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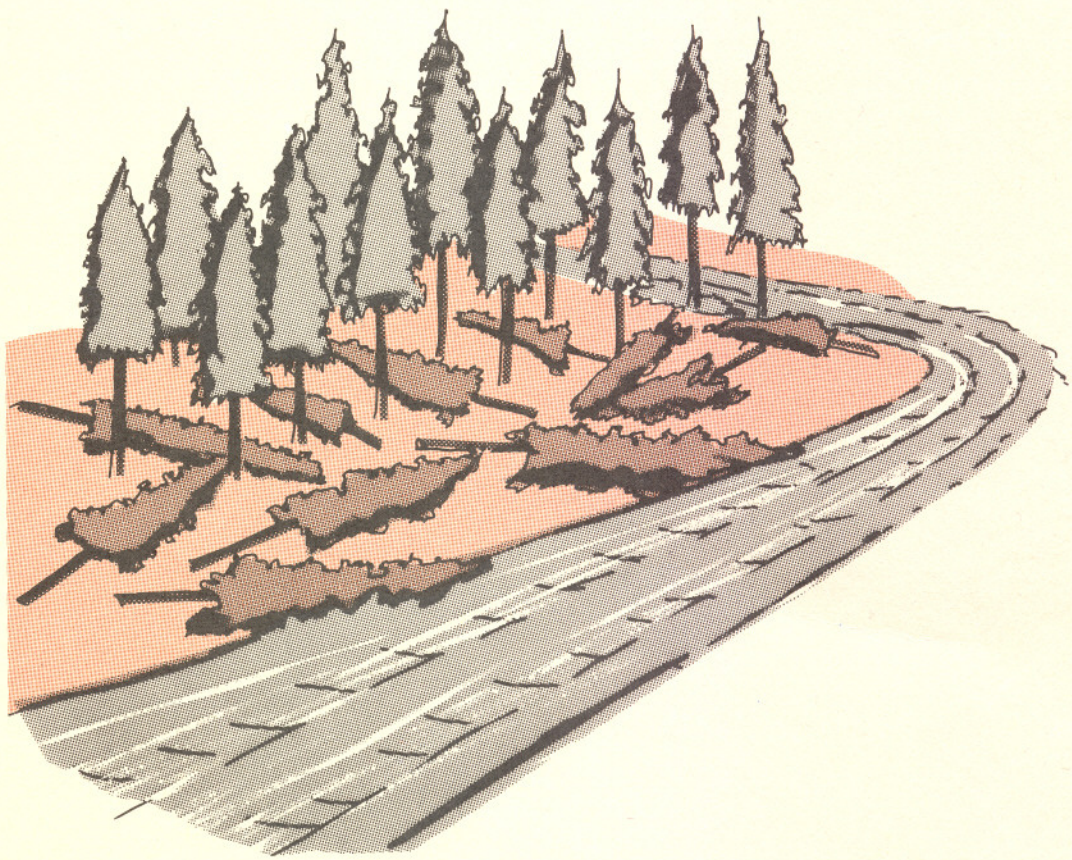
USE OF TRAP TREES FOR SPRUCE BEETLE MANAGEMENT IN BRITISH COLUMBIA, 1979-1984

A review with recommendations



PEST MANAGEMENT REPORT NUMBER 5

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USE OF TRAP TREES FOR SPRUCE BEETLE MANAGEMENT IN BRITISH COLUMBIA, 1979-1984

A review with recommendations

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First printed September 1985
Reprinted July 1991

Pest Management Report Number 5

Canadian Cataloguing in Publication Data

Hodgkinson, R. S. (Robert Sidney)
Use of trap trees for spruce beetle management in British Columbia, 1979–1984

(Pest management report, ISSN 0710-7935 ; no. 5)

Bibliography: p.
ISBN 0-7718-8519-9

1. Spruce bark beetles — Control — British Columbia. 2. Spruce — Diseases and pests — British Columbia. I. British Columbia. Ministry of Forests. II. Title. III. Series.

SB945.S69H62 1986 634.9'752676 C86-092093-3

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I. INTRODUCTION

The spruce beetle, ***Dendroctonus rufipennis*** (Kirby), is the most destructive pest of mature spruce, ***Picea*** Dietr. spp., forests in western North America. Approximately two to three million m^3 of spruce in North America are destroyed annually by this pest (Schmid and Frye 1977).

A series of outbreaks in British Columbia between 1962–1977 killed more than 18.2 million m^3 of mature timber and subsequent outbreaks have increased this total (Table 1). The Prince George Forest Region of British Columbia experienced an epidemic from 1980–1985, and in 1984 there were 26 120 ha infested to various degrees (Wood *et al.* 1985).

Spruce beetles commonly undergo a 2-year life cycle (Massey and Wygant 1954). Adults usually attack host material in late May or June and bore into the cambium where eggs are deposited. Emerging larvae feed during the summer, overwinter, then resume feeding in the spring. During the summer of this second year, the larvae pupate then develop into immature adults. The latter overwinter and emerge in the spring of the second year after initial attack to attack new hosts (Schmid and Frye 1977).

At lower elevations on warmer sites, spruce beetles may complete their life cycle in one year, overwintering as new adults and attacking the following spring (Massey and Wygant 1954). At higher elevations or in cooler than normal climates the beetle may take three years to complete it's life cycle. In this case, beetles overwinter twice as larvae and once as an adult. In all cases, the beetle must overwinter as an adult before emerging in the spring.

The spruce beetle attacks all species of ***Picea*** in North America. In British Columbia, Engelmann spruce, ***P. engelmannii*** Parry, and white spruce, ***P. glauca*** (Moench) Voss, are the principal hosts (Schmid and Frye 1977). The beetle prefers downed material such as fresh windthrow, logs, stumps, or logging debris (Dyer and Taylor 1971). When beetle populations are high and trees are susceptible, beetles will also attack and kill standing living trees. Even during epidemics, however, downed material is still preferred.

Spruce beetle control methods have included both harvesting of freshly attacked timber and the use of felled trees to act as traps. The latter are called trap trees and are designed to take advantage of the beetle's preference for such material. Although there are difficulties with early detection of problem areas and with treatment logistics, such as lack of access and size of the areas to be treated, opportunities nevertheless exist for effective spruce beetle management. A synthesis of spruce beetle management options is provided by Stewart (1984). The use of trap trees can play an important role in reducing losses to spruce beetle.

During the past two decades, the use and refinement of spruce beetle trap tree methodology has increased with the objective of improving management programs. Trap trees may be of two types: conventional and lethal. Although the particular treatments and applications differ, the objective remains the same: to absorb the beetle population into pre-selected downed material so that adjacent standing timber is protected.

Conventional 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 unbucked and unlimbed may absorb up to ten times the number of beetles a standing tree will absorb (Wygant 1960). Spruce beetles prefer downed material, they will attack a greater proportion of the bole, and the mean attack density is greater than on standing spruce (Schmid and Frye 1977). Conventional trap trees must be subsequently removed or treated to kill the trapped beetles.

The lethal trap tree technique is a modification of the original trap tree method of Nagel *et al.* (1957). Lethal trap trees are created by applying a silvicide into the axe-frilled cambium at the base of large diameter living spruce. After a two week period to allow translocation of the silvicide throughout the bole, trees are felled into the shade and left unbucked and unlimbed. Attacking adult spruce beetles and any subsequent brood are killed (Lister *et al.* 1976). Lethal trap trees, therefore, do not require further treatment.

The main objective of felling trap trees is to decoy spruce beetles away from living, standing spruce. Trap trees will effectively attract beetles from up to 0.4 km away, and have a lesser effect for up to 0.8 km (Nagel *et al.* 1957).

The purpose of this report is to: (1) outline the rationale for using conventional and lethal trap trees, (2) review and assess their use in British Columbia, and, (3) make recommendations for their future use.

Table 1. *Volume losses to spruce beetle in British Columbia from 1981–1984**

Forest Region	Volume losses to spruce beetle by year (000 m³)				
	1981	1982	1983	1984	Total by Region
Prince George	2 995	2 000	1 700	524	7 219
Prince Rupert	184	1 600	1 100	1 116	4 000
Cariboo	816	585	419	22	1 842
Kamloops	525	67	14	20	626
Nelson	450	250	51	116	867
Total by Year	4 970	4 502	3 284	1 798	14 554

* Information from Fiddick and Van Sickle (1982), Wood and Van Sickle (1983), Wood *et al.* (1984, 1985), and R. Edwards (former Pest Management Co-ordinator, Kamloops Forest Region, British Columbia Ministry of Forests).

II. TRAP TREE CHARACTERISTICS

The following trap tree characteristics are based in part on background data reviewed by Schmid and Frye (1977) and are applicable to both conventional and lethal trap trees. Trap trees take advantage of spruce beetle's preference for freshly cut, previously uninfested trees that have large diameters and thick bark.

(a) Trap tree sites should be clearly flagged and mapped to facilitate felling and, in the case of conventional trap trees, subsequent harvesting.

(b) Since fresh stumps are suitable spruce beetle habitat, all trap trees should be cut as close to the duff line as possible to ensure that a minimum amount of breeding material is left on site after the trap trees have either been extracted or injected with a silvicide.

(c) Trap trees should be felled in a direction which provides the greates amount of shade as spruce beetles are preferentially attracted to shaded, cooler bark surfaces. Felling should place the traps close to the ground, yet still permitting beetles to attack the underside of the felled trees.

(d) Trap trees should not be bucked or delimbed. Leaving the boles and branches intact increases trap tree shading and decreases the rate of drying, thereby favouring spruce beetle attack and discouraging competition from ***Ips*** spp.

(e) Trap trees should be felled as close to an infestation as possible and no further away than 0.8 km.

(f) Freshly windthrown spruce can be as attractive to spruce beetle as trap trees. Field inspections prior to felling should determine whether fewer trap trees are required in such instances. Windthrow used as trap trees should be treated or removed with other traps.

III. TRAP TREE QUANTITIES

The number of trap trees (conventional or lethal) to be felled mainly depends on the size of the attacking beetle population which is usually estimated by the number of adjacent infested standing trees. Nagel *et al.* (1957) recommended felling one trap tree for every four to five infested standing trees, while Wygant (1960) recommended the following ratios: 1:10 for static infestations and even as much as 1:2 for more severe infestations.

The total number of spruce beetles that a trap tree can absorb can be estimated from mean attack densities as determined from bark samples and approximate total bark surface area. Table 2 summarizes spruce beetle attack densities found on trap trees in two Forest Regions in British Columbia between 1981 and 1983 (Hodgkinson 1981 a, 1983 a, b; Price 1982) and indicates an average attack density[1] of about 85 attacks/m^2. The total number of attacks on the average trap tree[2] would then be about 2,600 attacks. This level of attack can be expected to occur on from three to five standing trees so that one trap tree can be thought to protect that number of standing trees. To precisely predict the number of trees to fell in an area it would be necessary to estimate the size of the attacking population (i.e., brood produced from nearby infested trees and windthrow) and fell an adequate number of trees. As this is difficult to determine, trap tree quantities are most commonly based on the ratios mentioned above as determined by Nagel *et al.* (1957) and Wygant (1960). It is usually considered prudent to have more traps to account for excessive populations.

Trap trees are most effective when depolyed against heavy infestations in very small areas or against light to moderate infestations over larger areas. In heavy infestations over larger areas, traps will absorb many beetles although it may not be cost-efficient to fell sufficient traps to absorb such a large population. As with any insect management technique, it's appropriateness varies according to specific situations and no universal guideline can be used.

When the density of attacking adults exceeds the available trap tree surfaces, the beetles may "spill over" to attack less attractive, adjacent standing timber. In this case, more trap trees might have been deployed. This illustrates the benefit of erring on the conservative side and employing more traps than calculated using the established ratios. Spill-overs are not an important problem with conventional trap tree programs as infested standing trees can be removed with the trap trees. Lethal trap tree programs must consider the possibility of spill-over at the time of felling. Since spruce beetles prefer shaded sites (Schmid and Frye 1977), Fiddick (1978) advised felling no more than one uninfested spruce for every five standing infested trees in any one spot so as not to excessively deplete the canopy. However, several spots may be used in a specific infestation and actual numbers per spot must be determined on a local basis.

[1] All calculations are based on entrance holes (i.e., number of females), as this represents the potential of the population.
[2] Assuming: basal diameter of 0.6 m, top diameter 0.15 m, and length of 26 m.

Table 2. *Mean number of spruce beetle entrance holes on conventional trap trees*

Year	Location[a]	Average Density of Attacking Population[b]	Deployment Strategy[c]	No. Trap Tree Sites Examined	Total No. Trap Trees Examined	Total No. Bark Samples Examined	Mean d.b.h.	Mean No. Successful Entrance Holes per 400 cm^2 Bark
1980	Bowron-Willow	Moderate	P	159	318	636	57 cm	3.4 + 1.3[d]
1981	Herrick Cr.	Light	P	11	54	216	45 cm	3.3 + 1.0
1982	Herrick Cr.	Light	P	4	8	32	50 cm	3.0 + 1.4
1981	Quartz Cr.	Moderate	P	10	10	24	62 cm	4.2
	Copper Cr.	Moderate	P	3	8	20	60 cm	5.4
1982	Pingston Cr.	Moderate	R	3	9	36	55 cm	2.5
1983	Pingston Cr.	Moderate	RL	3	15	60	55 cm	3.5
1983	Nicol Cr.	Moderate	RL	1	5	20	55 cm	2.4
	Caribou Cr.	Heavy	D	3	9	36	55 cm	3.1
							Mean	3.4 (85/m^2)

[a] First three locations in Prince George Forest District; remaining six in Nelson Forest Region.
[b] Approximation of current beetle stem attack on adjacent standing spruce: light=1-4%, moderate=5-20%, heavy=21% +.
[c] Deployment strategies: P=patches, R=pre-felled rights-of-way, RL=pre-felled rights-of-way and landings, D=decks.
[d] Standard deviations included in first three locations but unavailable in last six.

IV. TRAP TREE EFFICACY

Trap tree efficacy is assessed by: (1) beetle attack densities on trap surfaces relative to the density of the attacking population, and, more importantly, by: (2) simultaneous protection of adjacent healthy standing spruce from beetle attack. The latter is measured by annual surveys of a treated infestation's rate of spread and comparing that to similar but untreated areas.

Conducting step 1 is relatively simple. For example, when sampling is undertaken in the Prince George Forest Region, two or more traps are selected at random from a patch of 15–25 traps. One 400 cm^2 bark patch is removed from each side of each selected trap tree at the midline. The number of entrance holes and other data is recorded to provide a *partial* assessment of trap tree effectiveness. Other forest regions in British Columbia have employed similar bark sampling techniques, e.g., Prince Rupert Region has used 400 cm^2 bark samples (Rowsell 1982), while Nelson Region have occasionally used 250 cm^2 samples (Price 1982).

By correlating mean attack densities on trap trees to any attacks on adjacent timber, it may be possible to develop an index to determine if: (1) too few trap trees were deployed or if (2) trap tree numbers were adequate but they were simply unattractive for one or more reasons (Gray[3], pers. commun.).

It is recognized that intensive trap tree bark sampling as described above may not be operationally justifiable or practical with a large trap tree program over many thousands of hectares. In most Forest Regions of British Columbia, a minimum level of trap tree assessment has been a subjective (non-quantitative) visual examination of attack densities on trap trees prior to their extraction (Appendix 1). In many instances, no such assessments have been made.

Assessing trap tree protection of adjacent healthy, standing spruce (step 2) is much more difficult and complex. In developing the trap tree strategy, few studies have focused on trap effectiveness in reducing infestation levels in surrounding live spruce. Nagel *et al.* (1957) established rectangular blocks 40.3 m wide and 305 m long in undisturbed spruce surrounding trap tree patches. The blocks were subdivided into ten 30.5 m long areas as they progressed away from the centre trap trees. Unfortunately, the heavy spruce beetle population exceeded the capacity of the trap trees, and therefore, no correlation could be found between attack density or infestation frequency in standing timber and distance from the trap trees.

A further investigation was made on an operational trap tree program conducted by the U.S. Forest Service using Nagel's guidelines (Nagel *et al.* 1957). Examinations of timber surrounding trap tree groups revealed that 11 of 13 trap tree groups seemed to provide protection extending 0.4 to 0.8 km into the standing green trees. Beyond 0.8 km, standing infested trees were usually found. However, no check plots of timber isolated from the influence of trap trees were examined, and the results were therefore inconclusive.

Hodgkinson (1983 a, b) established probe lines with prism plots around trap tree patches in an attempt to compare timber protected by traps to timber not protected. Probe lines were extended up to 0.4 km in four quadrants radiating from both the centre of trap tree patches and from centre points in untreated (check) areas. Attacks on healthy spruce were less in areas protected by trap trees than in areas not protected. However, these differences could not be verified statistically because of the low beetle attack densities in this 2-year study.

To conclusively prove the effectiveness of trap trees in protecting adjacent standing timber, future operational research should be conducted in areas with at least moderate densities of attacking beetles, e.g., in locations with an expected stem attack of 6–25%. Alternately, small areas with heavy infestations (attack densities of 26–75%) might also be useful study sites. Sites with less than 6% stem-attack may not yield comparisons between treated and check blocks that can be verified statistically because of low beetle attack densities.

In areas of operational trap tree deployment, adjacent timber should be inspected each autumn via ground and aerial surveys to help assess trap tree success.

[3] Former Forest Entomologist, Nelson Forest Region, B.C. Ministry of Forests, Nelson, B.C.

V. CONVENTIONAL TRAP TREES

Conventional trap trees have been used against spruce beetle in British Columbia since the late 1970's. They have essentially been deployed to: (1) contain emerging beetles in cut-blocks prior to logging, (2) protect adjacent healthy timber or leave-blocks, and/or (3) "mop-up" beetles emerging from stumps and slash following logging. Table 3 summarizes their deployment by year (Appendix 1).

After conventional trap trees become infested, they must be extracted and milled or otherwise treated. Occasionally, extraction is not possible and it is mandatory that traps be burned, debarked or chemically treated to destroy the brood prior to the next beetle flight. Failure to extract or treat conventional traps subsequent to attack may actually increase the population in an area and prolong the infestation.

A. Trap Tree Felling and Extraction Periods

In the northern Rocky Mountain States, conventional trap trees felled in the early spring prior to beetle flight were more attractive to spruce beetle than those traps felled the previous September (McComb 1953). However, the spruce forest throughout the beetles' range often has considerable snow depths in May which occasionally makes access and felling of trap trees difficult just prior to beetle flight (Schmid and Frye 1977). By the same token, traps felled the preceding autumn in certain locations may be partially covered by obstructing snow when the spring flight commences.

To date in British Columbia, it has not been demonstrated that trap trees felled in the fall are any more or less attractive to spruce beetle than those felled in the spring. Felling times in British Columbia have traditionally been scheduled during periods of logging activity when roads are passable. Felling schedules will be further influenced by anticipated or actual snow depths.

Once conventional trap trees become infested, they should be removed after August of the same year and must be removed prior to April of the following year. Traps left on site after April may yield early-maturing 1-year cycle adults which could attack adjacent timber. Other methods of disposing of spruce beetle broods in trap trees are discussed in a separate section below.

B. Trap Tree Deployment Tactics

Although felling trap trees in a scattered pattern throughout an infested stand may be the most effective use, this tactic is constrained by the problems of safety in felling, economics of felling, and difficulties in extraction if the entire stand is not scheduled for harvest. Therefore, other tactics are usually employed.

1. Trap Tree Patches

Felling of trap trees in patches or truckloads adjacent to logging access roads has been used in 91% of all felling tactics in British Columbia from 1979–1984 (Table 3). Patches are usually 12–25 trap trees felled in a single group to facilitate eventual skidding and hauling (Hodgkinson 1981 b). In areas of light infestation (1–5% current stem attack), individual patches should be felled on opposite sides of the road every 0.4 km to absorb the scattered population. In areas of moderate (6–25% current stem attack) infestation, multiple patches should be felled at either the same spacing or closer together. Separate patches may be placed where epicentres have been identified.

It is not always possible to select natural or artificial clearings for initial felling of trap trees (Fig. 1). Therefore, their sequence of felling must be planned in order to avoid unnecessary brushing of standing timber by the trees being felled. This is a safety consideration and is in accordance with the Workers' Compensation Board Industrial Health and Safety Regulation 60.56 (Anon. 1980). To maximize shading, trap trees are felled in narrow patches so the bole of one is covered by the crown of the next. All advanced regeneration (up to 3 m high) and non-host species are left standing whenever possible to provide additional shade.

Of all the deployment tactics, trap trees felled in patches have the best shading and have probably been most effective in absorbing spruce beetle adults. This deployment pattern may also be the least costly method of establishing a trap tree program.

Once the traps have absorbed flying adults, the patches (along with any adjacently-attacked spruce) must be skidded to landings and hauled for milling or otherwise treated. Logistically, trap tree patches of multiples of truck loads may be the most feasible both for felling and subsequent extraction.

Aerial sketchmapping and ground assessments of spruce beetle flight potential after mid-August will dictate if the number of trap tree patches should be increased and/or re-located in specific areas before the next spring flight.

2. *Log Decks*

Winter-felled log decks left on landings or adjacent to roads during a spruce beetle flight often prove to be useful trap trees (Anon 1983 a). Right-of-way decks of approximately 170 m^3 (150–200 logs), or more, spaced at 0.4 km intervals can be used alone or in conjunction with other deployment tactics. The deck's outer logs, while not being a completely favorable habitat themselves, provide shade for the inner, cooler, more attractive bark surfaces.

Decks have been used in several Forest Regions of British Columbia since 1980 with visual confirmation of their success made in the Nelson and Prince George Regions (Appendix 1). Although decks on landings are easy to remove, they should not be used in lieu of the better shaded, and more effective trap tree patches. It appears, therefore, that decks are most suitably deployed during logging pre-development, e.g., from right-of-way felling and/or on pre-felled landings.

Further assessments are needed to substantiate log deck effectiveness, e.g., they may be more effective if the logs are stacked loosely to allow easier beetle access to the interior of the pile.

3. *Trap Tree Strips*

A variation of the trap tree patch tactic is to fell strips of spruce from north-facing timber faces along existing logged blocks or road rights-of-way (Fig. 2). The traps are felled parallel to the timber face and left unlimbed to maximize their shading and beetle attractiveness. They may also be felled into the stand; however this may contravene safety regulations.

Trap tree strips have been deployed in several Forest Regions such as Cariboo, Nelson and Prince Rupert with varying success (Appendix 1). Quantitative data from the Nelson Region revealed that adequately shaded strips sustained moderate attack densities of beetles. Those strips with less shading were heavily colonized by competing ***Ips*** spp.

4. *Pre-Felling Road Rights-of-Way and Landings*

Block pre-development for harvesting operations provides an opportunity for a relatively large scale trap tree program at a minimum of additional cost. When felling of timber on new access roads and landings is completed prior to the spruce beetle flight, this unpiled trap tree material can be left on site until after the beetle flight, then extracted after August in the same year.

This tactic has occasionally been attempted with some success (Appendix 1). However, since this timber is often felled in clearings and not piled, the resultant shading is relatively poor on these sites compared to areas with other deployment tactics. Therefore, pre-felling landings and road rights-of-way is probably the least effective option, however, this could be counteracted by the volume of timber felled (Anon 1983 a) or by piling trap material in more shaded locations.

In harvesting areas at risk or having endemic spruce beetle populations, pre-felling of road rights-of-way and landings should be a normal procedure provided the infested material can be removed within a year (Dyer 1981). Some consideration may have to be made if additional costs are incurred using this tactic.

C. *Other Trap Tree Disposal Techniques*

Conventional trap trees should never be felled in areas where they cannot be harvested. However, loss of road access occasionally prevents or delays trap tree removal thereby making it necessary to destroy the broods beneath the bark on site.

1. *Externally-Applied Insecticides*

Spruce beetle broods in trap trees may be destroyed by applying a bark penetrating insecticide.

In 1981, Hodgkinson (1983 a) sprayed a formulation of the insecticide chlorpyrifos[4] (2.4% Dursban-4E® a.i. in diesel oil) against spruce beetle broods in trap trees. One season after application, the formulation had killed 63%–74% of the brood and adults.

Before trap trees can be treated from a backpack sprayer, they must be delimbed so as not to impede applicator access to the bole. Hodgkinson (1983 a) required 30 minutes and 23–30 L of formulation to treat an average diameter trap tree of 42 cm d.b.h. to the drip-point with a backpack sprayer (included refilling time).

An unpublished trial in Prince George revealed that diesel oil alone was just as efficaceous as diesel oil + chlorpyrifos (2.4% a.i.) in killing 75–98% of spruce beetle broods in spruce bolts[5]. Since 1982, diesel oil has been used operationally in two locations in the Prince George Forest Region to

[4] Diethyl tricholorpyridyl phosphorothioate. An organophosphate insecticide available from Dow Chemical Canada Inc., Edmonton, Alta.

[5] Marshall, W. 1982. Comparative efficacy of Dursban-4E and diesel oil in fumigating spruce beetle adults and brood in spruce bolts. Unpubl. Rept. B.C. Ministry of Forests, Prince George Forest Region, 7 pp.

treat a few unharvested trap trees. The latter operations had approval of the Fish and Wildlife Branch because the applications were conducted in locations not subject to spring flooding. Further field assessments are necessary to substantiate the efficacy of other oil-based insecticides for trap tree "mop-up".

Externally-applied insecticides are efficacious against spruce beetle and simpler to apply than bark burning or debarking. However, the strategy is still labour intensive and it should only be used to "mop-up" small groups of infested trap trees that cannot be harvested because of unforeseen circumstances. Furthermore, externally-applied insecticides should not be used as a substitute for lethal trap trees.

Only insecticides registered for this purpose should be used and all label instructions must be followed.

2. *Burning*

Infested trap trees in British Columbia have occasionally been delimbed, bucked, piled and burned on site. Chainsaw gas and/or diesel oil has often been used to aid ignition. Subcortical bark temperatures exceeding 54.5°C for 30 minutes will kill all spruce beetle brood (Mitchell and Schmid 1973).

Although effective if thoroughly conducted, this procedure is also extremely labour intensive and cannot be endorsed for more than limited single-tree disposal of spruce in the non-fire season. As with any of these post-attack treatments, this should be avoided whenever possible and, when unavoidable, the most cost-effective technique should be chosen.

3. *Debarking*

Partial or complete mechanical disruption of bark destroys beetle broods or exposes them to weather elements (Whitney *et al.* 1978). However, this technique is also labour intensive and is probably beyond operational consideration when any large number of trap trees must be treated.

Table 3. *Summary of conventional trap tree deployment against spruce beetle in British Columbia from 1979–84*

Year	Total No. Trap Tree Deployment Locations	Per cent type of Trap Trees Deployed*				Per cent Reason for Trap Tree Deployment**		
		a	b	c	d	E	F	G
1979	94	94%	0	0	6.0%	1%	71%	28%
1980	211	99%	0.5%	0	0.5%	50%	45%	5%
1981	469	99%	0.4%	0.2%	0.4%	44%	54%	2%
1982	759	96%	0	1.0%	3.0%	27%	55%	18%
1983	959	93%	4.0%	1.0%	2.0%	20%	41%	39%
1984	598	67%	30%	3.0%	0	23%	14%	63%
	× =	91.3%	5.8%	0.9%	2.0%	27.5%	46.7%	25.8%

* a=patches, b=decks, c=strips, d=pre-felled road righst-of-way and landings
** E=containment before logging, F=protection of adjacent timber, G=clean-up after logging

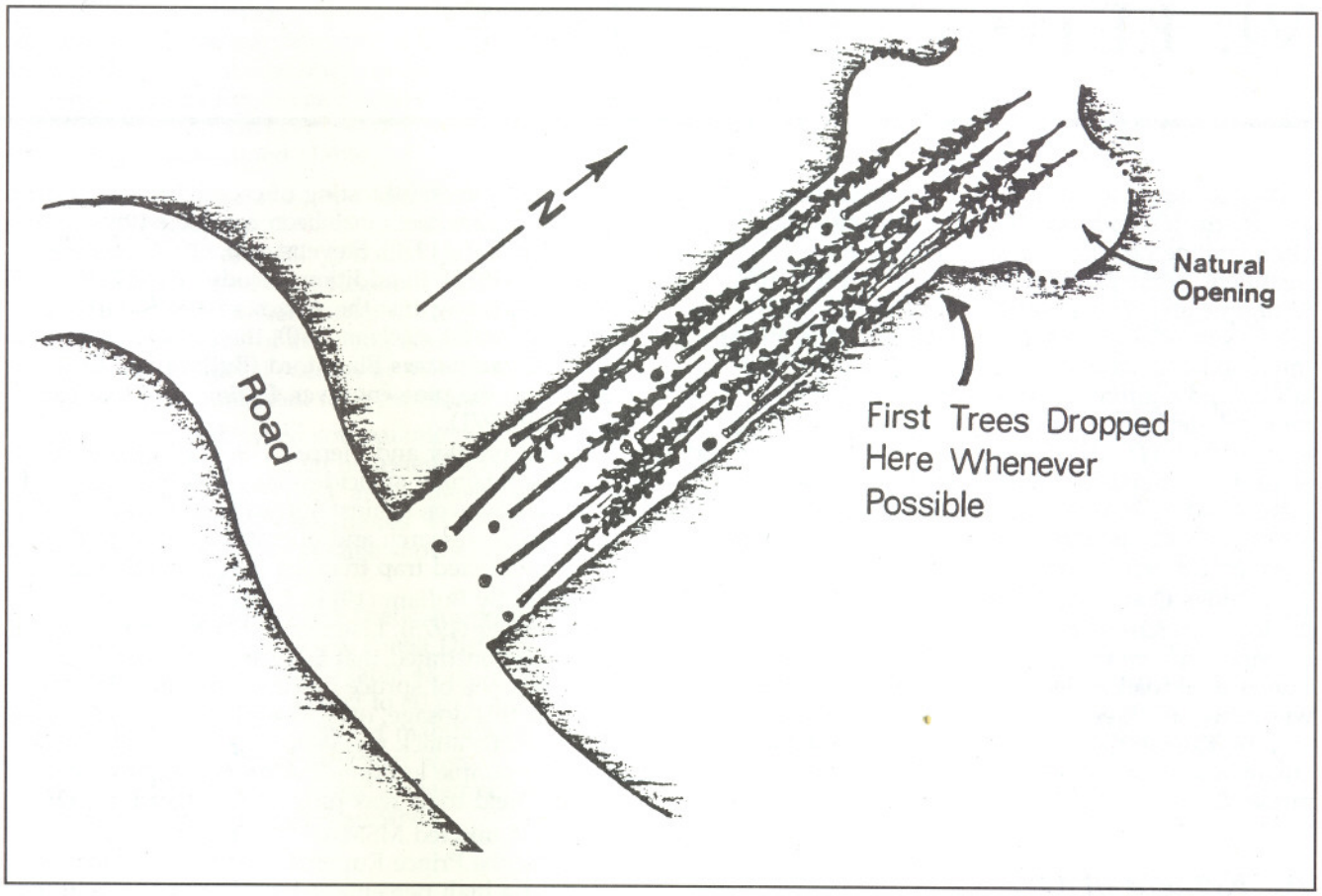

Figure 1. *An example of a felling pattern to create a trap tree patch.*

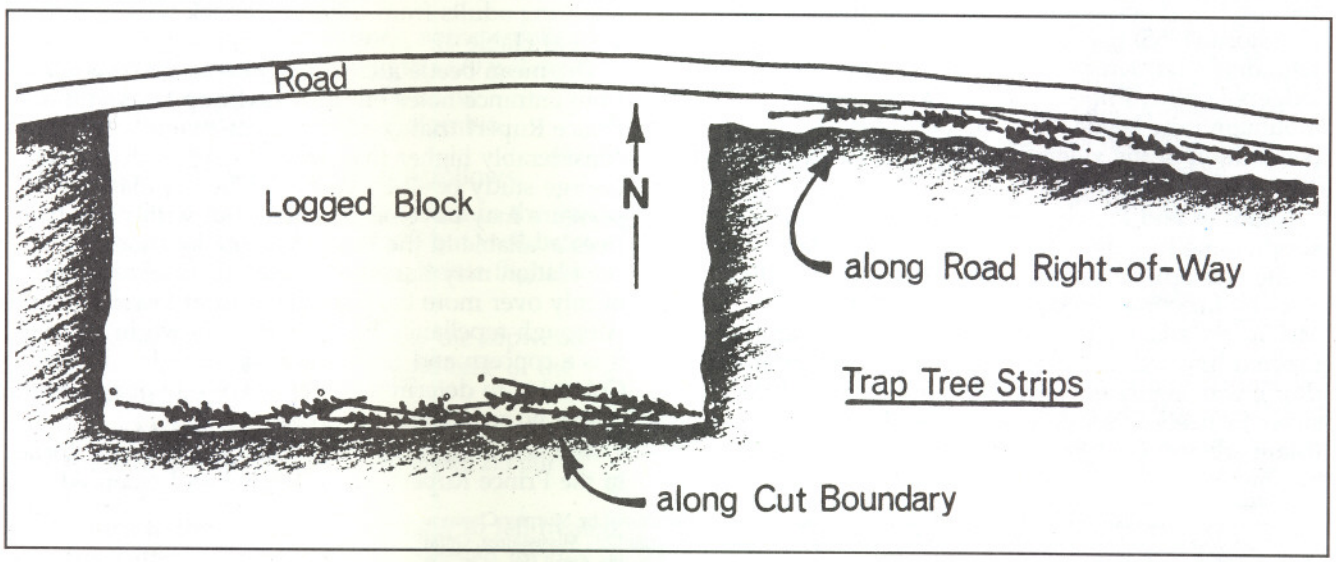

Figure 2. *An example of a felling pattern to create a trap tree strip.*

VI. LETHAL TRAP TREES

As discussed in the Introduction, lethal trap trees are pre-treated so as to kill arriving beetles and eliminate the need for subsequent extraction or treatment. Some advantages of the lethal trap tree technique are: (1) use in off-road or remote areas where subsequent trap tree extraction is difficult or impossible; (2) ease of application; (3) inexpensive labour and equipment costs (compared to tree removal, debarking, 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 insecticides to the bark exterior (Chansler and Pierce 1966; Frye and Wygant 1971; Minnemeyer 1975).

In British Columbia, lethal trap trees can be deployed in remote areas to contain pockets of emerging spruce beetle and to protect valuable spruce stands until road access can be constructed (usually within two to three years) (Hodgkinson 1983 b, Anon 1983 b). Conventional trap trees are recommended where access for subsequent extraction is not a problem.

A. Review of Use

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. Kinghorn (1955) injected two systemic insecticides, schraden[6] and demeton[7], 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 cacodylic acid[8] at 680 g/L a.i. McGhehey and Nagel (1967) found that Silvisar 510®[8] 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 fivespine ips, ***Ips lecontei*** Swaine (Stelzer 1970), the roundheaded pine beetle, ***D. adjunctus*** Blandford (Buffam and Flake 1971), and the pine engraver, ***I. pini*** (Say) (Newton and Holt 1971).

Since Chansler and Pierce's (1966) first experiment, arsenic-containing silvicides have had most use and success, however, against spruce beetle. Appendix 2 summarizes research and operational trials 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 Silvisar 510 at 340 g/L 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 six out of seven trap tree sample locations). A more complete review of these field trials was provided by Heath (1982).

Waters[9] injected MSMA[10] at 320 g/L a.i. into spruce in the Prince Rupert Forest Region and recorded a high percentage brood reduction with no significant difference in beetle attack densities on treated and untreated trap trees.

Operational trials in the Prince George Forest Region in 1981 revealed that MSMA at 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. Per cent brood reductions were higher than the above study, but unfortunately, the ½-strength dosage repelled some attacking adults from initiating attack (Hodgkinson 1983 a) (Table 4).

The mean beetle attack densities as determined from entrance holes on untreated trap trees in the Prince Rupert trial ($x=3.9/400$ cm^2) were considerably higher than those found in the Prince George study ($x=2.4/400$ cm^2). The population pressure may have been similar, but with more trap trees available in the Prince George location, the population may have distributed themselves more evenly over more bark surface area at lower densities. Although repellancy has not been shown in all trials, it is a concern and trials were conducted in British Columbia to determine an effective rate of application where no repellancy occurred.

Mitchell injected MSMA at 320 g/L a.i. into spruce in the Prince Rupert Forest Region and recorded

[6] octamethylpyrophosphoramide. Systam® no longer commercially manufactured by Murphy Chemical Co.
[7] $C_8H_{19}O_3PS_2$. Commercially available product called Systox® from Chemargo Ltd., Mississauga, Ontario.
[8] dimethylarsenic acid. Silvisar 510® no longer commercially manufactured by the Ansul Co.
[9] A. Waters. Formally with B.C. Ministry of Forests, Prince Rupert Forest Region, Smithers, B.C. (unpubl. report).
[10] Monosodium methane arsenate. Commercially available product called Glowon® from Yellowstone Agri Products Ltd., Richmond, B.C.

spruce beetle repellency in the lower ⅔ of the boles compared to check trap trees. Price (1982) injected MSMA at 160 g/L a.i. in trap trees at two locations in the Nelson Forest Region and achieved promising brood reductions; however, the rate of repellency could not be determined (Table 5).

In the second year of an operational research program, Hodgkinson (1983 b) tested MSMA at dosages of 80, 120 and 160 g/L a.i. in lethal trap trees in the Prince George Forest Region. The 80 g/L dosage, unlike the higher dosages, showed no significant repellency of attacking adults. Since all dosages reduced larval success by 99–100%, the lower dosage was recommended for operational use.

Holsten (1985) obtained comparable results to the Prince George studies when he tested MSMA in Alaska at 80 and 160 g/L a.i. and achieved a 99% brood reduction in both treatments. The 80 g/L dosage unlike the higher dosage showed no repellency of attacking adults.

Lethal trap trees for spruce beetle suppression have been used operationally in six Forest Districts of British Columbia since 1981 (Table 4). In 1983 the dosage of MSMA was lowered to 80 g/L a.i. in order to eliminate beetle repellency yet maintain high efficacy. Operational programs that were quantitatively assessed revealed a mean per cent brood reduction of greater than 90%.

B. Treatment for Lethal Trap Trees

MSMA has been shown to be effective as a translocating agent to produce a lethal trap tree which will kill arriving spruce beetles and any subsequent brood production.

As detailed in previous sections, some repellency may occur when using full strength (320 g/L a.i.) and, therefore, a dosage of 80 g/L a.i. is recommended for use in British Columbia.

The procedure for treatment is as follows:

1. select large diameter, living spruce in the spring when translocation has started but well before all snow has gone and before beetle flight is expected;
2. cut a shallow axe frill, just into the sapwood around the circumference at the base of the selected tree;
3. inject MSMA at the dosage mentioned above at the rate of 1 ml of formulation per 2.5 cm of circumference; and
4. return to the site two weeks later to fell treated trees after sufficient time has elapsed for the MSMA to translocate up the bole.

C. Lethal Trap Tree Deployment Strategies

1. Locations and Quantities

After the initial detection of a spruce beetle infestation has been made (e.g., via aerial sketchmapping) in an off-road or isolated area, ground probing is normally conducted to accurately delineate and assess the severity of the infestation. Access to these remote areas is usually only possible via a helicopter, float plane or boat. When a decision is made to undertake a lethal trap tree program, helispots or deployment locations must be chosen. These locations should be no further than 0.8 km from infested trees. In locations without natural clearings, helipads will have to be constructed to allow helicopter access.

In general, trap tree location and quantities are the same as has been discussed in previous sections. The locations should be as close to the infested trees as possible and no further away than 0.8 km. As with conventional trap trees, lethal traps are most cost-effectively felled in patches. Where helicopter access is necessary, it is advisable to select only those helispots where a minimum of 10–15 lethal trap trees are required.

2. Deployment Periods

Silvicides have been injected into spruce in either the spring prior to the spruce beetle flight, or in late summer/early fall in preparation for the following spring flight. In both strategies the trees have been felled two to four weeks later after silvicide translocation.

Frye and Wygant (1971) injected and felled lethal trap trees in Colorado in late May/early June with good results (Table 4). Buffam and Yasinski (1971) injected spruce in New Mexico after the beetle flight (between July 10–August 1) and felled them one month later. Although a proper statistical analysis was not made, it appears the lethal trap trees succeeded in attracting spruce beetle the following spring.

Buffam *et al.* (1973) stated that being able to deploy lethal trap trees in the early autumn "on bare ground" prior to the spring flight would simplify operational programs. With autumn injection and felling, Buffam obtained successful brood mortality in Arizona but only marginal results in Colorado because of inadequate silvicide translocation. With autumn treatments in Colorado, Lister *et al.* (1976) documented that spruce injected in late August, and felled one month later, were more attractive and efficacious than those injected in early August or late September.

All other lethal trap tree projects reviewed in Table 4 were successfully initiated in early spring before the beetle flight. To date in B.C. there have been no proper trials to determine if lethal trap trees deployed in late summer/early autumn are any more or less effective than those deployed in the spring. As with conventional trap tree deployment, anticipation of beetle-obstructive snow cover in certain areas may necessitate lethal trap trees being deployed in the spring. Prior to injection, trees should always be checked for active sap-flow to ensure proper translocation of MSMA.

3. *Special Characteristics*

The following lethal trap tree characteristics are based in part on the reviews by Schmid and Frye (1977) and Hodgkinson (1983 b). General trap tree characteristics outlined in Section II are also applicable here for lethal trap trees.

(a) Lethal trap trees should only be deployed in off-road or inaccessible areas (conventional trap trees can be deployed in accessible locations).

(b) Lethal trap trees are large diameter, uninfested spruce which are axe-frilled as close to the ground as possible (usually from mid-May to early June) and injected with MSMA (80 g/L a.i.) at the rate of one ml of formulation/2.5 cm phloem circumference.

(c) Lethal trap trees in the spring should be left for two weeks to allow MSMA translocation and then felled.

Table 4. *Summary of operationally-deployed lethal trap trees against spruce beetle in British Columbia*

Month/Year Felled	Location	No. of Patches	Average No. Lethal Trap Trees per Patch	Total No. of Lethal Trap Trees	MSMA[c] Dosage	Mean No. Successful Entrance Holes 400 cm² Bark	Per cent Brood Reduction
April 1980	Smithers[a] Landing	1	62	62	320 g/L	not measured	96%[e]
May 1981	Herrick Cr.[b]	67	10	670	160 g/L	2.4±0.9	98%[e]
	Quartz Cr.	7	24	169	160 g/L	unclear	unclear
	Copper Cr.	3	20	58	160 g/L	unclear	unclear
May 1982	Herrick Cr.[b]	39	10–20	490	160 g/L	1.4±1.3	98%[e]
	Top-of-the-World Park	58	10	580	160 g/L	3.7[d]	95%
June 1982	Traverse Cr.	2	11	22	160 g/L	1.4	99%
	Tangier Cr.	7	2	14	160 g/L	4.0	not measured
	Farm Cr.	6	5	31	160 g/L	6.0	100%
	Iron Bridge	7	12	78	160 g/L	4.7	70%
	Sale Cr.	7	3	23	160 g/L	3.7	90%
May 1983	Frisby Cr.	9	3	26	80 g/L	3.0	80%
	Farm Cr.	7	3	22	80 g/L	3.5	80%
	Iron Bridge Cr.	7	6	44	80 g/L	4.0	70%
	Kianuko Cr.	4	9	37	80 g/L	8.2	90%

[a] Prince Rupert Forest Region.
[b] Prince George Forest Region (all other locations in the Nelson Forest Region).
[c] Glowon® at either 320 g/L (full-strength, 160 g/L (½-strength), or 80 g/L (¼-strength).
[d] Standard deviations not available for Nelson Region projects.
[e] Adjusted by Abbott's Formula for natural mortality.

VII. CONCLUSIONS

Conventional and lethal trap trees have proven effective in attracting and disposing of spruce beetles in operational programs in western North America since the early 1970's. Although reduction of infestations and protection of stands is difficult to document, actual success of programs based mainly on beetle capture rates is quite possible given proper deployment tactics. Based on the information collected, the following conclusions can be drawn.

A. Conventional Trap Trees

In British Columbia the frequency of conventional trap tree use has increased substantially since 1979. In most Forest Regions conventional traps continue to be successfully deployed in patches, decks, strips and/or pre-felled rights-of-way and landings.

Although some quantitative data has been collected, most assessments of conventional trap tree effectiveness in British Columbia have been based on visual observations of the number of entrance holes on trap tree surfaces. Much less attention has been focused on the more difficult problem of determining the resultant level of protection of adjacent standing spruce. Clearly, more accurate record keeping and quantitative data is required to better document the success of conventional trap tree programs.

B. Lethal Trap Trees

Lethal trap trees were initially tested in British Columbia from 1979–1981 with MSMA at dosages of 160–320 g/L a.i. Since 1983 an operational dosage of MSMA at 80 g/L a.i. has been used because of its good success in reducing broods without producing beetle repellency.

As with conventional trap trees, further quantitative data is required to better substantiate their value in protecting adjacent timber, particularly in areas of light to moderate beetle attack densities.

Lethal trap trees might also be successfully deployed in late summer or early autumn in certain locations to avoid logistical problems of injecting and felling trees the following spring.

VIII. RECOMMENDATIONS

1. Conventional and lethal trap trees should be freshly cut, previously uninfested spruce with large diameters and thick bark. Traps should be cut as close to the duff line as possible and felled to lie as flat as possible on the ground in a direction which provides the greatest amount of shade. To provide additional shading, traps should not be delimbed or bucked. Only highly skilled, experienced fallers should be employed to fell trap trees.
2. Trap trees should be felled as close to the infested timber as possible, but no farther distant than 0.8 km. In areas of operational trap tree deployment, adjacent timber should be inspected each autumn by ground and aerial surveys to help assess the program's success.
3. Trap trees should mainly be deployed against heavy infestations in very small areas or against light to moderate infestations over larger areas.

   In accessible areas of light infestation, individual patches or truckloads should be felled on the shaded sides of roads every 0.4 km. In areas of moderate infestation, multiple patches should be felled at either the same spacing or closer together to deal with isolated concentrations of infested trees. If accessible, localized epicenters may be surrounded with multiple patches.
4. One trap tree should be felled for approximately every five standing infested trees. This may be modified to suit specific situations.
5. Conventional trap trees should be routinely felled every year in spruce harvesting areas to continually reduce the spruce beetle population. Trap trees can be deployed as patches, decks, strips and/or pre-felled landings and rights-of-way. Once the traps become infested, they *must* be removed or otherwise treated before the brood matures to attack new hosts.
6. Lethal trap trees should only be deployed in inaccessible locations where conventional trap trees could not be extracted. Lethal traps should be used to contain pockets of emerging spruce beetle, and/or to protect valuable spruce stands until road access can be constructed (usually within two to three years).
7. An operational dosage of MSMA at 80 g/L a.i. should be applied at the rate of one ml of formulation/2.5 cm phloem circumference at the frill line. Lethal trap trees should be axe-frilled and treated with MSMA in the spring when active translocation begins. Trees are to be subsequently left for two weeks to allow MSMA translocation and then felled.
8. An annual survey, aerial and ground (if possible) should be conducted over areas with trap tree programs to monitor the effectiveness of these programs and to aid in planning subsequent control actions.
9. Some aspects of trap tree deployment should be further examined whenever possible. These include: (1) more quantitative studies of effectiveness; (2) effectiveness of log decks as supplements to other deployment tactics; and (3) timing of felling (fall vs. spring) for both conventional and lethal trap trees.

IX. ACKNOWLEDGEMENTS

The author wishes to thank the following B.C. Forest Service staff for reviewing the manuscript: Dr. Robert DeBoo, Peter Hall and John Henigman of Protection Branch; Russ Cozens of Timber Harvesting Branch, and David Gray formerly of the Nelson Forest Region.

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APPENDIX I — *Trap Tree Deployment for Spruce Beetle Management in British Columbia*

Appendix I. *Conventional trap tree deployment against spruce beetle in B.C.*

Forest Region	Month/Year Felled	Trap Trees Felled by			No. and Type* of Trap Tree Deployment Locations	Approx. No. Trap Trees per Location	Reason for Deployment**	Pre-extraction Assessment			Comments/Observations
		Licencee	Under Sect. 88	Forest Service				Written	Visual	None	
Kamloops	March 1980	X	X		5[a]	35	G		X		heavily attacked
	March 1981	X	X		2[a]	85	G		X		heavily attacked
	Nov. 1981	X	X		2[b]	25	G		X		—
	Dec. 1981	X	X		4[a]	25	F		X		—
	Feb.-April 1982	X	X		30[a]	10-15	F	X			successful
		X	X		76[a]	24	G	X			low-mod. attack
		X	X		15[a]	14	G	X			low-mod. attack
		X	X		31[a]	7	G	X			low-mod. attack
		X		X	4[a]	10	F	X			—
		X		X	5[a]	25	F	X			—
		X		X	3[a]	20	F		X		—
		X		X	2[a]	13	F		X		—
	Feb.-March 1983	X	X		62[a]	10-15	F	X			successful
		X	X		78[a]	28	G	X			low-mod. attack
		X	X		12[a]	20	G		X		mod. attack
	Dec. 1983	X	X		3[a]	33	F		X		—
	Feb.-March 1984	X			60[a]	10-12	F			X	—
		X	X		2[b]	25	F		X		—
Prince Rupert	March 1978	X	X		1[d]	2,600	E		X		satisfactory
		X	TFL		1[d]	2,000	E		X		some not extracted
	March 1979	X	X		1[d]	1,636	E		X		satisfactory
	March 1980	X	X		1[d]	600	E		X		satisfactory
	March 1981	X	X		1[d]	2,000	E		X		satisfactory
	Feb.-March 1982	X	X		2[d]	1500	F, G		X		satisfactory
		X	X		17[d]	440	F, G		X		satisfactory
		X	X		3[d]	85	F, G		X		satisfactory
		X	X		2[d]	375	F, G		X		satisfactory
	Feb.-March 1983	X	X		18[a]	18	E	X	X		successful
		X	X	X	378[a]	20	F, G		X		successful
		X	X		110[a]	10	F, G		X		successful
		X	TFL		20[a]	100	F		X		successful
	Feb.-March 1984	X	X		21[a]	20	G	no assessments to date			felled one week late
		X	X		20[a]	10	G	no assessments to date			felled one week late

* Footnote key for deployment strategy: a=Patches, b=Decks, c=Strips, d=Pre-felled road Rights-of-way and Landings.
** Footnote key for reason of deployment: E=Containment before logging, F=Protection of adjacent timber, G=Clean-up after logging.

Appendix 1. *Conventional trap tree deployment against spruce beetle in B.C.* — Continued

Forest Region	Month/Year Felled	Trap Trees Felled by: Licencee	Trap Trees Felled by: Under Sect. 88	Trap Trees Felled by: Forest Service	No. and Type* of Trap Tree Deployment Locations	Approx. No. Trap Trees per Location	Reason for Deployment**	Pre-extraction Assessment: Written	Pre-extraction Assessment: Visual	Pre-extraction Assessment: None	Comments/Observations
Prince Rupert — *Continued*	Feb.-March 1984 — *Continued*	X	X		70[a]	20	E, G	no assessments to date			felled one week late
		X	X		33[a]	10	E, G	no assessments to date			felled one week late
		X	TFL		18[a]	20	E, G	no assessments to date			felled one week late
Prince George	Jan.-March 1979	X	X		10[a]	5	G			X	—
		X	X		67[a]	3-4	F		X		—
		X	X		16[a]	3-4	G	X			successful
	Jan.-March 1980	X	X		4[a]	200	G		X		—
		X	X		4[a]	3	E	X			moderately successful
		X	X		2[a]	10-12	E	X			some poorly shaded
		X	X		3[a]	10-12	E	X			successful
		X	X		190[a]	15-25	E, F	X			mean of 3.4±1.3
	Jan.-March 1981	X	X		328[a]	15-25	E, F	X	X		successful
		X	X		2[a]	22-81	G		X		some poorly shaded
		X	X		3[a]	20-30	G		X		successful
		X	X		2[a]	20	G		X		successful
	Jan.-March 1982	X	X		212[a]	15-50	E, F	X	X		mostly successful
	Jan.-March 1983	X	X		2[a]	25	E		X		—
		X	X		1[d]	600	E		X		—
		X	X		13[a]	30	F		X		—
		X	X		28[a]	10-20	E		X		mostly successful
		X			32[b]	20	E		X		—
		X	X		1[b]	100	E		X		—
		X	X		6[d]	130	E		X		—
		X	X		1[d]	65	E		X		—
		X	X		1[d]	1,400	E		X		—
		X	X		6[d]	170	E		X		—
		X	X		1[a]	30	E			X	—
		X	X		59[a]	50	E, F		X		—
	May 1983	X	X		25[a]	10-20	E			X	—
	Jan.-March 1984	X	X		150[b]	135	G		X		successful
		X	X		1[a]	100	E		X		—
		X	X		20[a]	16	F		X		successful
		X	X		26[b]	39	E		X		successful
		X	X		1[d]	700	E		X		successful
		X	X		3[a]	4	F		X		successful
		X	X		40[a]	10	G		X		successful
Nelson	March 1980	X	X		1[b]	25	G		X		heavy attack
		X	X		1[a]	15	F		X		heavy attack
	Jan. 1981	X	X		9[a]	13-14	F		X		—

* Footnote key for deployment strategy: a=Patches, b=Decks, c=Strips, d=Pre-felled road Rights-of-way and Landings.
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Appendix 1. *Conventional trap tree deployment against spruce beetle in B.C.* — Continued

Forest Region	Month/Year Felled	Trap Trees Felled by: Licencee	Trap Trees Felled by: Under Sect. 88	Trap Trees Felled by: Forest Service	No. and Type* of Trap Tree Deployment Locations	Approx. No. Trap Trees per Location	Reason for Deployment**	Pre-extraction Assessment: Written	Pre-extraction Assessment: Visual	Pre-extraction Assessment: None	Comments/Observations
Nelson											
— *Continued*	March 1981	X	X		70[a]	5	F		X		mod. heavy
		X	X		2[a]	150	F		X		mod. heavy
	May 1981			X	1[d]	397	F		X		—
	Sept. 1981			X	1[a]	46	F	X			—
				X	1[a]	34	F				x=2.3 attacks per 400 cm
	Jan. 1982	X	X		24[a]	11-12	F		X		—
		X	X		49[a]	8-12	F		X		—
	March 1982	X	X		12[a]	5	F		X		light attack
		X	X		31[a]	6-7	F				mod. attack
		X	X		17[a]	5-6	F				low-mod.
		X	X		42[a]	5-7	F				low-mod.
		X	X		34[a]	6-9	F		X		low-mod. attack
		X	X		2[a]	5-6	F		X		mod. attack
		X	X		2[a]	6	F			X	—
	May 1982			X	1[a]	7	—	X			x=5.0 attacks per 400 cm^2
		X	X		5[c]	200	F		X		heavy *Ips*
		X	X		3[c]	140	F	X			x=2.5 attacks per 400 cm^2
	June 1982			X	1[a]	44	F	X			—
				X	1[a]	79	F	X			—
		X		X	1[a]	22	F		X		x=1.4 attacks per 400 cm^2
				X	58[a]	10	E	X			x=3.7 attacks per 400 cm^2
	Sept. 1982			X	10[a]	10	E		X		heavy attack
	Jan. 1983	X	X		12[a]	11-12	F	X			mod. attack in adjacent stand
		X	X		6[a]	16-17	F	X			—
		X	X		4[a]	10	F		X		—
		X	X		2[a]	10	F		X		—
	March 1983	X			7[a]	14-15	E		X		light-moderate attack
		X			12[a]	20	E		X		mod. attack
		X			2[b]	215	E	X			x=2.4 attacks per 400 cm^2
		X			13[a]	5	E		X		mod. attack
	April 1983	X	TFL		15[a]	10	F	X			x=3.1 attacks per 400 cm^2
		X	TFL		3[b]	50	F			X	
	May 1983	X			4[a]	20	E		X		mod. attack
		X	X		6[c]	80	F			X	
		X	X		4[c]	50	F	X			x=3.5 attacks per 400 cm^2

* Footnote key for deployment strategy: a=Patches, b=Decks, c=Strips, d=Pre-felled road Rights-of-way and Landings.
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Appendix 1. *Conventional trap tree deployment against spruce beetle in B.C.* — Continued

Forest Region	Month/Year Felled	Trap Trees Felled by: Licencee	Trap Trees Felled by: Under Sect. 88	Trap Trees Felled by: Forest Service	No. and Type* of Trap Tree Deployment Locations	Approx. No. Trap Trees per Location	Reason for Deployment**	Pre-extraction Assessment: Written	Pre-extraction Assessment: Visual	Pre-extraction Assessment: None	Comments/Observations
Nelson — *Continued*	June 1983			X	3[a]	12	F	X			x=8.2 attacks per 400 cm²
Vancouver	April 1982	X			1[a]	12	E		X		traps successfully attacked
Cariboo	March 1981	X			40[a]	100	—		X		—
		X			1[c]	5,000	—		X		—
	March 1982	X			3[a]	500	E	X	X		—
		X			1[c]	20,000	E		X		—
				X	38[a]	20	E			X	—
	March 1983			X	9[a]	15	E			X	—
	March 1984	X			20[c]	250	E		X		successful
		X	X		109[a]	12-25	E, G		X		—
		X			2[a]	5	G		X		successful
		X	X		2[a]	15	G		X		—

* Footnote key for deployment strategy: a=Patches, b=Decks, c=Strips, d=Pre-felled road Rights-of-way and Landings.
** Footnote key for reason of deployment: E=Containment before logging, F=Protection of adjacent timber, G=Clean-up after logging.

APPENDIX II — *Summary of Research and Operational Trials on Silvicide-injected Trap Trees for Spruce Beetle Suppression*

Appendix II. *Summary of Research and Operational Trials on Silvicide-injected Trap Trees for Spruce Beetle Suppression*

Author	Location	Cacodylic Acid Formulation	Injection Time	No. of Trap Trees		Standing or Felled	Repellency	% Brood Mortality
				Injected	Check			
Chansler and Pierce (1966)	New Mexico	Full strength Silvisar 510[a] and Ansar 160[b]	Post-attack	15	7	Standing	N/A	87%
Buffam and Yasinski (1971)	New Mexico	Full-strength Silvisar 510	Pre-attack	757	1	Felled	Not Proven	Not Quantified
Buffam (1971)	New Mexico	Half- and Full-strength Silvisar 510	Pre-attack	16	12	Standing and Felled	None[c]	90%[d]–91%
Frye and Wygant (1971)	Colorado	Full-strength Silvisar 510	Pre-attack	10	10	Felled	None	94–95%
Dyer (1973)	British Columbia	Half-strength Silvisar 510	Pre-attack	80	80	Standing	None	5–19%
Buffam *et al.* (1973)	Colorado and Arizona	Half and Full-strength Silvisar 510	Pre-attack	180	90	Felled	None	37–71% (Colorado) 94–98% (Arizona)
Minnemeyer (1975)	Colorado	37%, 75%, and 75% (twice) Silvisar 510	Pre-attack	46	14	Felled	None	92%, 100%, 100%
Dyer (1975)	British Columbia	Full-strength Silvisar 510	Post-attack	60	40	Standing	N/A	62–68%
Lister *et al.* (1976)	Colorado	10%, 25%, 50% & Full-strength Silvisar 510	Pre-attack	40	10	Felled	Repellency in Full-strength and Half-strength	40% 70% 90% 94%
Frye *et al.* (1977)	Wyoming	10%, 25%, 50% & Full-strength Silvisar 510	Post-attack	80	20	Standing	N/A	10--67% 73–94% 55–99% 98–100%
Mitchell[f] (1981)	British Columbia	Full-strength Glowon[g]	Pre-attack	62	10	Felled	Unclear	96%
Waters[f] (1979)	British Columbia	Full-strength Glowon[g]	Pre-attack	4	4	Felled	None	92%

[a] Trade name of a solution manufactured by the Ansul Co. containing the equivalent of 680 g cacodylic acid/L (5.7 lbs/U.S. gal).
[b] Trade name of a solution manufactured by the Ansul Co. containing the equivalent of 390 g cacodylic acid/L (3.25 lbs/U.S. gal).
[c] No repellency in felled half-strength treatments compared to felled checks.
[d] Brood mortality of 90% in felled half-strength treatments compared to felled checks.
[e] Mortalities from ½ strength = 37% and 94%. Mortalities from full-strength = 71% and 98%.
[f] Unpublished report (see text footnote numbers 1 and 12, respectively).
[g] Trade name of a solution distributed by the Yellowstone Agri Products Ltd. containing the equivalent of 320 g MSMA (monosodium methane arsenate)/1 (2.67 lbs/U.S. gal).

Author	Location	Cacodylic Acid Formulation	Injection Time	No. of Trap Trees		Standing or Felled	Repellency	% Brood Mortality
				Injected	Check			
Price (1982)	British Columbia	Half-strength Glowon[g]	Pre-attack	46	44	Felled	Unclear	Unclear
Hodgkinson (1983 a)	British Columbia	Half-strength Glowon[g]	Pre-attack	670	55	Felled	Yes	98%
Hodgkinson (1983 b)	British Columbia	25%, 38%, 50% Glowon[g]	Pre-attack	510	10	Felled	None with ½ strength	99%, 99%, 100%
Holsten (1985)	Alaska	25%, 50%, Glowon	Pre-attack	20	10	Felled	None with ¼ strength	99%

[a] Trade name of a solution manufactured by the Ansul Co. containing the equivalent of 680 g cacodylic acid/L (5.7 lbs/U.S. gal).
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