Monitoring and dynamics of a Douglas-fir beetle outbreak in Jasper National Park, Alberta

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ABSTRACT

A Douglas-fir beetle outbreak in Jasper National Park was discovered at 10 sites in 1991, and has since expanded to 30 sites in 1992, and 55 sites in 1993. Individual sites surveyed in 1993 contained from 3 to more than 200 attacked trees covering areas of 10 m^2 to 1 km^2 respectively. Sites containing pheromone population monitoring funnel traps contained significantly more attacked live trees than those sites without pheromone traps, suggesting that the traps attract larger beetle populations to the site. Diameter measurements indicated that in the initial years (~1990) of the infestation, larger diameter trees were attacked more commonly. In 1993, freshly attacked green trees were of a smaller diameter.

INTRODUCTION

Jasper National Park's montane forest is unique because it contains the most northerly stands of natural Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in Alberta. Within Jasper Park's 10,920 km^2, a computer analysis of the Jasper Biophysical Vegetation Map (Holland and Coen 1982) shows only 0.02% (167 km^2) with Douglas-fir as a dominant tree and 0.01% (145 km^2) with Douglas-fir as a subdominant tree. The stands infested by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) are pure or mixed structures with individual trees as old as 575 years. The stand composition for sites with and without pheromone traps are similar, and both site types are near infested hosts.

In Jasper Park, there have been minor Douglas-fir beetle (DFB) infestations consisting of 60 trees in 1980 and three trees in 1986. The onset of the current infestations was first observed near Annette and Patricia lakes in 1987 (Cerezke and Edmond 1989). In 1988, additional sites were found between Jasper townsite and the west gate (Edmond and Cerezke 1989). It was not until 1990/91 that the DFB infestations became well established in several stands of mature Douglas-fir in Jasper and were present in low numbers in Kootenay, and Yoho National Parks (Cerezke *et al.* 1991). At the time of this study (1993), the Jasper Park infestation was the only one known in Alberta. DFB infestations have occurred previously in southern Alberta and caused an estimated loss of 538,000 and 238,000 m^3 (19 and 8.5 million ft^3) of timber in the Interior and Coastal regions of British Columbia between 1956 and 1970 (McMullen 1977).

Since the discovery of 10 DFB sites in Jasper Park in 1991, the number has increased to 30 in 1992, and 55 sites in 1993, each with 3 to over 200 attacked trees (Figure 1). The current outbreak of DFB in Jasper appears to parallel that in British Columbia; where tree mortality from DFB covered 115 ha in 1989, 800 ha in 1990, 1,500 ha in 1991, and 3,425 ha in 1992 (Humphrey and Ferris 1992). Almost half the damage in 1993, 1,400 ha, was in the Mount Robson Forest District, bordering Jasper National Park to the west.

Douglas-fir beetles are an important component of Douglas-fir montane forests, normally attacking weakened or dying Douglas-fir trees. Stand-age, lack of tree vigour, and disturbances (i.e. windstorms, root rot, drought, insect defoliation, and fire) are key factors that may increase DFB populations and allow them to attack standing Douglas-fir trees (Furniss *et al.* 1981). This may result in an aggregate pattern of attacked healthy trees leading to a "fine-scale gap dynamics that favour establishment and (or) the release of the next generation of its host, suggesting a co-evolutionary relationship", as Peterman (1978) suggested for mountain pine beetle in lodgepole pine forests. The reasons for the current infestation in Jasper are speculative. In 1989 before the height of the DFB outbreak, severe winter windstorms added to the dead Douglas-fir material available for DFB. In 1989, Parks Canada lit a prescribed fire in the sub-alpine forest region, east of Highway 16 and north of Jasper townsite, near some of the largest current DFB infestations. Some Douglas-fir trees may have been weakened or killed by spot fires associated with the main fire block allowing Douglas-fir beetles to multiply and move to nearby Douglas-fir stands that were not affected by the fire. Finally, the drought conditions of the early 1990's may have stressed Douglas-fir trees making them more susceptible to DFB attacks.

Jasper National Park's main purpose is to promote public understanding, appreciation, and respect for Canada's natural and cultural heritage. Its mandate states that the Park exists for its intrinsic value as an important component of the larger regional ecosystem. Park managers recognize the DFB as an important agent disturbing the natural Montane ecosystem. In 1992, Parks Canada initiated detailed monitoring of DFB, consisting of aerial surveys and two sites baited with pheromone funnel traps for population monitoring. This was continued in 1993 and the number of pheromone-baited sites was expanded to six. The purpose of my 1993 study was three-fold: 1) to continue aerial monitoring of the number and size of infestation sites; 2) to determine if the DFB initially favours larger diameter trees; and 3) to determine whether the presence of pheromone-baited traps increased the numbers of green attacked trees in baited sites.

METHODS

Stands where Douglas-fir is the dominant or sub-dominant tree species were identified using Jasper Park's biophysical vegetation maps (Holland and Coen 1982). Aerial surveys were conducted to map DFB outbreaks in these stands, as indicated by more than 2 or 3 clumped red or recently dead trees. Subsequent ground surveys were made for as many of the sites identified by air during the summer of 1993 as time would allow. Twenty-nine of the 55 sites identified by aerial surveys were checked. Ground surveys consisted of counting the number of beetle attacked trees that were dead and had no-foliage (bare), red foliage, yellow foliage, or green foliage, taking the diameter at breast height (DBH) of each of these trees, and verifying the location of each site. Because the surveyed infestations were only a few years old, I assumed that dead, red, and yellow trees were attacked three to five, two, and one year(s) ago respectively. I assumed that green attacked trees were attacked during the first or second beetle flight of 1993.

On one site where attacked green trees continued up-slope for some distance, trees were counted on a line randomly placed across the slope. A second site contained pheromone traps and trees within three 50 m^2 plots were sampled because this site had an obvious spotted infestation pattern over 500 m^2. Since the sampling method for these two sites was inconsistent with that used for all other sites, the second attack site was excluded from calculations related to the effect of pheromone traps, but both sites were used to determine the mean diameters of each infestation category (no-foliage, red, yellow, and green) for sites with and without pheromone traps.

Multiple funnel traps (Lindgren 1983) containing ethanol, frontalin (1, 5-dimethyl-6, 8-dioxabicyclo [3.2.1]octane), and MCOL (1-methycyclohex-2-enol) were used to monitor annual beetle population fluctuations. Lindgren (1992) found frontalin to be an effective aggregation pheromone for the DFB. Traps were placed in six sites (the two sites used in 1992 and four additional sites in 1993) under the direction of Dr. H. Cerezke of Forestry Canada (Figure 1).

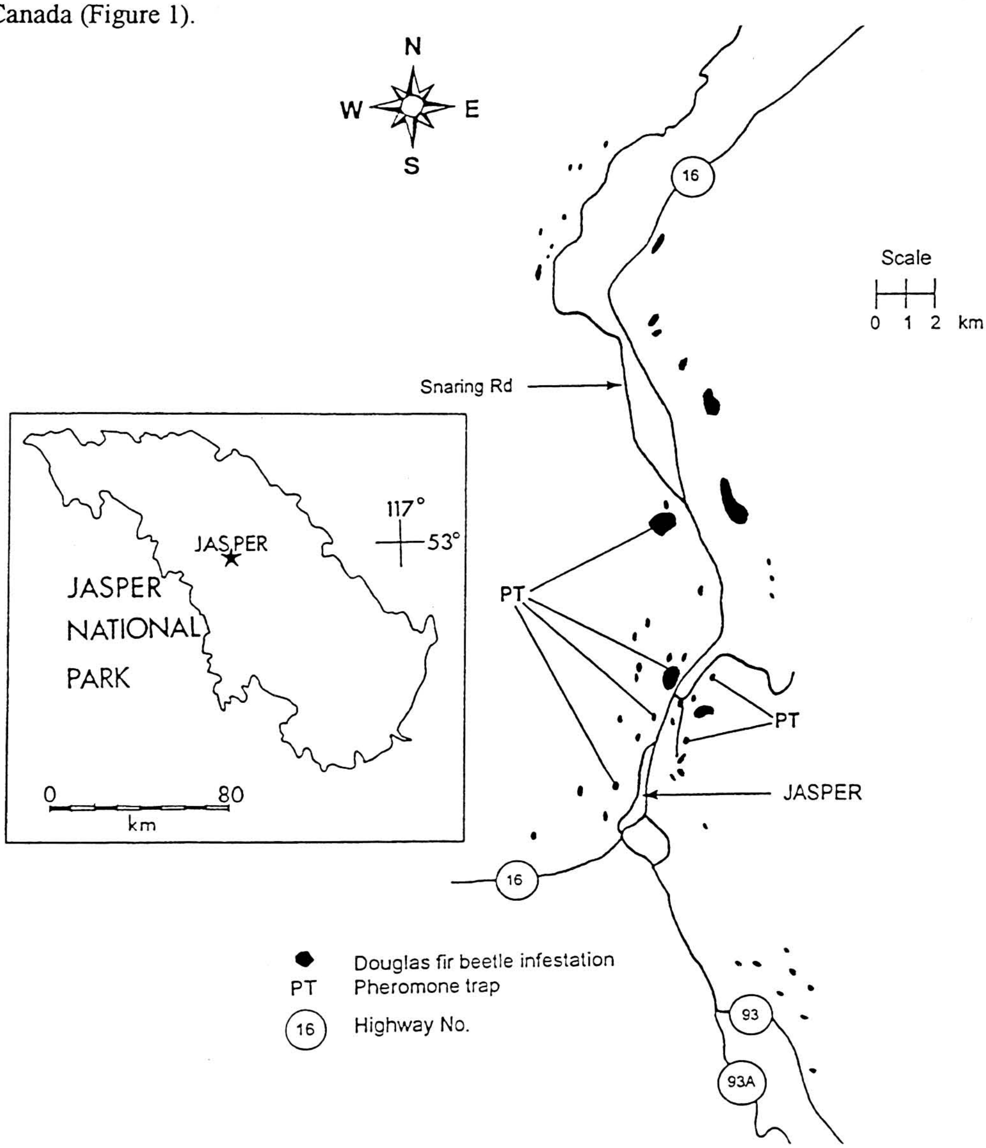

Figure 1. Douglas-fir beetle infestations in Jasper Park (inset). Sites with pheromone traps are marked.

The sites were chosen because they had active beetle populations and were accessible. Site size or possible tree stressing factors were not a factor in site selection. Each trap site contained three funnel traps, spaced 40 meters apart, in a triangle. Each trap was hung 2 meters above the ground on non-host trees. The traps were checked weekly to ensure they were intact and functional, and to collect captured beetles.

Data Analysis

The mean logarithms of tree diameter for each infestation category (no-foliage, red, and green) were compared using a two-sample, one-tailed t-test at the 99.5% confidence level. The yellow foliage category was not analyzed since very few trees had turned yellow, perhaps as a result of a cool and wet summer. The diameters were transformed to logarithms to give normal distributions. A total of 1,611 trees from all 29 infested sites was used in the diameter comparison. The logarithms of diameters were compared between sites with and without pheromones to determine if the pheromone had an effect on the diameter of any infestation category. All sites were used because there was no significant difference between the mean diameters of infestation categories in sites (excluding sampled sites) with and without pheromone traps.

To assess the effect of the pheromone traps on the infestations, first, the numbers of green attacked trees in sites with and without pheromone traps were compared using a two-sample, one-tailed t-test at the 99.5% confidence level. Secondly, to determine if the extent of the current infestation is related to its initial size, a correlation analysis of the number of bare (no-foliage) trees to the current number of green attacked trees was performed. These analyses assume that since the infestation in the Park is fairly new, the bare trees were attacked 3-5 years ago and the green trees with fresh boring dust were attacked in 1993.

RESULTS

From a total of 1,611 trees, the geometric mean diameter (DBH) for attacked bare (no-foliage) and red trees was 43 cm and 48 cm respectively. These were significantly different from each other (Table 1). Both bare and red trees had a mean diameter significantly larger than attacked green trees, mean DBH = 39 cm (t = 3.59 and 10.44 respectively, $p \geq 0.005$).

Table 1

Mean diameters (DBH) of four classes of attacked Douglas-fir trees in 29 sampled sites

Parameter	Green trees	Yellow trees	Red trees	Trees with no foliage
No. of trees	685	78	450	398
Mean (cm)	39	42	48	43
Log mean	1.596	1.623	1.684	1.631
Std. dev.	0.1	0.2	0.1	0.2

The five sites with multiple funnel traps (one trap site was excluded) had a significantly greater proportion of attacked green trees than sites without pheromone traps (Figure 2) (t = 3.32, DF = 20, $p \geq 0.005$). There was no linear relationship between the initial infestation size (number of attacked trees without foliage) and the current size (number of attacked green trees), since the x-coefficient (r = 0.26) was not significantly different from zero. Figure 2 shows that sites with pheromone traps were among those with the most attacked green trees.

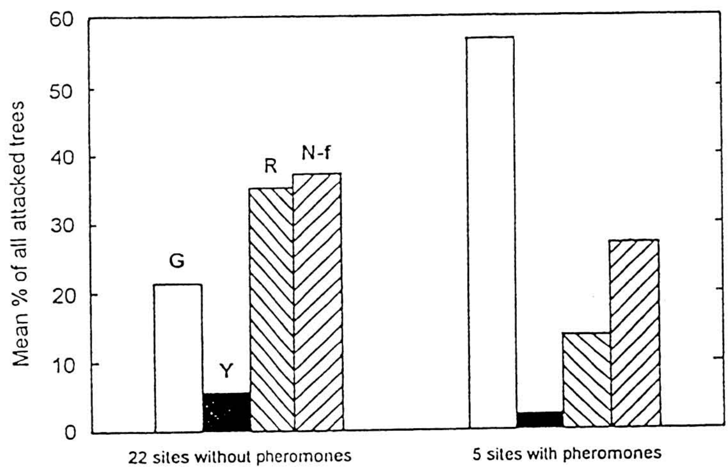

Figure 2. Comparison of the mean percent attacked green,(G) yellow,(Y) red,(R) and trees without foliage (N-f), for sites with and without pheromones. Two sampled sites, one with pheromones and one site without, are excluded from the analysis. Of 1611 Douglas-fir trees surveyed, 547 were in sites with, and 1064 in sites without pheromones.

DISCUSSION

The mean DBH of the no-foliage and red trees in all surveyed sites was 4 to 8 cm larger than that of the attacked green trees. In Idaho, Furniss *et al.* (1981) found that attacks tended to be more dense and more successful on larger size diameter trees since they produce more resin than the smaller diameter trees. Initially a high resin production may increase tree resistance, but the resin may also contain kairomones or pheromone precursors that attract more beetles, increasing the probability of a successful attack. The beetle population in Jasper Park may now be large enough to overwhelm the smaller diameter trees.

The mean diameter comparison, for each infestation category, used all infestation sites since there was no apparent difference between the mean logarithmic diameters of each category in sites with and without pheromones. This could be because the study design was not detailed enough to pick-up variances in attacked diameters with increased distance from the pheromone traps. Knopf and Pitman (1972) found that within a 10 m radius of the baits, 58% of 10 cm and larger diameter trees were attacked and larger diameters were progressively favoured as the distance increased from 4.3 -10.0 m.

There was a significant positive correlation between pheromone baited sites and the number of green attacked trees. Surprisingly, a large initial infestation (number of attacked trees with no-foliage) did not correspond to a large number of attacked green trees. Therefore, the current number of green attacked trees may be related to the recent practice of pheromone baiting. Figure 2 shows that sites containing pheromone traps were among those with the highest number of green attacked trees. Baker and Trostle (1973) also found that frontalin and camphene pheromones attracted more beetles into an area when 58.5% of the trees within 33 feet of the baits were attacked and only 3.6% were attacked in the control sites.

Although the pheromone sites had more green attacked trees, some of them may survive. In Montana, out of 739 attacked 188-year-old trees, 29% were unsuccessfully attacked (no reproductive galleries were established) and 22% of the trees survived the attack (Furniss *et al.* 1981). To minimize stress on the attacked Douglas-fir trees in the Park, I did not remove the bark to investigate the galleries. It is likely that a similar proportion of our green attacked trees may survive.

The DFB pheromone baits may have shifted and concentrated the attack centres to trees with funnel traps. The pheromone baits can result in spill-over onto neighbouring green host trees (Thier and Weatherby 1991), resulting in an increased concentration of natural pheromones, and thus significantly increasing the attractiveness of neighbouring trees. Stock *et al.* (1994) found a similar concentrating effect with aggregating pheromones of western balsam bark beetle *Dryocoetes confusus*.

Placing pheromone traps in Douglas-fir stands for population monitoring over several years may give misleading results. During the first few years of trapping it may appear that the beetle populations are increasing or have stabilized at a high level. Due to the continual pheromone emission from the traps combined with the natural tree and beetle pheromones many beetles may be attracted to the trapping site, causing an overestimate of population levels in the stand. Once most of the susceptible green trees are attacked in that locality, the populations may disperse, resulting in fewer beetles in the pheromone traps. This may give the false notion that the population has declined.

Some researchers now suggest that the pheromone lures be placed at least 100 m from the nearest Douglas-fir tree. This may reduce the risk of establishing and intensifying infestations in surrounding stands. However, if the baits are placed in the same place year after year, the results may still vary as the beetle infestation centres move through the forest over time. This would make it extremely difficult to determine population trends.

Pheromone traps have great potential in managed forests for attempting to contain certain insect outbreaks and for determining if a particular insect is present or absent. However, the results obtained over successive years from monitoring DFB population trends with pheromone traps may be difficult to interpret. In National Parks designated as wilderness or preserves with natural ecological processes, monitoring beetle populations with pheromone traps may be inappropriate. Pheromone traps are likely to alter beetle populations and the forest stand structure by modifying the number of trees attacked and killed, the infestation centres, and the diameter of trees attacked.

Jasper Park will continue to monitor the Douglas-fir beetle infestations aerially, but will no longer use pheromones. No plans have been made to control the infestations. Instead, park personnel conduct and encourage non-intrusive monitoring of the dynamics of the Douglas-fir beetle infestations and their effects upon its montane forest ecosystem.

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