BROOD PRODUCTION BY THREE SPP. OF *DENDROCTONUS* (COLEOPTERA: SCOLYTIDAE) IN BOLTS FROM HOST AND NON-HOST TREES

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ABSTRACT

Brood establishment and production by mountain pine beetles, Douglas-fir beetles and spruce beetles were investigated in the laboratory, in 40 cm bolts of subalpine fir, spruce *(Picea glauca* x *P. engelmannii* hybrid), lodgepole pine and Douglas-fir. In subalpine fir, a few eggs were laid by mountain pine and spruce and Douglas-fir beetles but no brood matured. Production of egg galleries by spruce beetles in this host was the same as it was in spruce, its principal host. In Douglas-fir, eggs were produced only by Douglas-fir beetles and the production of galleries by this bark beetle was significantly greater than that by either of the other beetles. All three beetle spp. produced mature broods in lodgepole pine and in spruce.

RESUME

On a étudié en laboratoire les couvains du dendroctone du pin ponderosa, du dendroctone du Douglas et du dendroctone de l'épinette dan des billons de 40 cm de sapin subalpine, d'épinette hybridge *(Picea glauca* x *P. engelmannii)*, de pin tordu et de Douglas taxifolié ainsi que leur devenir. Ces espéces de dendroctone ont pondu quelques oeufs dan le sapin subalpin mais aucune larve n'est parvenue à maturité. Le dendroctone de l'épinette a creusé dans cet hôte principal. Dans le Douglas taxifolié, seul le dendroctone du Douglas a pondu des oeufs, et les galeries qu'il a creusées étaient beaucoup plus nombreuses que celles des deux autres espèces. Dans le pin tordu et l'épinette, les trois espèces de dendroctone ont produit des oeufs qui sont parvenus à maturité.

INTRODUCTION

Some of the most destructive insect pests of mature forests in North America are *Dendroctonus* bark beetles. periodic outbreaks of the mountain pine beetle *(D. ponderosae* Hopk.), the spruce beetle *(D. rufipennis* [Kirby]), and the Douglas-fir beetle *(D. pseudotsuga* Hopk.) in the pine *(Pinus* spp.), spruce *(Picea* spp.) and Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) forests, respectively, of the British Columbia interior result in large scale tree mortality. Under outbreak conditions, some non-host trees may also be attacked and killed (Massey and Wygant 1954, Safranyik *et al.* 1974, Schmid and Frye 1977, Wood 1982). Since tree-killing is often equated with brood production, forest managers are concerned that bark beetle populations might be maintained in non-host trees. Reports, based primarily on field observations, indicate that in non-host trees broods are not produced (McCambridge and Knight 1972), rarely develop (Safranyik *et al.* 1974), or survive only in felled trees (Furniss *et al* 1981). However, there is little quantitative information on brood production in non-host trees by these three species of *Dendroctonus*. Such knowledge is of practical and theoretical importance in relation to the temporal and spatial distribution and abundance of populations.

Douglas-fir, lodgepole pine *(P. contorta* Douglas), spruce *(P. glauca* x *P. engelmannii* hybrid) and subalpine fir *(A. lasiocarpa* [Hooker]) often form mixed stands in the interior of British Columbia within the geographic range of the three *Dendroctonus* spp. We examined brood production, gallery length, adult size and sex ratio of these *Dendroctonus* spp. in the four species of trees under laboratory conditions.

MATERIALS AND METHODS

Between April 29 and May 4, 1981, three bolts, about 40 cm long and 25-32 cm in diameter, were cut from one tree each of Douglas-fir, lodgepole pine, spuce and subalpine fir. The Douglas-fir was obtained near Caycuse, the lodgepole pine near 100 Mile House, and the last two tree species near Hixon, all in British Columbia. The bolts were waxed on the ends and stored at 0° until used.

Two-year-cycle spruce beetles were collected from windfall spruce trees near Hixon on April 28, 1981. Bark containing adult beetles was removed, packed in plactic bags and held in the laboratory at 21 + 3°C. Beetles emerging May 7-11 were stored on moist paper towelling in a refrigerator at 2 ± 2°C. Mountain pine beetles were reared in the laboratory from naturally infested lodgepole pine bolts cut near Riske Creek, B.C. Beetles emerging

May 5 were stored as described. Douglas-fir bark containing adult Douglas-fir beetles were collected from naturally infested bolts near Caycuse. Beetles emerging May 14-15 were stores as described.

On May 11, all the bolts were removed from cold storage and allowed to warm to room temperature (21 ± 3 °C). Four equally spaced grooves were cut lengthwise through the bark and into the wood on each bolt, the grooves were waxed, and one bolt from each of the four tree species was assigned at random to each of the three bark beetle "treatments'. An entrance hole was cut through the bark with a 4.3 mm diameter arch punch in each of the four bark sectors on all bolts, 5 cm from the lower edges and half way between the grooves in the bark. The beetles were allowed to exercise in screened cages at room temperature for 24 hours prior to introduction into the bolts. One female beetle was introduced into each entrance hole in the period May 11-15. Non-boring females were replaced after 24 hours. Single male beetles were placed into the entry holes 1-2 days after the initiation of boring by the female beetles. Beetles were confined to the entrance holes by gelatin capsules (Lanier and Wood 1968). The bolts were incubated in the laboratory at 21 ± 3 °C. Thus four pairs of each of the three beetle species were placed on one bolt of each of four tree species.

One of the four egg galleries was sampled on each bolt July 15-16 to check brood development, and the remaining egg galleries (3 per bolt) were sampled August 12. The following variables were measured and recorded: number of egg galleries initiated/bolt, number of successful galleries/bolt length, of egg galleries to the nearest 0.1 cm, number of larvae/egg gallery, number of brood adults/egg gallery, along with the ratio of males and prothorax width to the nearest 0.01 mm. A gallery was defined as initiated when the egg gallery was at least 0.5 cm long and successful galleries were those that contained live brood at the end of the experiment.

A development index (D.I.) was computed for the live broods according to the method of Dyer (1969). This method assigns index numbers to the brood stages (egg = 1, larval instars = 2-5, pupa = 6, adult = 7), and the D.I. is a weighted average of these values. Male ratios and adult sizes between the principal host and the other tree species were compared by t - tests and the D.I.s were compared by chi-square tests.

RESULTS AND DISCUSSION

Subalpine fir bolts.

No successful egg galleries were made by any of the three bark beetle species although egg galleries were initiated in all cases (Table 1). All mountain pine beetles and Douglas-fir beetles introduced died in a few days. Intitially the female beetles did not show any aversion to this host; in fact, of all four tree species tested, gallery initiation was generally quickest in subalpine fir by all three *Dendroctonus* species.

The egg galleries were heavily resin soaked and the average gallery length was much shorter than normal for mountain pine and Douglas-fir beetles but was normal for spruce beetle (Table 1). Egg production followed the same pattern as egg gallery production; 0, 2, and 13 eggs were laid by Douglas-fir beetle, mountain pine beetle and spruce beetle, respectively. Ten of these eggs failed to hatch and the remainder died in the early larval instars.

The poor gallery production by mountain pine beetle in subalpine fir was unexpected because the related *A. grandis* (Douglas), is attacked occasionally (Amman 1978). The normal gallery production by spruce beetle may have been due to the common association of subalpine fir with white and Englemann spruce. If baited with frontalin and alpha-pinene, subalpine fir is attacked by spruce beetles according to the late J. A. Chapman. However, there is no report of natural attacks by spruce beetle on this tree species.

Douglas-fir bolts

The average egg gallery lengths for mountain pine and spruce beetles were much shorter than for Douglas-fir beetle (Table 1). No eggs were laid by mountain pine beetles or spruce beetles whereas an average of 30.2 brood (mostly adult beetles) were produced in the four egg galleries by Douglas-fir beetles.

All spruce beetles exited after construction of short egg galleries (Table 1) and all but one of the introduced mountain pine beetles died in small, irregular chambers constructed by the females in the inner bark. One male beetle died in the egg gallery.

The difference in the behavior between mountain pine beetle and spruce beetle in Douglas-fir may have been due to the different tolerances of these two bark beetle species to Douglas-fir resin or differences in the acceptability of Douglas-fir phloem. Although Douglas-fir is reportedly attacked on occasion by mountain pine beetle (Safranyik *et al.* 1974) it appears unlikely that broods would mature in this species.

Lodgepole pine and spruce

In lodgepole pine and white spruce, all three species of bark beetles established at least one successful egg gallery. For mountain pine beetle, average gallery length, no. brood/succesful egg gallery, development index, male ratio and mean sizes of the sexes were numerically greater in lodgepole pine than in spruce but only the development index and beetle size were significantly different (Table 1). For spruce beetle, there were no statistically significant differences ($p \geq 0.05$) between lodgepole pine and spruce in these variables. For Douglas-fir beetle, there were significant differences ($p \leq 0.01$) only in no. brood/successful gallery and male and female size between spruce and Douglas fir. However, no measurements were taken in lodgepole pine on beetle size and male ratio.

These results indicate that under laboratory conditions subalpine fir is not a suitable host for any of

TABLE 1. Mean gallery length (cm), brood development and production, size (mm) and male ratio of emerged adults of 3 species of **Dendroctonus** bark beetle in bolts from 4 species of tree.

Gallery and brood statistics	Insect sp.	Tree species: Lodgepole pine	Spruce	Douglas-fir	Subalpine fir
Galleries initiated	D. ponderosae	2[a]	4	4	4
	D. rufipennis	4	4[a]	4	4
	D. pseudotsugae	2	4	4[a]	4
Successful galleries	D. ponderosae	2	2	0	0
	D. rufipennis	2	3	0	0
	D. pseudotsugae	1	2	4	0
Gallery length ($\bar{x} \pm s_{\bar{x}}$)	D. ponderosae	33.7 ± 7.2	12.9 ± 5.1^{ns}	1.1 ± 0.1**	4.2 ± 1.4**
	D. rufipennis	15.2 ± 6.3^{ns}	12.7 ± 5.0	2.1 ± 0.2^{ns}	13.4 ± 4.9^{ns}
	D. pseudotsugae	27.5 ± 4.5^{ns}	16.0 ± 5.4^{ns}	23.0 ± 6.1	3.9 ± 1.2*
Development Index (D.I.)[b]	D. ponderosae	6.50	6.00**	0	0
	D. rufipennis	6.97^{ns}	6.93	0	0
	D. pseudotsugae	6.55*	6.43*	6.95	0
Brood per successful gallery	D. ponderosae	28.00	8.50	0	0
	D. rufipennis	19.00	33.33	0	0
	D. pseudotsugae	31.00	7.50	30.20	0
Male size[c] ($\bar{x} \pm s_{\bar{x}}$)	D. ponderosae	1.88 ± 0.03	1.51 ± 0.01**	-	-
	D. rufipennis	2.26 ± 0.03^{ns}	2.33 ± 0.02	-	-
	D. pseudotsugae	ND	1.81** ± 0.04	2.22 ± 0.01	-
Female size[c] ($\bar{x} \pm s_{\bar{x}}$)	D. ponderosae	2.09 ± 0.05	1.82 ± 0.03**	-	-
	D. rufipennis	2.23 ± 0.07^{ns}	2.25 ± 0.02	-	-
	D. pseudotsugae	ND	1.89 ± 0.04**	2.22 ± .02	-
Male ratio	D. ponderosae	0.39	0.33^{ns}	-	-
	D. rufipennis	0.54^{ns}	0.39	-	-
	D. pseudotsugae	ND	0.42^{ns}	0.46	-

[a] Principal hosts

[b] See Methods

[c] Average width of the prothorax

ND = No measurements were taken

ns,*,** Not significant, significantly different at the 95% and 99% probability levels, respectively, from mean for the principal host.

the three *Dendroctonus* species tested and that Douglas-fir is not a suitable host for mountain pine and spruce beetles.

Production of mature broods in the spruce and lodgepole pine bolts by Douglas-fir beetle, in the spruce bolt by mountain pine beetle, and in the lodgepole pine bolt by spruce beetle in the laboratory indicate that populations might be maintained in such alterntive hosts in the field. However, brood establishment and maturation following forced attacks on bolts of alternate hosts in the laboratory does not necessarily mean that natural attacks and brood development would occur in live trees. For example, the Douglas-fir beetle infests western larch in addition to its principal host, but progeny survive only in felled trees (Furniss *et al.* 1981). These workers suggest that attacks by Douglas-fir beetle on western larch are due to similarities in the monoterpene composition of Douglas-fir and western larch and intermingling of odours from neighbouring attacked Douglas-fir but they cannot explain the failure of broods in live western larch. Killing of lodgepole pine by the spruce beetle during epidemics in spruce forests and killing of spruce by mountain pine beetle during epidemics in pine forests have been documented (e.g. Schmid and Frye 1977, Wood 1982). Lodgepole pine and white and Engelmann spruce, however, are not considered hosts of the Douglas-fir beetle, although felled Brewer spruce (*P. breweriana* S. Watts) is an occasional host (Johnson 1960). Johnson's report and our results indicate that Douglas-fir beetle may occasionally attack lodgepole pine and some spruces in its range and that broods could mature in felled trees.

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