Spruce Beetle Population Suppression in Northern Utah

B.J. Bentz, *USDA Forest Service, Rocky Mountain Research Station, 860 N. 1200 E., Logan, UT 84321, and* **A.S. Munson,** *USDA Forest Service, Forest Health Protection, 4746 S. 1900 E., Ogden, UT 84403.*

ABSTRACT: *The spruce beetle is a widely dispersed, native bark beetle that attacks and kills North American spruces. We describe a project that was initiated to suppress an endemic spruce beetle population in an isolated 1000 ac area of spruce in northeastern Utah. Techniques used included baited pheromone traps, selective harvesting and burning of infested trees, and trap trees. Over the 3 yr period of monitoring, the number of standing, currently infested spruce trees was reduced 91%. Field surveys and data trends, in comparison with a nearby spruce beetle population that continued to increase, indicate that the treatments played a major role in decreasing the trend of spruce beetle-infested trees during the study period. This combination of suppression techniques was successful due to the isolated nature of the spruce stands, early detection of the beetle population, accessibility of the stands, and coordinated efforts of local, state, and federal agencies. West. J. Appl. For. 15(3):122–128.*

The spruce beetle (*Dendroctonus rufipennis*), a native bark beetle associated with North American spruces (*Picea* spp.), is widely distributed throughout North America. The beetle's range follows that of its host from Alaska southward along the Rocky Mountain range into eastern Arizona and western New Mexico and across the Canadian provinces into northeastern United States (Wood 1982). In general, spruce trees tend to be shallow-rooted with little windfirmness and consequently are prone to blowdown (Alexander 1986). The spruce beetle takes advantage of this particular aspect of its host behavior, preferentially attacking downed trees to live standing ones. As population levels increase, however, live standing spruce may also be attacked in large numbers, resulting in widespread tree mortality over expansive acreages (Schmid and Frye 1977). In northern Utah, spruce beetles emerge from brood trees and disperse to attack new hosts between May and late July when temperatures reach approximately 16°C (Dyer 1973). Throughout its host range, populations typically require 2 yr to complete a generation, although generation time depends greatly on temperature (Safranyik and Linton 1999, Werner and Holsten 1985, Bentz and Hansen unpublished data) and may require as little as 1 yr or as long as 3 yr. In 2 yr populations, brood emerge the second summer after a tree has been attacked.

One strategy for managing spruce beetle populations is the use of trap trees. This method takes advantage of the tendency for spruce beetles to attack downed trees. Larger diameter, green spruce are felled into the shade and left unbucked and unlimbed (Hodgkinson 1985, Nagel et al. 1957). Trap trees typically have greater mean attack densities than standing spruce (Schmid and Frye 1977) and can absorb as many as 10 times the number of beetles (Wygant 1960, unpublished). In areas with lower infestation levels, one trap tree is cut down for each four to five infested standing trees, with no more than 1/4 mi between an infested group of trees and the trap trees. When feasible, legal, and accessible, trap trees may be injected with a translocating silvicide to eliminate the need for trap tree removal or brood destruction through debarking or burning (Gray et al. 1990, Lister et al. 1976). Otherwise, infested trap trees must be removed from the stand, burned, or buried before the next beetle flight to avoid a localized increase in the beetle population. In areas that are accessible by road, sanitation-salvage logging of infested trees before beetle flight is a recommended treat-

NOTE: B.J. Bentz is the corresponding author and can be reached at (435) 755-3560; Fax: (435) 755-3563; E-mail: bbentz@fs.fed.us. Chuck Frank (silviculturist), Dwayne Bell (forestry technician), Evelyn Sibberson (forester), and Kent O'Dell (timber management coordinator) with the Wasatch Cache National Forest, and Jim Long with Utah State University were instrumental in the success of this project. Discussions with Pat Shea provided insight into funnel trap placement. The authors thank field crews from Forest Health Protection, Ogden, UT; Department of Forest Resources—Utah State University; and the Rocky Mountain Research Station, Logan, UT, for help with the extensive surveys. Tom Bradley was responsible for GPS measurements and GIS analysis. Jim Long, Ed Holsten, and an anonymous reviewer provided valuable input to the manuscript.

This article reports the result of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation by the USDA Forest Service for its use. Pheromones used in this study are not currently registered for use by the general public. Caution should be used when pheromones are deployed in a forest setting to avoid undesirable tree mortality. A qualified state or federal entomologist should be contacted for advice on the use of bark beetle pheromones.

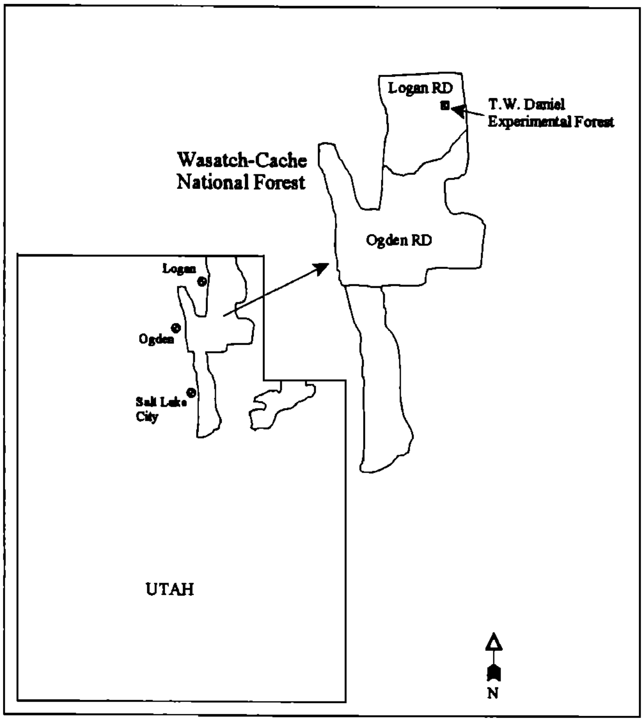

Figure 1. Location map of Logan and Ogden Ranger Districts (RD) and the T.W. Daniel Experimental Forest (study area).

ment. In areas that are not accessible, pheromone baited traps may be used (Werner and Holsten 1995).

Spruce beetle populations in southern Utah have been at epidemic levels since 1991 on the Dixie National Forest (Knapp et al. 1991) and since 1989 on the Manti-LaSal National Forest (Knapp et al. 1989). Populations on the Wasatch-Cache National Forest in northern Utah have recently begun to increase. We considered a population to be approaching the epidemic phase when there were more than two clumps of at least five standing, infested trees for every 5 ac. When the majority of beetles were confined to downed trees and only one or two standing infested trees over 5 ac were present, we considered the population endemic. An endemic spruce beetle population was first observed in the Engelmann spruce (*P. engelmannii*) component of the T.W. Daniel Experimental Forest in the summer of 1996 (J. Long, Utah State Univ., pers. comm.). That same year, a building spruce beetle population was also observed on the Ogden Ranger District of the Wasatch-Cache National Forest, which is approximately 15 air miles from the T.W. Daniel Forest (Figure 1).

The T.W. Daniel Experimental Forest is administered jointly by the Logan Ranger District of the Wasatch-Cache National Forest and Utah State University and is used primarily for teaching and testing silviculture strategies. The spruce-fir component of the T.W. Daniel Experimental Forest consists of approximately 1000 ac of varied topography with elevations between 2499 and 2697 m. Although the majority of the area is relatively flat and roaded, approximately 250 ac reside on slopes exceeding 35%. The Engelmann spruce and subalpine fir (*Abies lasiocarpa*) within this steep-sloped area have been intentionally unmanaged. No signs of logging have been found in the area, and historic records indicate no timber sales have occurred in this portion of the forest. The area holds immense value as a comparison for other areas on the Experimental Forest where active management occurs.

When the endemic spruce beetle population was first observed, a joint effort was initiated by the forester on the Logan Ranger District of the Wasatch-Cache National Forest, Utah State University, Region 4-Forest Health Protection, and the Rocky Mountain Research Station in an attempt to minimize spruce beetle-related impacts by reducing population numbers and associated tree mortality. Reported here are results from a coordinated effort to suppress spruce beetle population growth in this area of isolated spruce. We compare beetle population trends on the T.W. Daniel Experimental Forest, which were a result of suppression efforts, to beetle population trends on the Ogden Ranger District 15 air mi to the south.

Methods

The T.W. Daniel Experimental Forest lies within the Logan Ranger District of the Wasatch-Cache National Forest, which contains approximately 17,000 ac of spruce-fir vegetation type. The Experimental Forest makes up approximately 2,560 ac of the Logan Ranger District, with approximately 1000 ac of spruce-fir type. Mensurational information was gathered for three stands within the T.W. Daniel Experimental Forest (hereafter referred to as the study area) in 1996 when the beetle population was first observed (Table 1). The unmanaged area lies within Stand 9 (Table 1), which is located on the western edge of the study area in steeper terrain. Although the proportion of basal area (BA) comprised of Engelmann spruce varies throughout the study area, the unmanaged area had the highest proportion of spruce BA (62%) and the highest total stand BA (224).

In Fall 1996, a survey was conducted within the area to identify infested hosts. A tree was considered fully attacked if attacks on the tree bole exceeded 75% of the circumference and strip-attacked if the attacks were confined to less than one-third of the tree bole. In the roaded or managed area, all infested hosts were removed, and 85 green spruce trees were cut to serve as trap trees. The majority of trap trees were placed near infested tree clusters. Generally, two to five trap

Table 1. Site characteristics for three stands on the T.W. Daniel School Forest, measured 1996.

				Percent of stand basal area				
Stand #	Acres	Basal area (ft^2)	Live ES QMD (in.)	ES	SAF	ASP	LP	DF
1	75.0	165	18.0	49	36	5	11	0.2
6	45.9	155	19.9	32	46	4	14	4
9	259.7	224	21.6	62	33	3	0	2

NOTE: ES = Engelmann spruce, SAF = Subalpine fir, ASP = aspen, DF = Douglas fir, LP = Lodgepole pine, QMD = quadratic mean diameter.

Table 2. Site characteristics for 13 stands measured in 1997 on the Ogden Ranger District.

Stand #	Acres	Basal area (ft^2)	Live ES QMD (in.)	Percent of stand basal area			
				ES	SAF	ASP	DF, LP
68-1	247	147	11.9	42	27	17	14
68-2	51	60	6.0	11	0	78	11
59-15	25	170	10.8	71	29	0	0
59-32	29	130	10.0	8	23	0	69
30-14	35	127	19.1	53	47	0	0
30-9	21	216	19.9	72	26	2	0
27-5	59	146	16.3	78	12	10	0
27-2	90	133	12.2	82	8	0	10
27-1	33	175	9.7	77	20	0	0
27-6	155	175	20.1	87	13	0	0
62-6	74	120	15.5	38	28	27	7
25-8	8	370	17.0	92	8	0	0
66-2	171	209	15.2	65	9	26	0

NOTE: ES = Engelmann spruce, SAF = Subalpine fir, ASP = aspen, DF = Douglas fir, QMD = quadratic mean diameter

trees were placed near each infested cluster. To minimize logging impacts in the unmanaged area, no infested trees were removed, although 15 green trees were cut for use as trap trees. In an attempt to kill beetle brood in downed-attacked trees in this area, brush was piled around and under the trees then ignited using a diesel fuel/gasoline mix and drip torch. Due to wet weather, not all trees were fully scorched. In September of 1997 and 1998, 100% ground surveys were conducted where field personnel individually examined all susceptible hosts within the 1000 ac study area. Newly infested spruce trees were identified, both standing and windthrow. Infested trees were marked, and the spatial location measured using a geographic positioning system. Forty-two live trees were cut and left for use as trap trees in 1997.

To maintain the unmanaged nature of a portion of the area, strategies other than logging, including pheromone-baited traps, were employed on approximately 250 ac. In 1997, 42 clusters of three, 16-funnel traps (Lindgren 1983) were placed around the perimeter of the spruce-type in the unmanaged stand. Traps were placed just outside the host-type boundary in nonhost trees, with approximately 100 m between trap clusters. Four additional trap clusters were placed within the spruce-type boundary next to groups of recently killed spruce (5 to 10 dead trees/group). In 1998, 22 trap clusters were placed around the perimeter of the unmanaged stand. The number of traps was reduced in 1998 based on trap-catch results in 1997, although trap location and trap number were maintained. No traps were placed within clusters of dead spruce in 1998. Each trap was baited with α-pinene (1.8 ml) and frontalin (400 μl) (Pherotech, Inc., Delta, B.C., Canada). Traps were collected once/week in 1997 and twice/week in 1998. Air temperature was monitored using a data micrologger (21X Datalogger, Campbell Scientific Inc., Logan, UT) placed within the study area.

The Ogden Ranger District of the Wasatch-Cache National Forest, which is located about 15 air miles from the study area, was used as a comparison. Stand characteristics were measured throughout the spruce-fir type, which encompasses approximately 16,000 ac (Table 2). Based on a stand rating system for the spruce beetle (Schmid and Frye 1976), the study area and comparison area both possess stand characteristics suitable for a spruce beetle outbreak. Because beetle-killed trees require at least 1 yr to turn color, aerial detection surveys are used to detect mortality that occurred the prior year. Aerial surveys of the Ogden Ranger District in 1996, 1997, and 1998 were used to estimate the number of beetle-killed spruce trees in 1995, 1996, and 1997. In Fall 1997, the Wasatch-Cache National Forest cut trap trees and began removing infested trees along roadways on the Ogden Ranger District. In 1998, infested trap trees were removed in addition to 1523 standing infested trees. Air temperatures were measured (as described previously) in an infested stand within the Ogden Ranger District during the summer of 1998.

Results

Study Area

An aerial survey of the Logan Ranger District in 1997 revealed three groups of spruce mortality (containing 1 to 10 trees each) within the isolated 1000 ac spruce-fir type of the study area and an additional two groups of mortality outside this area. In subsequent years, no mortality was observed on the Logan Ranger District outside the study area. Infested trees identified in the Fall 1996 were not separated by attack year, and therefore 1995 and 1996 attacks in the study area are grouped. The total number of trees fully attacked within the study area decreased 56% from 1995–1996 to 1997, and a 71% decrease in attacked trees was observed from 1997 to 1998 (Figure 2). In 1995–1996, infested trees that were marked included 234 full-attacked trees and 30 strip-attacked

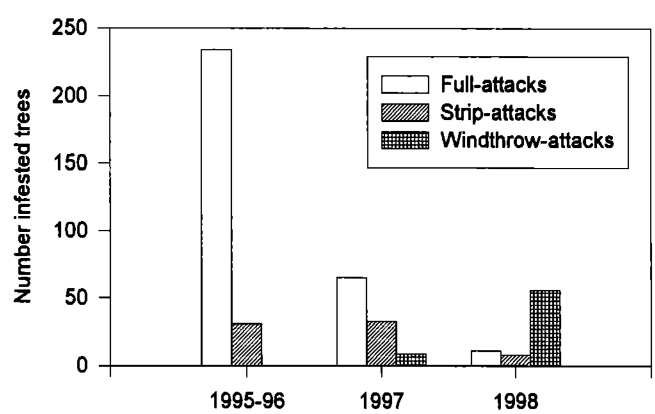

Figure 2. Number of spruce beetle-infested Engelmann spruce trees on the T.W. Daniel Experimental Forest, by attack type, for 1995–1996, 1997, and 1998.

trees. Of these, 199 infested trees were removed in October 1996. Eighty-five trap trees were cut down in Fall 1996. Sixty-five full-attacked trees, 33 strip-attacked trees, and 9 windthrow-attacked trees were found in Fall 1997. Spillover attacks occurred around the four trap clusters that were placed within the infested host clusters (Figure 3). The 85 trap trees dropped in 1996 were all infested and subsequently removed or burned in Fall 1997. An additional 116 infested trees were also removed in 1997. In 1998, 11 full-attacked trees, 8 strip-attacked trees, and 56 windthrow-attacked trees were found (Figure 4). The 42 trap trees dropped in Fall 1997 were all attacked in spring 1998, although attack densities were light. All identified infested trees were removed in the Fall 1998, and no additional trap trees were utilized. An initial goal was to refrain from logging in the previously unmanaged 250 ac on the western edge of the spruce type. Attacks in 1997 were heaviest in this area, and the decision was made to remove a portion of the attacked trees, resulting in an unmanaged area of approximately 140 ac.

Despite an effort to remove or burn all infested trees each year, some were missed and remained in the woods. For example, in the 1998 survey, 5 trees that had been full-attacked and 13 trees that had been strip-attacked in 1996 were found to be still in the woods. These trees provided beetles for the 1998 flight (based on a 2 yr beetle generation time). Twenty-seven of the 31 trees strip-attacked in 1996 were attacked again in 1997, and 2 of the 14 trees strip-attacked in 1997 and left in the woods were attacked again in 1998.

The majority of 1997 full-attacked trees were in the 24 and 26 in. diameter class, with distribution ranging from 12 to 48 in. (Figure 5a). Strip-attacks were spread throughout the 12 to 62 in. diameter classes. Windthrow was minimal in 1997, compared to 1998 when the majority of attacked trees were a result of blowdown. A small proportion of the blowdown in 1998 was concentrated around areas in which trees had been selectively removed the previous year (see Figures 3 and 4). Although there were far fewer trees attacked in 1998, the majority of full-attacked trees were again in the 26 in. diameter class (Figure 5b).

Trap Catches

Beetles were first caught in traps on July 2, 1997, with a peak spruce beetle flight the week of July 14. Maximum daily temperatures in the study area had been between 15 and 20°C a week prior to this, suggesting that flight may have started earlier than July 2 (Figure 6). Datalogger complications precluded an entire temperature record this year. In 1997, 22,166 spruce beetles and 5,871 clerid beetles *(Thanasimus dubius* and *T. undulatus)*, predators of the spruce beetle, were caught in the 42 trap clusters (126 total traps). Seventy-two percent of the spruce beetles were caught in three trap clusters (numbers 20, 21, and 28) situated close together on the northwestern edge of the study area (Figure 3). *Thanasimus* spp. were caught in all traps each week. Sixty-four percent of the traps caught more clerid beetles than spruce beetles throughout the flight. Traps catching the greatest number of clerid beetles also caught the greatest number of spruce beetles. *T. dubius* is a known predator of *D. rufipennis*, although *T. undulatus* prefers associated secondary beetles (Gara et al. 1995).

Due to the large number of traps that caught no beetles in 1997 or else caught predominantly clerid beetles, the number of traps was reduced in 1998. In 1998, beetles were first caught on June 30, coinciding with the time when maximum daily temperatures in the study area were between 15 and 20°C (Figure 7). Maximum daily temperatures remained above 15°C throughout the flight. Peak flight occurred the week of July 6. The 22 trap clusters (66 total traps) caught 13,943 spruce beetles and 2,646 clerid beetles (19%). Ninety-one percent of the traps caught more clerid beetles than spruce beetles. Ninety-three percent of the spruce beetles were caught in trap cluster number 27, which was located on the northwestern edge of the study area (Figure 4), in the same general location as the traps which caught the majority of beetles in 1997 (Figure 3).

Comparison Area

Using aerial survey maps, the number of trees infested on the Ogden Ranger District in 1995, 1996, and 1997 was aerially estimated. Approximately 287 infested trees were estimated to be infested in 1995, and the number increased to 1187 infested trees in 1996 (61% increase). The population trend on the Ogden Ranger District continued to increase to 1,635 infested trees in 1997 (16% increase). During the same time period, the number of trees infested in the study area declined dramatically (Figure 2). Our comparison is of the relative trend in number of trees infested rather than absolute numbers. Acreages of spruce-fir type on the Ogden and Logan Ranger Districts are similar (16,000 and 17,000 ac respectively), and all mortality on the Logan Ranger District, except for two groups of trees in 1996, were confined to the study area. However, treatments only occurred within the 1000 ac study area on the Logan Ranger District. Average daily air temperatures recorded in spruce stands in the two areas during June, July, and August were, on average, different by only 0.19°C. This suggests that rates of beetle development and emergence were most likely coincident between the study and comparison areas. Logging of infested trees began on the Ogden Ranger District after beetle flight in 1997. The effects of this logging are not reflected in our data due to the year time lag involved in detecting infested trees aerially.

Discussion

A combination of sanitation-salvage, trap trees, and pheromone-baited traps was used in an attempt to minimize impact by the spruce beetle in an area of isolated Engelmann spruce in northern Utah. Infested trees were removed in 1996 and 1997, and pheromone-baited traps were deployed in a portion of the area in 1997 and 1998. The number of trees fully attacked by the spruce beetle declined from 234 trees in 1995–1996 to 11 trees in 1998. The number of strip-attacked trees also declined, although there was an increase in windthrow in 1998 that may have reduced the number of standing attacked trees that year. Spruce beetle attacks on windthrow trees in 1998 were very light, however, compared

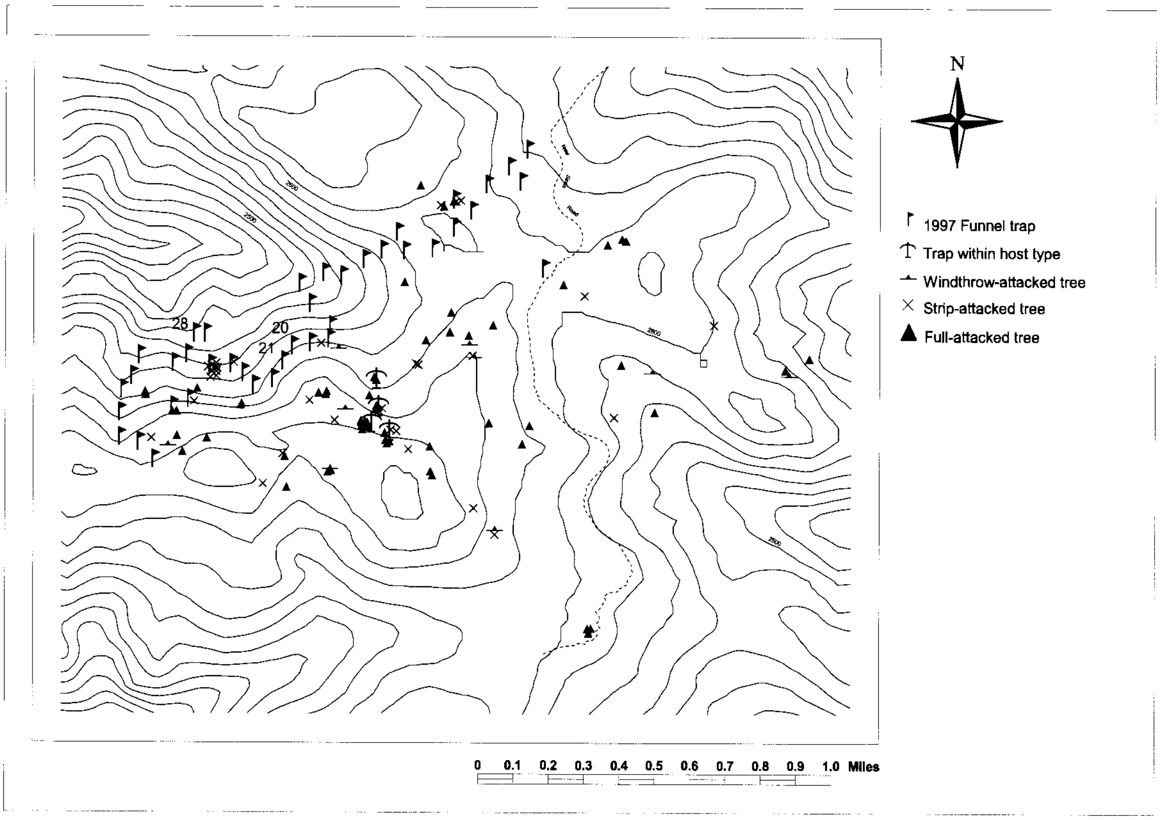

Figure 3. Spatial location of 1997 spruce beetle-infested trees, by attack type, and pheromone-baited funnel traps displayed on a topographic map. Elevation contours are displayed every 20 m. Of beetles caught in 1997, 72% were caught in trap numbers 20, 21, and 28 (see text).

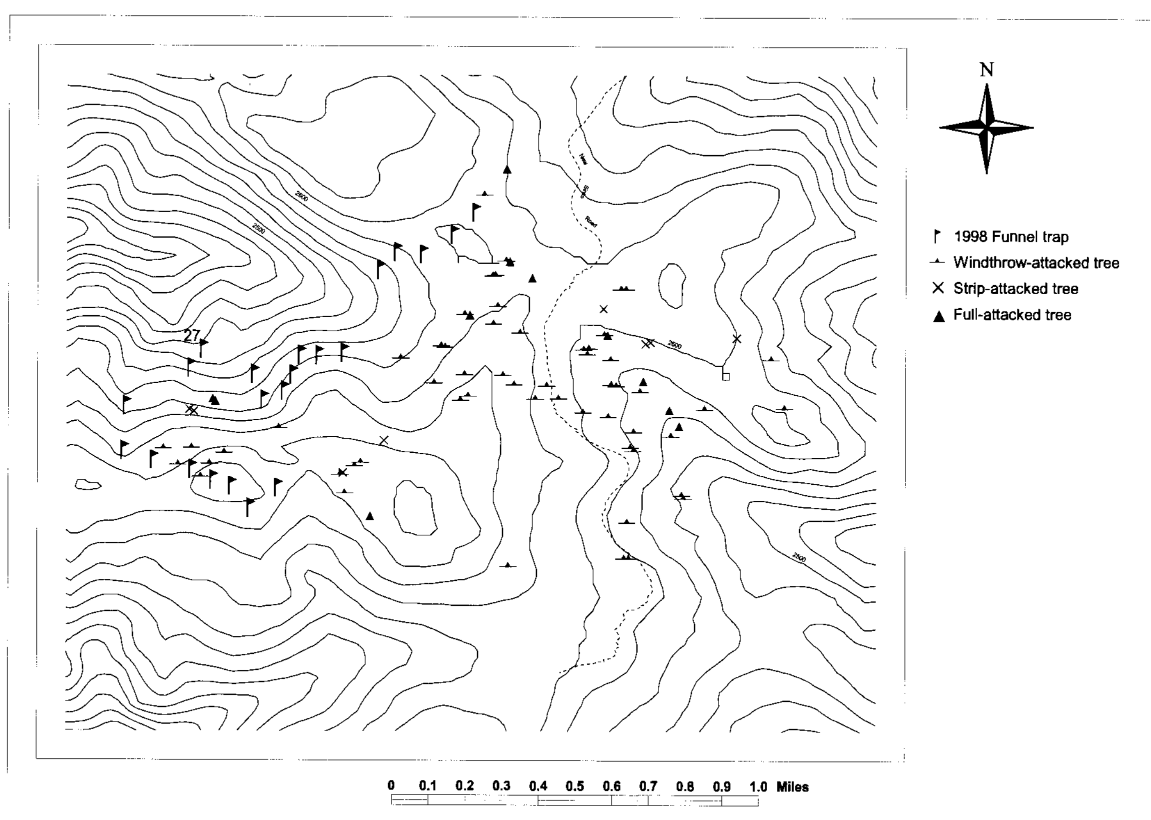

Figure 4. Spatial location of 1998 spruce beetle-infested trees, by attack type, and pheromone-baited funnel traps displayed on a topographic map. Elevation contours are displayed every 20 m. Of beetles caught in 1998, 93% were in trap number 27 (see text).

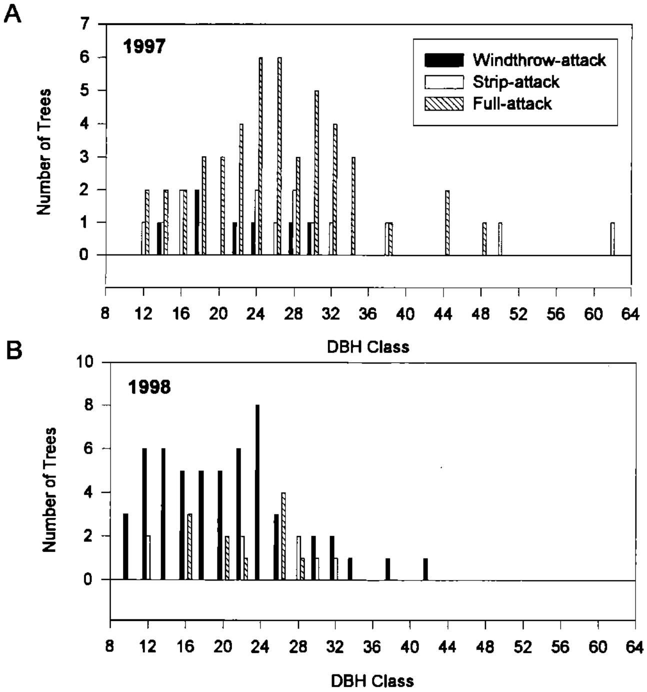

Figure 5. Diameter distribution of spruce beetle-infested trees in the study area (T.W. Daniel Experimental Forest), by attack type, in (a) 1997 and (b) 1998.

to previous years, which also indicates a decline in the population trend. Sections of downed trees that were exposed to the sunlight were colonized by *Ips pilifrons*, while spruce beetles were generally found on the underside of downed boles.

Several biotic and abiotic factors could be responsible for a decline in spruce beetle populations including: (1) lack of adequate food source, (2) unfavorable environmental factors such as temperature, and (3) excessive beetle mortality due to predators such as woodpeckers. Our surveys indicated an abundant source of susceptible host trees remaining in the area which could support a beetle population, and therefore this is not the reason the population has declined. Air temperatures during the spring

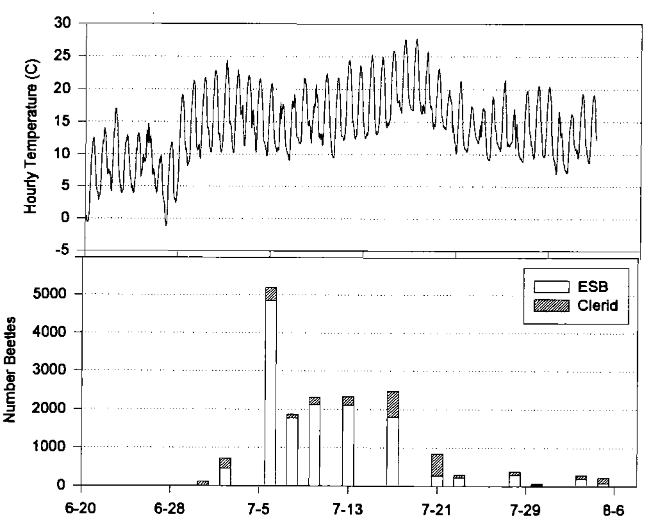

Figure 7. Hourly air temperatures (˚C) at the study site and pheromone-baited funnel trap catches of spruce beetles (ESB) and clerid beetles in 1998.

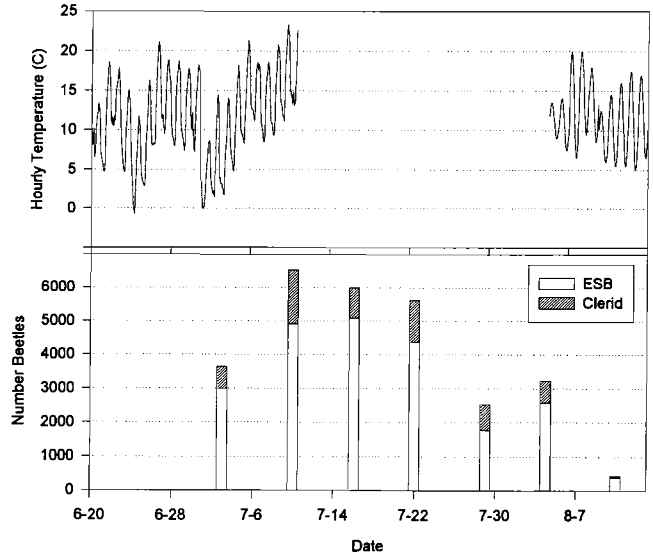

Figure 6. Hourly air temperatures (˚C) at the study site and pheromone-baited funnel trap catches of spruce beetles (ESB) and clerid beetles in 1997. Datalogger problems precluded an entire temperature record.

and summer of 1998 in the study area and the area used for comparison, where the beetle population trend had increased in the previous 3 yr, reveal similar temperature patterns. This suggests that environmental effects on beetle population rate of development and survival were similar between the two areas. Although we did not conduct a formal woodpecker study, there were no signs to indicate that woodpecker populations, the most important predator of the spruce beetle, were overly abundant in the area. Most infested trees exhibited little evidence (bark flaking) attributed to woodpecker feeding. Field surveys and data trends indicate that the sanitation-salvage treatment, in conjunction with pheromone-baited traps and trap trees, played a major role in the decreasing trend of spruce beetle-infested trees on the T.W. Daniel Experimental Forest from 1995 to 1998. This combination of techniques was successful in part due to the isolated nature of the study area, the early detection of the beetle population, and road access to the study area. The ability of federal and state agencies to act in a rapid and coordinated manner was also instrumental in the success of the project.

Placing pheromone-baited traps within the host type, even though they were within clusters of dead trees, resulted in focusing beetles into surrounding green trees. This practice should not be conducted in future suppression efforts of this type, unless the dead-tree groups are much larger than 10 to 15 dead trees. Traps should only be placed in nonhost type. Wind direction may have had an effect on beetle dispersal and subsequent trap catches. The majority of beetles for both years were caught in traps situated in the same relative location on the northwestern edge of the study area at the top of a drainage. Although we did not have wind measurements, personal observations indicated an easterly wind pattern in that area. Since our results indicate that wind direction may significantly affect spruce beetle-trap catches, a trapping array should be based on prevailing wind patterns to maximize spruce beetle catch and reduce clerid beetle catch.

Because the spruce beetle has a 2 yr life cycle in this area, beetles that initially infested trees in 1996 dispersed to attack new host trees in 1998. Assuming all infested trees were identified in our surveys, the 5 full-attacked trees and 13 strip-attacked trees remaining from 1996, in addition to the residual spruce beetle populations in the 199 stumps of trees removed, were responsible for production of beetles that attacked trees and were caught in traps in 1998. Because infested trees in 1996 were harvested in late October and November, which is after hibernation emergence, a large proportion of the adults could have moved to the lower bole of the tree. Thus, the stumps of the harvested trees may have contained a large number of adult beetles. If possible, selective harvest of infested trees should be conducted in early August following beetle flight, yet before hibernation emergence from trees infested the previous year.

Use of the techniques described here does not dramatically alter conditions of the treated stands, leaving the residual spruce component susceptible to further spruce beetle infestation. Although sanitation-salvage efforts in an isolated stand may help to reduce the beetle population to endemic levels, an increase in windthrow and/or favorable climatic conditions could result in another population expansion. Other silvicultural strategies, such as thinning, to reduce stand susceptibility to the spruce beetle have not yet been tested. To maintain minimal beetle-related impacts in susceptible, isolated spruce stands, population levels should be monitored and the direct suppression efforts identified previously employed if the population surpasses endemic levels of beetle activity.

Literature Cited

ALEXANDER, R.R. 1986. Silvicultural systems and cutting methods for old-growth spruce-fir forests in the central and southern Rocky Mountains. USDA For. Serv. GTR RM-126.

DYER, E.D.A. 1973. Spruce beetle aggregated by the synthetic pheromone frontalin. Can. J. For. Res. 3:486–494.

GARA, R.I., R.A. WERNER, M.C. WHITMORE, AND E.H. HOLSTEN. 1995. Arthropod associates of the spruce beetle *Dendroctonus rufipennis* (Kirby) (Col., Scolytidae) in spruce stands of south-central and interior Alaska. J. Appl. Ent. 119:585–590.

GRAY, D.R., E. HOLSTEN, AND M. PASCUZZO. 1990. Effects of semiochemical baiting on the attractiveness of felled and unfelled lethal trap trees for spruce beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera: Scolytidae), management in areas of high and low beetle populations. Can. Ent. 122:373–379.

HODGKINSON, R.S. 1985. Use of trap trees for spruce beetle management in British Columbia, 1979–1984. B.C. Min. of For., Pest Manage. Rep. No. 5.

KNAPP, A.J., ET AL. 1989. Forest insect and disease conditions in the Intermountain Region 1989, FPM Report. USDA For. Serv., Intermountain Region, Ogden, UT. 38 p.

KNAPP, A.J., ET AL. 1991. Forest insect and disease conditions in the Intermountain Region 1991, FPM Report. USDA For. Serv., Intermountain Region, Ogden, UT. 39 p.

LINDGREN, B.S. 1983. A multiple funnel trap for Scolytid beetles (Coleoptera). Can. Ent. 115:299–302.

LISTER, C.K., J.M. SCHMID, C.D. MINNEMEYER, AND R.H. FRYE. 1976. Refinement of the lethal trap tree method for spruce beetle control. J. Econ. Ent. 69(3):415–418.

NAGEL, R.H., D. MCCOMB, AND F.B. KNIGHT. 1957. Trap tree method for controlling the Engelmann spruce beetle in Colorado. J. For. 55:894–898.

SAFRANYIK, L., AND D.A. LINTON. 1999. Spruce beetle (Coleoptera: Scolytidae) survival in stumps and windfall. Can. Ent. 131:107–113.

SCHMID, J.M., AND R.H. FRYE. 1976. Stand ratings for spruce beetles. USDA For. Serv., Res. Note RM-309. 4 p.

SCHMID, J.M., AND R.H. FRYE. 1977. Spruce beetle in the Rockies. USDA For. Serv. GTR RM-49. 38 p.

WERNER, R.A., AND E.H. HOLSTEN. 1985. Factors influencing generation times of spruce beetles in Alaska. Can. J. For. Res. 15:438–443.

WERNER, R.A., AND E.H. HOLSTEN. 1995. Current status of research with the spruce beetle, *Dendroctonus rufipennis*. P. 23–29 *in* Application of semiochemicals for management of bark beetle infesteations: Proceedings of an informal conference, Salom S.M., and K.R. Hobson (eds.). USDA For. Serv. GTR INT-318.

WOOD, S.L. 1982. The bark and ambrosia beetles of North America and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Nat. Memoirs 6:1–1,359.