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Forest Restoration following Southern Pine Beetle

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Abstract

Forest restoration is the process of transforming a damaged or unhealthy forest into a healthy one. After the southern pine beetle (SPB) has damaged a forest, it is sometimes, if not most times, necessary to restore that forest. It is important to know the restoration goals, conditions prior to SPB, current conditions, and potential future conditions of the forest before beginning a restoration project. Restoration projects have political and social implications that also cannot be overlooked. The practical methods and concerns in conducting restoration will vary by location. Only within the proper conceptual framework can restoration following southern pine beetle outbreaks be successful.

24.1. WHY RESTORE?

The question regarding "why restore?" is intricately woven and intermingled with (a) how we define forest restoration, (b) where we are restoring forests, (c) how we are restoring forests, and (d) our world view of ecological systems and the concept of nature. If one is willing to accept that a forest has been damaged by human intervention and that the best recourse to fix that damage is through further human intervention, then the question has been answered. However, the answer to the question becomes fuzzier or clearer as more specific questions are asked and answered. Is the forest on public, private, or commercial land? Is the forest actively managed or is it wildlands? How much will it cost to restore the forest; is it worth it? What are the potential negative residuals from the restoration process? These questions and more are essential to ask before engaging in any restoration effort. Thus, a sound understanding of the ecological, political, economic, and social implications of the proposed restoration project is essential. Here, I will present these concepts in the context of restoration following damage by southern pine beetle (*Dendroctonus frontalis* Zimmermann) (SPB).

24.1.1. Ecological Implications

In the wake of growing human populations and subsequent land use changes, forests have become natural remnants in a human-dominated landscape. Because many of our existing forests were once fully or nearly clearcut, it is potentially difficult to maintain that even those are "natural." Aside from the previous assertion, forests are natural systems that provide a variety of ecological services. Forest stands that have been killed or damaged by SPB provide the potential to alter important ecological functions. This fact is particularly true in areas beyond the normal home range or in outbreaks of unprecedented size, where beetles act as invasive agents. One place where this is occurring is in the Southern Appalachian Mountains. In the Southern Appalachians, SPB threatens to eliminate Table Mountain pine (an Appalachian endemic). SPB also endangers habitats for other ecologically important species. Red-cockaded woodpeckers, for example, left the Daniel Boone National Forest because suitable pine habitat was no longer available (USDA 2005). Moreover, SPB outbreaks may increase the risk of severe wildfires. Fuel loading from wood debris has been found up to three times higher in infested stands (110.3 m^3) vs. uninfected stands (30.6 m^3) (Nicholas and White 1984).

However, there can also be negative implications from restoration activities. When damaged areas are replanted with dense monoculture pine stands, previous habitat could be altered and the potential for more future SPB outbreaks could even increase. Forest managers, therefore, should aim to conduct restoration activities in a sustainable context. The best way to mitigate potential negative residuals from restoration is to involve extensive preplanning research. Having positive/successful restoration outcomes is essential as the outcomes will have implications on policy regarding future restoration activities.

24.1.2. Policy Implications

The Healthy Forest Restoration Act of 2003 is the broadest piece of legislation governing forest restoration. Title IV of this act refers specifically to Insect Infestations and Related Diseases. More specifically Section 403(a)(1) states: "…the Forest Service and United States Geological Survey, as appropriate, shall establish an accelerated program to plan, conduct, and promote comprehensive and systematic information gathering on forest-damaging insects and associated diseases, including an evaluation of -

1. infestation prevention and suppression methods;
2. effects of infestations and associated disease interactions on forest ecosystems;
3. restoration of forest ecosystem efforts;
4. utilization options regarding infested trees; and
5. models to predict the occurrence, distribution, and impact of outbreaks of forest-damaging insects and associated diseases."

While this act does not provide support for restoration of SPB-damaged areas per se, it does highlight the need for gathering information regarding the extent of damage and an assessment of restoration efforts.

Below the Executive level, the Forest Service, particularly Forest Health Protection (FHP) and the Southern Research Station (SRS), provides funding through SPB initiative funds to focus resources on SPB restoration efforts. SRS-4552: Insects, Diseases, and Invasive Plants unit of the SRS funds millions of dollars in cooperative research to aid in SPB research. In 2003, the USDA Forest Service supported a meeting that identified SPB research, development, and applications, and has provided a framework for action (Coulson and others 2003). Also in 2003, the SPB Prevention and Restoration Program (SPBPRP) was established. The goal of SPBPRP is to encourage eligible nonindustrial forest landowners to improve forest health and reduce SPB damage through technical assistance and cost-sharing of recommended prevention practices. Approximately $60 million have been allocated to State and national forestry agencies since 2003, making it one of the larger Federal bark beetle prevention programs in the U.S. history of forest health management.

In addition, the National Association of State Foresters issued the statement "Southern Pine Beetle: A Time for Action to Protect the South's Forests." The statement emphasizes actions to reduce immediate and long-term threats to forest resources and associated impacts to forests that include:

1. Continued suppression of pine beetle epidemics using time-tested and effective control strategies
2. Reduction of future epidemics by making existing forests more beetle resistant
3. Prevention of loss of the southern yellow pine ecosystem through restoration of forests destroyed by the beetle, but in a form less susceptible to future beetle attack, including removal of beetle-killed trees that pose imminent hazards to people in high public use areas
4. Assistance to communities affected by beetle epidemics to protect jobs and to develop the infrastructure necessary to employ effective beetle control and prevention techniques
5. Funds necessary for full compliance with all laws, planning, implementation, monitoring, accountability, and coordination among Federal and State agencies
6. Funds for educating the public and landowners about the SPB and the need for suppression and prevention activities
7. Research to support suppression, prevention, and restoration activities

The relationship between SPB outbreaks, restoration activities, and policy is one of ongoing feedback. There are, of course, ecological consequences to this relationship in terms of forest management activities. In addition, there are also many potential economic and social implications as a result.

24.1.3. Economic and Social Implications

SPB is the most destructive forest insect pest in the Southeastern United States. The USDA Forest Service SRS-4802: Forest Economics and Policy working unit reports that the total value of damage caused by SPB from 1973 through 2004 was $3.57 billion. From 1991 through 2004 alone SPB has been responsible for over $1 billion in damage (Pye and others 2004).

While regional estimates vary, significant outbreaks can severely impact local economies. During the 1999-2001 outbreak, SPB affected more than 1.5 million acres of pine in North Carolina and destroyed timber valued at more than $12.4 million in 1 year. During the same outbreak period, Tennessee experienced the destruction of approximately 390,000 acres of pine timber valued at $358 million. The Bankhead National Forest in Alabama alone experienced more than $20 million in damage between 1986 and 2001 (Tchakerian and others unpublished data).

Restoration is a costly business whether conducted on public or private land. Many private landowners cannot restore their forests without financial assistance. The SPB cost-share program is one approach to restoring forests after SPB. In this program, eligible landowners receive funds at the cost-share rate of 70 percent. Landowners who accept funding are required to maintain those acres in forest land for a period of 10 years and to comply with provisions set forth in the approved forest management plan. Several States have issued policies and detailed guides on this program. Cost-share assistance is limited to $8,000/ownership/State/fiscal year. However, funding may be limited to costs associated with approved precommercial thinning practices. Many landowners are unaware that SPB is a source of timber loss or have little interest in limiting SPB impact. This lack of awareness creates an opportunity to educate landowners about the benefits of healthy management and ways to restore forests so that they are no longer conducive to massive beetle outbreaks.

24.2. BACKGROUND

24.2.1. Defining Forest Restoration

Forest restoration involves some transition from a damaged state, where damage can come in the form of an unnatural or unwanted change in forest pattern, process, and/or composition, to some desired condition. From an ecological perspective, forest restoration involves the reestablishment of natural ecological processes that produce dynamic ecosystem structure, function, and processes (Stanturf and others 1998). Stanturf and Madsen (2002) identify three restoration descriptors: afforestation, reclamation, and rehabilitation. Afforestation and reclamation involve some sort of change in landcover. Generally, afforestation refers to the reforesting of agricultural land, and reclamation is more extensive and can involve reforestation of urban areas or other areas where soil productivity has been altered (e.g., strip mines).

However, what makes restoration following SPB damage different from restoration following other forest disturbances? SPB-damaged forests fall under the rubric of forest rehabilitation. Rehabilitation does not involve a change in landcover. Rehabilitation is an action to correct instances where structure or species composition has been altered (Stanturf and Madsen 2002). In the case of SPB, specific restoration questions must be answered. Most important, forests should be restored in a way that will prevent or reduce damage from future outbreaks while maintaining the forest purpose (e.g., timber stock, biodiversity enhancement, game habitat, ecosystem preservation). Other questions regarding forest restoration can be further subdivided according to the specific restoration goals, namely the restoration of species, the restoration of ecosystem/landscape function, and the restoration of ecosystem service.

24.2.2. Restoration Goals

Before beginning to even plan forest restoration following SPB, it is first necessary to answer the question: What is the goal of restoration? There is no simple answer to this question, and not necessarily one answer to the question. The answer may depend on forest ownership (private, public, commercial) as well as the site location and forest use, among other issues. The goals of restoration, while varied, can fit under two general categories: restoring forest processes and restoring forest services. This section addresses each of these in detail.

Restoring Forest Processes

Forest processes refer to the workings of the natural forest system as unaffected by human intervention. Largely, in this context, the process that is most important for forest restoration is the reintroduction of fire. Fires play a key role in pine systems by providing the dual role of thinning forests, which helps prevent SPB outbreaks, and by promoting regeneration of serotinous pine species. Because allowing wildfires to burn unmanaged is impractical due to the potential threats to human habitations, prescribed burning is a reasonable alternative.

Prescribed burning (Figure 24.1) has been shown to be an effective tool at restoring pine and pine-hardwood mix stands in the Southeast (Vose and others 1999, Waldrop and Brose 1999, Stanturf and others 2002). Restoring fire into forest ecosystems requires knowledge of both how often to burn a site (fire rotation interval) and what severity of fire to burn (fire intensity). Depending on the ecosystem type, rotation intervals can vary from a few years to hundreds of years, and intensities can range from low-intensity surface fires to stand-replacing crown fires.

Recent modeling research (Waldron and others 2007, Lafon and others 2007) has verified the existing hypothesis (Williams 1998) that in natural systems, SPB and fire work in combination to maintain yellow pine woodlands on xeric slopes, ridges, and peaks in the Southern Appalachian Mountains (Figure 24.2). This same research also demonstrated that different ecological regions, defined by moisture and elevation gradients, require differences in both species and fire regimes to maintain ecological integrity. Further research by Cairns and others (2008b) demonstrates that as pine aggregation increases, so does the probability of SPB outbreaks. Because fire reduces pine aggregation, it is an ideal tool for structuring naturally fire-prone areas to be more SPB-resistant while promoting the growth of yellow pine species.

Restoring Ecosystem Services

Ecosystems provide valuable recreational, economic, and ecological services. Services can include providing scenery and habitat for passive recreation activities such as hiking, camping, and bird/wildlife watching; providing habitat for game species; increasing biodiversity; and acting as carbon sinks. Although these services can be very different from one another, they all involve the restoration of certain species at set densities.

Figure 24.1—Prescribed burning for restoration: (A) prescribed crown fire, (B) one day after burn, (C) six months after burn, and (D) six years after burn. (photographs provided courtesy of USDA Forest Service, Southern Research Station)

Ecologically, species restoration is important to consider when dealing with endemic and/or endangered tree species. It can also be important to restore species to repair biodiversity. Economically, species restoration is important to those people engaged in the timber industry. Commercial forests are of particular concern for restoration. While many factors such as global warming (Ungerer and others 1999, Tran and others 2007) and drought have been suggested as triggers for recent SPB outbreaks, silvicultural practices (particularly by industry) have by far held the most blame (Perkins and Matlack 2002). The goal of commercial forestry, as any industry, is the maximization of profit. Historically, this

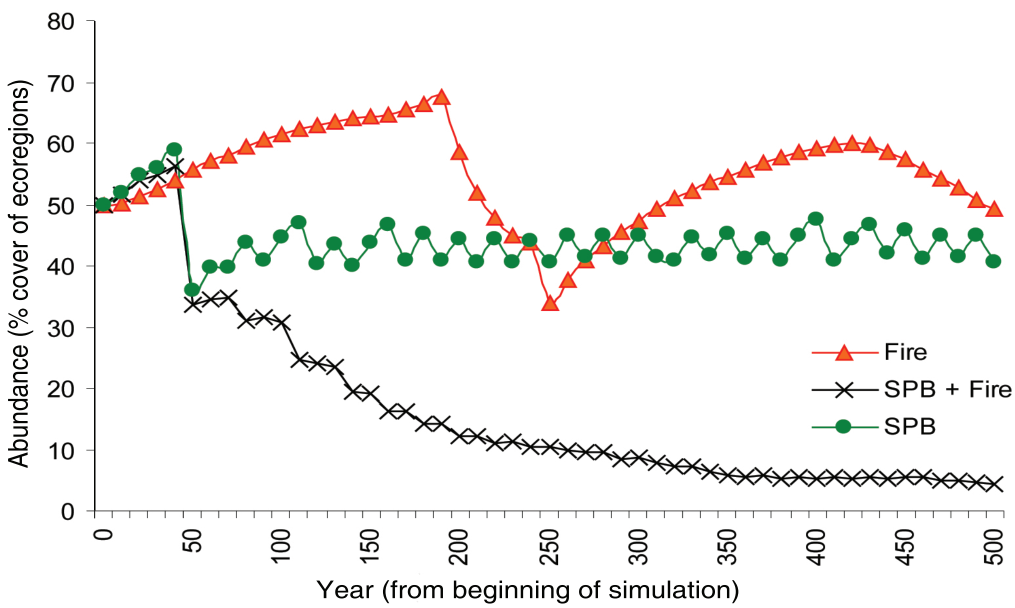

Figure 24.2—Table Mountain pine persistence on mid-elevation (~3,000-4,500 feet) ridges and peaks in the Southern Appalachian Mountains. Simulated using LANDIS 4.0.

has meant planting large, even-age, densely spaced, monoculture plantations of high-yield pines (usually loblolly). Of course, this creates prime SPB habitat, and hence, high outbreak potential. Finding a restoration scenario that will allow companies to maintain profit while reducing SPB hazard is not an easy task.

In general, industry should guide replant activities with SPB outbreak potential in mind. This means experimenting with alterative planting strategies such as spacing trees at greater than 20 feet apart, planting less-susceptible pines (e.g., longleaf pine), planting uneven-age stands, and intermingling non-hosts (hardwoods) with pine species. While there has been some research that suggests lesser density stands will result in higher biomass and yield (Baldwin and others 2000), the feasibility of convincing industry to follow one or a combination of these scenarios will require more research to find the scenario that can best balance SPB prevention and profit maximization.

24.3. PRERESTORATION PLANNING

Restoration, as with any activity, must begin with proper planning to ensure a successful outcome. Planning for restoration is usually a longer and more complex activity than the actual act of restoration. Prerestoration planning involves an understanding of pre-outbreak conditions, an assessment of current conditions, and predictions of post-restoration conditions to adequately understand how to direct restoration activities. In this section, these components are discussed in detail.

24.3.1. Understanding Preoutbreak Conditions

Before beginning any restoration effort, it is first necessary to have an understanding of the composition, structure, and dynamics of natural forests (Landres and others 1999, Bergeron and others 2002, Kuuluvainen 2002). The pre-outbreak conditions should guide restoration. That is not to say that forests should be restored to how they were immediately preceding an infestation. It is important to understand the forest conditions prior to outbreak so that we can be better prepared to not recreate a forest that will be susceptible to SPB outbreaks.

It is equally important to understand the ecological setting of the forest to be restored. Factors such as slope, aspect, soils, climate, surficial geology, precipitation, and proximity to different ecological zones/developed areas are all important in determining how to restore a particular piece of land. These factors will not only affect the establishment and growth of certain plant species, they will also have an impact on the probability of future SPB outbreaks.

In addition, it is important to have clear understanding of the ecological history of that forest, or at least have an ecological analog using a site in similar condition. In recent years, dendroecologists have made significant steps in reconstructing forest disturbance histories in terms of fire and beetle outbreaks (Lafon and Kutac 2003). As more of this data is collected and disseminated, a more accurate understanding of preoutbreak conditions can be gleaned. Also it is important to note the SPB outbreak history of a particular site. If a site has been the subject of multiple past outbreaks, a structural reconfiguration such as thinning may be required for areas adjacent to the restoration area in addition to the actual restoration activity.

24.3.2. Assessing Current Conditions

For a restoration project, a considerable amount of reconnaissance and assessment is needed to set goals for restoration and to evaluate the success of particular restoration actions (Lake 2001). In restoration plans, working towards desired future conditions (natural appearing forests and natural processes, species diversity, eliminating exotics, recreating native understory vegetation, structural components based on the restoration costs and benefits analysis) helps to prioritize activities (Holmes 2004).

Current forest conditions can be assessed through some combination of field visits and remotely sensed imagery. Important factors to assess include species of dead and damaged trees, composition and structure of undamaged areas nearby, spatial extent of the damage, condition and composition of the understory, and presence of invasive exotics. Without a complete and comprehensive understanding of both the conditions on the site to be restored and the conditions in the surrounding landscape, it would be nearly impossible to develop a successful restoration outcome.

24.3.3. Predicting Future Conditions

Restoration, while well intended, is still another form of human alteration of the natural processes. The only means available to determine if restoration efforts are going to achieve desired consequences is through computer modeling. When restoration goals are known and defined *a priori*, models can help determine management strategies to fit those goals. When restoration goals are not defined *a priori*, iterative modeling can be employed to investigate the potential consequences of a variety of single and multiple management strategies. Through this process, more defined restoration goals can be developed.

Models can be used at different spatial and temporal scales of inquiry, as well as to answer different sorts of questions. Four basic model types of interest to forest practitioners are: Forestry Growth and Yield, Stand Regeneration, Gap, and Landscape Models. A description of the first two of these types can be found at http://www.forestencyclopedia.net/p/p1609. The latter two are described below.

Gap models simulate changes in forest gaps or stands that are less than 1 ha in size. These models project the establishment, annual growth, death, and regeneration of individual trees within a defined area. Gap models continue to be important in developing and testing theories about the overall functioning of forests, and are also used in reconstructing past and future forest composition (Shugart 2002). These models are appropriate when restoration is limited to a small area, such as a confined SPB outbreak spot. One limitation of these models is that they preclude study over an extensive geographic range. However, the output from gap models can be, and has been, used to inform landscape models (He and others 1999).

In the wake of large beetle outbreaks that have damaged forest systems, a landscape modeling approach is recommended. Landscape models simulate temporal change using spatially referenced data across a course spatial scale (ca. 1~1,000s km^2). These models are used to investigate the reciprocal interactions between landscape composition and structure and a host of natural (e.g., insect outbreaks, fires, wind storms) and anthropogenic disturbances (e.g., land use change, harvesting) across and between multiple ecosystems. The limitation to these models is that they do not include the physiological detail of gap models. This approach has been tested successfully on SPB in the southern Appalachians using the LANDIS model (Waldron and others 2007, Xi and others 2007, Cairns and others 2008b).

24.4. CONDUCTING RESTORATION

When restoring SPB-damaged forests, one of the main objectives of the restoration initiative should be to create healthy forests by developing stands that are less susceptible to future SPB outbreaks. While there are several practical concerns (e.g., site access, organization of labor, cost) that must be addressed before any restoration effort, these concerns are so variable with time and location. Generally speaking, it costs landowners about \$200-\$250 per acre to restore an area damaged by SPB, including the costs of removing dead timber, site prep, and replanting (Nowak Personal Communication).

There are two distinct phases to the restoration process: site preparation and site restoration. Each of these phases involves its own set of activities and outcomes and will be described in detail in the following sections.

24.4.1. Site Preparation

After SPB outbreaks it is necessary to prepare the site for restoration. The goal of site preparation is to provide conditions that will enhance the growth and survivability of desired plant species. The removal of offsite and invasive species and dead or severely damaged trees is of paramount importance. Invasive exotic plant species have become an extremely detrimental problem in American forests. Because these species tend to thrive in disturbed areas, it is necessary to remove them immediately from the site of disturbance as well as from the immediate area due to the potential to seed-in during restoration. Dead and damaged trees also must be removed from the site. Leaving large amounts of dead or damaged trees on or near the restoration site will leave the stands vulnerable to future insect outbreaks and wildfires.

In addition to removal of damaged and/or undesirable species, there are a variety of soil preparation techniques that can be employed to improve tree vigor and productivity. Subsoiling (also known as ripping or deep-tilling) is one technique that has shown to be beneficial in promoting root growth (Gwaze and others 2007). However, many sites, particularly in mountainous areas, might not be easily accessible to tilling equipment. Other techniques can involve bedding (McKee and Wilhite 1986) or mounding (Knapp and others 2006). Bedding forms a linear mound of soil with a narrow two-axled disk or bedding plow (University of Florida 2006). Bedding is usually done on sites with poor drainage. On upland sites, bedding perpendicular to slopes can minimize soil erosion. Again, because bedding involves the use of heavy machinery, some sites may be inaccessible. Mounding has been used more commonly in Scandinavian and Canadian uplands as well as in the Great Lakes States (Sutton 1993, Londo 2001, Cohen and Walker 2006). Mounding also involves heavy machinery, but rather than using the plowing technique of bedding, it involves scooping soil into buckets and depositing it bottom-side up (Londo 2001).

One of the most economical site preparation techniques is prescribed burning (McKee 1982, Abercrombie and Sims 1986). Whether restoring process through continued burning or using it as a site preparation technique for planting, fire is a useful tool in restoring pine ecosystems (Knoepp and Swank 1993, Swift and others 1993, Waldrop 1997). Because fire is easily transportable compared to heavy machinery, it is an ideal choice for forest preparation in deep forest interiors and mountainous areas. More information on prescribed burning as a management tool can be found at http://www.forestencyclopedia.net/p/p139.

24.4.2. Site Restoration

Site restoration can occur through the restoration of some combination of species replant and/or prescribed burning as dictated by the environment at hand. For true ecological restoration, replanting efforts on SPB-damaged areas should concentrate on restoring those species that make ecological sense on the area undergoing restoration.

In some cases, restoration will entail restoring the species that existed during the outbreak; in other cases this could involve planting other species. Selection of species for planting should be dictated by determining which species should exist in the restoration area based on site factors. In addition to proper species, proper density must also be considered. In particular, when replanting monospecific pine stands, care must be taken to plant in low densities to impede future outbreaks (Figure 24.3). SPB spots are unlikely to appear in stands that have an inter-tree distance greater than 20 feet (Gara and Coster 1968).

Prescribed burning is currently used in southern pine forests to reduce understory competition and to establish and propagate fire-dependent species (Nowak and others 2008). Recent modeling efforts (Lafon and others 2007,

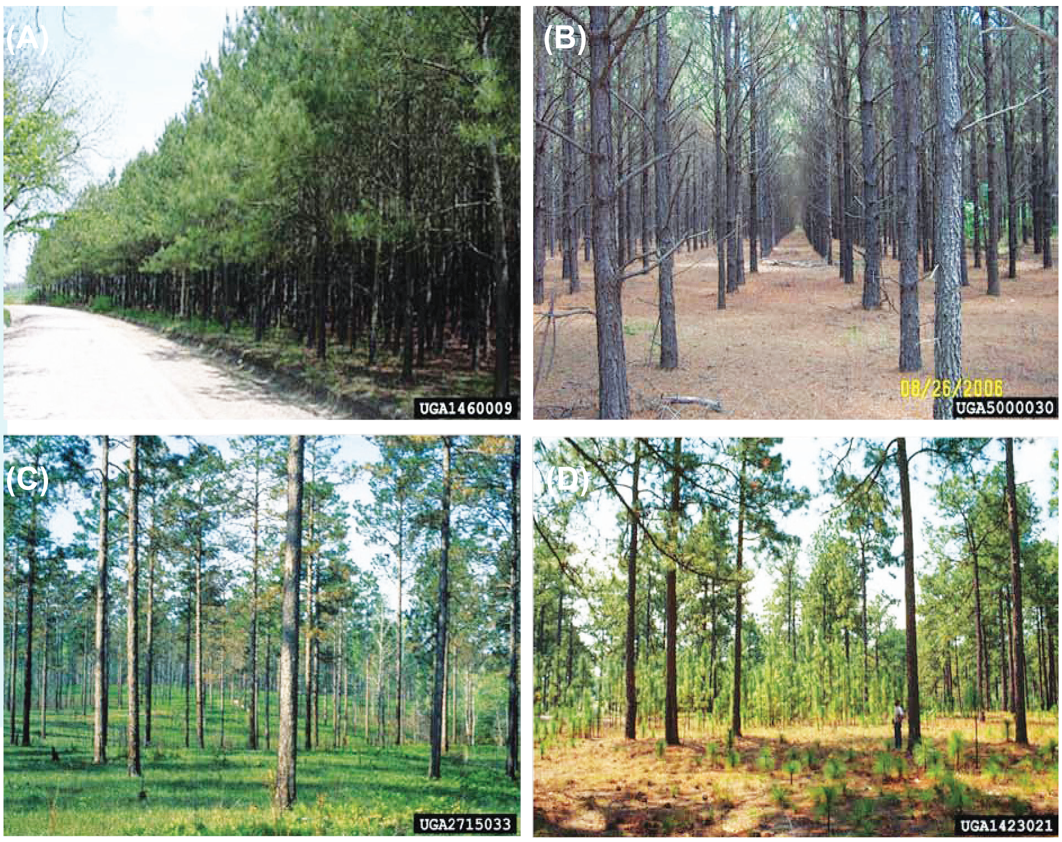

Figure 24.3—Comparisons of options for commercial pine stand types in relation to probability of SPB outbreaks. (A) poor option: very dense loblolly pines, (B) poor option: dense even-aged loblolly pine, (C) better option: less dese even aged longleaf pine, and (D) better option: less dense uneven aged longleaf pine. (photographs (A) by Chuck Bargeron, (B) by David Stephens, (C) by USDA Forest Service Archive, and (D) William D. Boyer, www.forestryimages.org)

Waldron and others 2007) have demonstrated the utility of using fire as a tool in ecological restoration of SPB-damaged areas in the Southern Appalachian Mountains. A more indepth examination of the use of fire as a management tool in the Southern Appalachians can be found at http://www.forestencyclopedia.net/p/p139.

24.4.3. Current SPB Restoration Activities

On January 21-22, 2004, a meeting, "After the Southern Pine Beetle—A Workshop to Discuss Options for Public Lands in the Southern Appalachians and the Cumberland Plateau," was held in Murphy, NC. The goal of this workshop was to have researchers, practitioners, and policymakers share information and discuss strategies on what to do with the hundreds of thousands, if not millions, of acres killed or severely damaged by SPB. The outcomes of this meeting were 3 fold. First, it was determined something has to be done. It was determined that in the modern context of danger from threats such as wildfires and invasive species, as well as the needs of multiple varied forest users, the hands-off scenario of natural regeneration was not a viable alternative. The second outcome of the meeting was that we do not know enough about how to restore these systems. The final outcome was that there is a disjunction in the flow of information between researchers and practitioners. While each of these groups possesses expert knowledge that can better inform restoration, practitioners and researchers more often work apart rather than together to develop viable restoration scenarios.

Current SPB restoration activities include both research efforts and silvicultural activities. The leader in SPB restoration research has been the USDA Forest Service SRS Insects, Diseases, and Invasive Plants Work Unit. Funded research has focused on a wide variety of studies, including silvicultural treatments, ecological modeling, and natural regeneration (Table 24.1). Each of these existing and former research projects has greatly contributed to our knowledge of how to restore SPB-damaged forests. However, much more research is needed to adequately address restoration solutions in the cornucopia of landscapes and forest use types that SPB affect.

The best available data on silvicultural activities are found through the USDA Forest Service Southern Pine Beetle Prevention and Restoration Program (Table 24.2). While I have included data on prescribed burns in this table, it is important to note that prescribed burning has usually been considered a prevention technique in this context rather than a restoration technique. Therefore, the amount of dollars actually spent on restoration, rather than prevention, is substantially lower. In some cases, it is also difficult to discern whether an activity would be classified as restoration or prevention. In fact, restoration should be performed in a way to prevent future outbreaks. Restoration is prevention.

24.5. SUMMARY

Restoration following the southern pine beetle is an intricate and complicated task. A sound understanding of the ecological, political, economic, and social implications of the proposed restoration project is essential. Restoring SPB-damaged areas, as with all restoration planning, involves following a series of steps. The first step in restoration is to determine the goal. Specific goals will vary depending on whether you are restoring ecosystem process or ecosystem service, or some combination of the two. The second step is prerestoration planning, which incorporates knowledge of preoutbreak conditions, current conditions, and potential future conditions. In the context of restoration following SPB, these first two steps are essential. Without proper planning the third and fourth steps have little chance for success at a large cost.

The third and forth steps in this process are the on-the-ground activities associated with restoring a site. The third step is site preparation. Before a damaged area can be restored, the site must be cleared of undesirable conditions to help ensure successful restoration. The final step is restoration itself. The specifics of restoration will vary depending upon the goals, extent of damage, and site location. It is important to keep in mind throughout the process that any action has with it resultant ecological, economic, social, and policy implications that should be addressed in the prerestoration planning phase.

Table 24.1—Restoration research funded by USDA Forest Service, Southern Research Station, Insects, Diseases, and Invasive Plants Unit

Project Title	Lead PI	Institution	Year
Direct Restoration Research			
Development of silvicultural treatments to restore southern pine beetle affected forests in the Francis Marion National Forest	G. Wang	Clemson University	2007
Forest restoration planning and assessment for the southern pine beetle and other invasive pest species	R. Coulson	Texas A&M University	2006-2007
Restoration planning and evaluation following damage by the southern pine beetle in southern Appalachian forests	R. Coulson	Texas A&M University	2003-2006
Restoration planning and evaluation following damage by the southern pine beetle in a sustainable forest management context	R. Coulson	Texas A&M University	2004
Revegetation and forest succession of southern pine beetle-killed shortleaf stands in the southern Appalachian/Cumberland Plateau region	L. Rieske Kenney	University of Kentucky	2004-2005
Guidelines for regenerating small patches of forest killed by southern pine beetle	J. Goelz	SRS-4158	2004
Research that Supports or Informs Restoration			
Determination of stand susceptibility to southern pine beetle during periods of endemic population levels	S. Roberts	Mississippi State University	2007
Southern pine beetle: The causes of transitions between endemic and epidemic conditions	M. Ayres	Dartmouth College	2005-2007
Simulation of dynamics of SPB hazard rating with respect to silvicultural treatment and stand development	J. Goelz	SRS-4158	2005
Landscape evaluation of establishment probability and outbreak potential for southern pine beetle in non-traditional host forests	F. Hain	North Carolina State University	2006
Developing and validating a methodology for monitoring and tracking changes in southern pine beetle hazard at the landscape level	R. Billings	Texas Forest Service	2004

Table 24.2—Outbreak Damage and Restoration Activity by State

	1999 - 2003 SPB Outbreak			2003 - 2007 Restoration Activity		
	Sawtimber killed (*Millions BF*)	Pulpwood killed (*1000s Cords*)	Dollars damaged	Funding given	Prescribed burn (*acres*)	Planting (*acres*)
AL	61	466	$30,144,329	$3,750,000	0	0
AR	0	0	$0	$2,700,000	1113	5120
FL	190	515	$64,080,257	$2,900,000	19563	0
GA	340	319	$82,493,736	$5,550,000	21283	7300
LA	0	0	$0	$950,000	20293	0
NC	191	218	$47,433,306	$9,825,000	0	0
SC	1,176	1,855	$374,601,351	$5,275,000	0	15848
TN	2,081	3,241	$477,904,932	$4,200,000	0	23269
TX	0	0	$0	$4,750,000	0	0
VA	7	31	$1,691,855	$2,025,000	0	171

Restoration activity refers only to funds distributed through the SPB Prevention and Restoration Program.

Funding dollar amounts include allocations for prevention activities which are not presented here. Data sources: http://www.srs.fs.usda.gov/econ/data/spb/, and John Nowak (Unpublished Data)

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