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SPRUCE BEETLE (*DENDROCTONUS RUFIPENNIS*) OUTBREAK IN  
ENGELMANN SPRUCE (*PICEA ENGELMANNII*)  
IN CENTRAL UTAH, 1986–1998

Alan D. Dymerski<sup>1</sup>, John A. Anhold<sup>2,3</sup>, and Allen S. Munson<sup>1</sup>

**ABSTRACT.**—Extensive Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) mortality caused by the spruce beetle (*Dendroctonus rufipennis* Kirby) has been occurring at the southern end of the Wasatch Plateau in central Utah. This spruce beetle outbreak is the largest recorded in Utah history. An extensive ground survey was conducted in 1996 on the Manti-LaSal National Forest, Sanpete and Ferron Ranger Districts, to document mortality and impact of a major spruce beetle outbreak on post-outbreak forest composition. In 1998 the same sites were resurveyed. Survey results indicate Engelmann spruce basal area (BA) loss averaged 78% in trees  $\geq 5$  inches diameter breast height (DBH) in 1996. Ninety percent of BA  $\geq 5$  inches DBH was lost within the same sites by 1998. Tree mortality of spruce  $\geq 5$  inches DBH expressed in trees per acre (TPA) averaged 53% in 1996. In 1998 TPA  $\geq 5$  inches DBH mortality averaged 73%. Before the outbreak live Engelmann spruce BA  $\geq 5$  inches DBH averaged 99 square feet, and TPA  $\geq 5$  inches DBH averaged 97. In the sites surveyed in 1996 and resurveyed in 1998, Engelmann spruce BA  $\geq 5$  inches DBH averaged 21 and 9 square feet, and TPA  $\geq 5$  inches DBH averaged 43 and 25, respectively. Overstory tree species composition changed from stands dominated by spruce to subalpine fir. Stand ratings for potential spruce beetle outbreaks were high to mostly medium hazard pre-outbreak and medium to primarily low hazard by 1998, as a result of reduction in average spruce diameter, total basal area, and overstory spruce.

*Key words:* *Dendroctonus rufipennis*, bark beetles, insect outbreak, Scolytidae, *Picea engelmannii*.

The spruce beetle, *Dendroctonus rufipennis* Kirby (Coleoptera: Scolytidae), is considered the most important natural mortality agent of mature Engelmann spruce (*Picea engelmannii* Parry ex Engelm.; Holsten et al. 1999). Large-scale outbreaks since the 1850s, affecting millions of spruce from New Mexico and Arizona through the Rocky Mountains and north to British Columbia, have been documented by Schmid and Frye (1977). Most outbreaks originate from disturbances such as windthrow, avalanches, road building, landslides, and logging residuals (Schmid 1981, Holsten et al. 1999). In the Manti-LaSal National Forest, a spruce beetle outbreak began in 1986, primarily the result of a landslide that felled large numbers of Engelmann spruce in the upper southeastern portion of Twelvemile drainage. Since 1986, Forest Health Protection aerial survey staff have annually monitored spread of the infestation. From 1987 through 1998, as a result of spruce beetle activity, 261,400 Engelmann spruce trees have died on the Sanpete and Ferron Ranger Districts, Manti-LaSal

National Forest. This represents the largest recorded outbreak in Utah.

Spruce beetle generally has a 2-year life cycle. Adult beetles attack weakened and currently downed hosts in late spring and early summer. Eggs hatch through mid-October, developing into 2nd through 4th instar larvae, which is generally the overwintering life stage. Approximately 1 year after attacking the host, larvae pupate, transforming into callow adult beetles. Following pupation, adult beetles overwinter and emerge as mature adults the following summer to attack new host material.

To document the vegetative effects of a spruce beetle infestation across a large landscape, we conducted a ground survey over 4600 infested acres on the Manti-LaSal National Forest (Fig. 1). Stands were selected because beetle populations were declining on these sites.

#### METHODS

Fifteen stands totaling 4616 acres were surveyed in 1996 based on access, topography,

<sup>1</sup>USDA Forest Service, Forest Health Protection, 4746 South 1900 East, Ogden, UT 84403.

<sup>2</sup>USDA Forest Service, Forest Health Protection, Arizona Zone Office, 2500 S. Pine Knoll Dr., Flagstaff, AZ 86001.

<sup>3</sup>Corresponding author.

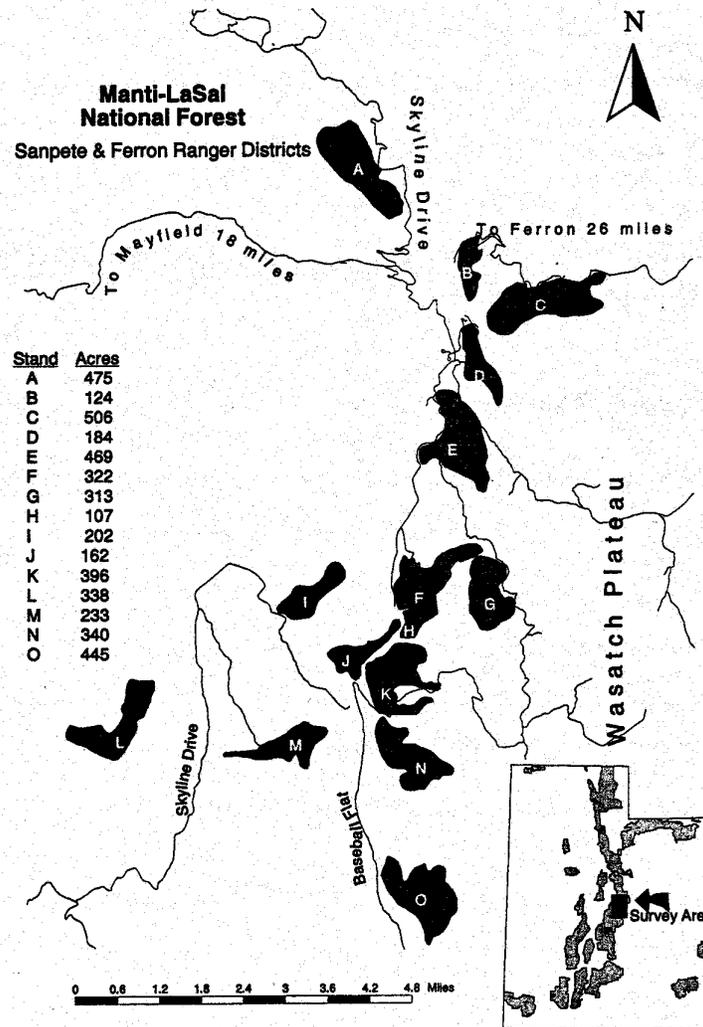


Fig. 1. Map of Wasatch Plateau, Manti-LaSal National Forest, Utah, showing Engelmann spruce stands surveyed to determine spruce beetle-caused impacts. Acres of each stand are also represented.

and successive years of spruce beetle activity. Surveyed boundaries were digitized into a geographic information system (ARC/INFO) to determine acreages and display stand locations (Fig. 1). Populations were declining in all sample stands. Within these stands, 403 variable-radius plots were measured. Thirteen of fifteen original stands were resurveyed in 1998. We measured 272 plots encompassing 4110 acres. The 1998 plot centers were not the same as the 1996 centers; however, they were in the general location. Uniform plot distribution throughout the stands was maintained to

adequately represent stand variability. Plot centers were systematically located at 10-chain (660-ft) intervals on transect lines spaced 10 chains apart. A 20 basal area factor (BAF) was used to select sample trees. We measured all sample trees  $\geq 5$  inches diameter breast height (DBH) and recorded the following characteristics for each: (1) DBH, (2) tree species, (3) tree condition as related to bark beetles (unattacked, current attack, previous year's attack, older attack, or strip attack), and (4) evidence of other insect or disease activity. FINDIT, a computer program for analyzing insect and

disease populations from stand level surveys (Bentz 2000), was used to compute average DBH of spruce >10 inches, total basal area, and proportion of spruce within a stand. Summary statistics were used in determining outbreak potential hazard rating using the system developed by Schmid and Frye (1976.) The Schmid and Frye (1976) rating system for spruce stands rates stand potential for spruce beetle outbreak. We applied this rating scheme pre-outbreak and to surveyed stand data collected in 1996 and 1998. To determine ratings for each stand, we examined 4 stand characteristics: (1) average diameter of live spruce >10 inches DBH, (2) stand basal area, (3) proportion of spruce in canopy, and (4) physiographic location. Physiographic location was classified as well-drained creek bottoms or by site index (SI) obtained from ranger district files. Calculated attributes were determined for each parameter and assigned points. Points were summarized for each stand to determine overall hazard. Mortality percentages were computed from FINDIT outputs. Weighted averages were calculated among stands using stand acres. Pre-outbreak stand averages were calculated using an average of both 1996 and 1998 stand data.

We used 1-way analysis of variance with Fisher's multiple comparison procedures to determine if there were any significant differences within sample periods: pre-outbreak, 1996 survey, and 1998 survey. The *F*-test was used to test specific differences within live basal area, trees per acre, and DBH for the sample periods to 95% confidence levels (Table 1).

## RESULTS

In 1996, BA spruce mortality was 78% and increased to 90% by 1998 (Table 1). A significant difference was found between pre-out-

break BA and both 1996 and 1998 levels. Spruce TPA mortality averaged 53% in 1996. In 1998 spruce TPA mortality increased to 73% (Table 1). Again, there was a significant difference between pre-outbreak TPA and both 1996 and 1998 levels. In addition, there was a significant difference between 1996 and 1998 TPA levels. Table 1 shows that pre-outbreak average spruce DBH was 14.1 inches; in 1996 and 1998, average DBH had decreased to 9.5 and 8.6 inches, respectively. Similar to the BA statistical findings, there was a significant difference between pre-outbreak DBH measurements and those determined in both 1996 and 1998. In all cases there was a trend within and among stands where stand DBH, TPA, and BA were reduced significantly during this outbreak.

Species composition pre-outbreak Engelmann spruce averaged 74% of total live BA  $\geq$ 5 inches DBH. Spruce BA was reduced to 37% in 1996 and 27% in 1998 (Fig. 2). Subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) comprised 22% of BA pre-outbreak, 51% in the 1996 survey, and 60% in 1998. Other species recorded were quaking aspen (*Populus tremuloides* Michx.), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), and limber pine (*Pinus flexilis* James). These species averaged 4% pre-outbreak, 12% in 1996, and 13% in 1998. Engelmann spruce BA composition was 34–88% pre-outbreak, 15–56% in 1996, and 12–50% in 1998.

Physiographic locations for Schmid and Frye's (1976) ratings for stands F, K, I, and M were classified as well-drained creek bottoms; J has an SI of 86, and remaining stands have indices between 40 and 80. Stand pre-outbreak ratings, along with 1996 and 1998 hazard ratings, are shown in Table 2. Before the outbreak all stands were classified as medium or high/intermediate hazard, with 2 rated high

TABLE 1. Mean ( $\pm$ SE) for stand variables measured pre-outbreak and as surveyed in 1996 and 1998, Manti-LaSal National Forest, Utah.

	Live spruce BA <sup>1</sup>	Range	% BA spruce mortality	Live spruce TPA <sup>2</sup>	Range	% spruce mortality	Live spruce DBH <sup>3</sup> >5"	Range
Pre-outbreak	99 (9.9)a <sup>4</sup>	57–134		97 (12.3)a	43–149		14.1 (0.4)a	11.9–15.9
1996 survey	21 (3.4)b	5–36	78 (2.8)	43 (6.6)b	26–70	53 (4.1)	9.5 (0.5)b	7.7–11.8
1998 survey	9 (0.9)b	3–14	90 (1.2)	25 (3.8)c	8–41	73 (2.0)	8.6 (0.5)b	6.9–11.8

<sup>1</sup>BA = basal area per acre (sq ft).

<sup>2</sup>TPA = trees per acre >5" DBH.

<sup>3</sup>DBH = diameter at breast height >5".

<sup>4</sup>Means within columns followed by the same letter are not significantly different at the 0.05 level; Fisher's least significant differences test.

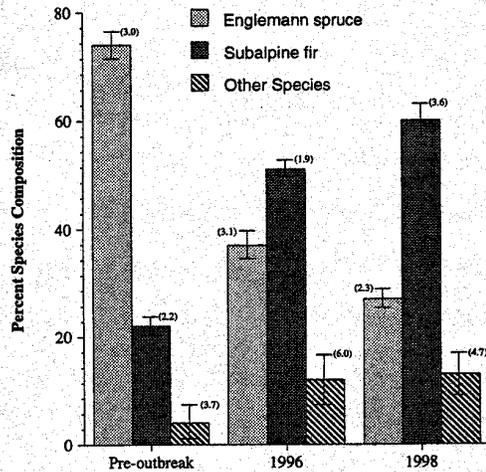


Fig. 2. Percent species composition pre-outbreak, 1996, and 1998,  $\pm$  standard error of the means ( $\pm s_x$ ). Other species includes aspen, Douglas-fir, and limber pine.

hazard. Results from both surveys indicate a dramatic shift in stand hazard, with stands primarily low and a few medium hazard. Stands with pre-outbreak medium ratings exhibited average spruce BA mortality of >76%; stands rated high/intermediate or high combined had an average spruce BA mortality of >81%.

#### DISCUSSION

Mortality of overstory Engelmann spruce within the survey area verifies the significant loss of large-diameter spruce associated with landscape-scale spruce beetle outbreaks. Many surveyed stands had pre-outbreak characteristics that contribute to an increase in spruce beetle populations, i.e., large diameter, high BA, and high proportion of spruce in the main canopy. As a result, once a disturbance event provides suitable downed host material and stands become infested, populations grow rapidly. In stands where the majority of overstory vegetation is composed of Engelmann spruce, visual effects of an outbreak can be quite dramatic. Immediate effects of this spruce beetle outbreak are changes in vegetative structure, species composition, and successional dynamics through the removal of large overstory spruce. Our results mirror those of past studies by Massey and Wygant (1954), Schmid and Frye (1977), and Veblen et al. (1991). A landscape once composed of large

overstory green spruce was, within a 5- to 6-year period, converted to a scene of grey, dead trees. Spruce beetle infestations reduce tree densities, sizes, and between-tree competition while increasing nutrient availability and accelerating growth of residual trees (Schmid and Frye 1977, Veblen et al. 1991). Subcanopy trees can be expected to sustain high growth rates for 40–100+ years (Veblen et al. 1994). The result of this change is smaller and younger surviving spruce. Successional changes caused by spruce mortality result in long-term effects on water yield, forage production, wildlife, and fire hazard (Schmid and Frye 1977). In the absence of salvage logging or fire, succession will accelerate toward the shade-tolerant and non-host species subalpine fir (Schmid and Frye 1977, Veblen et al. 1991, Jenkins et al. 1998). However, residual spruce seedlings will benefit more than fir seedlings from opening the overstory. Subcanopy trees of both fir and spruce will grow into the main canopy, but spruce, with its greater maximum size and longevity, will eventually attain basal area dominance as the shorter-lived fir gives way to disease and wind breakage. As the stand continues to develop, it becomes increasingly susceptible to another major spruce beetle outbreak (Schmid and Hinds 1974, Veblen 1986, Alexander 1987, Jenkins et al. 1998).

Stand susceptibility to spruce beetles can be reduced through silvicultural thinning, thereby reducing potential impact of outbreaks if compatible with management objectives. Through the use of stand rating schemes, forest managers can evaluate stand conditions, prioritize stand hazard, and initiate management practices to prevent or minimize outbreak impacts.

Outbreak populations of spruce beetle are occurring on 4 national forests in Utah (Table 3), suggesting widespread susceptibility to spruce beetle across many of Utah's spruce forests. Spruce beetle outbreaks will lead to extensive structural changes within these spruce-fir forests as mature spruce are replaced by understory seedlings and advanced regeneration.

#### CONCLUSION

This investigation of the spruce beetle outbreak on the Wasatch Plateau in central Utah documents widespread, heavy spruce mortality

TABLE 2. Pre-outbreak, 1996, and 1998 stand potential outbreak ratings.

Hazard	Pre-outbreak ratings	1996 ratings	1998 ratings
High	P,K	None	None
High/Intermediate	C,I,J,M,O	None	None
Medium	A,B,D,E,G,H,L,N	A,F,I,K	I,J,M
Intermediate/Low	None	J,M	H
Low	None	B,C,D,E,G,H,L,N,O	A,B,C,E,G,K,L,N,O

TABLE 3. Number of spruce trees killed by spruce beetles by national forest during 1997 as determined by aerial detections surveys.

Forest	Beetle population	Number of spruce trees killed by spruce beetles
Manti-LaSal	Epidemic	37,400
Dixie	Epidemic	23,800
Fishlake	Epidemic	2,700
Wasatch-Cache	Epidemic	1,400
Uinta	Endemic	500
Ashley	Endemic	200

and resultant changes in stand structure, species composition, and forest succession. A disturbance event of this magnitude highlights large-scale landscape changes and provides some insight regarding opportunities to minimize future outbreak impacts within vegetatively managed sites. Landscapes composed of dense, relatively even-aged, larger-diameter spruce are susceptible to outbreaks of spruce beetle. Further impact assessments should be conducted in other locations to capture the effects of this disturbance agent on Utah's spruce-fir forests.

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