United States
Department of
Agriculture

Forest Service

**Southern
Research Station**

General Technical
Report SRS–153

Guidelines for Regenerating Southern Pine Beetle Spots

J.C.G. Goelz, B.L. Strom, J.P. Barnett, and M.A. Sword Sayer

Authors:

Jeffery C.G. Goelz, Research Forester (retired); **Brian L. Strom**, Research Entomologist; **James P. Barnett**, Emeritus Scientist; and **M.A. Sword Sayer**, Plant Physiologist, U.S. Department of Agriculture, Forest Service, Southern Research Station, Pineville, LA 71360.

Cover: Longleaf pine regeneration. (Photo courtesy of Erich Vallery, USDA Forest Service, Southern Research Station, Pineville, LA)

April 2012

Southern Research Station
200 W.T. Weaver Blvd.
Asheville, NC 28804

www.srs.fs.usda.gov

Guidelines for Regenerating Southern Pine Beetle Spots

J.C.G. Goelz, B.L. Strom, J.P. Barnett, and M.A. Sword Sayer

Abstract

Southern pine forests are of exceptional commercial and ecological importance to the United States, and the southern pine beetle is their most serious insect pest. The southern pine beetle generally kills overstory pines, causing spots of tree mortality that are unpredictable in time and space and frequently disruptive to management activities and goals. The canopy gaps created may be large enough for regeneration activities to be considered, but the nature of southern pine beetle spots, and the residual stands of which they are a part, can make regeneration decisions complex. Spot size and shape, stand age, structure, silvicultural system, product markets, and management goals all are important determinants for obtaining successful regeneration of southern pine beetle spots. This paper provides a key to assist managers faced with the complexities of regenerating southern pine beetle spots in the context of the larger stand. Guidance is provided for the application of regeneration methods that are appropriate for particular management objectives, spot sizes, stands, and environmental conditions.

Keywords: Forest management, overstory pines, regeneration, residual stands, southern pine beetle spots.

INTRODUCTION

Southern pine forests are of exceptional commercial and ecological importance to the United States. Principal commercial species are loblolly pine (*Pinus taeda*), slash pine (*Pinus elliottii*), longleaf pine (*Pinus palustris*), and shortleaf pine (*Pinus echinata*). Loblolly pine, by far the most widely distributed and commercially important forest tree species in the South (Baker and Langdon 1990), is frequently affected by southern pine beetle (*Dendroctonus frontalis)* (SPB) infestations. All four species are susceptible to SPB, but slash and longleaf pines are considered more resistant, presumably due to greater quantities of oleoresin exudation that can "pitch-out" and kill attacking beetles (fig. 1).

The SPB is the most serious insect pest of nonjuvenile pine forests in the Southeastern United States. Successful reproduction requires host death, so impacts of this pest on forest health are primarily a result of overstory pine mortality. Unlike most native insects, SPB kills its hosts in clumps, called spots, which are mostly continuous areas of complete pine tree mortality (fig. 2). SPB spots may require intervention from managers, both to stop their progression and to regenerate stands following their occurrence.

Populations of SPB vary dramatically in time and space. In most years, there are outbreak populations somewhere in the Southern United States, but populations in a particular location come and go. Population fluctuations are dramatic and unpredictable, causing extreme variability in pine mortality (fig. 3).

In addition to SPB population density, the risk of spot formation is significantly affected by site, stand, and environmental factors. Forest health determinants such as tree vigor, stand density, and age are important for determining risk of infestation. When tree mortality occurs, it is rapid, causing overstory gaps to form quickly. Depending on stand structure and beetle populations, gaps may be large or small, diffuse or discrete. Large gaps—and potentially small gaps that can be coalesced—may be regenerated with the usual techniques (Barnett and Baker

Figure 1—The volume of oleoresin exuded from beetle attack sites is thought to be the most important resistance factor that a tree can employ against bark beetle attack. A copious flow of resin may kill attacking beetles and prevent tree mortality. (Photo courtesy of Erich Vallery, USDA Forest Service, Southern Research Station)

Figure 2—Southern pine beetle infestations, called spots, are usually relatively small with mostly continuous pine mortality within their boundaries. Thus, they are similar to group selection cuts for reforesting options. (Photo courtesy of Frank M. Riley, Jr., Georgia Forestry Commission, Bugwood.org [UGA1348016])

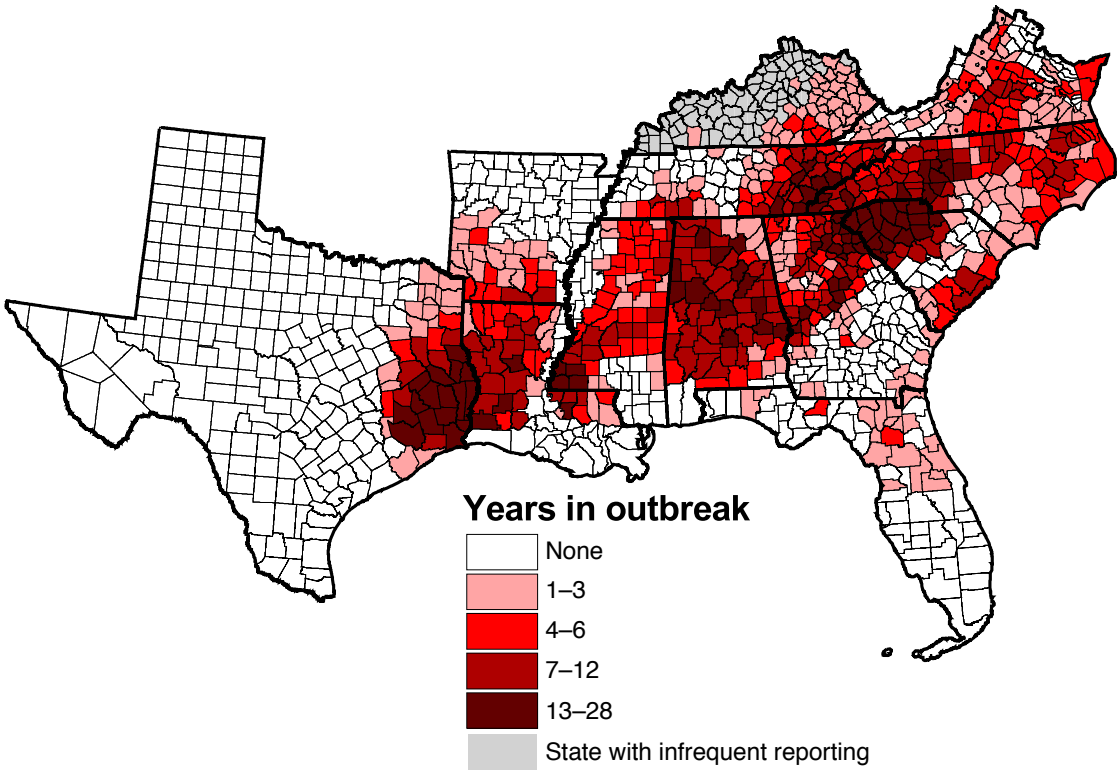

Figure 3—Populations of southern pine beetle are unpredictable and vary dramatically across time and space causing extreme variability in pine mortality. Outbreaks are defined as the presence of at least 3 spots per 1,000 acres of susceptible host type. (Image from Pye and others 2005)

1991), and future stands may be made less susceptible to SPB through lower planting densities, planting resistant species or perhaps more resistant families, and maintaining the vigor of individual trees by intermediate stand management activities. Small gaps are common following SPB infestation and offer particular challenges to forest managers (see Special Considerations in Regenerating SPB Spots in this report).

In summary, SPB-caused mortality of overstory pines can be severe, but is unpredictable in time and space. Resulting canopy gaps may impact management of a stand, in particular the decision to replant. This paper provides guidance for the application of regeneration methods appropriate for particular management objectives, spot sizes, stands, and environmental conditions.

REGENERATION METHODS OF SOUTHERN PINES

Southern pines can be regenerated naturally—by seeds from trees growing on or adjacent to the site—or artificially—by direct seeding or planting seedlings. Techniques for applying these methods are described by Barnett and Baker (1991).

Most landowners have several options for regenerating their forest lands, the best choice being largely influenced by their objectives. The southern pines can be regenerated naturally with clearcutting, seedtree, shelterwood, or selection reproduction cutting methods (fig. 4). Good natural regeneration requires an adequate, high-quality seed source. Seeding characteristics of the southern pines vary with species, physiographic region, climatic factors, and

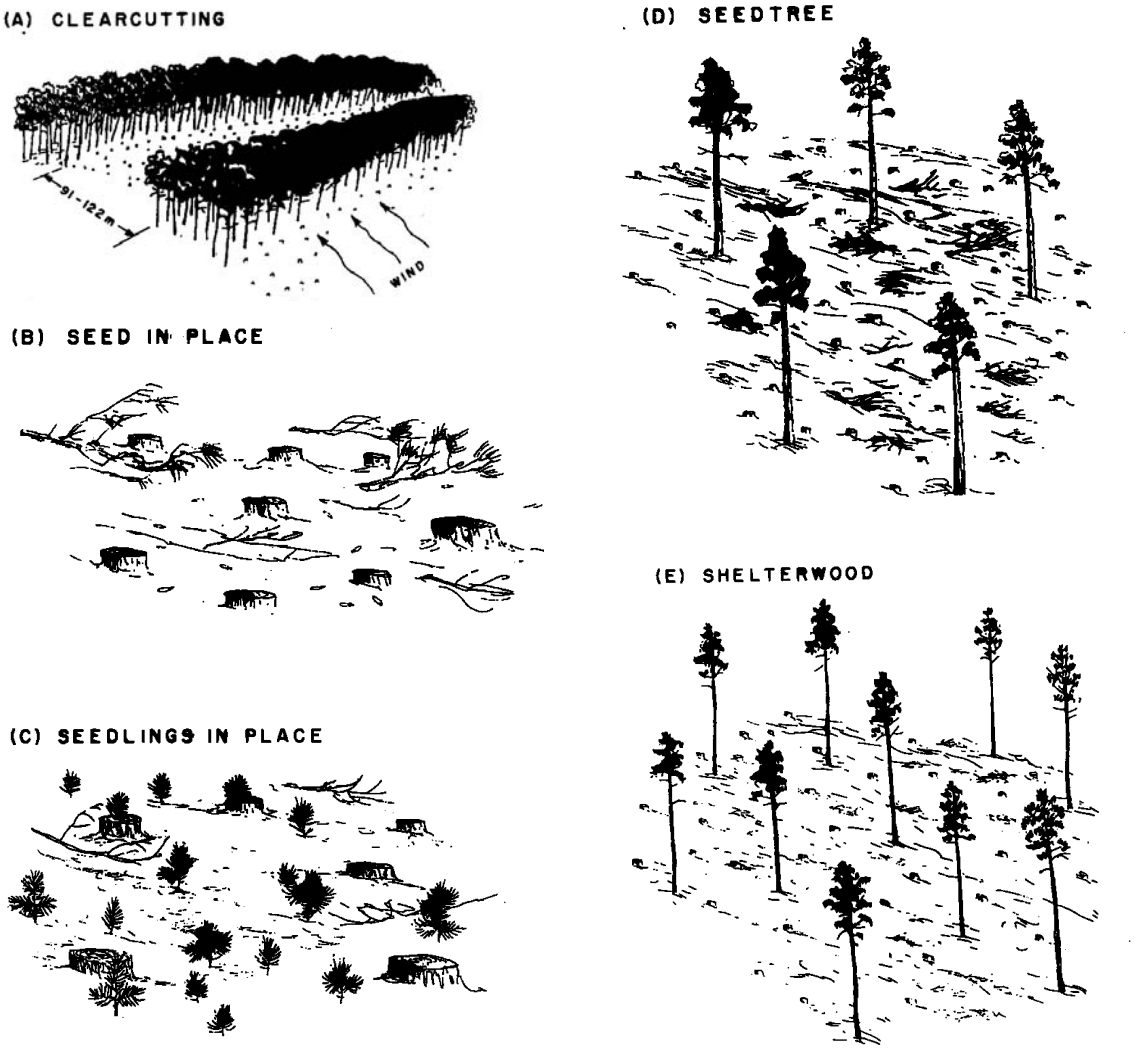

Figure 4—Natural regeneration by several methods: (A) Clearcutting in strips: Seeds are provided by adjacent stands. (B) Seed in place: Stand is clearcut after cone maturity and peak seedfall but before germination. (C) Seedlings in place: Stand is clearcut in late summer following a good seed year. (D) Seedtree: All but 4 to 20 trees per acre, depending on species and size, are cut. (E) Shelterwood: All but 30 to 50 trees per acre, comprising a basal area of 20 to 30 square feet per acre, are cut. (Adapted from Williston and others 1982)

tree and stand conditions. Some of these characteristics are summarized in table 1. Alternatively, regeneration can be done artificially, by direct seeding or planting container or bare-root nursery seedlings (fig. 5). However, when regenerating SPB spots, the scope of these options is reduced. Once the decision has been made to regenerate a spot, the unusual and heterogeneous seedling environments created by the SPB infestation require consideration before successful regeneration can be assured.

Figure 5—Planting of longleaf pine seedling by hand using a dibble bar. Such planting would be appropriate in small gaps where machine planting is not feasible.

SPECIAL CONSIDERATIONS IN REGENERATING SPB SPOTS

The geometry of small spots creates special circumstances for regenerating pine seedlings. Trees remaining from the original stand compete with seedlings for sunlight, water, and nutrients, making spot edges inhospitable for pine regeneration (fig. 6). Hardwood competition will be prevalent in gaps and typically must be controlled for successful regeneration of pines.

Typical regeneration practices are designed for implementation at the stand level, while SPB spots usually represent only a small portion of a stand. Most SPB spots are < 1 acre and extinguish themselves (Porterfield and Rowell 1981) (fig. 7); however, spots can be significantly larger and require management interventions for their control. While no estimates are available for the average size of SPB spots that were controlled with tree cutting, the Forest Service, U.S. Department of Agriculture defines a gap of 5 acres as the minimum necessary for mandatory replanting. However, as economic conditions change, the minimum size of gaps requiring mandatory planting may also change. Currently, many managers use 10 acres as the minimum size required for triggering regeneration practices.

Success in regenerating smaller spots is adversely affected by resource competition from the larger remaining trees at the gap edge (McGuire and others 2001); seedlings closer to the edge are more affected (fig. 8). Growth of established seedlings increases linearly from the gap edge to the interior portion of the gap (McGuire and others 2001). Differences in seedling establishment and growth in the gap occur at roughly 30-foot increments (fig. 8, generated from Brockway and Outcalt 1998, Gagnon and others 2003). Moving from the gap edge, the outer 30 feet (C, fig. 8) comprise a seedling exclusion zone where establishment is

Table 1—Seeding characteristics of southern pines for average sites

Species	Frequency of seed crops [a]	Period of peak seedfall	Effective distance of dispersal	Largest square spot that may be regenerated in acres [b]	Citation
	years		*feet*		
Loblolly	2-4	Late October-November	200-300	8.3	Baker and Balmer 1983
Shortleaf	3-6	November	200-300	8.3	Lawson and Kitchens 1983
Longleaf	3-5	Late October-November	60-70	0.45	Boyer and Peterson 1983
Slash	3	October	150-250	5.7	Shoulders and Parham 1983
Sand	4-6	October	200-250	5.7	Outcalt and Balmer 1983
Table Mountain	2-4	Late October-November	200-250	5.7	Della-Bianca 1990

[a] A seed crop is considered good when an adequate number of seeds are distributed to regenerate an area under average conditions. For loblolly and shortleaf pines, 80,000 seeds per acre is considered a good seed crop. About 50,000 seeds per acre is the minimum needed to adequately restock a prepared seedbed.

[b] Calculated as the square of twice the effective dispersal distance. This assumes that dispersal is multidirectional. If dispersal is unidirectional with the prevailing winds, the size should be one-fourth the number provided.

Figure 6—A small southern pine beetle spot where killed pine trees were felled to control beetle activity. The small size, edge effects, and competition make this spot difficult to regenerate. (Photo courtesy of Ronald F. Billings, Texas Forest Service, Bugwood.org [UGA0284008a])

Figure 7—A small southern pine beetle spot typical of many that extinguish themselves naturally. (Photo courtesy of Erich Vallery, USDA Forest Service, Southern Research Station, Bugwood.org [UGA0745093])

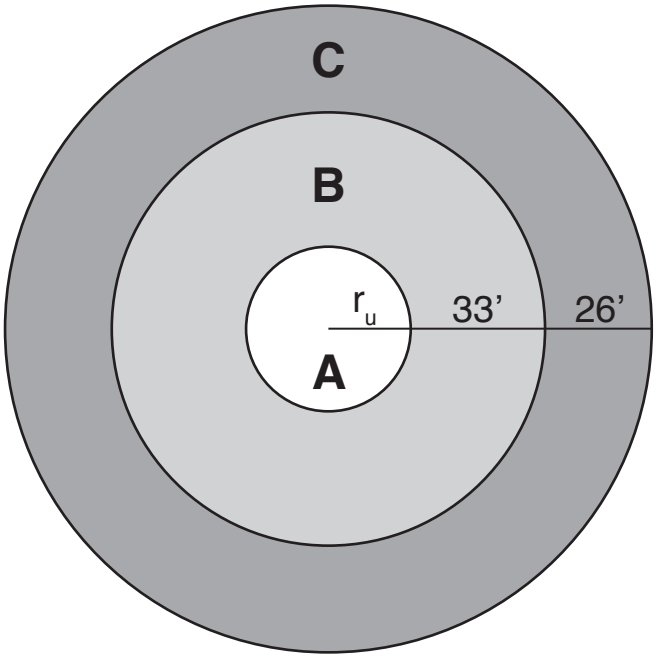

Figure 8—Regeneration zones in a gap in a pine forest. Extending 26 feet from the forest edge is the “regeneration exclusion zone,” C, dark grey. The light grey zone, B, is the “area of diminished growth,” which extends 59 feet from the forest edge. The white area, A, is the “area of undiminished growth.” The radius, r_u represents the radius of the opening minus 59 feet. The area of undiminished growth refers to growth of seedlings and small saplings; for larger trees, growth may be reduced relative to similar trees growing in even-aged stands. The white and light grey areas, together, comprise the “regenerable area” of the gap.

unacceptable; the next 30 feet (B, fig. 8) comprise a zone of diminished seedling growth; while the center of the gap (A, fig. 8) allows undiminished growth. We consider the regenerable area[1] of a circular gap to consist of zones A and B in figure 8. The size and shape of the spot, and the characteristics of the surrounding stand, determine the resources available to seedlings within the newly created gap. These characteristics affect seedling survival, growth, and establishment, and must be considered for regeneration to be successful.

GUIDELINES FOR MANAGERS

The objectives of the land manager and his or her available resources help guide the response following SPB infestations. Appropriate decisions regarding reforestation of gaps should be determined from these objectives, as well as the type of stand affected and characteristics of the infestation. Goals such as timber production, management of game and nongame species, preservation of water resources, and sustained recreational use may impact regeneration opportunities and will be prioritized differently depending on landowner objectives.

[1] We define the regenerable area as the area of a gap in which growth and survival of tree seedlings is not severely reduced by competition from the neighboring intact forest.

Stand Conditions

Principle stand characteristics that affect management responses to SPB mortality are: silvicultural system being used; stand age, size, and origin; and spatial characteristics that may facilitate or hinder operations.

Uneven-aged stands regularly have regeneration cuts that remove a portion of the stand as groups, individual trees, or both. Generally, smaller SPB spots will not compromise uneven-aged management unless there are many of them in a stand. Though natural regeneration is typically employed in uneven-aged management, artificial regeneration may be required if spots are large and advance regeneration is not present.

In an even-aged stand, regeneration decisions will depend upon the age and size of the stand and intensity with which the landowner chooses to manage. Older stands that are near rotation age generally do not warrant reforestation until final harvest of the surrounding stand. If the forest is managed on a long rotation, and beetles infest a relatively young stand, the regenerated spot may achieve sawtimber size before the final harvest. If the surrounding stand is large, the landowner may decide that regeneration of a limited number of spots is not economically warranted.

Economic Considerations

Although regeneration of small spots can be biologically feasible, carrying out such regeneration practices may not be economically justifiable. For example, it may not be possible to contract salvage harvesting of relatively small spots. Also, spots of 10 to 15 acres (or more depending on spot configuration) may be naturally regenerated by seed from surrounding stands. Landowner management objectives will affect the nature of regeneration options applied and may modify their application.

Characteristics of the Infestation

Characteristics of the SPB spots within a stand, and potentially in nearby stands, may influence the manager’s reforestation decisions. Pertinent characteristics are spot size, number of spots, cumulative area of the spots, and distribution of spots within the stand (i.e., diffuse, clumped, or discrete). For regeneration considerations, spot size should include any buffer area that would be harvested to limit spread of the infestation.

Generally, reforestation is more practical when spots are large or a number of spots can be combined to create economies of scale. While alternatives to normal sanitation practices may be used, regeneration practices will be hindered unless dead, dying, and buffer trees are felled and either removed or burned. Thus, all management

recommendations will be made for stands in which one or more spots are salvaged. There are no practical regeneration opportunities for small SPB spots that have not been salvaged (fig. 9). The retention of some dead trees may be acceptable to promote populations of natural predators of SPB or wildlife habitat. However, all trees currently infested with SPB and buffer trees should be felled and removed prior to the onset of regeneration activities.

KEY FOR MANAGEMENT DECISIONS

The following key is meant to provide a suggested course of action to regenerate SPB spots. It is meant as a guide for managers; reality is more complex than can be contained in any such key. The major value of the key is to help managers organize useful information so that the best course of action can be determined. The main underpinnings of the key are: (1) without a gap in the forest canopy, there is no point in viewing SPB spots as a regeneration opportunity; (2) if the stand is uneven-aged, or destined to be uneven-aged, any salvage should be considered a regeneration opportunity; (3) if the stand is even-aged, destined to be naturally regenerated, and close to final rotation, salvage of the spots should be integrated into a preparatory or final regeneration harvest; (4) southern pines are shade-intolerant making even-aged management the path of least resistance; (5) spot size must be large enough to provide an environment conducive to even-aged regeneration; (6) if wildlife habitat is a primary goal, it is not critical that all acres produce timber; (7) some managers may want to change stand composition; (8) regeneration practices should be integrated with treatment of the parent or adjacent stands; (9) unless stand age is very far from rotation age, the regenerated spots will never "catch up" to the surrounding stand; and (10) vegetation will always develop in the spot. In the absence of management, this will frequently be a mixture of loblolly pine and associated hardwood species.

Prescriptions

These prescriptions assume that the land manager has a suite of silvicultural options available. Thus, details about silvicultural practices are only provided when they differ from standard practices. For example, the manager probably has particular site preparation and vegetation management practices that they use for conventional regeneration, and we do not advocate changes to these protocols.

Prescription A—In an uneven-aged stand, SPB spots may be considered opportunities to integrate sanitation cuts into regeneration harvests. Removal of groups of trees and individual trees in dense portions of the stand can lessen the risk of future infestations in the stand. However, any harvest should be timed to minimize risk of site disturbance causing additional beetle problems.

Prescription B—Management will rely on natural regeneration because the spots are sufficiently small that supplemental planting will not be needed. However, natural regeneration success is subject to seedbed characteristics. The seedbed may be prepared by prescribed fire, mechanical

Figure 9—Southern pine beetle spot with overstory mortality and lack of pine salvage or felling. Without use of prescribed fire to reduce vegetative development, there is no opportunity for regeneration under these conditions of understory development. (Photo courtesy of David J. Moorhead, University of Georgia, Bugwood.org [UGA0010165])

A key to assist forest managers with regeneration decisions following stand disruption by southern pine beetle

This key consists of a series of two-part dichotomous statements (bulleted) that describe characteristics of southern pine beetle spots, the stands in which the spots occur, or possible management objectives. Each number in the key provides the manager with a choice between two options, each of which leads to an additional choice (one of the next consecutively numbered steps) or to a prescription that we estimate will best meet the manager's needs.

Step	Characteristics	Prescription or next step
1	• Stand currently uneven-aged or to be converted to uneven-aged	2
	• Stand under even-aged management	4
2	• Sufficient natural regeneration in spot	**Prescription A**
	• Natural regeneration in spot is insufficient or absent	3
3	• Individual spots narrower than dispersal distance for dominant pines (table 1), at least 20 living dominant or codominant seed-bearing pines per acre are present in surrounding stand	**Prescription B**
	• Individual spots wider than dispersal distance for dominant pines, or fewer than 20 living dominant or codominant seed-bearing pines per acre are present in surrounding stand	**Prescription C**
4	• Spot is larger than manager's criterion for minimum stand size	5
	• Spots are smaller than manager's criterion for minimum stand size	8
5	• Stand is within 2 years of being regenerated	**Prescription D**
	• Stand will not be regenerated soon	6
6	• Future plan for stand is artificial regeneration	**Prescription E**
	• Future plan for stand is natural regeneration	7
7	• Individual spots narrower than dispersal distance for dominant pines, and 20 or more dominant or codominant seed-bearing pines per acre are present surrounding the spot	**Prescription B**
	• Individual spots wider than dispersal distance for dominant pines, or neighboring seed-bearing trees are insufficient	**Prescription C**
8	• Multiple spots are sufficiently clustered that a reasonable increase in buffer width will coalesce spots into areas greater than manager's criterion for minimum stand size	**Prescription F**
	• Spots are solitary or scattered	9
9	• Spots are all undersize for salvage, and final harvest is scheduled within 25 years	**Prescription G**
	• Spots are large enough for salvage treatments and are not scheduled for harvest within 25 years	10
10	• Stand is mixed-species, but most of the pine species composition has been lost	11
	• Species composition of the stand as a whole has been little affected	13
11	• Stand is of low value for management objectives and value is not likely to improve	**Prescription H**
	• Stand currently achieves, or has the potential to achieve, most of the important management objectives	12
12	• Manager desires to increase the component of a pine species	**Prescription I**
	• Manager does not desire to change species composition	**Prescription J**
13	• Manager desires to change species composition[1]	**Prescription K**
	• Manager has no preconceived desire to change species composition	14
14	• Timber production is secondary to other forest uses	**Prescription L**
	• Timber production is the primary objective for the forest	**Prescription M**

[1] A manager may desire to change species composition to more fully achieve management objectives, to restore under-represented habitat (e.g., longleaf pine), or to reduce future risk of southern pine beetle infestation (by planting less susceptible species).

site preparation, or both. Often, logging operations can prepare the seedbed. Because seedfall declines with distance from a forest edge, attempt to improve the uniformity of regeneration by intensifying site preparation as distance from the forest edge increases. If the desired species is lacking along part of the spot margin, consider supplemental planting or seeding. This will provide an opportunity to introduce one or more species that are absent from the surrounding stand. Depending on the likelihood of desirable natural regeneration, supplemental planting density will be location-specific but less than that typically used in plantations.

Prescription C—Although natural regeneration is desired by the manager, the spot is too large to rely on natural regeneration unless it is already in place. Supplemental seed or seedlings are needed to attain adequate regeneration. If the surrounding stand has an insufficient number of seed bearing trees of the desired species, supplemental planting over the entire spot is indicated. If the spot is simply too large for adequate seedfall across the entire area, supplemental seeding or planting is suggested in part of the spot while the center of the spot may require planting at conventional rates for plantations. Beyond these considerations, the spot is large enough to allow standard practices for regeneration. If the manager prefers natural regeneration, broadcast direct seeding may produce stands more similar to naturally regenerated stands. Closer to the edge, the manager may rely on natural regeneration or may broadcast seeds at a lower rate. The site must be adequately prepared prior to seeding. Logging operations or burning may provide a suitable seedbed. Seeding is not appropriate where soils are likely to be flooded, very dry, grazed, or eroded following seeding.

Prescription D—Delay regenerating spots until the surrounding stand is harvested and use the practices planned for that stand. When even-aged management is preferred, it makes little sense to complicate management by regenerating spots when the surrounding stand is scheduled for regeneration in the near future. The definition of "near future" depends somewhat on management intensity. Where economic goals suggest that the entire forest must be productive, near future represents 1 to 2 years. When management is mainly concerned with providing nontimber forest products, a delay of 10 to 20 percent of the final rotation age may be tolerable.

Prescription E—Regenerate spots by conventional practices used by the manager. Trees need not be planted closer than 30 feet to surviving trees at the surrounding forest edge. If practical, identify spots as new stands to facilitate subsequent management. Protect regeneration from damage related to silvicultural practices conducted in surrounding stand.

Prescription F—Small spots are difficult to regenerate, or, if regenerated, do not produce usable timber products by the time the surrounding stand is harvested. Also, regenerating small spots is expensive. Thus, it may be prudent to increase the buffer area around the spot so that nearby spots are combined into one, more manageable area. Guidelines on combining versus not combining spots are difficult to provide because local conditions and management objectives often prevail. However, a manager should consider combining spots into a single management unit when: (1) spots would coalesce if buffer areas are expanded < 60 feet, (2) spots represent > 10 to 25 percent of the stand, or, (3) the manager is seeking opportunities to change species or genetic composition. If managers choose to not combine spots, they should reenter the key at the second "8" alternative and proceed to select a new prescription. If managers choose to combine spots, they should reenter the key at the first "4" alternative and proceed to select a new prescription.

Prescription G—When all spots are too small to be salvaged or the stand is scheduled for a regeneration harvest in 1 to 2 years, opportunities to regenerate the spot are absent. The manager should proceed with planned management of the surrounding stand. The manager may consider using nonregenerated spots as opportunities to provide wildlife habitat or food plots.

Prescription H—The manager should plan a regeneration cut for this stand. In this case, much of the pine component has been lost and the remaining stand is of low value. A regeneration harvest should be delayed if the stand is soon likely to pass from one product class to another (e.g., pulpwood to sawtimber) or otherwise increase in value or merchantability. As the desirable species is lacking, artificial regeneration is indicated. The manager should plan for control of undesirable species at the time of harvest or as part of the site preparation or vegetation management practices.

Prescription I—In this case, spots should be regenerated. The stand is young enough that pine regrowth in spots can provide timber products by the time the surrounding stand is harvested. This is relevant to managers who want ultimately to regenerate the stand by natural regeneration. Although trees in spots will probably be too young to be abundant seed producers when the stand is harvested, and this should be taken into account, they will likely provide some seed to assist with regeneration. This option is also valuable to managers that want to increase the component of an under-represented species in the stand. Spots may be regenerated by planting or seeding, either of which should commence no nearer than 30 feet from the gap edge. If seedlings are planted, planting density should be on the order of one-half the typical planting density (trees per acre) for the species

and landowner. Regardless of whether spots are seeded or planted, care must be taken to protect regeneration when silvicultural practices are carried out in the surrounding stand. If possible, regenerated spots should be thinned early, frequently, and heavily to allow the trees to catch up in diameter to the surrounding stand and to facilitate the development of good crowns for seed-bearing if the stand will be naturally regenerated. If neither species conversion nor natural regeneration is planned, the manager may consider doing nothing in these spots.

Prescription J—In this situation, the manager has basically chosen to manage a hardwood-dominated stand. No regeneration of pine is desired. Spots will naturally regenerate to some mixture of hardwood and pine.

Prescription K—This situation represents an opportunity for conversion to uneven-aged management. If the manager makes this choice, the key should be reentered with that objective in mind, and then the manager should choose the first "1" choice and proceed to a new prescription. If 25 percent or more of the stand is in spots, the manager should reconsider his or her criterion for minimum stand size. If practical, treat the spots (or coalesced groups of spots) as a new stand, reenter the key selecting the first "4" choice, and proceed to a new prescription.

The spots should be site-prepared, and the manager should protect the spots from damage by silvicultural activities in the surrounding stand. Pre-commercial and commercial thinning of the spots will likely be necessary. As the stand will be harvested as a whole at final rotation, thinning within the spots should be heavier than in comparable even-aged stands to allow the younger trees to catch up to the older trees in the surrounding stand. Even if nothing is done, the spots will likely seed-in naturally with loblolly or shortleaf pines if these species are common in the surrounding stands. In the absence of a seed source, seedlings may be planted in the spots. Planting seedlings may also be indicated when the manager desires to alter species or genetic composition. Be aware that considerable natural regeneration will occur within 60 feet of the gap edge. Protection of the seedlings and subsequent thinnings should be planned. It may be necessary to control competing vegetation in the spots.

Prescription L—If spots represent a significant portion of the stand but are relatively small, they do not represent a good opportunity for regeneration. On all but the harshest sites, some tree species will become established even if the manager does nothing. The stand will still provide most forest values at a satisfactory level. An exception to this is when habitat is desired for species that require old, open, and even-aged stands. In this case, action should be taken to discourage regeneration of the spots or the regeneration should be thinned by fire or felling. By doing this, the risk of future SPB infestation is reduced. If a manager arrives at this prescription, but seems troubled by the choice, a smaller threshold should be selected for minimum stand size.

Prescription M—If managers aim to maximize timber production of all acreage, they may choose to plant seedlings to regenerate spots. This might be practical if the following situation holds: (1) spots approach minimum stand size, (2) spots are accessible to existing roads, and (3) it is economically reasonable to regenerate the spots. Regarding the economy of scale issue, the manager must judge the minimum area that is reasonable to be contracted for planting, weed control, pre-commercial thinning, etc. To regenerate the spots, large seedlings should be planted 30 feet or more from the gap edge at approximately half the density that is typically used in plantations. Care must be taken to protect regeneration when silvicultural practices are carried out in the surrounding stand. If possible, the regenerated spots should be thinned early, frequently, and heavily to allow the trees to catch up in diameter to the surrounding stand. Thinnings may be integrated with thinnings in the surrounding stand or with nearby similarly aged spots or stands.

SUMMARY

This paper provides a key to assist forest managers with regeneration decisions in overstory gaps (spots) created by the southern pine beetle. Spots are typically small relative to the overall stand, so a number of unusual economic, ecological, and silvicultural considerations arise for decisionmakers. The key's major value is in helping to organize pertinent information so that an optimal course of action can be prescribed. In each case the key leads to a prescription—based on spot and stand characteristics, economic considerations, silvicultural principles, and land manager objectives—that helps determine the best course of action for meeting management objectives with both the present and future stands.

ACKNOWLEDGMENTS

The authors thank Donald Baker (Baker Land & Timber Management, Inc.), Dr. Mason Carter (Retired, LSU School of Renewable Natural Resources), Donald Feduccia (Retired, Louisiana Department of Agriculture and Forestry), and Dr. James Meeker (USDA Forest Service, R8-Forest Health Protection) for their time and efforts toward improving this report.

LITERATURE CITED

Baker, J.B.; Balmer, W.E. 1983. Loblolly pine. In: Burns, R.M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture Forest Service: 148-152.

Baker, J.B.; Langdon, O.G. 1990. *Pinus taeda* L. Loblolly pine. In: Burns, R.M.; Honkala, B.H., tech. coord. Silvics of North America. Volume 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture Forest Service: 497-512.

Barnett, J.P.; Baker, J.B. 1991. Regeneration methods. In: Duryea, M.L.; Dougherty, P.M., eds. Forest Regeneration Manual. London: Kluwer Academic Publishers: 35-50.

Boyer, W.D.; Peterson, D.W. 1983. Longleaf pine. In: Burns, R.M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture Forest Service: 153-156.

Brockway, D.G.; Outcalt, K.W. 1998. Gap-phase regeneration in longleaf pine wiregrass ecosystems. Forest Ecology and Management. 106: 125-139.

Della-Bianca, L. 1990. *Pinus pungens* Lamb. Table Mountain pine. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America. Volume 1. Conifers. Agric. Handb. No. 654. Washington, DC: U.S. Department of Agriculture Forest Service: 425-432.

Gagnon, J.L.; Jokela, E.J.; Moser, W.K.; Huber, D.A. 2003. Dynamics of artificial regeneration in gaps within a longleaf pine flatwoods ecosystem. Forest Ecology and Management. 172: 133-144.

Lawson, E.R.; Kitchens, R.N. 1983. Shortleaf pine. In: Burns, R.M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture Forest Service: 157-161.

McGuire, J.P.; Mitchell, R.J.; Moser, E.B. [and others]. 2001. Gaps in a gappy forest: plant resources, longleaf pine regeneration, and understory response to tree removal in longleaf pine savannas. Canadian Journal of Forest Research. 31: 765-778.

Outcalt, K.W.; Balmer, W.E. 1983. Sand pine. In: Burns, R.M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture Forest Service: 169-174.

Porterfield, R.L.; Rowell, C.E. 1981. Characteristics of southern pine beetle infestations Southwide. In: Coster, J.E.; Searcy, J.L., eds. Site, stand, and host characteristics of southern pine beetle infestations. Tech. Bull. 1612. Washington, DC: U.S. Department of Agriculture Forest Service, Combined Forest Pest Research and Development Program: 87-108.

Pye, J.M.; Price, T.S.; Clarke, S.R.; Huggett, R.J., Jr. 2005. A history of southern pine beetle outbreaks in the Southeastern United States through 2004. U.S. Forest Service, Southern Research Station. http://www.srs.fs.usda.gov/econ/data/spb. [Date accessed: November 2005].

Shoulders, E.; Parham, G. 1983. Slash pine. In: Burns, R.M., comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. No. 445. Washington, DC: U.S. Department of Agriculture Forest Service: 162-166.

Williston, H.L.; Balmer, W.E.; Sims, D.H. 1982. Managing the family forest in the South. Gen. Rep. SA-GR-22. Atlanta: U.S. Department of Agriculture Forest Service, State and Private Forestry. 90 p.

Goelz, J.C.G.; Strom, B.L.; Barnett, J.P.; and Sword Sayer, M.A. 2012. Guidelines for regenerating southern pine beetle spots. Gen. Tech. Rep. SRS-153. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 11 p.

Southern pine forests are of exceptional commercial and ecological importance to the United States, and the southern pine beetle is their most serious insect pest. The southern pine beetle generally kills overstory pines, causing spots of tree mortality that are unpredictable in time and space and frequently disruptive to management activities and goals. The canopy gaps created may be large enough for regeneration activities to be considered, but the nature of southern pine beetle spots, and the residual stands of which they are a part, can make regeneration decisions complex. Spot size and shape, stand age, structure, silvicultural system, product markets, and management goals all are important determinants for obtaining successful regeneration of southern pine beetle spots. This paper provides a key to assist managers faced with the complexities of regenerating southern pine beetle spots in the context of the larger stand. Guidance is provided for the application of regeneration methods that are appropriate for particular management objectives, spot sizes, stands, and environmental conditions.

Keywords: Forest management, overstory pines, regeneration, residual stands, southern pine beetle spots.

Scan this code to submit your feedback, or go to www.srs.fs.usda.gov/pubeval

You may request additional copies of this publication by email at pubrequest@fs.fed.us

The Forest Service, United States Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.