A comparison of traps and trap trees for capturing Douglas-fir beetle, *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae)

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ABSTRACT

We compared pheromone-baited traps and trap trees for managing Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae* Hopkins populations. Pheromone-baited traps caught significantly more DFB than did trap trees. More male DFB were caught in pheromone-baited traps than in trap trees, while significantly higher numbers of females were caught in the trap trees. Additional benefits of pheromone-baited traps include, easy deployment, less mortality of some beneficial insects, and low cost.

Key words: *Dendroctonus pseudotsugae*, Scolytidae, pheromones, trapping, trap trees

INTRODUCTION

The Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae) is found throughout the range of Douglas-fir, *Pseudotsugae menziesii* (Mirbel). Although endemic populations of DFB usually inhabit dead, dying, downed, or injured trees, epidemic populations may also attack and kill large numbers of apparently healthy trees. Tree mortality caused by these beetles can lead to severe economic losses and interfere with management objectives in the infested area.

Pheromones of DFB are well known (Pitman and Vité 1970; Kinzer *et al.* 1971; Furniss *et al.* 1972; Rudinsky *et al.* 1974; Libbey *et al.* 1983) and several have been implemented in management strategies. Aerial application of the DFB anti-aggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), can effectively prevent the infestation of windthrown trees (McGregor *et al.* 1984). Strategies incorporating pheromone-baited traps and MCH (Ross and Daterman 1994), or MCH alone (Ross and Daterman 1995a), have significantly reduced DFB infestations in live trees in high-risk stands. Aggregation pheromones have been used to create trap trees in areas where DFB population levels are high (Knopf and Pitman 1972; Pitman 1973; Ringold *et al.* 1975). Trap trees concentrate DFB in selected trees that are subsequently harvested, thereby removing beetles from the local population. Aggregation and anti-aggregation pheromones can be used to selectively create tree snags, an important wildlife habitat component (Ross and Niwa 1997).

Pheromone-baited traps may be an alternative to trap trees in some situations (Ross and Daterman 1995b). While trap trees have been used for a number of years in operational programs (Patterson 1992), pheromone-baited traps have been used only to a limited extent by managers. This study was designed to compare the efficacy of trap trees and pheromone-baited traps in managing DFB.

MATERIALS AND METHODS

Field research was conducted in the Nezperce National Forest in central Idaho. The study area was a mixed-conifer stand composed primarily of Douglas-fir, with ponderosa pine (*Pinus ponderosa* Laws.) and grand fir (*Abies grandis* Lindl.) present at lower densities. Elevation of the study area ranged from 1524 to 1584 m and it was bisected by a forest road, with a recent clearcut on one side and a mature mixed-conifer stand on the other.

On 28 April 1997, before the onset of DFB flight, pheromone-baited traps were placed in the clearcut area adjacent to the Douglas-fir stand. Seven 16-unit multiple funnel traps (Lindgren 1983) were baited with 400 mg of frontalin (1,5-dimethyl-6,8-dioxabicyclo [3.2.1] octane) and 200 mg of seudenol (3-methylcyclohex-2-en-1-ol) in polyvinylchloride (PVC) formulations, and 15 ml of ethanol in a plastic pouch formulation. Release rates and chemical descriptions can be found in Ross and Daterman (1997). Traps were positioned in a line approximately 75 m apart. A piece of dichlorvos-impregnated plastic was added to each collection cup to kill captured insects. Captured insects were collected weekly from 15 May to 26 August. Samples were sorted to remove DFB and three primary bark beetle predators, *Thanasimus undatulus* (Say) (Coleoptera: Cleridae), *Temnochila chlorodia* (Mannerheim) (Coleoptera: Trogositidae), and *Enoclerus sphegeus* Fabricius (Coleoptera: Cleridae). All DFB in the samples were counted and sexed. Beetles captured in each trap were summed over the trapping period to determine the total number of beetles removed from the population by each trap.

When the traps were deployed, seven trees in the Douglas-fir stand adjacent to the clear cut were baited with pheromones to initiate DFB attack. These trees were spaced about 75 m apart in a line roughly parallel to the trap line. The line of trees and trap line were 150-200 m apart. A commercially available tree bait (Phero Tech Inc., Delta, BC, Canada) containing frontalin and α-pinene was stapled to each trap tree at a height of 2-3 m. In addition to the commercial tree bait, frontalin (20 mg) and seudenol (10 mg) in PVC formulations were attached to the tree boles. Mean diameter at breast height (dbh) of trap trees was 66 cm (SE ± 2.5), and mean height was 36.3 m (SE ± 1.2).

Trap trees were sampled on 28 July 1997, after the DFB flight had ended. Each tree was climbed to determine height at the top of the infestation, circumference at the top of the infestation, and to remove bark samples to estimate attack densities. In addition, height at the base of the infestation and circumference at the base of the infestation were measured. An axe was used to cut through the bark to determine if DFB galleries were present. This was continued until no DFB galleries were found at the top or bottom of trap trees. The average of the circumference at the base and top of the infestation was used along with length of the infested bole to estimate the amount of infested bark area for each tree based on the equation for the surface area of a cylinder. The areas surrounding trap trees were surveyed to determine if there were any spill-over attacks on adjacent trees.

At three heights along the infested tree bole, four 100 cm^2 circular bark samples were removed with an electric drill and hole saw. Sample heights were near the top, middle, and bottom of the infested portion of the bole. Samples were placed in plastic bags and stored in an ice chest until transported to the lab. In the lab, attack sites were determined for each sample. Attack sites were distinguished from ventilation holes or exit holes by their angle and the presence of packed frass.

To determine attack sites per tree, mean number of attack sites per cm^2 was multiplied by the surface area of the infested tree bole. Because DFB is monogamous, each attack site represents one pair of beetles that entered the trap tree. The total number of attack sites was multiplied by two to determine total number of DFB caught in each tree.

Catches of traps and trap trees were compared using a t-test. A square root transformation was used to meet assumptions of equal variances. All tests were performed with the statistical software JMP (ver 3.1.5, SAS Institute Inc., Cary, NC)

RESULTS

Mean infested tree bole surface area was 29.8 m^2 (SE ± 4.0) ranging from 19.2 to 48.9 m^2. Mean number of attack sites per tree was 3,320.8 (SE ± 607.0). Mean attack densities were 90 per m^2 and did not differ significantly by height ($P = 0.26$). No trees adjacent to trap trees were attacked by DFB.

The mean of the total number of beetles caught per trap over the season was 13,740.6 (SE ± 2813.5). In comparison, trap trees captured on average 6641.6 (SE ± 1213.9) beetles. Significantly more beetles were captured in the traps than in the trap trees ($P = 0.04$). Significantly more males were captured in traps than in trap trees ($P = 0.04$), assuming a 1:1 sex ratio in trap trees. In comparison, significantly more females were captured in trap trees than in traps ($P = 0.009$). Mean percent male beetles caught in traps was 80.8 (SE ± 0.66).

DISCUSSION

Pheromone-baited traps are used extensively to study the biology and behavior of many bark beetle species. In addition, pheromone-baited traps have been implemented in strategies to manage or monitor some pest species, or both (Lindgren and Borden 1983; Billings 1985; Shore and McLean 1985). However, trap trees have been used more commonly in the past to manage DFB populations than pheromone-baited traps. We could find no published data comparing the efficacy of trap trees and pheromone-baited traps in the management of DFB.

In our study, pheromone-baited traps were more effective at capturing DFB than trap trees. More beetles were removed from the population with pheromone-baited traps than trap trees. Because of damage to pheromone-baited traps, total trap catches were likely higher than our final results indicate. Throughout the study, ten trap collections were lost due to trap damage. Four of these occurred on 11 June when DFB activity was high. The average trap catch for the two undisturbed traps on that date was 1,307 beetles. We do not know exactly when the traps were damaged. If they were damaged immediately after they were last emptied then they likely caught few beetles. However, if they were damaged just before they were visited, then they may have caught as many as 5,228 additional beetles that were not included in our estimate of the total catch. In operational programs, damage to traps might be reduced by suspending them in non-host trees at a height where wildlife and livestock could not disturb them. However, deploying and maintaining suspended traps takes more time and, therefore, is more costly than for traps that are placed at ground level.

Although our estimate of captured beetles in traps is higher than in trap trees, it is possible that traps have an even greater impact on local beetle populations than suggested by a simple comparison of numbers of captured beetles. Because the brood sex ratio is 1:1 (Bedard 1937; Vité and Rudinsky 1957) and DFB is predominantly monogamous, removal of one beetle could actually represent the removal of a mated pair. Since we do not know what proportion of beetles collected in traps would have mated with one another if they had not been captured, we cannot determine the actual impact of trapping on local beetle populations. At one extreme, assuming that no beetles in the traps would have mated with each other, then the traps actually could have removed twice as many mated pairs from the population as indicated by the number of captured beetles.

There is evidence from laboratory studies that suggests some male DFB may mate with more than one female (Vité and Rudinsky 1957). However, there are no published data to indicate how often this occurs under natural conditions. If DFB males mate more than once under natural conditions, the removal of a single male beetle would not be equivalent to removal of a mated pair. Courtship in DFB is initially aggressive (Ryker 1984) and beetles may suffer significant damage during the mating process and gallery construction. Consequently, it is likely that many re-emerging male beetles are damaged and incapable of prolonged flights to locate new host trees and female beetles. With extended time searching for host trees and female beetles, DFB males would be exposed to higher levels of predation and other mortality factors. Until research is conducted to determine the sexual behavior of DFB under field conditions, we cannot be certain of the impact of removal of males from local breeding populations.

One possible reason that traps caught more DFB is that they continuously remove beetles from the population for the entire season. In comparison, trap trees have a finite capacity for trapping beetles. Once trees are fully colonized, MCH is released by adult DFB to deter other beetles from colonizing the tree. Consequently, beetles arriving at trap trees after they are fully colonized will attack nearby host trees if they are present, or they will disperse in search of suitable habitat.

Pheromone-baited traps removed a significantly higher number of male beetles from the population than trap trees. In comparison, trap trees removed a significantly higher number of female beetles than traps. It is possible that by manipulating trap lure components, a higher number of females could be captured. For example, addition of ethanol to the trap lure increases both total number of beetles and the proportion of females captured (Ross and Daterman 1995c). However, this may not be important, because DFB broods have a 1:1 sex ratio and the beetle is monogamous. Consequently, as discussed above, removing a male or a female theoretically removes a mating pair of beetles from the local population.

While a higher number of DFB are removed from local populations using traps compared to trap trees, impacts on beneficial insects are likely less. For example, when trap trees are harvested, beneficial insects inhabiting those trees are also removed from the local population. Beneficial insects, including predators and parasitoids, have been shown to cause high levels of mortality to several bark beetle species (Linit and Stephen 1983; Weslien 1994; Schroeder and Weslien 1994; Schroeder 1996) and some may have a regulating effect on populations (Reeve 1997; Turchin *et al.* 1999). Depending on timing of DFB infestation and removal of trap trees, beneficial insects including *Coeloides brunneri* Vierick (Hymenoptera: Braconidae), *Medetera aldrichii* Wheeler (Diptera: Dolichopidae), *Thanasimus undatulus*, *Enoclerus sphegeus*, *Temnochila chlorodia*, and possibly others could still be developing within or inhabiting host trees. Removal of these species may significantly impact natural controls in subsequent bark beetle generations.

While traps catch several predaceous beetle species, the impact on local populations is unknown. Many *T. undatulus* are often captured in traps. This beetle preys on DFB, but laboratory studies suggest that it prefers smaller species of *Scolytus* and *Pseudohylesinus* (Schmitz 1978). To minimize the possible impact of removing predators from the population, trap modifications can be employed to prevent their capture or provide for their escape (Ross and Daterman 1998). Additionally, traps do not capture parasitoids because they are not attracted to pheromones.

In addition to catching higher numbers of bark beetles, traps have several other advantages. First, traps are easily deployed and can be placed almost anywhere there is the threat of tree mortality. Traps, unlike trap trees, can be located in non-host stands or openings to minimize attacks on nearby host trees. Pheromones and traps are relatively inexpensive and traps can be used for several to many years depending upon their method of construction. Also, by using traps, no trees need be sacrificed.

Pheromone-baited traps are effective at capturing large numbers of DFB, thus removing beetles from the breeding population in local areas. Natural resource managers should consider substituting traps for trap trees in their management plans for DFB. By doing this, more beetles may be removed from local populations, while valuable trees need not be sacrificed.

ACKNOWLEDGEMENTS

The authors thank Tiffany Neal for technical assistance in the field. We also thank personnel on the Salmon River Ranger District, Nez Perce National Forest, particularly Jennifer Nelson and Cynthia Onthank, for locating the research site, providing maps and access to the site, and for technical assistance in the field. This research was supported by funds from the USDA Forest Service, Forest Health Protection, Special Technology Development Program. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by USDA or Oregon State University.

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