FACTORS OF SUSCEPTIBILITY IN SPRUCE BEETLE ATTACK ON WHITE SPRUCE IN ALASKA

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ABSTRACT

Spruce bark beetle activity was monitored over 14 years on a transect through a mixed white spruce stand on the Kenai Peninsula, Alaska. Data confirmed bark beetle preference for attacking large-diameter, slow-growing spruce. Increased bark beetle activity was noted on north facing slopes; the least activity was on ridge tops. Moisture stress brought about by low soil temperatures is believed to be the cause for increased susceptibiity of white spruce to beetle attack on north facing slopes. A rudimentary guide is given to rate uninfested spruce timber for probable high or low losses if attacked by spruce beetles.

INTRODUCTION

The spruce bark beetle *(Dendroctonus rufipennis* [Kirby]) is the most devastating forest insect pest of white *(Picea glauca* [Moench] Voss), and Sitka spruce *(P. sitchensis* [Bong.] Carr.) in south-central Alaska. Beetles infested 130,000 hectares of forested land in 1983[1] of which 14,000 hectares occurred on Chugach National Forest on the Kenai Peninsula. Some of these areas such as the East Fork drainages (Fig. 1), have sustained chronic beetle infestations for the past 20 years (Crosby and Curtis 1968, Baker and Curtis 1972).

Spruce beetles preferentially attack and breed in slow-growing, large diameter spruce where the spruce component of the stand is greater than 50% (Schmid and Frye 1976, Werner *et al.* 1977). Recently, Hard *et al.* (1983) showed that on the Kenai Peninsula, diameter is not important for spruce susceptibility to attack, unless large diameter is related to slower than average cumulative radial growth in the last five years. Likewise, in the early stages of an outbreak, mean spruce radial growth is inversely related to the total number of trees of all species per hectare since trees in dense stands grow more slowly due to competition.

Institute of Northern Forestry personnel established (early 1969) a transect through mixed spruce stands in the Dry Gulch Creek area on the Kenai Peninsula to evaluate the impact of a spruce beetle outbreak (Fig. 1). Losses were related to such stand factors as tree diameter and age. Forest Pest Management re-evaluated the transects in 1980 and 1983 when additional data were collected to determine the influence of radial growth, stocking and aspect on spruce beetle attack.

MATERIALS AND METHODS

Description of study area:

A chain-wide transect extended in a northerly direction traversing four main aspects: bottomland (BL), south-aspect slope (SA), ridge top (RT), and north-aspect slope (NA) (Fig. 1). Elevation along the transect varied from 213 to 274 m above M.S.L.

The stand was composed of white spruce, paper birch *(Betula papyrifera* Marsh.), and mountain hemlock *(Tsuga mertensiana* [Bong.] Carr). Average spruce diameter at breast height (dbh) along the transect was 27.7 ± 11.7 cm and average spruce height and age were 19 ± 6 m and 133.5 ± 34 years, respectively.

Experimental design:

Spruce greater than 10.2 cm dbh along the transect were labeled at breast height with numbered aluminum tags (366 trees). Diameters were recorded from each spruce as well as crown position and tree condition in relation to beetle activity as non-infested, infested, pitch outs, and beetle killed.

Data were recorded in the early summers of 1969, 1970, 1974 and again in 1980 and 1983. Four variable plots (basal area factor,BAF = 10) were established in each of the four main aspects in 1983. Diameter at breast height of all species within each plot was recorded. An increment core, approximately 2.54 cm long, was removed from the uphill side at dbh from as many spruce as posible (297) along the transect. Cumulative width of the last five annual rings was measured, in the field, to the nearest 0.2 mm using a hand lens and ruler.

Data compilations:

Bark beetle attack was first analyzed on spruce trees along the transect over a 14 year period without regard to basal area, stocking, and aspect. Bark beetle attack was then compared between the four main aspects and their corresponding basal areas, stocking, and growth.

RESULTS AND DISCUSSION

Spruce diameters average 27.7 cm dbh along the transect. The diameters of spruce attacked and killed by bark beetles over 14 years averaged 35.6 cm; uninfested spruce averaged 22.9 cm dbh (Fig. 2a). The tendency of spruce beetles to attack and kill large-diameter spruce is re-confirmed and is also demonstrated in Figure 2b, which shows that large-diameter trees are selected in the early years of an

[1]Data on file with Forest Pest Management, USDA Forest Service, Anchorage, Alaska.

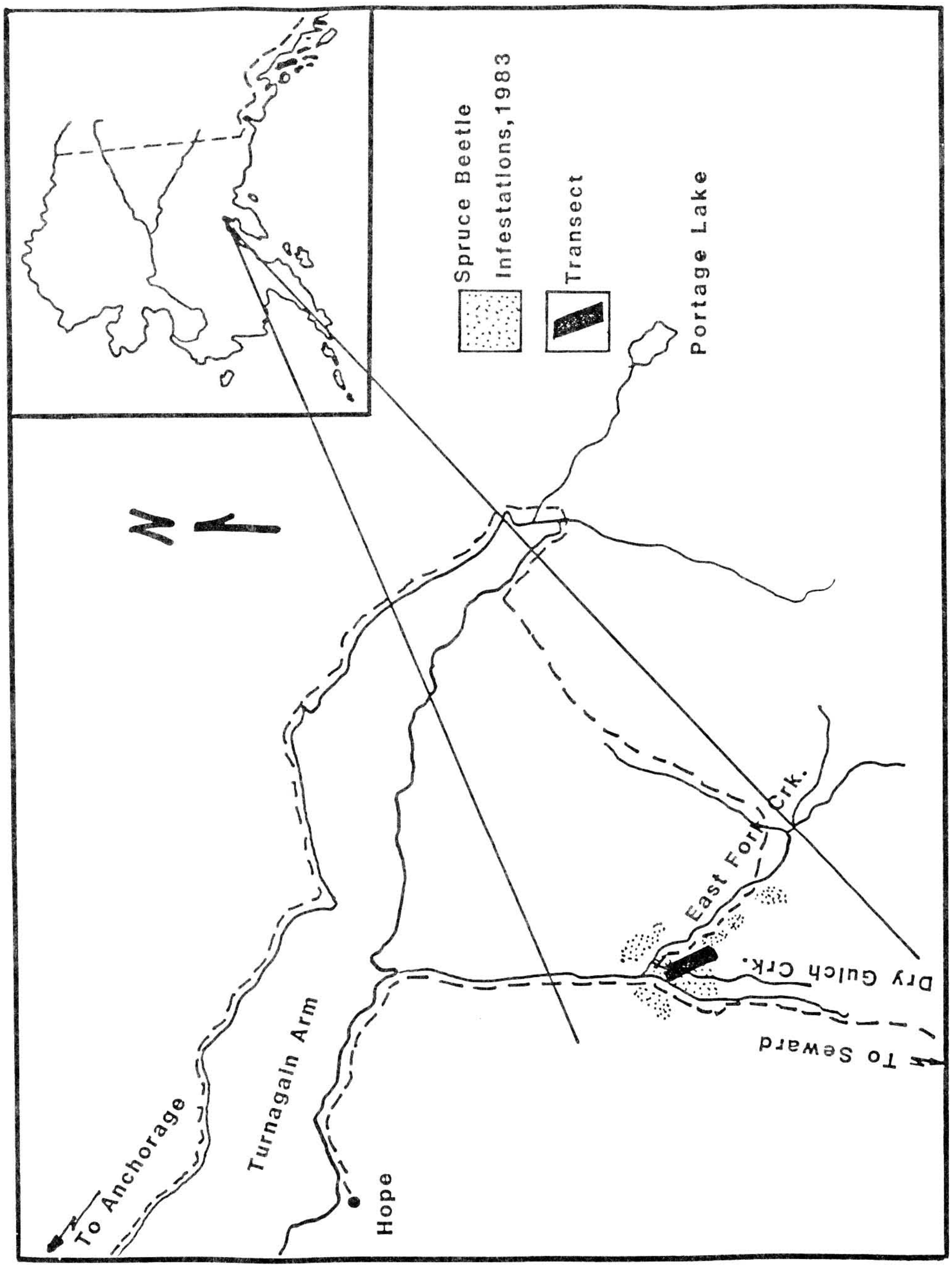

Fig. 1. 1983 spruce beetle infestations and location of the transect along the Dry Gulch drainage.

outbreak and selection decreases thereafter. By 1974, diameters of attacked and killed trees averaged 27.9 cm dbh, which approximated endemic levels (Fig. 2b), when only 3% of the live spruce were killed. Beetle attack increased in 1977 along a powerline right-of-way adjacent to the transect (Holsten 1981). Average diameters of killed spruce increased from 31.8 cm. in 1980 to 38.4 cm in 1983 when 19% of the live spruce were attacked and killed (Fig. 2b). Over the 14 year period, 161 tagged spruce (44%) were killed.

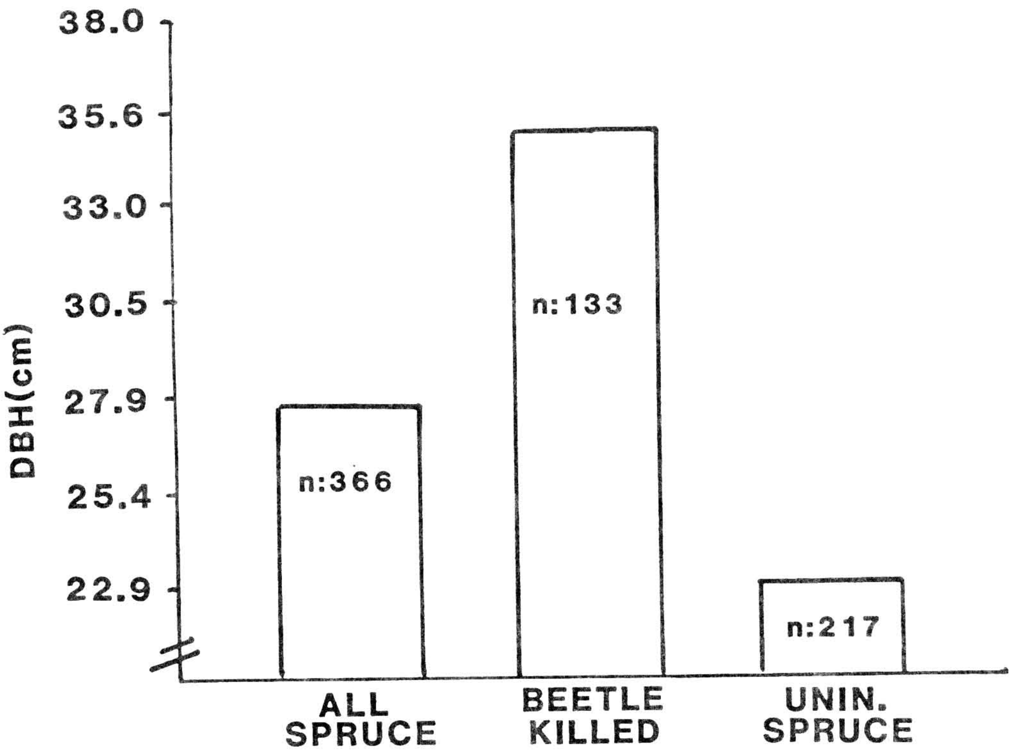

Fig. 2a. Condition of spruce over 14 years as related to diameter.

Hard *et al.* (1983) found that as mean cumulative radial growth of spruce for the last five years was approximately 4 mm or less, the incidence of spruce beetle attacks resulting in tree mortality increased. Growth data from the Dry Gulch Creek transect support this finding (Fig. 3a,b). Average growth of all killed trees was 2.4 mm *vs* 5.0 mm for uninfested spruce. Pitch outs, or unsuccessfully attacked trees, showed an average growth rate of 4.6 mm, slightly lower than the uninfested spruce. Pitch outs occur when the density of attacking beetles is insufficient to overcome host resistance, or the host is growing vigorously and resists attack. Spruce beetles not only selected large-diameter spruce at the beginning of the outbreak, but also selected less vigorous spruce as reflected by the low cumulative radial growth (Fig. 3a). As the outbreak progressed and subsequent beetle density increased, smaller diameter and faster growing spruce were attacked until the outbreak subsided in 1974. But with the increased beetle population density again in 1977, large-diameter and fast-growing spruce were attacked as most of the slow-growing spruce were already killed. Growth rates of attacked spruce were substantially lower than uninfested spruce (2.5 mm vs. 5.0 mm, respectively) even at the apparent peak of the outbreak in 1983.

Beetle attack was not uniform throughout the transect; increased mortality was apparent in certain areas. Table 1 depicts beetle attack as related to aspect with reference to growth rate, diameter, basal area, stocking, and percent mortality. The NA site had the highest mortality (49%) and the lowest average spruce growth rate (2.8 mm). Percent mortality decreased while spruce growth increased in the following order: NA, BL, SA, and RT which sustained only 20% mortality and had the highest growth rate (5.7 mm).

Hard *et al.* (1983) found that mean radial growth of spruce was inversely related to the number of trees of all species per hectare. However, the results from the variable plots in this study indicated that high beetle attack and low growth were related to the lowest stocking (Table 1). Percent of spruce basal area in the stand was highest (67%) in the heaviest attacked areas and lowest (26%) in the lighter attacked stands on the ridge tops. Schmid and Frye (1976) have shown that increased percentage of spruce in the canopy increases the risk of

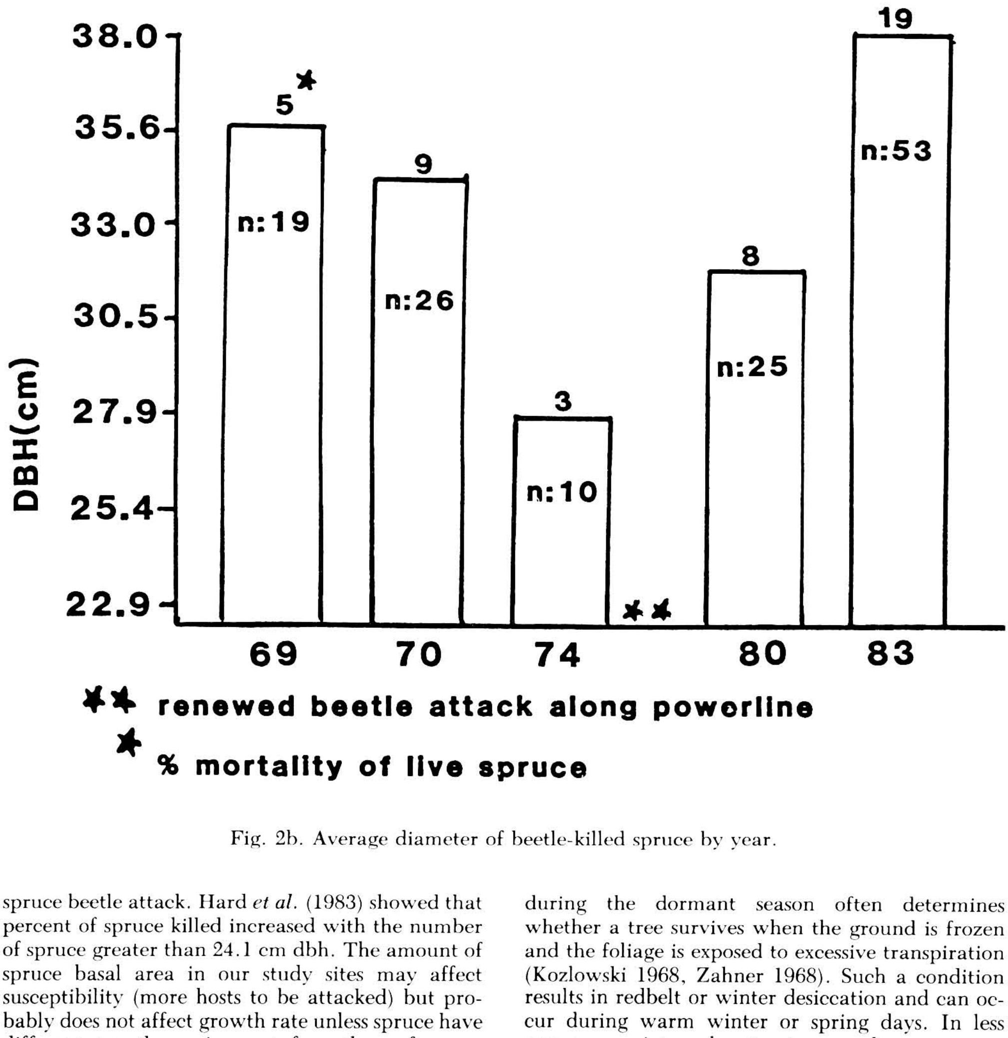

Fig. 2b. Average diameter of beetle-killed spruce by year.

spruce beetle attack. Hard *et al.* (1983) showed that percent of spruce killed increased with the number of spruce greater than 24.1 cm dbh. The amount of spruce basal area in our study sites may affect susceptibility (more hosts to be attacked) but probably does not affect growth rate unless spruce have different growth requirements from those of mountain hemlock in a mixed stand. If so, then "high" spruce basal area would be important in affecting growth of competing trees.

The possibility exists that some additonal site factor(s) is/are responsible for radial growth levels which are directly related to spruce susceptibility to beetle attack. Soil moisture is probably the most important factor affecting tree growth. In most forest areas soil moisture levels are rarely optimal during a growing season since northern latitude soils are usually cold. It is known that water uptake by plants is reduced at low soil temperatures (Whitehead and Jarvis 1981). Water uptake can be reduced by 60% with a drop of 15°C in soil temperature. For *P. sitchensis* seedings, critical soil temperatures for transpiration and photosynthesis are around 1°C (Whitehead and Jarvis 1981).

In northern environments, internal water stress during the dormant season often determines whether a tree survives when the ground is frozen and the foliage is exposed to excessive transpiration (Kozlowski 1968, Zahner 1968). Such a condition results in redbelt or winter desiccation and can occur during warm winter or spring days. In less severe cases, internal water stress can become severe in winter, and recovery and cambial growth may be delayed in the spring. Safranyik *et al.* (1981) showed that when radial growth ceased due to moisture stress, the formation of callus tissue, traumatic resin ducts and wound periderm were prevented, significantly reducing host resistance to spruce beetles. Spruce beetles select weakened and stressed trees and the availability of such trees is necessary in the development of outbreaks (Safranyik *et al.* 1981). Their data suggest that spruce beetles can detect and respond to stress conditions (water stress) in live trees.

It is possible that the observed low growth rates as well as the higher percent mortality along the NA portion of the Gulch Creek transect is related to water stress brought about by the low soil temperatures commonly encountered on north slopes (Buckman and Brady 1966). Soil

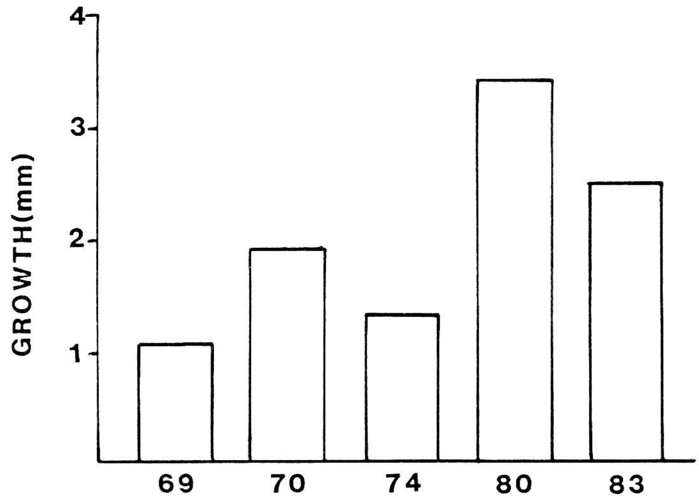

Fig. 3a. Condition of spruce as related to cumulative radial growth for 5 years.

temperatures, recorded from a northeast aspect on the Kenai Peninsula, were as low as -6°C at a depth of 15 cm during June 1983 (Table 2)[1]. A possible condition for the Dry Gulch area could be: 1) from May-June, soil temperatures are very low (less than 1°C) due to aspect, but ambient temperatures meet or exceed the flight threshold temperature for spruce beetles (16°C); and 2) soil moisture deficits exist because of increased transpiration and low soil temperatures; and 3) spruce beetles detect and successfully attack these water stressed trees.

A rudimentary guide to rate uninfested spruce timber for probable high or low losses if attacked by

#1Personal communication — Dr. Richard Werner, Institute of Northern Forestry, Fairbanks, AK 99701.

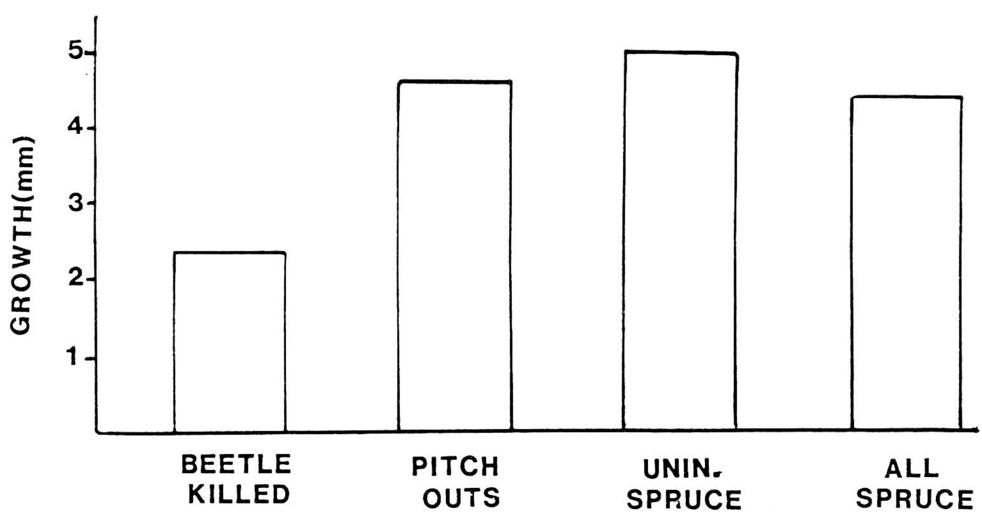

Fig. 3b. Cumulative radial growth for 5 years of beetle-killed spruce by year.

TABLE 1. Spruce beetle mortality and stand characteristics as related to four main aspects: north-aspect slope (NA), bottomland (BL), south-aspect slope (SA), and ridge top (RT).

	NA	BL	SA	RT
Percent Mortality -	49 (n=140)	44 (n=87)	25 (n=88)	20 (n=44)
Aver. Cumulative Spruce Radial - Growth (5 yrs.)	2.8 mm	4.4 mm	5.6 mm	5.7 mm
Aver. Spruce DBH -	30.7 ± 12 cm	23.6 ± 8.6 cm	26.7 ± 13.2 cm	26.2 ± 10.4 cm
Stocking (per ha) -	544 ± 312 stems	659 ± 242 stems	997 ± 320 stems	1360 ± 615 stems
Total Basal Area - (per ha)	32.7 ± 5.1 m^2	21.2 ± 7.6 m^2	34.4 ± 8.3 m^2	39.6 ± 9.4 m^2
Spruce Basal Area - (per ha)	21.8 ± 10 m^2	20.7 ± 8.4 m^2	20.2 ± 14.7 m^2	10.3 ± 3 m^2

TABLE 2. Soil temperatures (°C) from a northeast aspect along Snug Harbor Road on the Kenai Peninsula[1], 1983.

	MAY (26-31)			JUNE		
Depth (cm)	Max	Min	Mean	Max	Min	Mean
15	- 1	- 2	-1.86	- 1	- 6	-2.84
12	- 1	- 3	-1.81	0	- 4	-1.67
9	+ 1	- 2	-0.50	+ 4	- 4	+1.91
6	+ 3	0	+1.81	+ 8	0	+4.55
3	+ 6	+ 1	+2.91	+12	+ 2	+6.89

[1]Data on file with the Institute of Northern Forestry, Fairbanks, AK 99701.

spruce beetles can be based on these preliminary findings and those of others. High risk stands would be characterized by large diameter spruce, high spruce basal area, less than 4.0 mm cumulative radial growth the last five years, and a north aspect. A major precaution must be taken, however: these findings were developed from data collected in a single infestation and cannot be safely extrapolated to other areas until additional data from other areas on the Kenai Peninsula support the findings. Future studies should research such variables as elevation, slope, soil type, soil temperatures, and proximity to tidewater in order to develop a regional system for risk rating spruce stands to attack by spruce beetles.

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