The Application of Behaviour-modifying Chemicals to Contain Infestations of the Mountain Pine Beetle, *Dendroctonus ponderosae*^{1,2}

by

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Abstract

Five replicates of paired forest blocks containing lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., infested by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were chosen in the spring of 1982 in various interior British Columbia locations. Within the experimental block of each pair, one lodgepole pine every 50 m (4 trees/ha) was baited with the attractive semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin. The baiting program caused the attack in 1982 to be concentrated in and around the baited trees, whereas it was more dispersed in the control blocks. The overall ratio of 1982: 1981 attacked trees was 2.5 in the baited blocks and 1.8 in the controls, suggesting that dispersal of beetles out of the baited blocks was inhibited. Baiting of trees with semiochemicals is recommended to contain infestations within prescribed boundaries when sanitation-salvage logging cannot be completed prior to mid-summer flight of emergent brood beetles.

Résumé

Cinq répétitions de blocs forestiers paires de pin lodgepole (*Pinus contorta* var. *latifolia* Engelm.) infesté par le (*Dendroctonus ponderosa* Hopkins) furent choisies au printemps 1982 dans divers sites de l'intérieur de la Colombie Britannique. Dans le bloc expérimental de chaque paire, un pin à tous les cinquante mètres (4 arbres/ha) a été traité au "myrcène", au "trans-verbenol" et à l'"exo-brevicomin" pour servir d'élément attractif. Le traitement d'appât a causé en 1982 une attaque concentrée autour des arbres appâtés, alors que l'attaque a été plus dispersée dans les blocs de contrôle. Le rapport d'arbres attaqués de 1982 sur 1981, étant de 2.5 dans les blocs appâtés et de 1.8 dans les contrôles, suggère que la dispersion du dendroctone en dehors des blocs d'appâts était inhibée. Le traitement d'appât est recommandé pour contenir certaines infestations à l'intérieur des limites prescrites lorsque la récupération des bois ne peut être réalisée avant le vol de la mi-été des nouvelles dendroctones.

Introduction

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is in outbreak throughout much of Western North America (Van Sickle 1982; McGregor 1982). One means of inhibiting small infestations from expanding to outbreak proportions is sanitation-salvage cutting, whereby infested trees with live brood beetles as well as susceptible, uninfested trees are removed from the forest (Safranyik *et al.* 1974). Such harvesting may be hindered by the absence of roads, poor road conditions, lack of adequate pre-harvest inventory, problems in issuing cutting permits, preoccupation of contractors with

other priorities, or poor timber markets. If the cut cannot be made prior to emergence of the brood beetles, an infestation may intensify and expand. This problem often occurs in infestations in lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., and ponderosa pine, *P. ponderosa* Laws., in the interior of British Columbia.

A complex of three semiochemicals (message-bearing or behaviour-modifying chemicals) is known to mediate mass attack by *D. ponderosae* in hard pines in BC (Conn *et al.* 1983; Borden *et al.* 1983a). These chemicals are the host tree monoterpene, myrcene, and two aggregation pheromones, the female-produced *trans*-verbenol, and the male-produced *exo*-brevicomin. They can be effectively used to induce attack on trees baited with them, as well as to concentrate attack on nearby surrounding trees (Borden *et al.* 1983a,b). A similar effect has been demonstrated with semiochemicals used by other bark beetles, e.g. the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins (Ringold *et al.* 1975), and the spruce beetle, *D. rufipennis* (Kirby) (Dyer 1975). These results led us to adapt Pitman's (1973) strategy of semiochemical contain-

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ment of *D. pseudotsugae* for *D. ponderosae*. We hypothesized that a systematic program of semiochemical baiting could be used against *D. ponderosae* to contain within prescribed boundaries a growing infestation that could not be logged before brood flight. This paper presents the results of a controlled experiment designed to test this hypothesis.

Materials and Methods

Five replicates of paired forest blocks, each harbouring a *D. ponderosae* infestation, were chosen (Table 1). Three replicates were in the Bulkley Forest District of the Prince Rupert Region (Graphite Creek and Keulsh Rd. blocks), and two were in the Cranbrook Forest District of the Nelson Region (Plumbob Rd., Suzanne Lk., and Fish Lk. Jn. blocks). The paired blocks were selected as much as possible for similarities in area, stocking, tree size and component of susceptible lodgepole pine (Table 1), as well as for similar levels of infestation (red trees) in 1981 (Table 2). In addition, two blocks without paired controls, Bristol Rd. in the Bulkley Forest District and West Yahk River in the Kootenay Forest District, Nelson Forest Region (Table 1) were selected for treatment.

The experiment was set up in the Prince Rupert Region on 14-17 June and in the Nelson Forest Region on 21-23 June, 1982, well before the first emergence was expected. Well marked lines were established by compass at 50 m intervals through each block. Every 50 m, a tree on or within 15 m of the compass line was marked with paint, and in the experimental blocks, baited with semiochemicals. The baiting system employed a foldable, aluminum holder nailed to the north side of the tree. The holder contained vials releasing myrcene and *trans*-verbenol at laboratory-determined rates of 17 and 2 mg/day, respectively, and a capillary tube releasing *exobrevicomin* at 0.5 mg/day (Borden *et al.* 1983b).

In this systematic method of baiting on a grid basis, a density of 4 baits/ha was achieved. Unless the lack of pine dictated that there was > 50 m between baited trees, no beetle could emerge from the infestation without flying within 25-30 m of a baited tree.

The experiment was assessed in the Prince Rupert Region on 7-15 September, and in the Nelson Forest Region on 27-29 September, 1982. In each block, a 100% survey was done for trees attacked by *D. ponderosae* in 1981 (red-topped trees) and 1982 (green-attacked trees). One person in a three person crew walked the compass line and took notes, while the other two searched for infested trees. The diameters at breast height (dbh) of all infested trees were taken, and the attack density on green-attacked trees was counted in two, 20 × 40 cm frames held at eye level on the bole. The position of each baited or marked tree, as well as each red-topped and green-attacked tree was plotted on a map.

Results and Discussion

The semiochemical baiting program had a marked effect on the pattern of the 1982 attack by *D. ponderosae*. Of particular significance was the fact that for two replicates and for all replicates combined, the ratio of the green-attacked to red-topped trees was significantly higher in the baited than in the control blocks (Table 2). Never was the ratio higher in a control block than in a baited block. Interpreted in another way, there were 250 green-attacked trees for every 100 red-topped trees in the baited blocks, and 180 green-attacked trees for every 100 red-topped trees in the control blocks. This result suggests that the baiting program inhibited beetles from leaving the baited blocks or attracted beetles from outside them. As each

block was chosen for its relative isolation from surrounding infestations, the former hypothesis is more likely. An alternative hypothesis that the baiting program induced attack of lesser density on proportionately more trees than in the control blocks is refuted by the nearly equal percentages (70.5 and 68.6%) of the attacked trees that were mass attacked in control and baited blocks, respectively (Table 2).

The difference in distribution of infestation caused by semiochemical baiting can be seen in Table 2 and Fig. 1. In each case, the attacked trees were significantly closer to the baited trees in baited blocks than to marked trees in control blocks (Table 2). Between 40.2 and 100% of the attack ($\bar{x}$ = 70.9%) in the experimental blocks was concentrated within a 10 m radius around the baited trees. In contrast, the majority of attacked trees in the control blocks were in the much larger area from 10-25 m from the marked trees, reflecting a much greater dispersion (Fig. 1). A similar redistribution of attack was achieved for *D. pseudotsugae* by Pitman (1973).

Attack beyond 25 m of the baited or marked trees occurred primarily when there was > 50 m between suitable pines on or near the compass line. These attacked trees undoubtedly provided focal points for attack which diverted beetles from the baited trees, particularly in the Graphite Creek and Bristol Road blocks. The former area was characterized by diverse forest type and beaver ponds, while the latter had large patches of blowdown as well as numerous swamps. In addition, high brush at Graphite Creek and blowdown at Bristol Road resulted in many baits being placed just above the understory canopy. Thus the odour plumes of the released volatiles probably descended into a stratum at which few beetles were flying, further decreasing the efficacy of the baited trees in these areas, and causing the distribution of attacked trees to approach a pattern more characteristic of that in unbaited blocks (Fig. 1). These results suggest that baiting on a 50 m grid is preferable to a greater between-tree distance, and that baits should be well above the ground or understory canopy so as to intercept the maximum possible number of flying beetles.

In general, one would not expect a great difference in green-attacked to red-topped ratios between baited and control blocks (Table 2), as *D. ponderosae* commonly attacks fairly near the trees from which it emerges. Relatively few beetles would migrate further afield, causing an infestation to expand. It appears that the baiting program deterred these beetles from leaving.

In large infestations such as those at Graphite Creek and Bristol Rd., it would be immaterial where the beetles moved within the infestation. Only when beetles approached the periphery and threatened to fly outside the boundaries of the infestation would they present a threat to its expansion. Therefore, we recommend that only small infestations, e.g. 2-20 ha, be baited on a grid basis. Larger infestations could be baited only near their peripheries, e.g. on a 50-150 m deep boundary corridor that would intercept departing beetles, as well as possibly draw in migrating beetles passing near the infestation. This procedure might be supplemented by occasional baiting of a few trees in "hot spots" within the larger infestation.

We conclude that semiochemical baiting for *D. ponderosae* can be applied immediately on an operational basis, as the cost of baits and labour permits. Optimally, it should be applied on a regional basis, e.g. on an entire drainage, with all infestations that cannot be removed before brood flight baited and removed later. The course of infestations within baited regions could then be followed and compared with events in any regions in which semiochemical baiting is not applied.

Table 1. Descriptive data on semiochemical-baited and control blocks in interior BC locations. Forestry data taken from BC Forest Service cruises.

Rep. no.	Approximate location and description of block	Lodgepole pine inventory					dbh (cm) of baited or marked trees	
		Area	No. trees/ha	$\bar{x}$ dbh (cm)	Net merchantable volume		$\bar{x}$	Range
					m ³ /ha	% of total vol.		
1	Graphite Ck, 3.5 km W of Moricetown	75.0	168	29.3	115	43	32.3	19.4-56.9
	Control block	63.0	224	29.1	157	43	32.8	24.6-51.2
2	Keulsh Rd. A, 45 km N of Smithers	7.3	92	41.8	134	29	40.8	29.5-55.0
	Baited block	8.0	403	32.8	299	71	40.1	27.9-53.7
3	Keulsh Rd. B, 45 km N of Smithers	5.5	230	29.0	143	58	37.8	24.0-51.8
	Baited block	9.8	193	38.7	225	63	33.8	20.7-44.5
4	Plumbob Rd., 48 km S of Cranbrook	9.7	434	25.0	193	82	25.2	17.8-35.8
	Baited block	3.8	334	28.2	195	100	39.0	22.9-39.2
5	Fish Lk Jn, 45 km S of Cranbrook	8.8	574	20.6	129	78	28.3	22.0-39.6
	Suzanne Lk, 45 km S of Cranbrook	7.0	606	18.5	109	78	25.5	19.2-37.5
—	Bristol Rd., 36 km N of Smithers	31.0	281	31.7	207	67	37.9	22.1-48.9
—	West Yahk R., 27 km S of Yahk	3.0	350	25.9	130	100	34.6	23.7-49.0

Table 2. Attack by *D. ponderosae* in paired baited and control blocks and in two baited blocks with no paired controls.

Rep. no.	Location and treatment	Surrounding trees										No. red (1981) trees	Green: red (1982: 1981) ratio ^c
		Marked or baited trees						No. attacked	Mass attacked ^a		$\bar{x}$ Distance $\pm$ SD from nearest baited or marked tree ^b		
		Attacked			Mass attacked ^a				No.	%			
		No.	No.	%	No.	%		No.	%				
1	Graphite Ck. Control	239	9	3.7	4	1.7	414	291	70.2	18.8 $\pm$ 9.0	200	2.1	
	Baited	188	90	47.8	49	26.1	317	219	69.0	14.3 $\pm$ 8.7**	131	3.1**	
2	Keulsh Rd. A Control	30	1	3.3	1	3.3	32	27	84.3	22.1 $\pm$ 8.3	37	0.9	
	Baited	32	21	65.6	17	53.1	47	35	74.4	12.0 $\pm$ 9.2**	58	1.2	
3	Keulsh Rd. B Control	41	0	0.0	0	0.0	15	12	80.0	20.5 $\pm$ 3.2**	16	0.9	
	Baited	21	19	90.4	12	57.1	28	16	57.1	8.5 $\pm$ 8.5	26	1.8	
4	Plumbob Rd. Control	35	0	0.0	0	0.0	42	30	71.4	16.6 $\pm$ 6.1	39	1.1	
	Baited	12	11	91.6	11	91.6	43	32	74.4	8.6 $\pm$ 6.2**	24	1.7*	
5	Fish Lk. Jn/ Suzanne Lk Control	28	0	0.0	0	0.0	57	35	61.4	15.9 $\pm$ 8.0	20	2.9	
	Baited	27	24	88.8	22	81.5	23	12	52.1	3.4 $\pm$ 1.3**	15	3.1	
Summary of paired blocks													
	Control	373	10	2.7	5	1.3	560	395	70.5	18.5 $\pm$ 8.6	312	1.8	
	Baited	280	165	58.9	111	39.6	458	314	68.6	12.5 $\pm$ 8.8**	254	2.5**	
—	Bristol Rd. Baited	110	54	49.0	21	19.1	48	18	37.5	18.5 $\pm$ 18.4	72	1.4	
—	West Yahk R. Baited	12	12	100.0	12	100.0	42	24	57.1	9.4 $\pm$ 9.3	27	2.0	

^aMass attacked trees arbitrarily designated as those with ≥ 5 attacks in two, 2 $\times$ 40 cm frames, an attack density of 30.75/m².^bSignificant difference (t-test) between paired means indicated by **, $p < 0.01$.^cBaited trees included in 1982 attack. Significant difference (χ^2 test) between control and baited blocks indicated by *, $p < 0.05$ and **, $p < 0.01$.

Figure 1. Distribution of attack by *D. ponderosae* surrounding baited trees (baited blocks) or marked trees (control blocks).

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