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Review of the operational IPM program for the southern pine beetle

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Abstract

The operational Integrated Pest Management program for the southern pine beetle (SPB), *Dendroctonus frontalis*, currently consists of five components: prevention, prediction, detection, evaluation, and direct control. Full implementation of the program is hampered by economic, regulatory, and management constraints, and devastating SPB outbreaks still occur periodically. Recommendations for improving implementation include gaining public acceptance of the program, devising new management strategies, developing area-wide suppression techniques, coordinating efforts among landowners and government agencies, and revising the environmental analysis process. Severe outbreaks will continue without the creation of less susceptible forest conditions and more stable timber markets, plus the development of improved prediction, detection, communication, and suppression practices.

In response to devastating losses from the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann (Coleoptera: Scolytidae) and two other insect pests, the U.S. Department of Agriculture initiated the Combined Forest Pest Research and Development Program in 1974 (Ketcham & Shea 1977). A well-funded (~$1.9 million/year), five year initiative, the Expanded Southern Pine Beetle Research and Applications Program (ESPBRAP) was begun in 1975. Building on previous research, the goals of ESPBRAP included a coordinated effort to develop methods and technology to predict and manage SPB populations and to reduce damage to forest stands (Thatcher 1980). ESPBRAP was followed by another five year initiative, the Integrated Pest Management (IPM) Research, Development, and Applications Program for Bark Beetles of Southern Pines. This program was designed to transfer the technology developed in ESPBRAP to end-users, and to develop and promote IPM systems for bark beetles in the southeastern U.S. (Shea 1985). The U.S. National Science Foundation and Environmental Protection Agency also funded two block-grant projects that focused on IPM, including bark beetle management (Waters *et al.* 1985).

These programs resulted in a great increase in forest pest managers' abilities to predict, prevent, and suppress SPB outbreaks. Among the tools developed were a SPB spot growth model, hazard-rating systems, and thinning guidelines to reduce SPB impacts (Mace 1985). A series of handbooks on all aspects of SPB pest management was published and distributed, including guides on aerial detection (Billings & Doggett 1980; Billings & Ward 1984), ground evaluation (Billings & Pase 1979), direct control (Swain & Remion 1981), silvicultural procedures to reduce losses (Belanger & Malac 1980), and IPM (Thatcher *et al.* 1986). A compendium of the current state of knowledge on SPB was also published (Thatcher *et al.* 1980), as well as the proceedings of a symposium summarizing accomplishments of the IPM program (Branham & Thatcher 1985). Though research and technology development on SPB has continued in the interim, these handbooks and publications remain the primary guides for managing SPB.

Despite the wealth of knowledge available for SPB management, destructive outbreaks continue to severely affect southern pine forests in the U.S. All states within the range of the SPB experienced at least one outbreak in the 1990s, and losses in Arkansas, South Carolina, Florida, and Virginia exceeded those in any of the three previous decades (Price *et al.* 1998). Recent outbreaks in Kentucky, Tennessee, and North Carolina have been so severe that marginal hosts such as eastern hemlock and spruce have been significantly impacted (USDA 2001).

Given our current knowledge of SPB prevention and suppression and the tools available to land managers to predict, detect, and control infestations, why have SPB problems persisted? The objectives of this paper are to (1) describe the current status of SPB IPM, (2) discuss the factors and restraints that hamper efforts at implementing SPB IPM, and (3) suggest potential solutions to these restrictions. Rather than address the all components involved in the research and development of IPM in forests (see Coulson & Witter 1984), this paper will focus on the operational aspects of the current SPB IPM program in forestlands. Also, the detection, suppression, and prevention of urban SPB infestations pose a unique set of challenges, and will not be discussed in detail.

Current SPB IPM Program

Using information, data, and handbooks generated during the ESPBRAP and IPM initiatives described above, the author developed a concise operational SPB IPM program for inclusion on the SPB Internet Control Center (www.spbicc.vt.edu). The program consists of five major components: prevention, prediction, detection, evaluation, and direct suppression. The program describes proven techniques for SPB prevention, detection, and suppression, and also lists new tactics and technology currently in development. Links to other informational sites and to on-line publications also are provided. A brief description of the program components is given below.

Prevention. Prevention consists of silvicultural treatments designed to minimize the effects of SPB infestations within a forest stand. Hazard-rating systems are used to identify high-hazard stands (Mason *et al.* 1985). Thinning of overstocked pine stands can reduce their susceptibility to SPB (Brown *et al.* 1987; Burkhart *et al.* 1986; Nebeker & Hodges 1983). Management practices such as planting less susceptible species, maintaining a mix of pine and hardwoods, and matching the pine species with the site also can reduce losses to SPB (Belanger & Malac 1980). Other silvicultural treatments that reduce competing vegetation and ultimately increase stand vigor, such as prescribed burning, may decrease the impacts of SPB when applied judiciously. Prevention also includes the use of insecticides for the protection of high-value trees, avoiding practices that injure trees, and sanitation removals of severely diseased, damaged, and overmature trees.

Prediction. The south-wide SPB pheromone trap survey (Billings 1988) is used to forecast SPB activity in a given area. Each spring, funnel traps baited with SPB aggregation pheromone and turpentine are deployed in susceptible forests. The daily catch of SPB and the ratio of SPB to one of its predators, *Thanasimus dubius* (F.) are used to estimate current SPB population levels and predict future trends. The results are used to plan the level of funding and manpower required for SPB suppression and detection for the remainder of the year. The Arkansas spot growth model also is used to predict the future growth of individual SPB infestations (Stephen & Lih 1985).

Detection. Aerial surveys are flown to detect SPB infestations. The frequency of detection flights is based on predictions from the south-wide surveys and the current level of SPB activity. Visual detection is dependent on observing changes in crown color as the foliage of infested trees fades. Environmental conditions affect the rate of fading, and often infestations initiated in the spring cannot be detected until summer. Infestations are prioritized for ground checking based on size, location, and an estimate of current expansion based on numbers of fading trees. A recently developed digital aerial sketch-mapping system is now operationally utilized in many areas. This system allows an aerial observer to plot the location of infestations using an on-board GPS unit linked to a computer with a touch-sensitive screen displaying a geo-referenced backdrop. Infestation coordinates and other spot data can be downloaded into GPS units for ground checking or into GIS programs to produce maps displaying spot locations.

Evaluation. Once suspected SPB infestations are located on the ground, the ground-checking personnel must evaluate each spot's potential for growth and assess the need for control (Billings & Pase 1979). The presence of trees under attack by SPB and of susceptible host type in the direction of spot expansion indicates continued growth is likely and suppression is necessary. The ground-check crew assigns a treatment tactic and priority. The data required to run the spot growth model can be collected to assist in these decisions.

Direct control. Direct control is designed to stop the expansion of individual SPB infestations. There are four methods with proven efficacy for treating SPB infestations: cut-and-remove, cut-and-leave, cut-and-hand spray, and pile-and-burn (see Billings 1980 or Swain & Remion 1981 for complete descriptions of application procedures). All currently-infested trees must be felled during the application of these tactics. In addition, cut-and-remove and cut-and-leave require the felling of a buffer strip of uninfested trees around the expanding edge of the infestation. Cut-and-remove is generally the treatment of choice when environmental and economic conditions allow salvage operations, as the beetles infesting the trees are moved off-site and the landowner receives a monetary return on the salvaged trees. Two new tactics using the beetles' anti-aggregation pheromone have been developed and tested (Clarke *et al.* 1999), but they have not been operationally used to date.

Factors Limiting Implementation of IPM for the SPB

The framework of the IPM program described above has been in place for at least 15 years, and yet SPB outbreaks continue to plague the southeastern U.S. Full implementation of the program has yet to be accomplished. Many factors constrain the land manager's ability to implement a comprehensive IPM program (Stark *et al.* 1985), and the major constraints on SPB IPM are discussed below.

Diverse land ownership. Forested lands throughout the range of the SPB are owned by a variety of groups. In 1999, 89% of the more than 81 million hectares of timberland in the southern U.S. were privately held, with the other 11% owned by various Federal, state and local government agencies (Wear & Greis 2002). Approximately 22% of the private timberland was owned by forestry industry, with other corporations, farmers, and individuals holding the remainder. These landowners and groups have varying objectives and economic resources for managing their lands, and SPB prevention and suppression may not be a concern or an option. The checkerboard pattern of land ownership also makes the planning and enactment of a cohesive SPB IPM program across the landscape very difficult.

Mandated maintenance of high-hazard stands. In the past two centuries human intervention has altered the interaction between bark beetles and the forest ecosystem (Crookston & Stark 1985). Harvesting, species conversion, fire prevention and suppression, short rotation forestry, and various government policies and practices have promoted the establishment and maintenance of forest types and structures that are highly susceptible to the SPB (Clarke *et al.* 2000; Schowalter *et al.* 1981). Older, natural stands of longleaf pine, *Pinus palustris* Mill., a species resistant to SPB attack, were replaced by plantations of loblolly pine, *P. taeda* L. a highly susceptible species.

Now in many areas on federal and state lands, high-hazard stands are perpetuated due to legal mandates and the public demand for areas of limited management. Management restrictions in forests set aside for wilderness, old-growth, or roadless areas often allow dense stands of overmature pines to develop. SPB infestations can expand rapidly in these highly susceptible stands, as evidenced by the large infestations observed in Texas wilderness (Billings 1998; Clarke 1995). The requirement for older pines in some wildlife habitats (USDA 1995) may limit SPB prevention and suppression activities.

Regulatory restraints. Federal and state land management agencies receiving federal prevention and suppression funds must comply with the National Environmental Policy Act (NEPA). In compliance with NEPA, the USDA Forest Service prepared the Final Environmental Impact Statement (FEIS) for the Suppression of the SPB (USDA 1987), describing the approved techniques and guidelines for SPB suppression on federal lands. The potential environmental impacts of new suppression techniques, such as those involving behavioral chemicals, await analysis. These analyses are expensive and time-consuming, and the results must then be incorporated into the SPB FEIS as a supplement or amendment. Analyses are subject to public comment, and there is always the possibility that the Forest Service would be required to prepare a new EIS. The National Forests, National Parks, Indian lands, and other land management agencies also must prepare management plans which detail proposed management activities. In addition, a site-specific Environmental Analysis (EA) that examines the consequences of several management alternatives is necessary before SPB suppression funds may be expended. The cost and time requirements of these analyses often cause delays in the response to developing outbreaks.

State and federal regulations also mandate specific analyses that must be completed before forest management practices can proceed. These regulations have resulted in an increase in the number of biologists, archeologists, and other specialists hired by federal land management agencies. This increase has in turn led to a reduction in the number of foresters and silviculturists, so fewer personnel often are available to plan and implement SPB IPM.

Federal, state and local governments either lack the authority to regulate SPB control measures on private property, or usually are unwilling to exercise this authority. The public has historically accepted such regulatory actions when the damaging agent has been wildfire or an exotic organism (e.g. citrus canker and Asian longhorned beetle), but mandated SPB suppression remains highly controversial.

Economic constraints. Budget cuts and downsizing of the workforce impede the implementation of SPB IPM on state and federal lands. SPB IPM programs often are a low priority when endemic population levels are present, and federal monies generally are available only after SPB begin to cause unacceptable losses. In addition, thinning for SPB hazard reduction and cut-and-remove for SPB suppression are dependent on timber markets. If timber prices are low or if mills are full or no longer in business, then prevention and suppression activities may lose much of their economic incentive. Most private forest owners are reluctant to spend money on SPB IPM unless they are assured of a return on their investment from improved future growth yields. Limited resources may dictate that only large infestations are treated. Industry may not treat infestations until they reach a size that makes both salvage and regeneration of the site economical and practical.

Legal challenges. SPB prevention and suppression tactics often require tree-felling and/or temporary road construction. Due to opposition to these actions on federal lands, lawsuits have been filed in response to announced forest management plans and projects that involve SPM IPM. These suits usually seek to halt all management activities until further analyses of environmental impacts are conducted. These legal challenges delay or even prevent the timely application of SPB IPM practices, resulting in increased tree loss. Conversely, no legal precedent has been firmly established regarding the liability, if any, for knowingly allowing an infestation to enlarge or spread onto adjacent property. Land managers may opt to avoid costly control measures, severely impacting the forest resources on neighboring lands. Without such liability, as exists for other destructive agents such as fire and hazard trees, the affected landowner has little legal recourse for recouping losses.

Lack of area-wide suppression techniques. SPB suppression currently is applied on an infestation-by-infestation basis. The control tactics are labor-intensive and time-consuming, as are the detection and evaluation procedures. And while the suppression tactics are very effective at controlling individual infestations and reducing additional tree loss (Billings 1995; Clarke & Billings 2003), their effects on area-wide SPB populations are unclear. Currently there are no pesticides or biological control agents that can be applied over wide areas to suppress SPB outbreaks.

Recommendations for Effective Implementation of the Current SPB IPM Program

As detailed above, land managers face great challenges in implementing SPB IPM. The following section provides recommendations that may assist in long-term reductions of impacts by the SPB.

Treat individual infested trees and small infestations during the winter or when populations are at endemic levels. Several authors have suggested that treating infested trees when populations are endemic or in small, scattered groups during the winter may greatly affect future population levels (Lorio 1984; Miller & Parresol 1992). These small infestations serve as reservoirs for the SPB (Moore & Thatcher 1973), and subsequent population increases may result. Once detection systems are developed that can identify individual or small groups of infested trees, efforts should be made to locate and treat these small infestations. Suppression treatments, combined with prevention operations, could prevent or reduce the magnitude of SPB outbreaks.

Organize a coordinated IPM program among all landholders within a region. Each agency, industry, or private landowner is currently responsible for detecting and controlling SPB on their lands. Private landowners may not know they have SPB on their property until the state or their management consultant informs them of the infestation, often well after high levels of mortality have occurred. Scheduling planes for detection flights is often difficult due to competing interests. A more unified approach would simplify SPB IPM. Detection flights could be flown across all ownerships, with the coordinates of suspected infestations distributed to the appropriate land manager. This type of system is being used successfully by the state of Alabama to alert private landowners (Hyland & Bradley 1997). Similarly, large-scale hazard-rating surveys could be conducted to identify high-hazard stands within a region (Billings *et al.* 1985). The creation of a coalition of land managers to implement SPB IPM would facilitate the collection of predictive data and the technology transfer of new management and control techniques. The creation of a regional database that includes all SPB infestations would help track treatment progress and aid in landscape analyses of SPB population patterns and trends.

Rethink management strategies in susceptible forest types. Forest managers should alter management policies that increase the risk of SPB infestation. Recommended initial planting densities in plantations of susceptible pine types are 1000–1750 stems per hectare, but 1750–24,500 stems per hectare often are planted to account for tree mortality (Wakely 1954). Improvements in seedling quality and forest management practices have resulted in increased survival (C. Brown, Texas Forest Service, pers. comm.), negating the need to plant as many trees per hectare. Plantations with lower planting densities would be less susceptible, as SPB infestations are frequently located in overstocked stands (Lorio 1980). First thinnings could be delayed until trees reach commercial size, assisting landowners who are reluctant to implement pre-commercial thinning due to the costs. The wider spacing could also improve the log quality of trees removed in these thinnings (Campbell *et al.* 1995). Agencies and landowners that rely on seed-tree, shelterwood, or other natural seeding systems may need to increase pre-commercial thinning operations to reduce the SPB hazard. They also should consider restoring less susceptible pine species in appropriate areas rather than allowing more susceptible species to regenerate naturally.

Managers also need to reconsider management actions and designations that create high-hazard conditions. Pine forests considered for special area designation often have been previously managed for pine timber and contain old, dense stands of susceptible hosts. Designation of these forests as wilderness or roadless areas precludes or limits SPB IPM activities. Once SPB outbreaks occur within these areas, large infestations can develop (Billings 1995; Clarke 1995). The forests lose the character that led to their consideration for special area status. High-hazard forests should be restored to a less susceptible condition before they receive special area classification. Thinning, promoting a hardwood–pine mix, or planting less susceptible species all can reduce the threat of future SPB infestations.

Reducing the hazard of SPB infestation is especially important in current efforts to conserve habitat for the red-cockaded woodpecker (RCW). This endangered species constructs its nesting cavities only in living pines, and usually prefers mature, longleaf pines. SPB are a primary mortality agent of active cavity trees, particularly those in loblolly pine (Conner *et al.* 1991). A RCW recovery plan is currently in place (USDA 1995), and most aspects of the recovery plan are designed to reduce impacts of SPB in RCW habitat. Pine basal area (BA) in cavity tree clusters, recruitment stands, and replacement stands is kept at 14–18.5 m^2/ha, a stocking that is not conducive for expanding SPB infestations. Thinning to a pine BA of 16–23 m^2/ha is recommended in foraging habitat, and restoration of longleaf pine within its historical range is encouraged.

Though these policies generally reduce the incidence of SPB infestations in RCW habitat, SPB problems persist. Thinning within foraging habitat may be delayed due to environmental conditions or other factors. The RCW recovery plan requires that no more than 7 m^2/ha of pine BA may be removed in a thinning in a RCW management area, so dense pine stands may remain in a moderate to high-hazard state. During thinning operations, mature, large pines are retained due to their potential for selection as cavity trees and their quality for foraging. Longer rotation schedules are used in RCW habitat management areas, resulting in older, more susceptible stands. Due to loss of prime habitat, isolated cavity trees may be discovered in off-site loblolly pine. Wildlife biologists should consider the consequences of classifying these areas as RCW habitat and immediately implementing the recovery plan. Translocation of the birds and restoration of the stand may better serve the long-term recovery of RCW.

Increase public awareness of SPB impacts and IPM. Public input is an integral part of forest management on federal lands. Input is required and solicited during the formulation of forest management plans and during the analyses of projects designed to implement the forest plans. Forest pest management specialists must do a better job of educating the public on SPB issues to ensure that informed decisions are made in the management of public and private lands. The public should be provided with an accurate and comprehensive view of the potential impacts of various SPB management strategies. Access to detailed and updated information on SPB through publications and websites such as the SPB Internet Control Center should be increased.

Revise EA and regulatory processes. An EA must be prepared before SPB suppression can be undertaken on federal lands. The lengthy processes required for the preparation of an EA can delay suppression and result in significant tree loss, as can lawsuits filed against managing organizations. Rules should be changed to allow SPB management guidelines in the current Forest Plan and SPB FEIS to remain in effect during EA preparation or lawsuit adjudication, provided it is determined that sufficient public input was received and considered in the initial planning. The process for integrating efficacious new suppression tactics into management plans also should be expedited, particularly for environmentally-friendly techniques that do not involve pesticides and that require less tree-felling than existing, approved tactics.

As with wildfire, SPB infestations may develop quickly and require an emergency response. Regulations should be streamlined for SPB control to speed the response time and protect forest resources. For example, cut-and-remove operations are considered to be timber sales. Reclassifying cut-and-remove as emergency suppression would accelerate treatment implementation.

Future Needs for SPB IPM

Adoption of the above recommendations by forest managers would reduce the impacts of SPB. However, it is doubtful their implementation would prevent periodic severe outbreaks within the pine forests of the southeastern U.S. The following needs must be addressed before a fully efficacious IPM program can be established for the SPB.

Development of new methods of prediction, detection, prevention, and suppression

Prediction. The pheromone trapping survey conducted each spring provides estimates of SPB activity for the summer and fall. These predictions may not provide adequate lead-time for mobilizing the required workforce and acquiring the funding to adequately respond to anticipated high levels of SPB infestation. Long-range prediction systems that provide accurate forecasts are vital for land managers.

Detection. Infestation detection is dependent on changes in foliage color, which often becomes apparent only after substantial mortality has already occurred. Pre-visual detection would decrease response time, improving suppression and reducing tree loss. Several methods of pre-visual detection utilizing remote-sensing are being tested (Carter *et al.* 1998). A primary stumbling block has been the inability of the sensors to distinguish SPB infestation from other types of tree stress and mortality agents. This discrimination is crucial for verifying small SPB infestations during endemic conditions; otherwise time is wasted ground-checking misidentified SPB spots.

In the future, satellite imagery may replace detection flights. These images would be downloaded to websites accessible to land managers. Scale, frequency, resolution, and cost are concerns that must be addressed.

Prevention. Formulations of chlorpyifos commonly used to prevent SPB attack have or are losing their forestry labels. Homeowners and special area managers need efficacious insecticides for the protection of high-value trees.

Suppression. To combat SPB in special management situations and lessen the objectionable aspects of SPB suppression, new tactics for infestation suppression that do not require tree-felling must be developed, refined, and applied operationally. Area-wide suppression tactics, which focus on population reduction rather than individual infestation suppression, must be developed and tested on a landscape scale for efficacy. New strategies include the supplemental feeding of SPB parasitoids (Mathews & Stephen 1999; Stephen *et al.* 1997), the mass-rearing of SPB natural enemies for population augmentation (J. Reeve, Southern Illinois University, pers. comm.; Sullivan *et al.* 2000), and the establishment of trap trees. The control of individual infested trees or small infestations is complicated (Lorio 1984) and methods are needed that do not damage the residual trees in the stand. Trapping the emerging beetles or debarking the standing trees are potential techniques.

Create stable and/or alternative timber markets. Stable timber markets are dependent on reliable sources of wood and the implementation of south-wide prevention programs would play an integral role. Thinnings would provide a continual source of timber as well as reduce flooding of mills with beetle-killed trees during outbreaks. To increase their application, end uses must be found for the small trees removed in what are now termed 'precommercial' thinnings. Novel markets and utilization for smallwood and wood biomass are available or in development (see http://www.forestprod.org/smallwood02powerpoints.html). Application of these new technologies would benefit not only the prevention and control of SPB problems, but also assist in reducing the region's hazardous fuel loadings and associated wildfire risk.

Summary

Dendroctonus bark beetles have a primary role in determining the productivity of pine forests, and it is essential that forest managers have strategies for regulating their impacts (Waters 1985). At the initiation of the SPB IPM research and development program in 1980, there were no experimentally proven area-wide prevention or suppression treatments available to forest managers (Wood *et al.* 1985). This is still the case. The current operational IPM program has been effective in reducing tree loss by the SPB, but outbreaks continue. SPB IPM can and must continue to evolve and expand through research, technology development, and public education and feedback. The thrust of the IPM program must shift from suppression to prevention. A cooperative effort among all regional forest managers for SPB detection and suppression is necessary. Relief from regulatory and economic restraints would ensure timely application of prevention and suppression treatments. Researchers must develop novel methods of detection, prediction, and suppression. A revised, coordinated IPM program would alleviate the detrimental effects of SPB outbreaks, such as those that have occurred in the past two years.

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