

# Application of Semiochemicals in Post-Logging Manipulation of the Mountain Pine Beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae)<sup>1</sup>

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**ABSTRACT** Lodgepole and ponderosa pines, *Pinus contorta* var. *latifolia* Engelm. and *P. ponderosa* Dougl. ex. Laws., respectively, in the interior of British Columbia were baited with the semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin to induce attack by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. In one post-logging application, semiochemical baiting was effective in shifting the locus of a small infestation so that it could be cut and removed from the forest. In another application after a selective, sanitation-salvage cutting, semiochemical baiting was successful in concentrating a residual population in baited trees and trees surrounding them.

Infestations of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, can be managed through various methods, including selective and partial cutting (Cahill 1978) and sanitation-salvage clearcutting (Safranyik et al. 1974). However, no logging method ensures that all infested trees are removed. If undetected and allowed to remain, these trees may harbor enough beetles to renew an infestation and return it to an outbreak level.

Myrcene, *trans*-verbenol and *exo*-brevicomin have been identified as attractive semiochemicals for *D. ponderosae* infesting lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., and *P. ponderosa* Dougl. ex. Laws., in British Columbia (B.C.) (Conn et al. 1983, Borden et al. 1983a). The demonstration that these semiochemicals can be used reliably to induce attack on baited trees (Borden et al. 1983a) suggested that they could be used to manipulate the beetle in various situations. This paper describes two examples of their application as post-logging treatments.

From 4 January to 28 February 1982, a sanitation-salvage clearcut (B.C. Forest Service Cutting Permit [CP] 84) removed beetle-infested trees from a site located 23.5 km east of Princeton, B.C. Part of this clearcut extended in a 50-m-wide strip (Fig. 1) between uninfested forest on publically owned, Crown land and a private property which supported a 41-tree infestation (12 ponderosa and 29 lodgepole pines) that was not cut because of the owner's objections.

We hypothesized that creation of a source of attraction by baiting trees with semiochemicals could draw all or part of the infestation from private to Crown land, from which infested trees could be removed with impunity.

By the fall of 1981, an isolated *D. ponderosae* infestation in a lodgepole pine forest near the eastern boundary of Manning Park, B.C., had grown to outbreak status on >65 ha. A survey in March 1982 identified 3,568 currently attacked trees (Andrews 1982). Many of the

trees were in a 17-ha portion of the infestation in which a 1981 semiochemical baiting program had induced a 2.5-fold higher rate of trees attacked than in the remainder of the infestation (Borden et al. 1983a).

In the winter of 1981-1982, the B.C. Ministry of Lands, Parks and Housing made a decision to selectively cut and remove the infested trees from the infestation. Between 1 May and 15 June 1982, all of the 3,568 marked trees, plus an additional 1,932 unmarked trees, were removed, and the stumps were peeled.<sup>4</sup> None of the estimated 7,000 unattacked pines in the area was cut.

As a check of the effectiveness of the first year of the sanitation-salvage operation, and in an effort to localize attack by any residual beetles, we carried out a semiochemical tree-baiting program.

## Materials and Methods

### *Shifting the Locus of an Infestation*

On 7 July 1982, 16 trees (12 ponderosa and 4 lodgepole pines) on the Crown land side of the clearcut strip on CP 84 were each baited with the following semiochemicals, with receptacles and release rates as determined in the laboratory: (1) myrcene, 6-ml glass vial with 3-mm-diameter hole in lid, release rate 17 mg/day; (2) *trans*-verbenol, two open 2-ml glass vials, release rate 1 mg/day; and (3) *exo*-brevicomin, glass capillary tube, 1 mm internal diameter, with one end closed, release rate 0.5 mg/day. The source and purity of the chemicals as well as methods for determining release rates were as given by Conn et al. (1983). The bait receptacles were placed in foldable, aluminum holders nailed to each tree (Borden et al. 1983a).

A preliminary check for attack was made on 29 July 1982. On 30 September through 1 October the locations of all pines with diameters at breast height (dbh)  $\geq$  10 cm within the previously infested (1981) and baited (1982) areas were mapped. The numbers of emergence holes or attacks were counted within two flexible plastic frames (20 by 40 cm) held on the bole at eye level.

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*Post-Logging Mop Up*

On 25 June 1982, 50 trees, well spaced throughout the Manning Park infestation (Fig. 2), were baited with myrcene, *trans*-verbenol, and *exo*-brevicommin as described above.

A preliminary check of the baited area on 29 July 1982 indicated that attack was in progress, and that 11 of 11 baited trees examined were undergoing attack. On 1 October, attack on the baited trees and on trees within a 12-m radius surrounding them was assessed. The dbh and attack density were recorded for all attacked trees as described above. On 15 October, a further assessment was made of all attacked trees that could be located outside the 12-m radius as a supplement to an independently conducted survey of the area (Wood 1982).

**Results**

*Shifting the Locus of Infestation*

By 29 July, all 16 baited trees were attacked, as were 19 trees immediately surrounding them. The post-attack assessment disclosed 61 attacked trees in the baited area and none in the mapped area surrounding the 1981 infestation (Fig. 1). However, an intensive search in a 50-m-wide band surrounding the 1981 infestation revealed

one lodgepole pine attacked in 1982. (Fig. 1). The dbh of this tree was 33.7 cm, and it had an attack density of 131.3/m<sup>2</sup>.

The data for unbaited trees in each species in Table 1 reflect the preference of the beetles for larger-diameter trees (Cole and Amman 1980). However, the data show no difference in diameter of trees in the two infestations that would have made the trees in one area preferable to trees in another. The trend for higher attack density on the baited compared with unbaited trees is consistent with the results of Borden et al. (1983a), and is probably due to the continuous release of attractive compounds from the bait receptacles which overrides the antiaggregative effect of frontalin produced by mated males (Ryker and Libbey 1983).

Comparison of emergence holes with attack density (Table 1), conservatively assuming a male-female sex ratio of 1 to 2 (Reid 1958, McGhehey 1969, Safranyik and Jahren 1970), assuming that attack height was similar in 1981 and 1982, and finally assuming that all emergent females survived, the females from the 1981 infestation could account for only 48.2% of the 1982 attack. At a more realistic mortality rate of one-third of the emergent females (Cole and Amman 1980), 32.2% of the 1982 attack could be attributed to emergent fe-

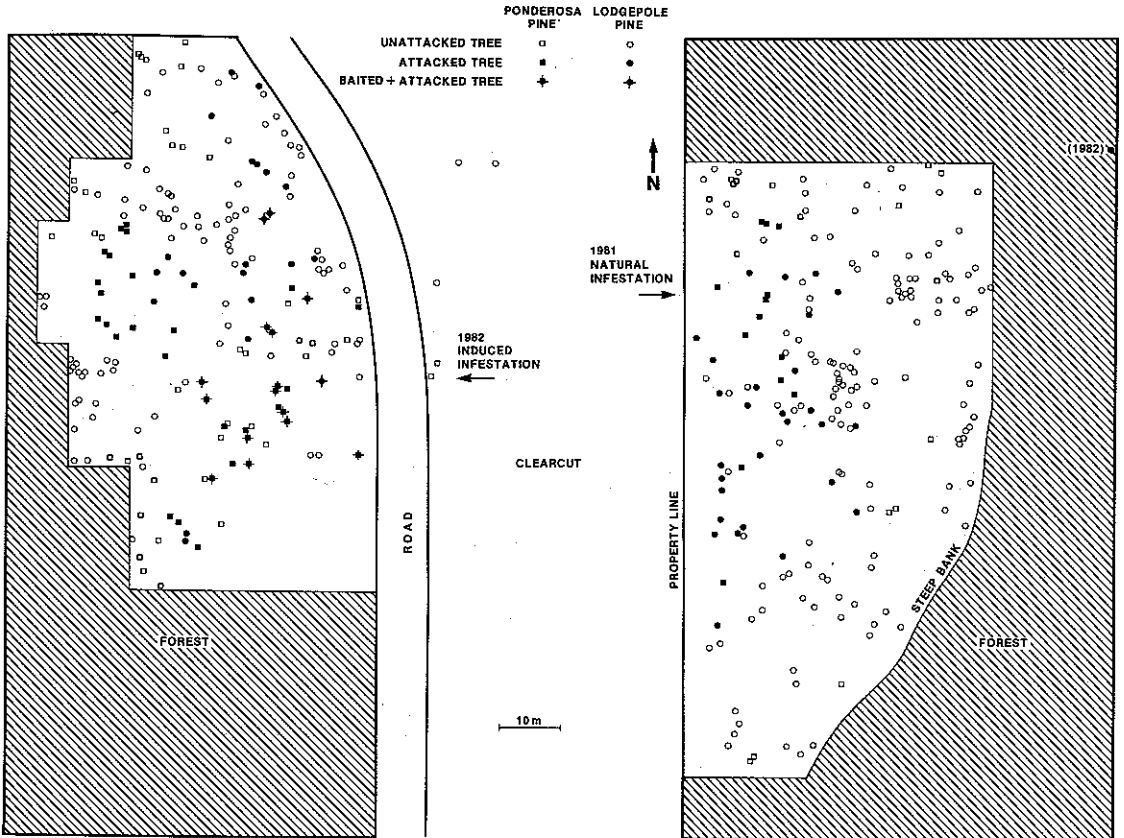


FIG. 1. Map of natural (1981) *D. ponderosae* infestation and semiochemical-induced (1982) infestation separated by 50-m-wide clearcut, CP 84, 23.5 km east of Princeton, B.C. Note single tree attacked in 1982 at top right. The four trees within the clearcut are noncommercial trees not taken by the loggers.

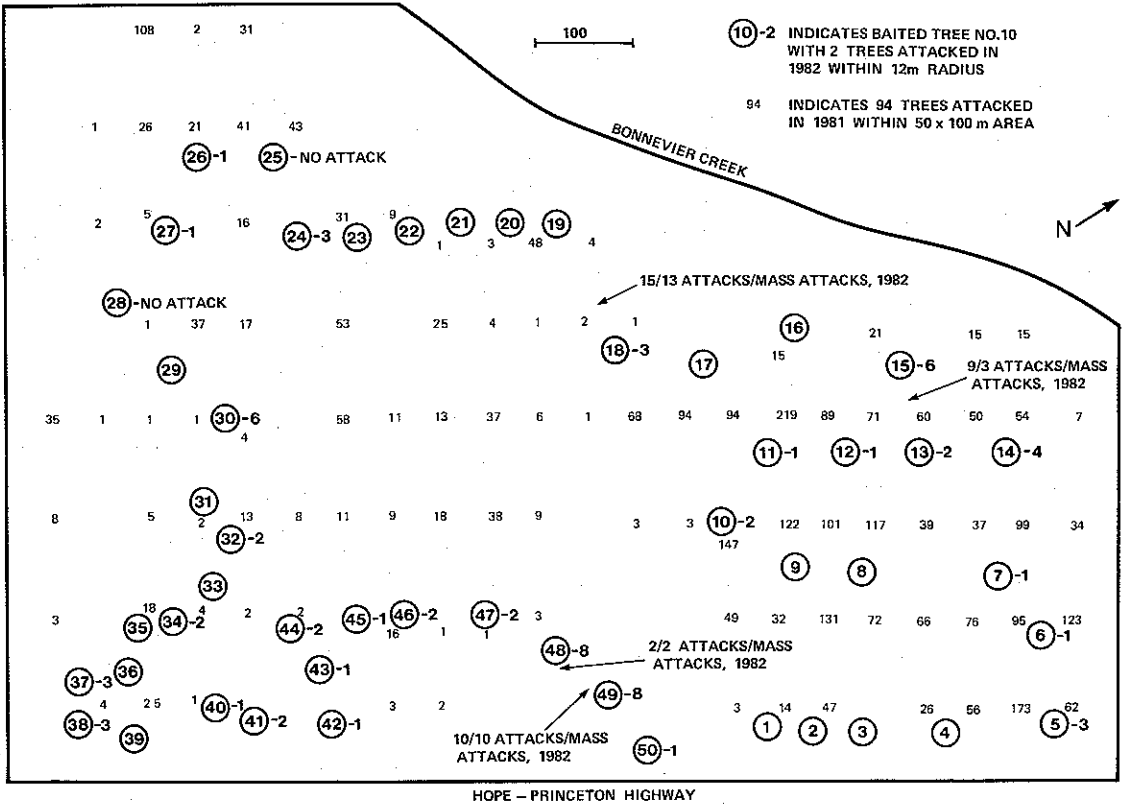


FIG. 2. Map of *D. ponderosae* infestation at Manning Park, B.C., showing distribution of infested trees in 1981 before selective, sanitation-salvage cutting, and locations of 50 semiochemical-baited trees and surrounding, attacked trees in 1982. Adapted from Andrews (1982).

males from the 1982 infestation. Therefore, the other 51.8 to 67.8% of the 1982 attack was probably by beetles drawn into the baited area. Although the nearest observed 1981 infestation was >1 km distant, the study area is in the advancing path of a major infestation, which could have produced large numbers of exploring beetles.

Thus, the 16 baited trees apparently had two functions: (1) they attracted and trapped the emergent brood from the 1981 infestation, effectively shifting the locus of the infestation from private to Crown land, and (2) they concentrated attack by exploring beetles into a defined area in which the newly infested trees could easily be located and cut.

#### Post-Logging Mop Up

All baited trees except no. 25 and 28, as well as many surrounding trees, were attacked by *D. ponderosae* in 1982 (Fig. 2, Table 2). Thus, although it was carried out in exemplary fashion, the logging operation did not totally sanitize the area. However, the baiting program was successful in inducing the majority of the remaining beetles to attack the baited trees and those surrounding them (Fig. 2, Table 2).

The data in Table 2 indicate that 59.8 and 68.1% of all attacked trees and mass-attacked trees (threshold mass

attack level arbitrarily set at  $\geq 31.25$  attacks per  $m^2$ ), respectively, comprised the baited trees and those surrounding them. Moreover, significantly more baited trees were mass attacked than unbaited ones. Of the 86 trees more than 12 m from the baited trees, 9 and 3 (attacked and mass attacked, respectively) were between two baited trees (no. 13 and 15) which were ca. 80 m apart, 15 and 13 were in a large group attack ranging from 36 to 80 m from tree no. 18, 10, and 10 were 14 to 51 m from tree no. 48, and 2 and 2 were 14 to 19 m from tree no. 49 (Fig. 2). We conclude that these attacks were also under the influence of the baited trees. Therefore, 79.4% of the attacked trees and 91.1% of the mass-attacked trees were under the influence of the baited trees.

Because of the baiting program, the planned, follow-up cut and burn, sanitation operation in the fall and winter of 1982-1983 was allowed to concentrate primarily around the 48 baited and attacked trees (Fig. 2), rather than in many more locations within and possibly beyond the 1981 infestation boundaries.

#### Discussion

There are numerous studies which demonstrate that semiochemicals can be used to induce attack by bark beetles on and around baited trees (e.g., Knopf and Pit-

**Table 1.** Stand and attack characteristics of natural (1981) and semiochemical-induced (1982) *D. ponderosae* infestations in CP 84, 23.5 km east of Princeton, B.C.

Year of attack	Category of tree	No. of trees	Diam ( $\bar{x}$ cm $\pm$ SE)	Emergence holes/m <sup>2</sup> ( $\bar{x}$ $\pm$ SE)	Attack density/m <sup>2</sup> ( $\bar{x}$ $\pm$ SE)
1981	Ponderosa pine				
	Attacked	12	24.0 $\pm$ 10.6	69.0 $\pm$ 46.2	—
	Unattacked	21	21.1 $\pm$ 9.7	—	—
	Lodgepole pine				
	Attacked	29	24.3 $\pm$ 5.6	62.7 $\pm$ 44.5	—
	Unattacked	133	19.8 $\pm$ 6.8	—	—
1982	All trees				
	Attacked	41	24.2 $\pm$ 7.3	64.6 $\pm$ 44.5	—
	Unattacked	154	20.0 $\pm$ 7.3	—	—
	Ponderosa pine				
	Baited and attacked	12	29.8 $\pm$ 5.7	—	82.8 $\pm$ 26.3
	Unbaited and attacked	27	23.1 $\pm$ 7.8	—	50.5 $\pm$ 36.6
1982	Lodgepole pine				
	Unbaited and unattacked	40	17.1 $\pm$ 7.3	—	—
	Baited and attacked	4	28.2 $\pm$ 5.2	—	64.1 $\pm$ 29.9
	Unbaited and attacked	18	22.5 $\pm$ 6.2	—	58.0 $\pm$ 44.4
	Unbaited and unattacked	83	16.2 $\pm$ 4.0	—	—
	All trees				
Baited and attacked	16	29.4 $\pm$ 5.5	—	77.3 $\pm$ 27.5	
Unbaited and attacked	45	22.8 $\pm$ 7.2	—	53.5 $\pm$ 39.6	
Total attacked	61	24.6 $\pm$ 7.3	—	59.9 $\pm$ 38.1	
Unbaited and unattacked	123	16.5 $\pm$ 5.3	—	—	

**Table 2.** Distribution of attack by *D. ponderosae* on and around 50 semiochemical-baited trees, Manning Park, 1982

Category of tree	No. of attacked trees	% Of total attacked trees	Mass-attacked trees <sup>a</sup>		
			No.	% Of attacked trees/category <sup>b</sup>	% Of total mass-attacked trees
Baited	48	22.4	42	87.5a	31.1
Within 12 m of baited trees	80	37.4	50	62.5b	37.0
Beyond 12 m of baited trees <sup>c</sup>	86	40.1	43	50.0b	31.9
Total	214		135		

<sup>a</sup>Mass-attacked trees arbitrarily designated as those with  $\geq 5$  attacks in the two frames (20 by 40 cm), an attack density of 31.25/m<sup>2</sup>.

<sup>b</sup>Percents followed by the same letter not significantly different, by Newman-Keuls test modified for testing frequencies performed on proportions transformed by arc sine  $\sqrt{p}$ .

<sup>c</sup>Includes 23 and 11 attacked and mass-attacked trees, respectively, not found by us but estimated to be present from evaluation of Canadian Forestry Service survey data.

man 1971, Pitman 1973, Dyer 1975, Ringold et al. 1975). We have demonstrated two practical applications in which this technique can be integrated with silvicultural controls for *D. ponderosae*. In another study, Borden et al. (1983b) utilized semiochemical baiting on a grid basis to contain *D. ponderosae* infestations so that sanitation-salvage logging could be effectively concentrated in small, intensively attacked areas. Instead of utilizing semiochemicals in costly programs to mass trap beetles and reduce their population size (Bedard and Wood 1981), tree baiting simply manipulates the beetles into attacking selected trees. In intensively managed forests, beetle-infested trees should be removed before an outbreak develops. Semiochemicals can be used to limit the number of trees that need to be removed, and to induce attack as much as possible in trees and stands specifically designated for cutting. The precise treatments will vary in

each instance with such factors as infestation size, stand characteristics, and silvicultural procedures, and will require the input of highly skilled specialists in forest pest management.

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