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Forest Health in the Southeastern United States

Assessment of the State of the Science

Clifford S. Duke, Corrie Mauldin, and Harold Balbach

June 2008

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Final report

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Abstract: In order for the Army, and other land managers, to meet responsibilities for sustainable management of natural resources, they must closely monitor the health of those resources and respond to potential threats. A number of recent studies and reviews have suggested there may be declines in the health of southeastern forest ecosystems that support these facilities. These apparent declines involve multiple hardwood and softwood species such as oaks and pines, and appear to have a wide range of potential causes, including fungal and insect pests, air pollutants, and even climate change and the pre-military land use history. As an example, one facility has special concerns about the function of its pine-dominated forests in supporting endangered species, particularly the Red Cockaded Woodpecker (RCW). In their opinion, too many mature Loblolly Pines, which represent the majority of RCW cavity trees on that site, are dying. Younger trees and longleaf pine may also be affected. Other installations have reported concerns with other aspects of pine forest management as well. In a June 2007 workshop, researchers and land managers from several states met to examine the nature and possible causes of the problem from a regional perspective. The questions developed from the workshop by no means cover all the possible issues. Underlying all discussions were concerns that present long-term plans to manage these forest systems to support the recovery needs of the RCW might have to be totally revised. This report represents a summary of several separate reports prepared by groups of workshop participants.

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Preface

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) Office under SERDP Work Unit SI-1114, "SERDP Ecosystem Management Program (SEMP)." The technical monitor at the time of the activities included in this report was Dr. John A. Hall, Program Manager. The Executive Director of SERDP is Bradley P. Smith.

This report was prepared largely from a series of invited manuscripts prepared following a June 2007 workshop in Atlanta, GA. The authors of those manuscripts are acknowledged as the source of all original material contained here. They were L. G. Eckhardt, M. A. Sword Sayer, D. W. Imm, R. Mitchell, J. Walters, C. Hedman, R. Johnson, W. J. Otrosina, H. Balbach, P.C. Spaine, and S-J.S. Sung.

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COL Richard B. Jenkins is Commander and Executive Director of ERDC and the Director is Dr. James R. Houston.

Acronyms

ESA	Ecological Society of America
FIA	Forest Inventory Analysis
FR	Federal Register
GIS	Geographic information system
GPS	Global positioning system
RCW	Red-cockaded woodpecker
SEMP	SERDP Ecosystem Management Project
SERDP	Strategic Environmental Research and Development Program
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

1 Introduction

Background

Southeastern forest ecosystems are a critically important resource, providing forest products such as timber and pulp, ecosystem services such as water purification and flood mitigation, and habitat for endangered species. For the U.S. Army to meet its responsibilities for both realistic military training and sustainable management of its natural resources, Army land managers must closely monitor the health of these resources and respond to potential threats to them.

A number of recent studies and reviews have suggested that the health of these ecosystems may be threatened. Threats involve multiple hardwood and softwood species such as oaks and pines, and appear to have a wide range of potential causes, including fungal and insect pests, air pollutants, and pre-military land-use history. However, the nature and extent of the threat to ecosystem services and products posed by forest decline have neither been confirmed nor quantified, and to date no focused effort has been mounted to either assemble a comprehensive assessment of the problem or develop management recommendations.

In response to these concerns, the Ecological Society of America (ESA), as an initiative within the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP – SI-1114), developed and facilitated a workshop entitled, "Forest Decline in the Southeastern United States: Assessment of the State of the Science." It involved more than 40 experts from a range of disciplines to address the nature and extent of the problem and make recommendations for short- and long-term management responses (ESA 2007). Members of four workshop groups prepared a series of review papers exploring these issues in more detail. This report summarizes the workshop and review paper discussions, conclusions, and recommendations for use by foresters, land managers, and others charged with responsibility for managing Federal, state, and private forests in the southeastern United States.

Report structure

The workshop participants were asked to address four significant unknowns:

- What is the forest health/decline problem and how widespread is it (scope/scale/magnitude)?
- What are the underlying causes and do these differ across the region?
- Are there management actions that can be taken immediately that would help minimize the impact of a potential forest health problem?
- How would a significant forest health problem affect achievement of long-term plans (desired future conditions, endangered species recovery, troop readiness, etc.)?

This report first summarizes how the study groups addressed the nature and extent of the problem, hypothesized underlying potential causes, and discussed the implications of the problem for management of one critical endangered species, the red-cockaded woodpecker (*Picoides borealis* (Vieillot) [RCW]). The report then presents a case study of forest management at Fort Benning, GA, to illustrate the nature of the problem and concludes with general research and management recommendations and additional specific potential responses for Fort Benning managers to consider.

2 Nature and Extent of the Problem

Overview

Southeastern yellow pine forests, both planted and naturally established, seem to be experiencing local or regional decline in function and productivity. The principal concern is that, if such a local forest health problem were to expand, it may have adverse impacts on current longleaf pine (*Pinus palustris* Mill.) ecosystem restoration and associated endangered species recovery efforts. At broader scales, such a problem would have serious landscape and watershed implications as well as effects on local economies that depend upon the forest products industry.

Forest types that appear particularly susceptible to decline include those dominated by loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* Mill.). However, some longleaf pine stands also appear to be affected. The problem seems to be more prevalent across the Sandhills physiographic region, which lies below the Piedmont and above the Coastal Plain provinces. Relative to the Coastal Plain, the Sandhills region has a greater proportion of unproductive soils. These forests may be sensitive to multiple stressors and disturbances. The Sandhills region is also characterized by several large Federal installations (e.g., Fort Bragg, Fort Jackson, Savannah River Site, Fort Gordon, Fort Benning) that have different levels and types of disturbances, but most have similar land histories and land management objectives.

A possible increase in the type or extent of forest health problems in southern pine systems would be important because these forests are a dominant landscape feature in the southeastern United States and are necessary to meet regionally important ecological (e.g., wildlife recovery) and nationally important economic (e.g., timber and nontimber forest products) expectations (Prestemon and Abt 2002; Trani 2002). Potential setbacks to the ecological expectations are particularly problematic because, during the past 15 years, public land management has emphasized longleaf pine ecosystem restoration to support the habitat needs of “at risk” species such as the RCW (Hoctor et al. 2006; Owen 2002). In the process of restoration, many areas supporting “off-site” species (i.e., growing on sites/soils where conditions are not optimal for the species) or forests characterized by poor forest health, have already been converted to

more appropriate pine species that are more compatible with the goals of the habitat restoration efforts (Stanturf et al. 2004).

Observations of decline

Although widely used, there are no standard definitions of the terms "forest decline" or "forest health." However, a number of field observations provide a frame of reference for how researchers and forest managers use these terms and evaluate the underlying phenomena in a number of different contexts. Since 1990 several reports have suggested an increase in the occurrence of local forest health problems in different southern pine systems (Eckhardt et al. 2007; Hess et al. 1999, 2005a, 2005b; Menard et al. 2006; Otrosina et al. 1999). Many of these reports have been specific to particular locations (e.g., Fort Benning, GA; Talladega National Forest, AL; Shaw Air Force Base, SC; Sumter National Forest, SC), but imply that similar problems are occurring in surrounding areas. The majority of these events have occurred in mature loblolly pine and mixtures of mature loblolly and shortleaf pine near the interface between the Piedmont Province and either the East Gulf Coastal Plain or the Atlantic Coastal Plain physiographic regions, as well as in the Fall-line Sandhills between these regions. Loblolly pine is considered off-site at many of these locations; conditions are more compatible instead with the needs of longleaf pine (Hess et al. 1999, 2005a; Menard et al. 2006). Recent evidence further suggests that this forest health problem may also affect younger forest types including planted longleaf pine forests (Menard et al. 2006; Zanzot and Eckhardt unpublished data). Evidence of pine decline in the southeastern United States has been reported by the U.S. Department of Agriculture (USDA), Forest Service, Forest Inventory Analysis (FIA), although no clear causal factors have been identified (Bechtold et al. 1991; Gadbury et al. 2004). Until a specific causal agent, or syndrome of combined agents, can be identified, the term "decline" seems appropriate to use as a collective descriptive term.

Loblolly pine mortality has been reported in National Forests of Alabama since 1968, when the first published survey and attempt at diagnosis was conducted (Brown and McDowell 1968). They described the decline of loblolly pine trees growing in the Oakmulgee and Talladega Ranger Districts of the Talladega National Forest in Alabama as having been observed since 1959. The reported symptoms were present mostly in sawtimber stands greater than 50 years old. Generally, these trees exhibit symptoms not unlike littleleaf disease of shortleaf pine, i.e., progressively thinning crowns, shortening needle length, and off color needles (Campbell and

Copeland 1954). Since 1968 two other reports have dealt with this issue on National Forests in Alabama (Hess et al. 1999; Eckhardt et al. 2003). Crown symptoms generally appear at about age 40 while stands older than 50 to 60 years may sustain severe mortality. Trees apparently succumb within a few years after the initial onset of symptoms. It is noted that this age is beyond that normally planned for final harvest in commercial plantings of this species.

Anecdotal information from public land managers (Conner et al. 2004; Johnson and Wells 2005; Atkinson 2006; Thomas 2006; Crawford 2007) suggests pine decline is not currently a catastrophic regional forest health problem, but rather a localized problem. Pine decline appears to be more prevalent when the more resource-demanding loblolly and shortleaf pine are planted on sites that originally supported the less resource-demanding longleaf (Hess et al. 1990, 2005b). Further, this phenomenon is seen on sites characterized by soil resource limitations, either inherent or anthropogenic (Otrosina et al. 1999; Menard et al. 2006). Collectively, the reported occurrences are often associated with three forest settings: (1) “off-site” plantings or under-managed settings, (2) forest ages above 50 years, and (3) high densities that lead to overstocking (Conner and Hartsell 2002).

3 Potential Causes

Based on current research, as combined with numerous observations of tree decline, the underlying potential causes of decline appear to be:

1. The combined effects of multiple stressors associated with past and current land uses, site and soil quality, and, possibly, climate change,
2. Opportunistic root pathogens, including imbalances in populations of insect pests and root-infesting fungi (e.g., *Leptographium* species), that may degrade tree physiological responses to multiple stressors, and
3. A higher susceptibility of mature or maturing plantations compared to seedling and sapling stands.

Land use, soils, and climate

Land use

Most of the Atlantic and East Gulf Coastal Plains, lower Piedmont Province, and Fall-line Sandhills have similar land-use histories (USDA 1988; Barrett 1995; Jose et al. 2005), though the timing and duration of land use may vary from east to west (Jose et al. 2005). Before European settlement, Native American communities existed along major rivers and on floodplains (Frost 2006). Frequent fires started by residents or lightning led to development of fire-tolerant vegetation communities consisting of woodlands and sparsely treed savannas with canopies consisting of pines and some oaks (*Quercus* spp.) (Komarek 1968; Frost 1993, 1998, 2006).

During the 18th and 19th centuries, European settlers cleared most of the arable land for subsistence agriculture. Erosion and nutrient depletion quickly reduced crop yields in many areas and agriculture was abandoned. Some abandoned areas were naturally reseeded to loblolly pine and other early successional forest types, but most of the landscape became severely eroded as a result of the lack of cover. During the early and mid-20th century, Federal and state agencies took action to rehabilitate eroded areas, and many of these efforts involved planting the fast-growing loblolly pine (USDA 1988). To their credit, much of the erosion ceased and natural mitigation began. However, some of these forests, planted without respect to soils, have been unhealthy and unproductive (Conner and Hartsell 2002; Ward and Mistretta 2002; Gadbury et al. 2004).

Increases in local forest health problems cannot be attributed solely to the combined influence of legacy land uses. Since the planting of these loblolly pine-dominated forests, other potential stressors have increased, including variability in year-to-year weather patterns (Jentsch et al. 2007), pest occurrence (Ward and Mistretta 2002), air pollutants such as ozone (Moore et al. 2002), and mechanized forest management practices that may damage roots (Ward and Mistretta 2002). Other factors include reduced stand-level genetic heterogeneity (Ward and Mistretta 2002) and reintroduction of fire onto the landscape (Brockway and Lewis 1997; Boyer 2000; LeJeunesse et al. 2006). Past and present use of off-road tracked vehicles for military training surely is also an element.

Soils

Soil type and condition are basic foundations of silviculture and site productivity (Smith 1962). Farming has caused extensive erosion and disturbance of most soils on the southeastern upper Coastal Plain and Piedmont (MacCleery 1992; Foster et al. 2003). Approximately 1 meter of topsoil (or A horizon) is estimated to have eroded in many sites of the Piedmont. In many places the uppermost soil layers now seen were the subsoil layers of the original soil. Repeated cropping has also reduced soil nutrients and organic matter, affecting both current and potential future forest nutrient status and productivity over long periods (Richter et al. 2000; Foster et al. 2003).

Other factors also influence soil conditions (e.g., the physical demands placed on soils by military use). Intensive training use may cause large areas to remain indefinitely in a “tilled” state, lacking any vegetative cover, even short-term growth. When these sites are revegetated, plant growth may be much less than anticipated due to the loss of nutrients and almost total absence of organic matter. In areas used for tracked vehicle training, these surface layers are continually churned and mixed. While such areas do not cover entire installations and show extreme disturbance only in localized zones, the situation is not conducive to successful reforestation even after training use is shifted to another area.

Weather and climate

Several aspects of weather and climate may be affecting the observed decline. This area suffered a period of high temperatures combined with low precipitation from 1999 to 2001 (Lozar 2004). While not the most severe drought of record, it matched the most extreme moisture deficit of the

1920s. These conditions surely stressed all forest species to some degree. The stress and resultant loss of a substantial portion of the annual increment of root growth for 3 years in a row may have weakened many loblolly pine trees. The observations of apparent excess decline and death of the trees followed shortly thereafter, so there is some association in time of onset of symptoms. This may be occurring at present as well, given that the precipitation deficit appears similar and the region has been identified as being in extreme drought.

Fire

Prescribed fire is an important tool for management and control of hardwood competition in loblolly pine stands (Schultz 1997). For example, a majority of the pine and mixed forests on Fort Benning have been prescribed burned for 15 or more years, largely on a 3-year return cycle. The role of fire in the present decline is unknown, although fuel buildup in duff layers and infrequent fire regime for this species can contribute to stress by damaging fine roots. Otrosina et al. (2002) describe a mechanism that explains a delayed decline and mortality following prescribed burning in longleaf pine. They hypothesize that duff buildup in an established stand after at least 7 years of fire absence contributes to excessive stress following fire reintroduction. Mortality of fine roots present in the organic layer following fire reintroduction exacerbates stress levels and contributes to further root colonization by fungi such as *Leptographium* sp. Root disease caused by the fungus *Heterobasidion annosum* (Fr.) Bref. was also a factor in the decline of longleaf pine on these sites. A relationship between fire severity and the number of root feeding bark beetles was observed within the first weeks post burn (Sullivan et al. 2003). Direct heat effects such as cambial damage from excessive fire temperatures and heat pulse duration are also stressors.

Pathogens and insects

Root pathogens, particularly those affecting woody roots, may be primary causes or secondary consequences of disturbance (Otrosina 2005; Otrosina and Ferrell 1995), depending on a host of pathological, ecological, and environmental factors. Some pathogens are intimately associated with insects for dispersal and thus the factors that influence disease impact in these cases become very complex. For example, root feeding bark beetles such as *Hylastes* sp. and *Hylurgops* sp. (Coleoptera: Scolytidae), are likely vectors for the *Leptographium*/Ophiostomatoid fungi (Eckhardt et al. 2004). Spores of these fungi are not suited to aerial dispersal so insects are

a critical component of overland spread. The roles fungi play in the overall decline syndrome are not clear, but most are opportunistic pathogens attacking already compromised trees (Harrington and Cobb 1988). Trees weakened by abiotic stressors (e.g., drought, high temperatures, or nutrient deficiencies) or by fungi are subsequently more susceptible to pathogens and insects.

4 Implications of Pine Decline for Red-cockaded Woodpecker Habitat Management

A key reason for concern about pine decline is its implications for management of habitat for the RCW, which is endangered throughout its range (35 FR [Federal Register] 16047, October 13, 1970). RCW require open pine woodlands and savannahs with large old pines for nesting and foraging habitat. Longleaf pine stands about 60 to 120 years of age, depending on the site, are preferred, but numerous other species of southern pine are also suitable, including loblolly, shortleaf, and slash (*Pinus elliottii*). Current observations indicate that:

- Large numbers of mature loblolly pine are declining and dying
- These are the trees that contain RCW nest cavities
- Longleaf pines, which have been extensively planted since 1990, are too small to support the RCWs
- It will be 20 or more years before they are large enough for nest cavities
- RCW managers are concerned that not enough suitable trees will be available to support RCW recovery for a 10 to 30 year period starting in about 2015.

Thus pine decline presents a major challenge in terms of attaining endangered species recovery goals, as well as maintaining a forest management program and sustaining the military training mission.

5 Fort Benning Case Study

This chapter illustrates the forest decline issue with a case study of a specific installation, Fort Benning, GA.

Case study background

Fort Benning's primary mission is to train infantry soldiers and units, while secondarily maintaining the ecological integrity and stewardship of the installation, particularly with respect to sustaining populations of endangered species. The majority of Fort Benning was established through land acquisitions between 1918 and 1942. It currently encompasses approximately 182,000 acres along the Chattahoochee River near Columbus, GA; 93 percent of which are in Georgia and the remaining 7 percent in Alabama. Fort Benning straddles the "Fall Line" – the landform that demarcates the Piedmont and Coastal Plain physiographic provinces.

The forest history of Fort Benning is similar to the region and is characterized by over a century of deforestation, followed by subsistence farming and consequent soil erosion. The lands comprising Fort Benning were almost entirely eroded, consisting of abandoned agricultural land with patches of forest in places not suitable for farming. Some of these patches included loblolly pine, while others held longleaf and shortleaf pines, all of which are native to the general area.

Regionally, loblolly pine now has the most extensive acreage on the landscape, comprising about half of the standing pine volume in the region (Baker and Langdon 1990). Due to its rapid growth, loblolly has become a very important commercial species, and is aggressive in colonizing abandoned agricultural fields and other disturbed areas. Despite its extensive range, from east Texas to southern New Jersey, it grows best on soils with imperfect or poor internal drainage and thick medium textured surface layers over fine texture subsoils. The more arid upland sandhills of Fort Benning are not inherently well suited to loblolly pine, although it has expanded there by both natural invasion and deliberate replanting from the 1930s through the mid 1970s. It is these trees, the oldest of which are now 50 to 70 years old, which have become the cavity base for the RCW population and currently have become subject to high mortality rates.

The RCW requires frequent burning and older forests (Jackson 1994; U.S. Fish and Wildlife Service [USFWS] 2003). Past land use has tended to convert sites from multi-aged stands, often dominated by longleaf pine that were frequently burned, to even-aged stands of younger pines, mostly loblolly and shortleaf. Most of these stands have gone through periods of fire suppression that promoted development of a hardwood midstory and reduced groundcover. Plantation forestry, usually based on the loblolly pine, though sometimes on slash pine, effectively suppresses all strata below the canopy, and provides no useful habitat for the RCW. The desired condition for the RCW and other species characteristic of southern pine forests on historic longleaf sites is open, mature stands, preferably of longleaf pine, with a sparse hardwood midstory and a rich groundcover dominated by forbs and grasses (USFWS 2003).

Causes of pine decline at Fort Benning

The causes of pine decline at Fort Benning are the same as those in the region, as presented previously. Tree death rates differ among species, with the majority of trees either dying or of low vigor being loblolly and shortleaf pine. The progression from poor vigor to mortality may be a function of the severity of stand conditions, pathogenic root fungi (e.g., *Leptographium*/Ophiostomatoid fungi) that destroy root vascular tissue, or insect pests that either kill trees directly or vector root pathogens. Also as described previously, weather and climate may be implicated in decline. This area suffered a period of high temperatures combined with low precipitation from 1999 to 2001 (Lozar 2004), and the stress and resultant loss of a substantial portion of the annual increment of root growth for 3 years in a row may have weakened many loblolly pine trees.

Conditions at Fort Benning do not appear to be atypical for 60- to 70-year old loblolly and shortleaf pine in this part of the species range – especially given its land use history (detrimental long-term agricultural practices, accelerated prescribed burning program, intensive military training). Many or (possibly) most sites on Fort Benning supporting stands of loblolly pine may not have suitable, much less optimal, soils for long-term productivity of this species. In regional forestry practice, the species is managed on a short rotation and only rarely will stands be maintained beyond 50 years, or 30 to 35-cm stem diameter, except for stands dedicated to support of the RCW. These larger sizes are exactly those being used for RCW management, and the expectation that healthy life will continue much beyond this age does not appear to be realistic when all the above factors are taken into account. A majority of the pine and mixed forests on

Fort Benning have been prescribed burned for 15 or more years, largely on a 3-year return cycle. The role of fire in the present decline is unknown. Fuel buildup in duff layers and infrequent fire regime for this species could contribute to stress by damaging fine roots, although current conditions show little of such buildup, and fire has been regular since the 1980s.

Fort Benning and RCW

Conservation-based desired future conditions described in the current natural resource management plan for the base (Fort Benning 2006) are centered on maintaining: (1) native species richness and biodiversity; (2) viability of all rare, threatened and endangered species, and species of conservation concern; (3) upland areas in high-quality longleaf pine communities that grade downslope into rich hardwood slope and bottomland communities; and (4) intact riparian areas, wetlands, ephemeral ponds, and streams. It is also desirable to minimize point and nonpoint source pollution and the ecological impacts of invasive species and disturbances.

Fort Benning's RCW management program has been in place for more than 10 years. The goal is to increase the RCW population from the current 280 potential breeding groups to 350, at which point the population will be considered recovered (USFWS 2003). Fort Benning has been increasing its RCW population at a rate of 7 to 8 percent per year and thus continues to make progress toward this goal. The installation wishes to achieve a desired future condition in which longleaf forests will occupy 85,000 to 90,000 upland acres and grade downslope into high quality mixed hardwood-pine and hardwood communities (Fort Benning 2006). Prescribed fire regimes will be variable in return interval (1 to 3 years), intensity, season of burn, and ignition pattern. Fire and forest management will be practiced with the goal of maintaining healthy, uneven-aged, open longleaf pine stands. These stands are to exhibit compositional variation, stability, and resilience to light anthropogenic or natural disturbance, and provide sustainable settings for military training.

Fort Benning will increase mission flexibility when recovery is achieved, and a forest health problem that impedes RCW recovery would therefore compromise both conservation and training objectives. The USFWS requires Fort Benning to provide two resources for the birds, nesting habitat and foraging habitat. Providing nesting habitat will not be an issue because the density of mature trees required is very low, and even where trees for natural excavation are insufficient, artificial cavities can be provided readily. However, a forest health problem might make it difficult to

maintain sufficient basal areas of mature pines to meet RCW foraging habitat recommendations detailed in the Recovery Plan (USFWS 2003). This difficulty would make it more likely that proposed actions would reduce flexibility in planning and executing the military mission.

RCW clusters affect training to some degree, but the impact has been minimized by several practices that provide mission flexibility while protecting the birds. These practices are described in the Management Guidelines for the Red-cockaded Woodpecker on Army Installations (U.S. Army 2007). Managers can exchange designations between supplemental and primary clusters, further increasing flexibility in establishing the desired training environment. So the ability to designate supplemental clusters and make reassignments between supplemental and primary clusters is particularly critical to maintaining flexibility with respect to range development and other forms of construction. If some areas can no longer support a RCW group because of excessive tree mortality, then the quantity and distribution of habitat on which the recovery goals will have to be achieved will change. This change could result in loss of mission flexibility and, in the extreme, loss of training land.

6 Research Recommendations

At present, pine decline appears to primarily affect public land managed for multiple objectives that include but do not emphasize timber production (Eckhardt et al. 2007; Hess et al. 1999, 2005a, 2005b; Menard et al. 2006). Commercial forest management appears to avoid the problem largely by harvesting at a smaller size (younger age) than that at which the trees are affected seriously. Information is insufficient to determine whether this problem is approaching threat status or even has the potential to become a regional forest health threat. Even if pine decline is not a severe region-wide problem and lacks a standard operational definition, the suite of concerns encompassed by it remain significant to RCW management, especially on military installations. Mitigating the negative effects of pine decline first requires knowledge of the scope and cause of the problem. Some of these studies could logically be rather short term and would not require massive efforts to acquire relevant data. Funding of appropriate studies immediately would help provide actual data for many of these factors. Resolution of the problem in the long term will require a multidisciplinary approach using regional comparisons among ecosystems. As a precaution, additional measures can be suggested so that adequate information is available in the future if pine decline becomes a forest health threat.

Mortality

More research is needed to determine the causes of mortality, including local and regional patterns. Gauging the relative severity of the problem would be furthered by better knowledge of which specific forest stands are declining. A first step in understanding severity would be to obtain and analyze mortality data for overstory trees (e.g., snags per acre, relative age of snags, pattern of mortality [aggregated, randomly distributed, etc.], and potential causes) on a stand/compartment basis over a wide area. Additional location-specific (stand/compartment) data (e.g., slope, aspect, land use history, stand stocking, known pathogens, and burn regime) could be used to determine patterns in mortality. Additionally, understanding baseline or typical mortality rates for each species could be helpful in determining if the patterns observed locally are cause for added concern. Data sources include forest, fire, and endangered species management data sets and time-series aerial photographs and remote sensing images of the installation.

It may be possible to use remote sensing technology to identify declining trees. In addition, coring of symptomatic and asymptomatic trees may provide information on growth impacts leading to mortality. This research would ideally be conducted in conjunction with other studies such as complete root system excavation to correlate tree symptoms, fungal infection, root feeding insects, and site conditions. Longleaf pine should be studied concurrently with loblolly pine to assess proactively the potential risk to this species.

Questions to help guide mortality research include:

- What is the actual loss rate of the affected loblolly pines? Is there really a significant increase in mortality, or is this a perception influenced by the special concern for suitable den trees to support the RCW? Reliable numbers of tree deaths over time must be acquired so that a loss rate may be calculated.
- Did the drought of 1999-2001 affect root growth such that it left some trees weakened and more susceptible to other stresses? Is this a recurring problem?
- Are conifers in general (or loblolly pines in particular) becoming more susceptible to disease because of increased stress due to global climate change?
- Are the same root pathogens present in multiple regions? Are the same root-feeding insects present in all regions? Are they a primary causal factor? Or are they secondary, attacking already weakened trees?
- When do we consider a stand in decline? Is there some numeric threshold which should or could be applied? Both temporal and spatial patterns must be considered.

Pathogenicity

Studies and other manipulative experiments with suspected fungi (e.g., various *Leptographium* species, *Heterobasidion annosum*) on trees should be conducted to determine correlations between site factors and disease susceptibility. Questions to be explored include:

- What are the pathological consequences of *Leptographium* sp. in longleaf pine roots? Can this be tested by inoculation of the fungus on roots?
- Does *Leptographium* have long-term survival in soils? Does this have implications for reforestation objectives?

- Are the same symptoms occurring on loblolly pine growing within its optimal site conditions as presently observed on "off-site" pine growing in nonoptimal locations?
- Do *Leptographium* populations have the same genetic diversity in different areas? Do they differ between areas?

Regional data needs

Regional forest health data are needed in order to gain a better understanding of the relative condition of stands at particular installations such as Fort Benning. An analysis of such data could then be used to develop distribution maps of "relative forest health." Regional data needs include:

- A better understanding of southern pine (with an emphasis on longleaf) physiological responses to interacting environmental stresses including those associated with climate extremes. To address longleaf responses, these analyses should be conducted both in naturally regenerated forests and in plantations that have followed land abandonment.
- An integrated and managed list of geographic locales and health problems.
- Continued development of scale- and forest setting-appropriate remote sensing technology that can be integrated with field monitoring information using global positioning and geographic information systems (GPS/GIS).
- Models that reflect spatial and temporal patterns of species- and forest system-specific pathogenic infection and spread, and tree mortality rates as well as relationships between these patterns and local and regional stressors and stand conditions.
- Information on whether decline is evident more so in the Piedmont / Fall Line than in the Coastal Plain. (Anecdotal evidence suggests decline is not present in Coastal Plain conifer forests.) Are soil types different and a contributing factor?
- Information on whether longleaf is also declining. If so, does the same pattern of decline exist as in loblolly pine? (Anecdotally and partially supported by recent surveys, no).

Regeneration

More precise predictions of the rate of development of regeneration under a wide range of conditions will be needed to more accurately project how long it will take cohorts of underplanted seedlings to develop into over-

story trees. Establishing longleaf seedlings as advanced regeneration and releasing them later from either mortality and/or selective harvesting may be a strategy that allows for slow conversion while the undesirable pine species provide habitat until longleaf is habitable. In sites where it is desirable to more rapidly establish and grow longleaf, patch clearcut is an option. However, considerable thought needs to be incorporated into silvicultural prescriptions for the type, density, and pattern of arrangement of legacy trees that are retained in the patch cut. The efficacy and consequences of the retention should be closely monitored (e.g., do live trees that are retained have greater risk of mortality).

RCW

Loss of many existing trees, leading to the development of very low-density mature pine stands, might have several implications for RCW management. First, such stands might prove to be high-quality foraging habitat and the birds would continue to thrive despite excessive pine mortality. Second, RCW groups might continue to do well but would expand territory sizes such that population density was reduced, forcing changes in the allocation of space to groups. Third, RCW foraging conditions could be compromised affecting fitness and, ultimately, population dynamics, which would make it difficult or impossible to achieve recovery objectives. Research on use of such stands by RCWs and impacts on fitness both on Fort Benning and elsewhere is needed to distinguish between these possibilities. An additional question is whether something can be done to extend the life of RCW trees to avoid a bottleneck. One suggestion that may be feasible is to fertilize individual trees, although one experimental attempt to do this had poor results (Balbach, personal observation, 2007).

7 Management Recommendations

Monitoring

Development of a monitoring program that can detect changes in the landscape, coupled with landscape-level simulation models of forest structure and woodpecker population demography, should be a high priority. As with regional data needs, a robust monitoring program could use remote sensing technology integrated with field monitoring information using GPS/GIS. An emphasis on site characteristics, past land use, current stand conditions, and the spatial distribution of unique habitats and rare species populations would allow assessment of causes and consequences of patterns in mortality to be more fully evaluated. The range of forest health conditions could then be identified by compartment or stand.

Next, an initial classification could be mapped of each compartment or stand based on overall forest health condition. Ideally, the condition of each compartment or stand would be analyzed based on similar aged stands on similar sites with similar land use and management histories. Stands should be characterized as:

- *Poor*: Stand health conditions are characterized by dying or dead trees (concentrated pockets or dispersed) that exceeds what is considered typical/expected;
- *Fair*: Characterized by scattered, random mortality of overstory trees that would be considered typical/expected;
- *Good*: Mortality and/or signs of weakened trees are not evident or are less than what would be considered typical/expected.

Ground-truthing of these initial classifications would allow refinement as needed.

Fire

Development of desired groundcover condition and inhibition of the hardwood midstory requires being able to burn the habitat effectively. Without fire, the release of hardwoods in gaps created by heavy mortality can be problematic in this ecosystem. Little guidance exists on how low pine basal area stands due to mortality will respond to fire. Pine mortality influences fuels in several ways. Pine fuels are critical in maintaining fre-

quent fire needed for diverse southern pine grassland woodlands (Mitchell et al. 2007). Secondly, hardwoods in the mid- and understory can be released by disturbances to the pine overstory. Since fire-sensitive hardwoods have fuel characteristics that differ widely from pine grassland fuels, fire prescriptions will need to be altered to deal with changing stand structural conditions. Monitoring hardwood dynamics in stands and treating them when necessary should be a high priority.

It seems unlikely that pine mortality will create difficulties in applying fire at the landscape scale that cannot be resolved by varying fire prescriptions. At the stand level, however, pine mortality quite likely will make it difficult to conduct effective burns (i.e., fires that suppress the hardwood midstory and promote desired groundcover) in some locations. Although other techniques (chemical and/or mechanical) can approximate the short-term effect of prescribed fire, none have proven effective in the long term in sustaining this ecosystem without fire (Provencher et al. 2002). In the long term, regeneration must be accommodated to sustain this forest.

Additional specific recommendations for Fort Benning

All general recommendations stated previously apply to Fort Benning and the region. This section presents several recommendations specific to the installation.

A further review of the Southern Forest Resource Assessment (2003) and FIA data may help determine whether the apparent forest health issue at Fort Benning is an anomaly or typical when viewed in a regional context. Given the unique set of disturbances and management necessities or constraints in Fort Benning and other bases, the connections among silvicultural treatments including fire, thinning regimes, herbicide use, etc. should be investigated in regard to the decline of loblolly pine.

Rather than attempt to adhere strictly to foraging habitat quality guidelines for RCW (USFWS 2003), Fort Benning should develop its own guidelines, driven by the objectives of providing a rich, herbaceous groundcover to provide prey for RCWs and mature trees on which the birds can forage. Basal areas of mature trees should be allowed to drop below the standards. In stands experiencing high levels of mortality of mature longleaf pine, cutting of other mature trees should be avoided as they will provide opportunities for natural regeneration. The impact of this on affected RCW groups should be monitored to inform future management strategies.

Silvicultural prescriptions for Fort Benning stands should at a minimum address the following, based on the stand characteristic classifications described in the Monitoring section at the beginning of this chapter:

In a poor stand: Assess current fuel loads and fire history. If conditions warrant, follow guidelines established by the Longleaf Alliance for restoring fire to long-unburned stands of longleaf (modify for loblolly and shortleaf pine as needed). Employ patch clearcuts/group selection harvests (with retention) within pockets of dead and/or dying trees (include a buffer zone to ensure containment). Regenerate these newly created pockets as soon as possible and restore to longleaf pine. In other stands where mortality is relatively high but scattered, run a cool, fast-moving fire through them (consider fuel loads and time since last fire) and mark to upgrade stand quality and health. Remove as much overstory basal area as necessary to foster successful survival, growth, and development of underplanted longleaf pine.

In a fair stand: Conduct cool, fast moving fire if not burned in the past 3–5 years. Mark stands to upgrade stand quality and health. Remove as much overstory basal area as necessary to foster successful survival, growth, and development of underplanted longleaf pine. Develop a multiyear action plan in accordance with the triage goal and prioritize the allocation of time, money, and resources.

In a good stand: Continue to burn these stands at the appropriate time, and place them lower on the priority list for selection harvests and conversion to longleaf pine.

This monitoring and management action plan should be implemented as soon as possible, and continued monitoring will be needed to determine effectiveness and make changes as appropriate

8 Conclusions

Research to date has not produced a consensus about whether the phenomena grouped under the term “pine decline” are linked either to each other or to a single underlying cause. Substantiating the extent and severity of these phenomena will provide useful information to understanding the causes and putting boundaries on the definition of pine decline. Presently its scope appears broad, but regional surveys of the extent of decline symptoms, and creative and inferred mathematical and statistical approaches, can narrow the scope of the issue. Survey information should incorporate species’ requirements for sustained productivity, the occurrence of soil resource limitations, climate and silvicultural activities that affect soil resource availabilities, forest management practices, and other anthropogenic patterns that exceed acceptable and natural patterns. Assessments of overlap between pine decline and forest management activities such as site preparation, fertilization, and prescribed burning may provide insight regarding the cause of pine decline.

It may be that the growing conditions for loblolly pine on Fort Benning and on similar previously abused sites across the region will not be sustainable for long-term successful growth to potential maturity of the species. The conditions on these sites are simply not comparable to those on sites where this growth potential for loblolly was originally observed. Rather, these sites are very different with respect to soil fertility, compaction, and disturbance. The ecology has become that of a permanently altered environment that could require centuries (or longer) to return to the conditions which supported growth originally. The decline of loblolly at this age and size on these sites may thus be entirely predictable and normal, with few proven measures available to prevent it.

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14. ABSTRACT

In order for the Army, and other land managers, to meet responsibilities for sustainable management of natural resources, they must closely monitor the health of those resources and respond to potential threats. A number of recent studies and reviews have suggested there may be declines in the health of southeastern forest ecosystems that support these facilities. These apparent declines involve multiple hardwood and softwood species such as oaks and pines, and appear to have a wide range of potential causes, including fungal and insect pests, air pollutants, and even climate change and the pre-military land use history. As an example, one facility has special concerns about the function of its pine-dominated forests in supporting endangered species, particularly the Red Cockaded Woodpecker (RCW). In their opinion, too many mature Loblolly Pines, which represent the majority of RCW cavity trees on that site, are dying. Younger trees and longleaf pine may also be affected. Other installations have reported concerns with other aspects of pine forest management as well. In a June 2007 workshop, researchers and land managers from several states met to examine the nature and possible causes of the problem from a regional perspective. The questions developed from the workshop by no means cover all the possible issues. Underlying all discussions were concerns that present long-term plans to manage these forest systems to support the recovery needs of the RCW might have to be totally revised. This report represents a summary of several separate reports prepared by groups of workshop participants.

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