Trapping mountain pine beetles *Dendroctonus ponderosae* (Coleoptera: Scolytidae) using pheromone-baited traps: effects of trapping distance

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ABSTRACT

Mountain pine beetles (*Dendroctonus ponderosae* Hopkins) were released and recaptured using pheromone-baited Lindgren traps at various distances from the release point to determine the effects of distance on trapping effectiveness. Very few beetles were recaptured more than 500 m from the point of release, although this may have been due to interference by intervening traps. Trapping effectiveness depended on trap location, date of release, wind speed and distance from the point of release. Between 2 and 3% of the released beetles were recaptured in total.

Key words: Mountain pine beetle, pheromone trapping, dispersal

INTRODUCTION

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is a highly destructive insect pest of mature pine forests in western North America (Safranyik *et al.* 1974). Beetles instigate pheromone-mediated mass attack of pine trees, killing them when the attack level is high enough or when the resistance of the trees is low, or both. Traps baited with only the beetle pheromone components, *exo*-brevicomin and *trans*-verbenol, are not very attractive to beetles, but the standard mountain pine beetle bait containing a combination of *exo*-brevicomin, *trans*-verbenol and .the tree-produced myrcene (PheroTech Inc., Delta, BC) readily catch flying adults, although traps are not as effective as baited trees. Pheromone-baited traps are routinely used to monitor mountain pine beetle populations and to detect the presence of these insects in areas where they may occur only sporadically (Borden 1985). However, the baits may also attract some dispersing beetles into the area and induce some of them that are not captured to attack suitable trees in baited areas. This has led to the concern that the use of monitoring traps without thorough follow-up surveys could lead to establishment of incipient infestations. One question to answer in this respect is "How effective are pheromone-baited traps in capturing mountain pine beetles at various trapping distances?" This question is of interest in other species of bark beetles as well (Turchin and Opendaal 1996; Werner and Holsten 1997) and the experiment described here is aimed at addressing it. We released mountain pine beetles to determine trapping success at various distances from a release point.

MATERIALS AND METHODS

An area of about 2000 hectares of immature Douglas-fir located 35 kilometres southwest of Williams Lake, BC (Latitude 51° 53' N; Longitude 122 ° 12' W; altitude 1320 m) was selected for the experiment. In this area we established three sites along a road for beetle release and recapture. Because Douglas-fir is not a host of the mountain pine beetle, the probability of infestations resulting from these releases was minimized. In addition, the trees would not be attractive to the beetles and thus would not interfere with the experiment. Releases were made in July of 1996 prior to the onset of the main flight period of the local beetle population; in 1997 the main flight period had started at the time of the first release.

In late April 1996 we obtained beetle larvae from Saturday Creek, near Princeton, BC, by cutting eight infested lodgepole pine trees and taking the lowest 2-4 metres of the boles back to the laboratory. These were incubated at 20°C until adult beetles emerged. Emerged adults were kept at 6°C in containers with moistened fresh wood shavings until the time of the releases. In early May 1997 beetles were obtained near 100 Mile House, and similarly reared.

At each of the three release-recapture sites we set out three pheromone-baited Lindgren traps across a road and into the forest about 15 m apart; these three traps are referred to as one trap location (M, Fig. 1). Once established, the trap locations did not change during the experiment. We established three release positions at each site based on distance from the trap location. Releases were made at distances of 100 m, 250 m and 500 m downwind (according to the prevailing wind direction) from the trap location M at each site. The three traps were all equidistant from the release position, and thereby represented one distance for the pheromone to be detected; thus trapping distance was not confounded by traps at intermediate distances from the release positions.

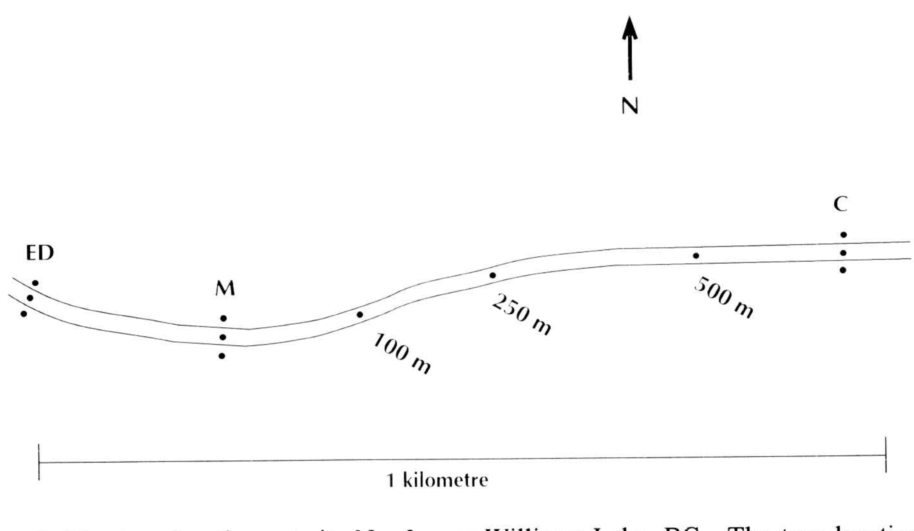

Figure 1. The trap locations at site No. 3 near Williams Lake, BC. The trap locations were: ED - extra distance traps, M - main traps, C - conjugate traps. The three distances mark the positions of the release platforms relative to M.

Releases were made from platforms consisting of a wooden frame with a fine-mesh screen bottom and a chicken-wire covering to keep out birds and dragonflies; these platforms were 1m above the ground. In 1996 we made nine releases, three on each of 3 release days, with one release at each site on a given day. Each release was at one of the three release positions with a different release distance at each site and with approximately 1300 beetles per release. At a given site a different distance was used on each release day. The prevailing wind was from the west, and came straight down the road, being funneled down by the trees on each side. Wind speed was measured using an anemometer at the times of release. We thought that releases every second day would make trapping from the different releases effectively independent of each other. Thus, our releases were made on July 10, 12 and 14 in mid morning.

Initially we monitored the traps every 2 hours to count recaptured beetles, but later reduced that to three times a day due to low capture rates. Since the number of beetles released varied somewhat, the recaptures were adjusted by multiplying by "1300 divided by those released", as the average number per release was about 1300.

In 1997 we repeated the experiment, except that two sets of traps were set up on opposite sides of the release positions (Fig. 1) because the wind was quite variable in 1997 and there was no guarantee that the trap positions that yielded substantial numbers of beetles in 1996 would again be effective in 1997. Otherwise the same design was used as in 1996. In addition, because beetles were caught at 500m in 1996, an additional three traps were set out 250m beyond the main traps in site no. 3 in 1997. The traps at the locations used in 1996 were referred to as the 'main' traps, those on the other side of the release locations (750m down the road to the east of the main traps) were referred to as the 'conjugate' traps, and those 250m beyond the main traps in site no. 3 were referred to as the 'extra-distance' traps, being 750 m from the farthest release platform in that site (Fig. 1). The traps remained at those locations while the releases were made from the three different distances (100m, 250m and 500m) from the main traps, with corresponding distances from the conjugate traps being 650m, 500m and 250m respectively. Although the inclusion of more traps allows the potential for confounding of trap effects to occur, if the wind were blowing from the direction of the conjugate traps, the beetles would only receive pheromone from those traps. If the wind were blowing from the direction of the main traps, then the extra-distance traps (at one site only) might introduce some confounding at that trap location and this would presumably be more of a problem for the 100 m trapping distance than for the longer distances. The other two trap sites would be unaffected because there were no extra-distance traps at those sites. In 1996 the beetles were not colour-coded, whereas in 1997 beetles were coloured (Linton *et al.* 1987) with fluorescent powder (Day-Glo Inc.) prior to release and beetles on each release day were coloured differently.

The numbers caught in the three traps at each location were summed to provide one datum. The data were pooled for a given factor and all the results were analyzed using χ^2 analysis.

RESULTS

In 1996, 12,500 beetles were released and 206 beetles were recaptured, while in 1997, 9,000 beetles were released and 276 were recaptured. In 1996 both the date of release ($\chi^2 = 43.3$; df = 2; $p < 0.001$) and the trap location ($\chi^2 = 19.3$; df = 2; $p < 0.001$) were important in determining recaptures. Pooling over other factors, the numbers captured from the July 10, 12 and 14 releases were 25, 98 and 83 respectively. Similarly, the numbers captured at the east, centre and west trap sites were 73, 41 and 92 respectively. Wind speed may have influenced catches on different release days. At wind speeds (i) $\leq$ 2, (ii) 3-5, and (iii) > 5 km/h, captures were 69, 100 and 37 respectively. Intermediate wind speeds (3-5 km/h) were most conducive to recapturing beetles ($\chi^2 = 28.8$; df = 2; $p <$ 0.001). In 1997 both the speed and direction of the wind were highly variable and probably were largely responsible for the poorer results obtained that year. The effects of distance were significant in both years; χ^2 for 1996 was 12.2 and for 1997 was 17.8, although the 250 m and 500 m distances did not separate for 1997. Fewer beetles were caught in the conjugate traps than in the main traps (χ^2 = 109.1; df = 1; $p < 0.001$), indicating that the main traps were the most effective, even with the variable winds (Fig. 2). Since the extra-distance traps were only at one site, the comparisons are shown in Table 1. Fewer beetles were caught at the extra-distance traps than at the main traps and all the extra-distance traps caught fewer than the main traps did at the 500 m distance.

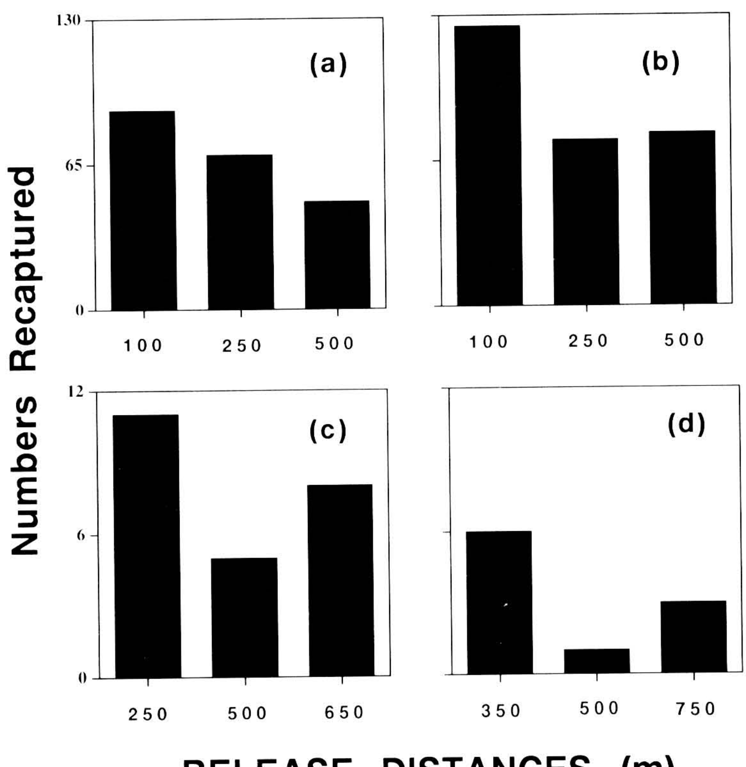

Figure 2. Numbers of beetles recaptured from releases at each of the three distances. (a) The traps in 1996; (b) the main traps in 1997; (c) the conjugate traps in 1997; (d) the extra-distance traps in 1997.

A problem that became apparent in 1996 was the assumption that captures would reflect only the most recent releases. Beetles from the previous release were still being recaptured 48 hours later on the morning of a subsequent release, and catches at 500 m following another release followed a suggestive pattern. The release at 500 m that followed a release at 100 m had the highest recapture rate of the three 500-m releases (taken as a proportion of the recaptures from all three locations on that date), while the release at 500 m following the 250 m release had the lowest proportional recapture rate. This suggests that some of those recaptured at traps 500 m distant from the most recent release may have been left over from the release at 100 m distance two or three days before, and since the beetles in 1996 were not colour-coded, this could not be tested directly. However, the time sequences of captures for both 1996 and 1997 show that the trap yields in the mornings were greater than later in the day (Fig. 3) indicating that most captures occurred between 4 pm and 9 am the following morning. In addition, in 1997 few marked beetles were captured after the morning of the third day (release being on the first day). Thus it seems probable that few beetles were recaptured after the morning of the third day in the 1996 trials as well and that the beetles recaptured for each 2 day period were mostly the results of releases within that time period.

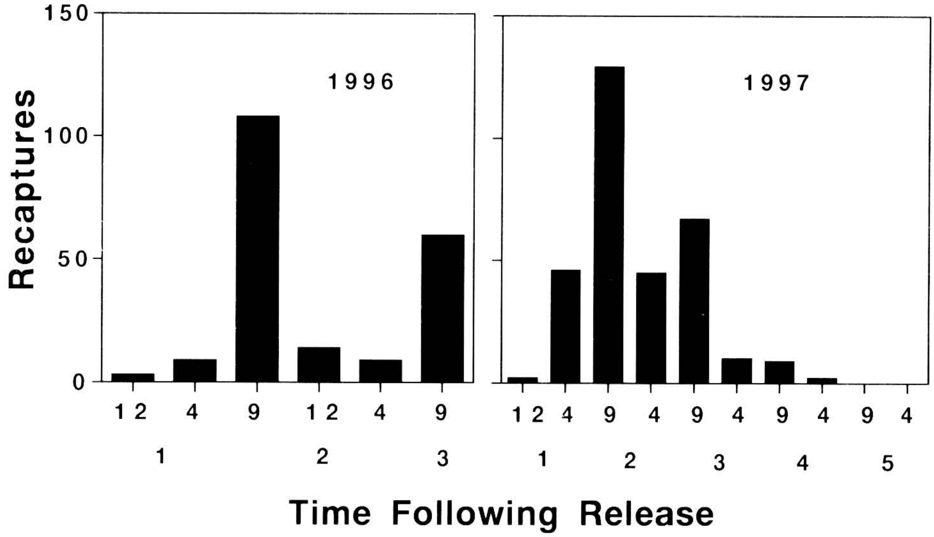

Figure 3. Time sequences of recapture for the 1996 and 1997 release periods. The horizontal axis shows the hour of collection (upper numbers; 12 noon, 4 pm, 9am) and the day of collection after release (lower numbers). Releases were made about 10 am on day one.

Table 1

Number of beetle recaptures from the main traps and the extra distance traps in 1997. All numbers are from the same site.

Trap type	Release Period	Distance (m)	Recaptures
	1	100	26
Main	3	250	16
	2	500	32
	1	350	6
Extra Dist.	3	500	1
	2	750	3

DISCUSSION

Differences among trap sites are obviously quite important to the success of the trapping experiments. This may relate to the direction of the road at each site; at two sites the road ran E-W, at the third site it ran NW-SE. Also, differences between release dates were important. Differences in captures correlated with wind speed, and although we could not manipulate wind speed, the correlation strongly suggests that wind speed influences the ability of beetles to find the traps. The differences in release dates presumably relates to differences in weather conditions (mainly wind) on the three release days, although other factors may also have been involved. Although the beetles were not colour-coded in 1996 and it was thus impossible to separate the catches from different release dates, it is probable that most of the beetles recaptured within a given 2-day time period resulted from beetles released on day one of the period. Safranyik *et al.* (1992) found that over 80% of released and recaptured mountain pine beetles were captured within 3 days of release regardless of temperature and wind direction. In addition, our finding that most trap captures occurred between 4 pm and 9 am the following morning agrees with the finding of Rasmussen (1974) that the maximum flight activity was between 4 pm and 6 pm in Utah and Idaho.

The chances of any of the results being caused by the capture of wild beetles endemic to the area were remote in 1996, since the lab-reared beetles were phenologically about 2 or 3 weeks ahead of the wild population. In addition, the use of a non-host stand also helped ensure that there would be few wild beetles present. Two baited traps put out in the experimental area about a month before the releases took place did not trap any mountain pine beetles. However, in 1997 the reared beetles were not ready for release until late July and about half of all beetles captured were wild ones, being non-dyed. The odour of the usual host, lodgepole pine, is important in the attraction of the beetles and this odour was included in the trap baits by adding myrcene. Since the odour of Douglas-fir is unlikely to affect the behaviour of the beetles, the odour of the host trees was only present at the traps. The pheromone would likely be funneled down the corridor (road) between the two rows of trees, rather than being diffused more broadly as it would be if it were travelling through the trees. Thus our results might be seen as an upper limit to trapability, since conditions were close to being ideal for pheromone transport and detection.

Recaptures at the conjugate traps were all fewer than those at the main traps indicating that the up-wind direction was preferred, at least by those beetles that "responded" to the baited traps, even though the wind was quite variable and was sometimes blowing the opposite way at the time of release. There is evidence (Gray *et al.* 1972) that without sources of attraction, beetles disperse passively downwind. Recaptures at the extra-distance traps were also much fewer than at the main traps, even at 500 m, suggesting that the beetles tended not to fly much past the first traps encountered.

Under conditions of little wind, most mountain pine beetle recaptures would be close to the point of release or to brood trees (Safranyik *et al.* 1992). However, where wind is stronger, the patterns are not so clear, and beetles may actively fly or be passively carried further, in which case the dispersal distances can be quite long. Safranyik *et al.* (1992) only captured about 1% of the total recaptured marked and released mountain pine beetles 250 m from the release point under the canopy of a mature lodgepole pine stand; the rest were recaptured closer to the release point. We conjecture that even with stronger wind, a very small proportion of beetles would respond directly to traps located more than 1 km from their point of release.

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