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ENTOMOLOGY

Spruce Beetle Mortality in Stumps Following an Operational Broadcast Burn. — The spruce beetle *(Dendroctonus rufipennis* [Kirby]) normally infests logging slash (cull-logs, tops, and stumps) in mature spruce (white spruce, *Picea glauca* [Moench] Voss, Engelmann spruce, *P. engelmannii* Parry) forests. In stumps, large proportions of beetle attacks and broods can occur below duff (Safranyik, unpublished). Earlier studies indicated that in most years slash absorbs more beetles than it produces (Dyer and Taylor, Pac. Forest Res. Cent. Inf. Rep. BC-X-62, 1971) but that, under conditions favoring beetle survival, populations can increase to outbreak levels in large amounts of fresh logging slash (Knight and McCambridge, Ecology 53:830-839, 1972). Close utilization (low stumps and tree-length logging) and/or slash-burning after brood establishment are the commonly recommended practices for preventing population buildup in slash. However, there is a lack of information on the effectiveness of slash-burning, and little is known of the relationship between beetle mortality and fire intensity. This paper reports density and mortality of spruce beetle larvae and adults in stumps above and below duff following an operational broadcast burn.

The study area, a 40.5 ha clear-cut area of slash, was located in spruce-subalpine fir *(Abies lasiocarpa* [Hook] Nutt.) forest type, in central British Columbia, about 65 km southeast of Prince George. The area was logged, with mechanical shears, in the winter of 1974-75. The slash was infested by spruce beetles during late spring and early summer of 1975 and broadcast-burned in October of the same year. The spruce stumps had an average density of 163/ha, an average height of 0.48 m and an average mid-diameter of 49 cm. Logs were removed in tree lengths, and thus only a few scattered pieces of fresh spruce slash greater than 20 cm in diameter remained in the logged area. Other fuels were branches and numerous old wind-thrown trees. Spruce beetle mortality was studied on the north side of stumps above and below duff. The intensity of burn was indexed on the north side of stumps above duff, as follows: (1) not burned (control=treatment 1), (2) 50% or less of the bark area scorched (treatment 2), (3) more than 50% of the bark area scorched (treatment 3), (4) bark either burned off or charred to the sapwood (treatment 4). Twenty stumps were selected from each of these four treatment categories along lines of random walk. Control stumps were located in unburned areas within the study area. These unburned areas varied from a few square meters to about 0.1 ha. Paired 20.3 x 25.4 cm bark samples were removed in treatments 1 to 3, one above duff, the other below duff, from May 17 to 22, 1976. Bark samples were dissected in a laboratory; the numbers of live and dead spruce beetle larvae and adults were tallied, and bark thickness was measured to the nearest millimeter. Treatment 4 stumps were sampled only below the duff line. The lower edges of above-duff samples and the upper edges of below-duff samples were located about 2.5 cm from the duff line. Live larvae and live adults were active during the sampling period, and this allowed easy separation from the respective dead individuals. Also, dead larvae were easily distinguished from live larvae by the former's gray-brown to black color and desiccated or distended appearance. The sum of the densities of live and dead beetles was designated to constitute the density of live beetle population before the slash burn. The percentage of mortality was expressed in relation to this figure. The percent mortality figures were converted to a square-meter basis and analyzed by analysis of variance in a split-plot design. The whole plots (stumps) were arranged in a completely random design for treatments 1 to 3 with treatment 4 added as an extra. The samples had unequal numbers of replicates (stumps) because, in each treatment group, some of the samples from the 20 stumps did not contain beetles either above or below duff. Adult and larval mortality were analyzed separately. The treatment means were compared by Duncan's Multiple Range Test and weighted t-test (Steel and Torrie, page 235 *in* Principles and Procedures of Statistics, McGraw-Hill, 1960). The difference between adult and larval mortality was subjected to t-test.

Mortality in control stumps was mainly due to cold temperature and other factors unrelated to the slash burn. In burned stumps, mortality was due to fire intensity, natural mortality factors as in control stumps, and the

TABLE 1

Analysis of variance of *D. rufipennis* larvae and adults in spruce stumps following broadcast burning of slash and winter mortality

Source of variation	Adults			Larvae		
	D.f.	Mean square	F	D.f.	Mean square	F
Treatment 1 to 3 (T)[1]	2	10,477.62	6.69[2]	2	16,992.45	19.50[2]
Error (a)	26	1,539.16		44	652.62	
Whole units=stumps	28	2,177.33		46	1,363.05	
Above duff vs. below duff (D)	1	5,800.00	5.54[3]	1	13,057.90	27.10[2]
DxT	2	7,421.79	7.09[2]	2	15,849.19	32.90[2]
Error (b)	26	1,047.42		44	481.75	
T. vs. treatment 4[1]	1	18,986.57	12.11[2]	1	610.56	0.70
Stumps within treatment 4	6	116,85		9	1,940.94	
TOTAL	64	2,007.95		103	1,420.71	

[1] The treatment 1-3 and T vs. treatment 4 mean squares were tested against the pooled error (a) and stumps within treatment 4 mean square.
[2] Significant at the 99% probability level.
[3] Significant at the 95% probability level.

TABLE 2

Density and percent mortality of *D. rufipennis* larvae and adults in spruce stumps following broadcast burning of slash and winter mortality

Treatments	Below duff				Above duff			
	Adults[1]		Larvae		Adults[1]		Larvae	
	Density (Live + dead /m²)							
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
Not burned (1)[2]	90.7	40.0	370.8	68.8	89.0	22.7	186.1	44.1
50% or less of bark scorched (2)	35.2	15.9	568.2	122.7	50.4	15.1	122.3	42.4
50% or more of bark scorched (3)	30.0	10.5	449.9	101.5	65.8	15.1	230.5	49.7
Bark charred above duff (4)	63.3	31.7	251.9	77.8	—	—	—	—
Mean	54.8	13.6	410.2	92.2	68.4	10.4	179.6	26.3
	Percent mortality (p)							
Treatments	$\bar{p}$	$s_{\bar{p}}$	$\bar{p}$	$s_{\bar{p}}$	$\bar{p}$	$s_{\bar{p}}$	$\bar{p}$	$s_{\bar{p}}$
Not burned (1)	20.6[a]	10.5	19.6[a]	6.5	14.0[a]	8.0	15.4[a]	5.3
50%or less of bark scorched (2)	31.2[a]	16.2	27.0[a]	7.8	44.4[b]	13.9	42.4[b]	10.4
More than 50% of bark scorched (3)	28.1[a]	15.9	34.7[a]	8.4	98.2[c]	1.7	99.8[c]	0.2
Bark charred above duff (4)	95.9[b]	4.1	31.6[a]	10.2	—	—	—	—

[1] Parents plus young adults.
[2] Numbers 1 to 4 indicate treatments 1 to 4.

Treatment means marked by the same letter are not significant, and those marked by different letters are significant at the 99% probability level, except those in the treatment 1 vs. treatment 2 comparison for adults, which is significant at the 95% level.

interaction of fire intensity and natural mortality factors. Thus, differences between percent mortality in burned stumps and control stumps at the time of sampling measured the direct and indirect effects of the slash burn.

Before the slash burn, the average density of spruce beetles (dead plus live larvae and adults) below duff (466.4) was significantly greater than the corresponding density above duff (244.3) ($p<.01$). Approximately 12% of the beetles below duff and 28% of those above duff were adults. The adults were predominantly young beetles; the remainder was parent adults. In control stumps, adult and larval mortality below duff was not significantly different from the corresponding mortality above duff.

There were significant differences in percent mortality of adults and larvae among burning intensity treatments 1 to 3(T), above duff vs. below duff (D), and in the interaction between treatments T and D (Table 1). For adult beetles, there was also a statistically significant difference between the mean percent mortality for the combined burning intensity treatments 1 to 3 and treatment 4.

Mean percent mortality of larvae in stumps with more than 50% scorched bark was significantly different at the 99% probability level from the corresponding mortality in unburned stumps and stumps with less than 50% scorched bark, but there was no difference between the two latter treatments. Mean percent mortality of adults with more than 50% scorched bark was significantly different only from the corresponding mortality in unburned stumps and at the 99% probability level. Adult and larval mortality increased with burning intensity more above duff than below duff, and this is indicated by the highly significant interaction between treatments T and D (Table 1). Below duff, there were no statistically significant differences in mean percent mortality among treatments 1 to 3 for adults and among treatments 1 to 4 for larvae. In the adult stage, treatments 1 to 3 were significantly different from treatment 4 at the 99% probability level (Table 2). Above duff, there were significant differences in mean percent mortality of adults and larvae among all treatments at the 99% probability level except the treatment 1 vs. treatment 2 comparison for adults, which was significant at the 95% level. There was nearly complete mortality of adults (98.2%) and larvae (99.8%) in stumps with more than 50% scorched bark. There was no significant correlation between bark thickness and mortality of adults or larvae either below or above duff in any treatment.

Below duff, adult mortality was significantly different from larval mortality only in charred stumps. This greater mortality of the adults below duff apparently resulted from the fact that the bulk of the adult beetles was found close to the upper edges of the samples, i.e. close to the duff line, where beetles were subjected to more intense heat than larvae which were generally located deeper under duff.

Examination of 264 stumps throughout the slash indicated that 8.3% had bark with no burn, 6.0% with $\leq$ 50% burn, 74.6% with > 50% burn, and 11.1% charred bark. Accordingly, in the burned-slash area, the adult and the larval mortality below duff attributable to the slash burn was approximately 24% and 14% respectively, and the corresponding mortality above duff was 68% and 62%.

The mortality of adults by treatment in this study reflects the total direct and indirect effects of the slash burn on their survival in the study area. However, since the larvae will develop under the bark for one or more years following the slash burn, indirect fire effects on the larval habitat, such as faster drying and more frequent cracking and peeling of scorched bark in relation to unscorched bark, will cause further mortality. This additional mortality needs to be evaluated.

Because a large proportion of spruce beetle broods in stumps can occur below the duff line, slash burns that result in less than 50% scorching of bark on most stumps are not effective in reducing beetle population, especially when broods develop on a 1-year life cycle. — L. Safranyik, Pacific Forest Research Centre, Victoria, B.C.

Field Test for Primary Attraction of the Spruce Beetle. — The spruce beetle *(Dendroctonus rufipennis* [Kirby]) (Coleoptera: Scolytidae) infests several species of spruce across North America. Under endemic conditions, the beetles breed in wind-thrown, cut and severely damaged or diseased trees and stumps; apparently healthy standing trees are seldom attacked. Under epidemic conditions, however, standing trees, as well as down host material, are infested. The host selection behavior of the spruce beetle has not been investigated by methods that take into account the secondary attraction (pheromones) produced by virgin female beetles (Dyer and Taylor, Can. Entomol. 100:769-776, 1968). A field test was designed to determine whether spruce beetles could orient by means of olfaction to uninfested cut host material.

The study was conducted in 1975, near Prince George, B.C., in the Naver Forest. Two sites for trap placement were chosen: A) a closed stand of old growth spruce *(Picea engelmannii* Parry, *P. glauca* [Moench] Voss) mixed with subalpine fir *(Abies* lasiocarpa [Hook.] Nutt.), and B) a landing at the edge of a large clearcut area slash-burned in 1974 and flanked by a severely wind- and fire-damaged stand edge of a species composition similar to A (above). Both sites had large numbers of emerging spruce beetles.

Twenty "greenhouse" cages (Chapman, Can. Entomol. 98:50-59, 1966) 76 x 76 x 72 cm high were used in control-test pairs, five pairs at each site. The control cages were empty, whereas the test cages contained four or five bolts, approximately 68 cm long, cut from freshly felled white spruce. Two window flight traps were placed at right angles to each other on top of each cage. Members of a cage pair were placed 10 to 15 m apart, whereas cage pairs were separated by at least 15 m. Trapped beetles were collected at 3- to 7-day intervals, eight times in area A and seven times in area B, from May 29 and June 2, respectively, to July 3. After trapping ended, all test bolts were stripped of bark and checked for possible insect attacks.

TABLE 1

Trap catches of *Dendroctonus rufipennis* (Kirby) at empty control cages and test cages containing spruce bolts, Naver Forest, 1975

Test area	Trapping days	Numbers of *D. rufipennis* caught					
		Control cages (empty)			Test cages (bolts)		
		♂	♀	♂+♀	♂	♀	♂+♀
A	35	0	0	0	4	5	9
		1	3	4	7	7	14
		0	0	0	5	5	10
		0	0	0	3	3	6
		0	0	0	7	7	14
B	31	0	0	0	2	6	8
		0	0	0	3	5	8
		0	1	1	1	3	4
	Totals	1	4	5	32	41	73

Total catches of *D. rufipennis* by sex for each control-test cage pair are given in Table 1 (two cage pairs in area B were eliminated from the analysis because log dissection revealed that spruce beetles had gained access to the logs and produced galleries and presumably pheromones, as evidenced by increased numbers of beetles caught — 102 beetles on two cages in the same time period). Catches of males, females, and both sexes together on the test cages were significantly higher than on controls at $p = 0.005$ (Wilcoxon matched-pairs signed-ranks test, one-tailed; Siegel, Non-Parametric Statistics, McGraw-Hill Co., 1956), indicating that spruce beetles are capable of orienting to sources of odors from cut host material in the absence of normal visual cues.

The sex ratio of trapped beetles favors males slightly (43.8% males) over that found in emerging beetles (41.2% males) (L. Safranyik, Pacific Forest Research Centre, pers. comm.). The response of male spruce beetles to host odors is interesting, since the males do not initiate gallery construction. A similar phenomenon has been reported for other Scolytid species, for example *Trypodendron lineatum* (Oliver) and *Gnathotrichus sulcatus* LeC. (females in the latter species) (Moeck, Bi-mom. Res. Notes 27:11-12, 1971), and *Hylastes nigrinus* (Mann.) (Rudinsky and Zethner-Møller, Can. Entomol. 99:911-916, 1967). The simultaneous arrival of both sexes on suitable host material would facilitate mate-finding and gallery establishment.

Gara and Holsten (Z. Angew. Entomol. 78:248-254, 1975) stated that uninfested spruce bolts were unattractive to Scolytidae encountered in Alaska, including the spruce beetle. The difference in results may be due to differences in methodologies as well as study areas; the level of primary attractiveness of spruce bolts is low (average 0.27 beetle/cage per day), so that sensitive methods of detection must be used. — H.A. Moeck, Pacific Forest Research Centre, Victoria, B.C.