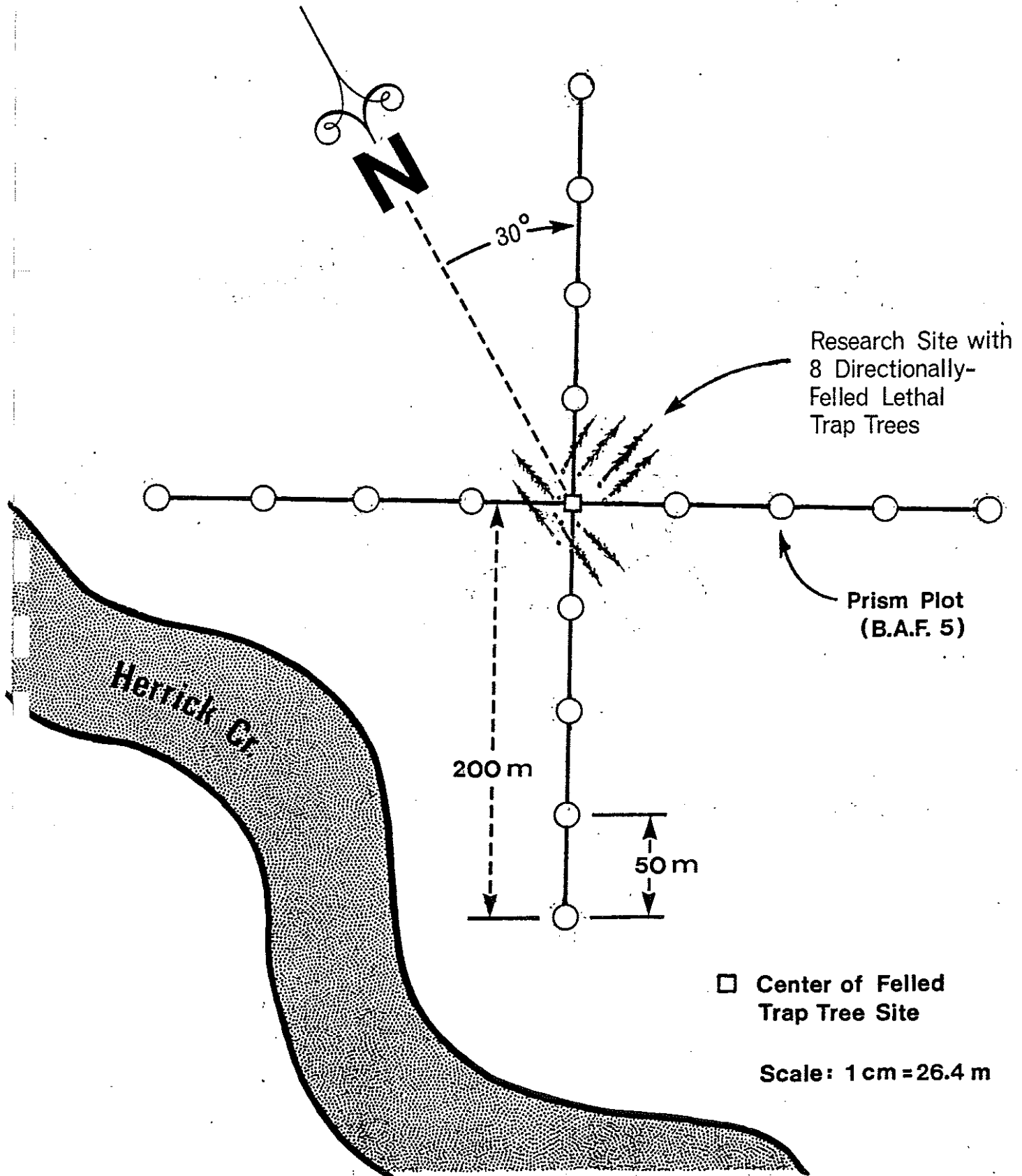
* 30 sites had 10 lethal trap trees each
9 sites had 20 lethal trap trees each

^a 1/4-strength MSMA

^b 3/8-strength

^c 1/2-strength

Fig. 2. Probe Line Prism Plot Configuration



B. Spruce Beetle Emergence

A Lindgren Funnel Trap[®] (originally designed to capture ambrosia beetles) was set up on the junction of the Muller and Framstead Creeks (Fig. 1) on June 1, 1982. A slow release vile containing 1 cc of a spruce beetle pheromone Frontalure³ was attached by wire to the apex of the middle (4th) funnel. The trap was used in speculation that it might capture flying parent adults, thus helping to determine the start of the beetle flight. In conjunction with the pheromone trap, bark samples were removed from 2 recently (1981/82) wind-felled spruce on June 15, 1982 in a further attempt to ascertain the progression of the beetle flight/attack period.

C. MSMA Efficacy Sampling

Lethal and check trap trees on the 5 research sites were sampled for brood survival by a 2-person crew during August 30 - September 2, 1982. Four 400 cm² bark samples were cut from each of the 8 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 approximately 20 m from the butt end where the tree diameter equalled approximately 20 cm. Data recorded were: (1) trap tree d.b.h., (2) number of entrance holes, (3) number of successful

³ A synthetic compound containing 67% frontalin and 33% alpha-pinene (terpene). Frontalin is the principal pheromone of the southern pine beetle, *D. frontalis* (Zimmerman) and is a compound of "spruce beetle secondary attraction" (Dyer and Chapman 1971).

egg galleries, (4) egg gallery lengths, (5) larval and adult survival, and (6) presence of secondary beetles and other insects.

D. Arsenic Sampling

A 2.5 cm x 7.5 cm phloem sample was cut at 20 m from the butt end on each of the 1/4-strength treated trap trees on the 5 research sites between August 30 - September 3, 1982. Samples were wrapped in aluminum foil and frozen prior to XES⁴ analysis of translocated arsenic in phloem at the Faculty of Forestry, University of British Columbia in Vancouver, B.C.

E. Chlorpyrifos⁵ Application

On completion of the MSMA efficacy sampling, the surviving broods in the 2 check trap trees and stumps on each of the 5 research 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[®], 4% a.i. diluted to 2.4% a.i. in type 3, winter grade diesel oil) to fumigate parent adults and brood under the bark.

In early July after the beetle flight and prior to application, the 2 check trap trees in each site were delimbed and the branches were pulled

⁴ X-ray Energy-dispersive Spectroscopy

⁵ Commercially available product called Dursban-4E[®] from Dow Chemical of Canada Ltd., Vancouver, B.C.

away from the trap trees and stumps to allow walking access along each side of the bole for the chlorpyrifos applicator.

Chlorpyrifos was applied on September 23, 1982 by 2 applicators and an assistant. The formulation was transported in the helicopter and carried into the sites in 22.73 L plastic fuel containers. The insecticide was applied to the drip point from 2 manually-pressurized backpack sprayers (13.6 L capacity) with a fan nozzlehead. Insecticide coverage of the bole was thorough, therefore it was not deemed necessary to buck and roll sections of the traps in order to achieve additional coverage.

Application logistics were similar to the 1981 project (Hodgkinson 1983). Lack of adequate budget in 1983 prevented efficacy assessment of this phase of the project.

F. Probe Lines

A series of probe lines and prism plots (B.A.F. 5) were established around the 5 research sites to assess the effectiveness of lethal trap trees in protecting adjacent standing timber from spruce beetle attack in 1982. An additional 7 check probe sites were randomly established in adjacent helicopter-accessible locations in the drainage. Wherever feasible, check sites were established as far distant as possible from any trap tree sites so as to minimize natural pheromone interference. Figure 2 depicts the probe line configuration for both the 5 research and 7 check sites, and Figure 1 shows their locations. Probe line data was collected in a 5-day period between October 19-27, 1982.

III. RESULTS AND DISCUSSION

A. MSMA Application and Total Costs

The mean d.b.h. of the 40 felled trap trees on the 5 research sites was 54.5 ± 12.6 (SD) cm. The mean diameter of MSMA-injected spruce at the frill line was 59.5 cm (approx. 5 cm greater diameter than at d.b.h.). A mean of 73.6 ml of MSMA formulation (various concentrations of a.i.) was applied to this average diameter tree. Cost of MSMA⁶ (alone) per tree averaged:

36¢ for 160 g/L a.i.

27¢ for 120 g/L a.i.

18¢ for 80 g/L a.i.

Application methodology and helicopter logistics were similar to the 1981 program (Hodgkinson 1983). Total cost of the operational project (excluding chlorpyrifos application and all efficacy assessments) was \$54.87 per lethal trap tree based on a dosage of 1/4-strength MSMA (Appendix 1).

B. Spruce Beetle Emergence

Results of the brief monitoring period with the Frontalure-baited Lindgren Trap[®] are depicted in Table 2. It is recognized that in the absence of other replicated and unbaited traps, one could say that the beetles were simply attracted to the physical shape of the trap, or entered it via random contact. Nevertheless, this brief curiosity test demonstrates

⁶ Glowon[®] (320 g/L a.i.) cost \$9.70/l in June 1982.

Table 2. Spruce Beetle Capture by Frontalure-Baited
Lindgren Trap in Herrick Creek in 1982

Pheromone trap installed
on June 1 at 0745 hrs.

<u>Time Inspected</u>			<u>No. Adults Captured</u>	<u>Capture Per Day</u>
<u>Month</u>	<u>Date</u>	<u>Time</u>		
June	3	0800	0	0
	10	1000	10	1.4 (approx.)
	11	0939	7	7.0
	14	1400	47	13.4 (approx.)

that spruce beetles will fly to the Lindgren Trap⁷

Two weeks after deployment of the pheromone trap, bark samples were removed from 2 recently (1981/82) wind-felled spruce on 2 operational sites between research sites 3 and 5 (Fig. 1). The mean gallery length of the 7 samples was 3.6 cm. In conjunction with the pheromone trap captures (Table 2), this indicated that "early" spruce beetles probably attacked between June 4-10, 1982. On June 25, 1982, examination of trap trees felled June 14-15 (at research sites 3 and 5, Fig. 1) revealed a high density of fresh attacks.

C. MSMA Efficacy

Results from the Herrick Creek trial in 1981 revealed that 28% of spruce beetles were repelled from attacking lethal trap trees injected with a 1/2-strength dosage of MSMA (Hodgkinson 1983). Consequently, lower dosages of MSMA were tested in this study.

There was no significant difference in the mean number of entrance holes per 400 cm² bark between 1/4-strength treated trap trees (2.4) and check trap trees (3.0)(Table 3). Significantly fewer attacks on 3/8- and 1/2-strength treated trap trees compared to the checks, confirmed beetle

⁷ The baited Lindgren Trap[®] was subsequently moved to the Narrow Lake area in the Prince George East Forest District where it continued to capture spruce beetles in the same season.

Table 3. Comparison of the Number of Spruce Beetle Attacks on MSMA-Treated and Untreated Trap Trees in 1982

Treatment	Mean No. of Spruce Beetle Entrance Holes per 400 cm ² of Bark Surface ^a
80 g/L	2.4 ± 1.4 ^b
120 g/L	2.0 ± 1.5 ^c
160 g/L	1.4 ± 1.3 ^d
Check	3.0 ± 1.4 ^b

^a Based on the $\bar{x}$ data from 40 bark samples; four 400 cm² samples from each of 10 trees per treatment

^{b,c,d} Means within this column followed by the same letters are not significantly different at the 0.05 level (± Standard Deviations) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

repellency from these higher dosages. Repellency may depend in part on population densities of attacking beetles and/or MSMA (arsenic) concentrations in phloem. The latter is discussed in section III E.

Five of the 8 trap trees on research site no. 3 (2 checks and 1 each of the 3 different treatments) were felled on low lying ground. During efficacy sampling it was noted that part of their boles had been subjected to an unexpectedly high flash flood from the Herrick Creek sometime in late June - early July. Since this flooding may have affected beetle survival, these trap trees were eliminated from all efficacy assessment except attack densities and translocated arsenic. All arsenic samples were taken above any water marks.

All 3 dosages of MSMA applied to trap trees caused a significantly lower mean number of successful egg galleries⁸ than those found in check trap trees (Table 4). MSMA at 1/2-strength caused the greatest percent reduction (83%), while 1/4-strength caused the least (61%) (Table 5).

Mean lengths of spruce beetle egg galleries exposed to the 3 MSMA dosages were significantly lower than the check. Percent reductions ranged from 27% - 35% (Tables 4,5).

⁸ A successful spruce beetle egg gallery is defined as one having 1 or more laterally-branching larval galleries.

Table 4. Efficacy of Three Different Dosages of MSMA on Spruce Beetle Egg Galleries, Larvae and Parent Adults in the Herrick Creek in 1982

Data Collected per 400 cm ²	Means ($\bar{x}$) * per MSMA Dosage			
	80 g/l	120 g/l	160 g/l	Check
<u>Egg Galleries</u>				
A. No. of Successful	1.4 $\pm$ 1.4 ^b	0.9 $\pm$ 1.3 ^{bc}	0.6 $\pm$ 0.8 ^c	3.6 $\pm$ 1.5 ^a
B. Length in cm	6.5 $\pm$ 1.9 ^b	5.8 $\pm$ 2.4 ^b	5.9 $\pm$ 2.5 ^b	8.9 $\pm$ 2.5 ^a
<u>No. of Larvae</u>				
C. Living	0.6 $\pm$ 1.8 ^b	0.6 $\pm$ 2.5 ^b	0 ^b	40.6 $\pm$ 17.7 ^a
D. Dead	8.7 $\pm$ 9.5	5.0 $\pm$ 8.4	3.4 $\pm$ 7.9	4.5 $\pm$ 4.7
Total	9.3	5.6	3.4	45.1
<u>No. of Adults</u>				
E. Living	1.8 $\pm$ 1.9 ^b	1.9 $\pm$ 2.2 ^b	1.1 $\pm$ 1.4 ^b	3.3 $\pm$ 2.2 ^a
F. Dead	0.8 $\pm$ 1.0	1.6 $\pm$ 1.8	1.0 $\pm$ 1.1	0.7 $\pm$ 0.9
Total	2.6	3.5	2.1	4.0

* Based on the $\bar{x}$ data from 32-36 bark samples (four 400 cm² samples from each of 8-9 trap trees per treatment)

a,b,c Means within rows A,B,C,E followed by the same letters are not significantly different at the 0.05 level ($\pm$ Standard Deviations) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

Table 5. Summary of MSMA Efficacy in Herrick Creek in 1982

Data Collected	Percent Reductions from Treatment ^a		
	Dosage		
	80 g/L	120 g/L	160 g/L
<u>Egg Galleries</u>			
No. of Successful	61%	75%	83%
Length in cm	27%	35%	34%
<u>No. of Living Larvae</u>	99%	99%	100%
<u>No. of Living Adults</u>	44%	42%	67%

^a All percentage reductions are calculated by comparing each individual treatment to the check in Table 4. Based on the $\bar{x}$ data from 32-36 bark samples; four 400 cm² samples from each of 8-9 trap trees per treatment. See Appendix 2 for efficacy calculations.

Means of 0 - 0.6 living larvae found in MSMA-treated bark samples were significantly different than the mean of 40.6 living larvae found in the check samples (differences of 99-100%) (Tables 4,5, Appendix 2 - Sect.1). MSMA at 1/4-strength was, therefore, just as effective in preventing brood survival as the higher dosages of 3/8- and 1/2-strength (Table 5).

Means ranging from 2.1 - 3.5 total number of adults (living and dead) were found in MSMA-treated trap trees compared to a mean of 4.0 found in check trees (Table 4). The percent difference between the mean total number of adults found in 1/4-strength treated samples (2.6) and those in the checks (4.0) was 35%. This suggests that 35% of the attacking beetles left the lethal trap trees either before or during gallery construction (Appendix 2, sect. 5a).

There was a 20% numerical difference⁹ between the mean number of beetles initiating gallery construction in 1/4-strength treated trees (2.4) versus the number in check trees (3.0)(Table 3). The total difference of 35% in the number of adults found (calculated above) minus the 20% that failed to initiate galleries = 15%. Therefore, 15% 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.

⁹ A non-significant difference at the 0.05 level.

Percent natural mortality of parent adults that remained in trap trees was 17.5% (Appendix 2, sect. 4). Percent mortality of adults that remained in treated trees (from the 3 separate dosages of MSMA) ranged from 12% - 29% at the time of efficacy sampling (Appendix 2, sect. 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. Trap Tree Shading

Effective shading of trap trees increases spruce beetle attack densities (Nagel et al. 1957, Schmid and Frye 1977). Since all trap tree sites in the Herrick Creek were judged to have moderate shading, it was of interest to see if directional felling within these sites made any significant difference in trap tree attractiveness.

Table 6 indicates there was no significant difference between the mean number of beetles attacking 400 cm² bark samples on north-south felled trap trees (2.7) or on east-west felled traps (3.3). Therefore, direction of felling underneath moderate (or heavier) canopy shading had no impact on trap tree attractiveness.

E. Arsenic Analysis

The quantity of translocated silvicides (containing arsenic) in lethal trap trees may be one of the main factors influencing spruce beetle attack densities (Lister et al. 1976).

Table 6. Comparison of Spruce Beetle Attack Densities
on Directionally-Felled Untreated Trap Trees

Trap Tree Felling Direction	Mean No. Spruce Beetle Entrance Holes per 400 cm ² Bark Surface ^a
North-South	2.7 ± 1.3 ^b
East-West	3.3 ± 1.3 ^b

^a Based on the $\bar{x}$ data from 20 bark samples
(four 400 cm² samples from each of 5
trap trees per felling direction).

^b Means followed by the same letter are
not significantly different at the 0.05
level (± Standard Deviations) (Paired
t-Test, Snedecor and Cochran 1972).

In 1981, Hodgkinson (1983) injected 1/2-strength of MSMA into spruce and recorded a mean of 24.7 ± 7.3 (SD) ppm of translocated arsenic in phloem samples 20 m from the butt. Preliminary results of this study in 1982 indicated that 1/4-strength MSMA appeared to be the most cost-effective of the 3 dosages (Sect. IIIc), therefore, the expensive arsenic analysis was only conducted on the latter dosage.

The analysis of 1/4-strength (80 g/l) MSMA revealed a mean arsenic level of 9.6 ± 4.8 (SD) ppm at the 20 m height. This dosage had no significant repellent effects against attacking adults (Table 3), and was equally effective as the higher dosages in preventing brood survival (Table 5).

It is interesting that Lister et al. (1976) tested an even lower dosage of silvicide (Silvisar-510[®] at 68 g/l a.i.) than ours, and also observed no attack repellency. However, only a 40% brood reduction was achieved with the latter dosage. Other silvicide dosages and repellencies were reviewed by Hodgkinson (1983).

F. Probe Line Assessment

Table 7 shows data collected from probe line prism plots adjacent to the 5 lethal trap tree research sites in the Herrick Creek. Of the mean of 3.9 spruce per prism plot, only 0.7% were "green-attacked" by spruce beetle in 1982.

Table 7. Data from Prism Plots Adjacent to Lethal Trap Tree Sites in 1982

Site No.	No. Prism ^a Plots	No. Spruce ^b Tallied	Mean DBH in cm of Spruce per Prism Plot ^c	Percent Grey-Attacked ^d Spruce per Site	Percent Red-Attacked ^e Spruce per Site	Percent Green-Attacked ^f Spruce per Site
1	20	75	34.7 ± 14.2	6.7%	0	2.7%
2	21	75	33.1 ± 10.2	0	0	0
3	19	87	38.9 ± 12.8	1.1%	0	0
4	24	66	35.2 ± 10.9	0	1.5%	1.5% ^g
5	27	135	43.1 ± 12.4	3.7%	0	0
Totals	111	438	(Avg. = 37.0)	$\bar{x}$ = 2.5%	$\bar{x}$ = 0.2%	$\bar{x}$ = 0.7%

^a Wedge Prism Basal Area Factor = 5

^b *Picea engelmannii* x *glauca*

^c (± Standard Deviations)

^d Spruce attacked in 1980 or before

^e Spruce attacked in 1981

^f Spruce with more than 50% of the circumference attacked by spruce beetle in 1982

^g Spruce with less than 50% of the circumference attacked by spruce beetle in 1982

Table 8 depicts the same information collected from probe line prism plots in 7 check (untreated) locations of the Herrick Creek. Of the mean of 3.7 spruce per prism plot, only 1.6% were green-attacked by spruce beetle in check areas in 1982.

In 1981, beetle green-attack densities on spruce in the drainage were considered low - 1.3% in check areas and 0.2% in areas adjacent to, and protected by, lethal trap trees (Hodgkinson 1983). The 1.6% green-attack in check areas in 1982 (Table 8) suggest low attack densities similar to the 1981 level.

Beetle green-attack densities in 1982 in healthy standing spruce were 2.3 times higher and more severe in check areas of the drainage than in areas protected by lethal trap trees (Tables 7,8). Unfortunately, as in the 1981 study, this difference could not be verified statistically because of the low levels of beetle attack in the drainage in 1982. The mean number of beetle entrance holes on untreated trap trees in 1982 (3.0 ± 1.4 attacks/400 cm² bark) also reflect similar attack densities to those found in 1981 (3.3 ± 1.0 attacks).

Table 8. Data from Prism Plots Adjacent to Check Sites in 1982

Site No.	No. Prism ^a Plots	No. Spruce ^b Tallied	Mean DBH in cm of Spruce per Prism Plot ^c	Percent Grey-Attacked ^d Spruce per Site	Percent Red-Attacked ^e Spruce per Site	Percent Green-Attacked ^f Spruce per Site
1	24	70	43.2 ± 11.9	4.3%	0	0
2	30	115	43.5 ± 15.6	0	0.9%	0.9%
3	24	98	31.1 ± 17.6	0	0	0 ^g
4	21	91	40.7 ± 12.7	9.9%	0	3.3% ^h
5	19	82	34.6 ± 10.3	3.7%	0	3.7%
6	8	22	40.5 ± 11.0	13.6%	0	0
7	8	22	32.7 ± 9.6	0	0	4.5%
Totals	134	500	(Avg. = 38.0)	$\bar{x}$ = 3.6%	$\bar{x}$ = 0.2%	$\bar{x}$ = 1.6%

^a Wedge Prism Basal Area Factor = 5

^b *Picea engelmannii* x *glauca*

^c (± Standard Deviations)

^d Spruce attacked in 1980 or before

^e Spruce attacked in 1981

^f Spruce with more than 50% of the circumference attacked by spruce beetle in 1982

^g Had 1 green-alive strip attack in 1981

^h 1 green-alive strip attack, 2 green-dead (full) attacks

IV. SUMMARY AND CONCLUSIONS

The silvicide MSMA (Glowon[®]) was applied at the rates of 80, 120, or 160 g/L (a.i.) to basal frills on standing spruce in early June in central British Columbia. Trees were felled 2 weeks later after translocation of MSMA.

When attacked by spruce beetles, trap trees treated with 1/4-strength MSMA (80 g/L a.i.):

- (i) showed no significant repellency to attacking adults (unlike the 2 higher dosages),
- (ii) reduced egg gallery success by 61%,
- (iii) reduced egg gallery lengths by 27%,
- (iv) reduced the number of living larvae by 99%, and
- (v) killed at least 14% of parent adults which remained in treated trees.

Therefore, 1/4-strength MSMA (mean of 9.6 ± 4.8 (SD) ppm arsenic in phloem at 20 m) had a significant toxic impact on the success, survival and mating of parent adults which attacked and remained in lethal trap trees.

MSMA at 1/4-strength was just as effective as the higher dosages (3/8- and 1/2-strength) in reducing the number of living larvae, but, unlike the higher dosages, did not repel a significant number of attacking adults. Therefore, until proven otherwise, 1/4-strength MSMA is judged the best dosage for operational use.

Direction of trap tree felling underneath moderate canopy shading made no difference in trap tree attractiveness.

Total deployment cost in 1982 was \$54.87 per lethal trap tree. This was 16% higher than the \$46.15 expended per tree in 1981 (Hodgkinson 1983), because of increases in labour, equipment rental and transportation costs.

Preparations were made to assess the efficacy of chlorpyrifos (sprayed in 1982) and re-test and confirm the efficacy of 1/4-strength MSMA in 1983, but inadequate funding necessitated cancellation of these plans.

Spruce beetle attack densities in 1982 on healthy standing spruce were 2.3 times higher and more severe in check areas of the drainage than in areas protected by lethal trap trees. Unfortunately, this could not be verified statistically because of the low level of spruce beetle attack in the drainage in 1982. Accordingly, future operational research should be conducted in areas with higher densities of attacking beetles.

V. RECOMMENDATIONS

1. Until proven otherwise, the operational dosage for injecting lethal trap trees for spruce beetle suppression in B.C. should be 1/4-strength MSMA (80 g/L a.i.) applied at a rate of 1 ml solution/2.5 cm bark circumference at the frill line.
2. MSMA should be re-tested to confirm the recommended operational dosage of 1/4-strength. Small-scale testing of an even lower dosage (i.e., 1/8-strength: 40 g/L a.i.) would help confirm the above.
3. A study should be undertaken in 1984 to inject and fell lethal trap trees in late summer-early fall; this strategy has promising logistical advantages which needs refinement in B.C.
4. To conclusively prove the effectiveness of trap trees in protecting adjacent standing timber, future operational research should only be conducted in areas with at least moderate densities of attacking beetles, i.e., in locations with an expected stem attack of 5-20%.

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Appendix I. Costs of Lethal Trap Tree Deployment in Herrick Creek in 1982^a

1. MSMA Application

- wages of 8 Forest Service Staff of various pay rates (376 man-hours)	\$4207.91
- 24 man-days of room and board @ \$35.00/day	840.00
- MSMA cost at \$0.18/tree ^b x 510 trees	91.80
Total =	\$5139.71

Cost of MSMA application per lethal trap tree = \$10.08

2. Lethal Trap Tree Felling Costs

- 3 fallers @ \$28.83/hr. x 30 man-hours	\$2594.70
- wages of 5 Forest Service staff of various pay rates (150 man-hours)	1740.00
- 24 man-days room and board @ \$35.00/day	840.00
Total =	\$5174.70

Cost of felling per lethal trap tree = \$10.15

3. Helicopter Transportation Costs

- 1 Bell 206B Jet Ranger III rental @ \$503.07/hr. x 34.7 hrs. (including fuel and oil)	\$17456.53
- Pilot's room and board @ \$35.00/day x 6 days	210.00
Total =	\$17666.53

Cost of helicopter transportation per tree = \$36.64

Total Cost of project per felled lethal trap tree = \$54.87

^a Excludes chlorpyrifos application and all efficacy sampling

^b Assuming an operational dosage of 1/4-strength MSMA (80 g/L a.i.) on all sites

Appendix 2. MSMA Efficacy Calculations

(refer to Table 4 for means used in calculations)

1. Percent Reduction in No. of Living Larvae in Treated Samples

a) 80 g/L

$$\begin{aligned}\bar{x} &= 40.6 \text{ live larvae in check} \\ \bar{x} &= 0.6 \text{ live larvae in treated} \\ &\quad (0.6 \div 40.6) \times 100 = 1.5\% \\ &\quad 100 - 1.5 = \underline{98.5\% \text{ reduction}}\end{aligned}$$

b) 120 g/L

$$\begin{aligned}\bar{x} &= 0.6 \text{ live larvae in treated} \\ &\quad (0.6 \div 40.6) \times 100 = 1.5\% \\ &\quad 100 - 1.5 = \underline{98.5\% \text{ reduction}}\end{aligned}$$

c) 160 g/L

$$\begin{aligned}\bar{x} &= 0 \text{ live larvae in treated} \\ &\quad (0 \div 40.6) \times 100 = 0\% \\ &\quad 100 - 0 = \underline{100\% \text{ reduction}}\end{aligned}$$

2. Percent Natural Mortality of Larvae

$$\begin{aligned}\bar{x} &= 40.6 \text{ live larvae in check} \\ \bar{x} &= 4.5 \text{ dead larvae in check} \\ \hline \text{Total} &= 45.1 \text{ larvae in check}\end{aligned}$$

$$(4.5 \div 45.1) \times 100 = \underline{10.0\% \text{ natural mortality}}$$

3. Percent Reduction in No. of Living Adults in Treated Samples

a) 80 g/L

$$\begin{aligned}\bar{x} &= 3.3 \text{ live adults in check} \\ \bar{x} &= 1.8 \text{ live adults in treated} \\ &\quad (1.8 \div 3.3) \times 100 = 56.3\% \\ &\quad 100 - 56.3 = \underline{43.7\% \text{ reduction}}\end{aligned}$$

b) 120 g/L

$$\begin{aligned}\bar{x} &= 1.9 \text{ live adults in treated} \\ &\quad (1.9 \div 3.3) \times 100 = 57.6\% \\ &\quad 100 - 57.6 = \underline{42.4\% \text{ reduction}}\end{aligned}$$

(cont'd)

Appendix 2. (con't)

c) 160 g/L

$$\begin{aligned}\bar{x} &= 1.1 \text{ live adults in treated} \\ (1.1 \div 3.3) \times 100 &= 33.3\% \\ 100 - 33.3 &= \underline{66.7\% \text{ reduction}}\end{aligned}$$

4. Percent Natural Mortality of Adults

$$\begin{aligned}\bar{x} &= 3.3 \text{ live adults in check} \\ \bar{x} &= 0.7 \text{ dead adults in check} \\ \text{Total} &= 4.0 \text{ adults in check} \\ (0.7 \div 4.0) \times 100 &= \underline{17.5\% \text{ natural mortality}}\end{aligned}$$

5. Percent Reduction in Presence of Adults caused from Treatment

a) 80 g/L

$$\begin{aligned}\bar{x} &= 2.6 \text{ total adults in treated} \\ \bar{x} &= 4.0 \text{ total adults in check} \\ (2.6 \div 4.0) \times 100 &= 65.0\% \\ 100 - 65.0 &= \underline{35.0\% \text{ reduction}} \\ &\quad \underline{\text{in presence of adults}} \\ &\quad \underline{\text{caused by 80 g/L MSMA}}\end{aligned}$$

b) 120 g/L

$$\begin{aligned}\bar{x} &= 3.5 \text{ total adults in treated} \\ (3.5 \div 4.0) \times 100 &= 87.5\% \\ 100 - 87.5 &= \underline{12.5\% \text{ reduction}} \\ &\quad \underline{\text{in presence of adults}} \\ &\quad \underline{\text{caused by 120 g/L MSMA}}\end{aligned}$$

c) 160 g/L

$$\begin{aligned}\bar{x} &= 2.1 \text{ total adults in treated} \\ (2.1 \div 4.0) \times 100 &= 52.5\% \\ 100 - 52.5 &= \underline{47.5\% \text{ reduction}} \\ &\quad \underline{\text{in presence of adults}} \\ &\quad \underline{\text{caused by 160 g/L MSMA}}\end{aligned}$$

(cont'd)

Appendix 2. (con't).

6. Percent Adult Mortality from Treatment

a) 80 g/L

Natural mortality = 17.5%

$17.5\% \times 2.6 = 0.5$ died naturally in treated

$0.8 - 0.5 = 0.3$ died from MSMA

$(0.3 \div 2.6) \times 100 = 11.5\%$ mortality from
80 g/L MSMA of those
beetles that remained in
treated trees.

b) 120 g/L

Natural mortality = 17.5%

$17.5\% \times 3.5 = 0.6$ died naturally in treated

$1.6 - 0.6 = 1.0$ died from MSMA

$(1.0 \div 3.5) \times 100 = 28.6\%$ mortality from
120 g/L MSMA of those
beetles that remained in
treated trees.

c) 160 g/L

Natural mortality = 17.5%

$17.5\% \times 2.1 = 0.4$ died naturally in treated

$1.0 - 0.4 = 0.6$ died from MSMA

$(0.6 \div 2.1) \times 100 = 28.6\%$ mortality from
160 g/L MSMA of those
beetles that remained in
treated trees.