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Southern Pine Beetle

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The southern pine beetle, *Dendroctonus frontalis* Zimmermann, is one of the most destructive insect pests of pines. Its range covers the southeastern United States from Pennsylvania and New Jersey to Texas, and from Arizona and New Mexico through Mexico to Nicaragua (Fig. 1). Loblolly, shortleaf, pitch, pond, and Virginia pines are the favored hosts in the southeast U.S., while *Pinus oocarpa* and *P. caribaea* are preferred hosts in Mexico and Central America. During outbreaks, the southern pine beetle may infest all pine species, and even marginal hosts such as spruce and hemlock may be killed.

Populations often are concentrated in infestations or "spots." Periodically beetle numbers may rapidly increase to outbreak levels, and healthy, vigorous pines may be attacked and killed as infestations expand. The southern pine beetle generally is in outbreak status every year somewhere within its range. Average annual tree mortality in the U.S. often exceeds 100 million board feet of sawtimber and 30 million cubic feet of pulpwood. From 1999-2002, an outbreak in the eastern U.S. caused in excess of one billion dollars in timber losses. Over 225,000 acres of pine forests in Central America were killed over that same period.

Figure 1. Range map for southern pine beetle; Mexico distribution adapted from Salinas-Moreno et al. 2004.

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Life Stages and Attack Sequence

The southern pine beetle has four life stages: egg, larva, pupa, and adult. The adult is dark red brown to black in color and 2-4 mm in length (Fig. 2). The rear end is rounded and the head is visible from above. The egg is pearly white (Fig. 3). The crescent-shaped larva is white with a reddish brown head (Fig. 3). There are four larval stages, with the fourth stage averaging 3 mm in length. The pupa is white (Fig. 3) and develops into a callow adult, which is soft and amber-colored prior to darkening and hardening.

Figure 2. Adult southern pine beetle.

The female initiates the attack. Once a suitable host is located, the female releases aggregation pheromones, primarily frontalin. Frontalin, in combination with host odors, attracts a male for mating plus additional males and females. Arriving males also release pheromones, including *endo*-brevicomin, which may increase aggregation. If sufficient numbers of beetles are attracted, host resistance is overcome and the tree is successfully colonized. Verbenone is a pheromone produced essentially by males, and at high concentrations it can inhibit landing and cause beetles to switch attacks to adjacent pines.

Attacking females bore through the bark into the cambial layer. These attacks usually occur in the bark crevices. During initial attacks, the tree produces resin and the beetles may be "pitched out." The male and female may work together to clear away the resin and successfully enter the bark. As a result, trees attacked by southern pine beetles are characterized by pitch tubes in the bark crevices, which, dependent on tree species, may be white or yellow and resemble popcorn or may be reddish (Figs. 4a, 4b).

Once beneath the bark, females begin constructing S-shaped egg galleries in the cambium (Fig. 5). Eggs are laid in niches cut in the wall of the gallery. The male follows behind the female, packing the galleries behind them tight-

Figure 3. Left-right: Southern pine beetle egg, early instar larva, late instar larva, pupa, callow adult, mature adult.

Figure 4 A (above) and B (left). Southern pine beetle pitch tubes.

ly with frass. The beetles occasionally bore ventilation or reemergence holes leading straight out from the gallery to the bark surface. Newly-hatched larvae mine away from the gallery in the inner bark. Later-stage larvae move into the outer bark to feed and pupate. New adults chew small, round exit holes, creating a shotgun pattern on the bark surface after mass emergence (Fig. 6). Both brood adults and reemerged parent adults can fly and attack new trees. Beetles also inoculate pines with blue stain fungi which penetrate the sapwood. The girdling of the host tree from gallery construction and the blockage of the water conducting tissue by the blue stain fungi lead to rapid tree death.

Trees attacked by southern pine beetles typically are divided into three categories: fresh attacks, faders, and vacated. Fresh attacks are characterized by the

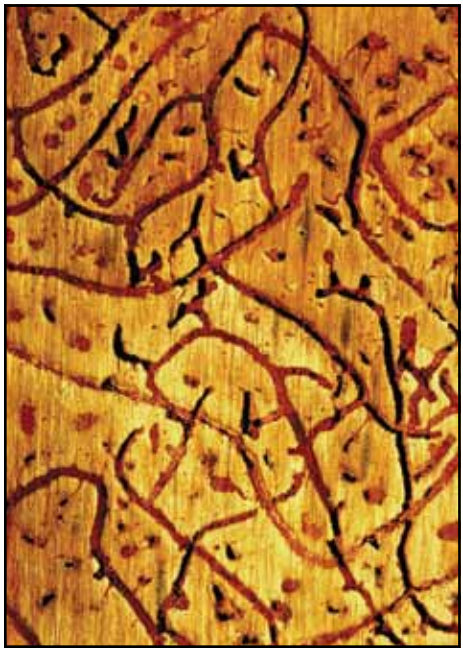

Figure 5. Southern pine beetle egg galleries and larvae.

Figure 6. Southern pine beetle brood adult exit holes.

presence of reddish-white boring dust, tight bark with white phloem, and green crowns. Adult southern pine beetles may be observed working in the pitch tubes, and clerid beetles, *Thanasimus dubius*, often are present (Fig. 7). Once egg gallery construction is complete and the larvae hatch and begin feeding, the foliage begins to fade in color. A fading crown is symptomatic of a successfully colonized pine and usually indicates that southern pine beetle brood is present. When a section of bark is removed from fading trees, the S-shaped egg galleries characteristic of the southern pine beetle are clearly visible and the surface of the sapwood is brown in color. Adult clerid beetles are no longer present on these brood trees. Trees vacated by the brood adults have numerous exit holes in the bark and the needles are either red or have fallen off. The bark is very loose and peels away easily. White sawdust produced by wood-boring ambrosia beetles often is abundant at the base of vacated trees (Fig. 8).

Seasonal Patterns

Most multiple-tree infestations are initiated in the spring. Overwintering beetles emerge and disperse in search of suitable host trees. Lightning-struck or severely-stressed pines with compromised defense systems are often the target for these "pioneer" beetles. Once a susceptible host is located, the attack sequence and pheromone release described above occur. As a tree becomes fully colonized, attacks switch to adjacent pines. When beetle populations within an area are high, an expanding infestation can develop. However, only about ¼ of trees attacked by dispersing beetles in the spring develop into expanding spots of 20 or more trees.

Figure 7. Adult of Thanasimus dubius*, a clerid beetle and predator of the southern pine beetle.*

Generations overlap in the late spring and summer, and eventually an expanding infestation will contain trees with all beetle life stages. Small infestations usually have one area with trees under attack, called the spot head (Fig. 9). As infestations enlarge, additional spot heads may develop. The continual emergence of brood and parent adults, coupled with pheromone production of attacking beetles at the spot head(s), sustains infestation growth. Large infestations may spread at a rate of >120 ft/day, and satellite infestations may develop nearby.

During the warm summer months disper-

Figure 8. Boring dust of ambrosia beetles around the base of a tree vacated by southern pine beetles.

Figure 9. Infestation "spot" head with fading trees.

sal is limited, and most beetles are located within expanding spots. As temperatures cool in the fall, beetles may remain in spots or disperse to individual trees for the winter. Beetles may overwinter in all stages within a tree. Development slows during the winter, but there is no diapause. During warm winter periods, development continues and some emergence may occur. Winter-emerging adults may colonize unoccupied portions of the same trees from which they emerged. A few infestations may remain active throughout the winter when temperatures are favorable.

Natural Control

Natural enemies, including predators, parasitoids, and diseases, can maintain or reduce population levels. *Thanasimus dubius* is a major predator of both adult and larval southern pine beetles. However, there is no evidence that natural enemies can stem the development of outbreaks. *Ips* bark beetles and borers may compete for reproductive space and food resources within the bark. Woodpeckers may feed on beetle larvae, pupae and callow adults, often completely stripping the bark from the main stems of infested trees during the winter. Persistent, freezing temperatures can lead to brood mortality, particularly eggs and early larvae. Continuous high daily temperatures in excess of 95° F also may kill broods.

Population Patterns

Southern pine beetle populations within an area can range from undetectable to outbreak levels. An outbreak is defined as one or more multiple-tree southern pine beetle infestations per 1000 acres of susceptible host type. In the past 50 years in the Gulf Coastal Plain, outbreaks have occurred on a 6-10 year cycle, though recently patterns have varied. The causes for the onset of outbreaks are unknown, though outbreaks have been linked to extremely wet conditions in low-lying loblolly pine stands in the Western Gulf Coastal Plain. Population collapses have been attributed to lack of susceptible hosts, unfavorable environmental conditions, high numbers of natural enemies, and/or competition for habitat beneath the bark.

Southern Pine Beetle Management

An effective southern pine beetle management program consists of the following components:

Monitoring and Prediction. Funnel traps baited with frontalin and host volatiles are set out each spring during the southern pine beetle's primary dispersal phase. The mean daily catch of southern pine beetle and the ratio of southern pine beetle to *T. dubius* are used to predict current year southern pine beetle activity.

Detection. Most southern pine beetle infestations are detected from aerial flights. Active infestations are indicated by groups of 10 or more dying pines, including some with fading crowns. Suspect infestations may be marked manually on maps, or a digital sketch-mapping system can be used. The sketch-mapping system utilizes a computer with a touch-sensitive screen displaying a geo-referenced map selected by the user. The system is tied into the plane's GPS system and displays the current location of the plane. Observers record suspect infestations by touching the screen on the corresponding point on the map display, and the coordinates for the infestation are automatically recorded. Coordinates of the infestations can be downloaded into a handheld GPS unit. The initiation and frequency of detection flights is based on predicted and observed southern pine beetle activity. During outbreaks, flights every two weeks may be needed from May through September.

Evaluation. Detected infestations are ground-checked to determine the bark beetle species responsible, current level of beetle activity, and the need and practicality of suppression. Crews navigate to the spots using maps and/or the coordinates in a GPS unit. Access into the infestation is flagged, as is the current spot boundary. The infestation is classified as active or inactive, and the number of total and currently-infested trees recorded. Other data usually collected include spot head direction, number of spot heads, basal area, host type, mean host diameter, and number of freshly-attacked trees.

Suppression. Based on the data collected during the ground evaluation, a suppression treatment is assigned to all active infestations. Prompt suppression is the key to reducing tree loss. Suppression treatments include cut-and-remove, cut-and-leave, cut-and-hand spray, and pile-and-burn. For cut-and-remove and cut-and-leave treatments, all currently-infested trees are felled toward the center of the infestation. In addition, a buffer of uninfested trees around the expanding spot head also is felled (Fig. 10). The downed trees are salvaged in the cut-and-remove treatment, and left on the ground for cut-and-leave. Cut-and-remove is the most effective treatment, with an efficacy rate of 97% or higher. It also is the most recommended method, as landowners benefit from the sale of harvested trees and developing beetles are removed from the area. When cut-and-remove can't be applied in a timely manner due to lack of access or no market for beetle-killed trees, cut-and-leave is the preferred alternative. Cut-and-leave is most effective when used on smaller infestations (< 100 trees) in smaller diameter trees, and when applied between May and October. Cut-and-hand spray is rarely used, and insecticides labeled for this use may not be currently available. Pile-and-burn may be used on infestations in pine plantations when the infested trees can be pushed into piles with a bulldozer and promptly burned. Suppression tactics using southern pine beetle pheromones have been tested, but none are currently operational. Small, slow-growing spots may be monitored until they go inactive (vacated by beetles) or grow to a size that warrants direct control.

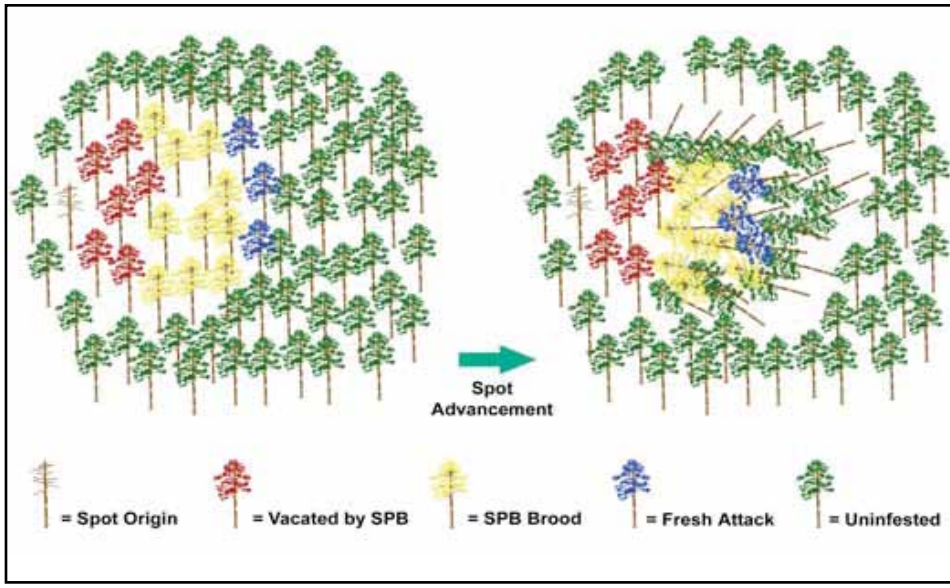

Figure 10. Diagram of cut-and-leave treatment illustrating buffer around currently-infested trees.

Prevention. Direct tactics to suppress southern pine beetle populations have proven successful, as discussed above. However, forest managers and forest health specialists commonly believe that the most effective method of managing southern pine beetle is through preventing outbreak populations and creating forest conditions that lessen impacts once outbreaks occur. Stand density is thought to be one of the most critical factors in determining the chances of spot initiation and the rate of spot expansion within a stand. Thinning is the preferred forest management tool used to attain desired stand densities, and it is widely recommended that stands with a basal area greater than 120 ft^2 per acre should be thinned below 80 ft^2 per acre. Thinning reduces the likelihood that expanding infestations will become established by increasing tree vigor and by changing the stand's microenvironment. Increased tree vigor increases the likelihood that beetles will be "pitched-out" due to higher resin flows. The changes in the stand's microenvironment include increased wind flow beneath the tree canopy and the greater potential for disrupting the pheromone communication system of the southern pine beetle. In urban settings, it is recommended that the spacing between pines should be >20 feet.

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