

Loblolly pine decline on Ft. Benning: An analysis of potential underlying causes

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Abstract. The so-called loblolly pine decline syndrome apparently occurring at the Ft. Benning, Georgia military base is reviewed in the context of similar declines in some conifer forests in the southeastern United States. Loblolly pine is a prolific colonizer of abandoned agricultural sites and has been extensively planted and managed on many soil types from Texas through Virginia. Ft. Benning undergoes unique environmental impacts and the constraints which are compounded by constraints imposed by federal requirements for restoring and maintaining habitat for the red cockaded woodpecker. The current decline and mortality in existing mature loblolly pine stands threatens habitat restoration goals on this military base. Several interacting factors involving soil conditions, age class of existing loblolly pine stands, root disease causing fungi, insects, and silvicultural treatments are identified as potential contributing agents. Given the involvement of these factors in loblolly pine mortality, researchable questions that should be addressed are articulated in this paper that involve both short term and long term studies.

Introduction

The Ft. Benning, Georgia, management program for the endangered Red-cockaded Woodpecker (RCW) has been in place for more than 10 years. While the RCW is traditionally associated with the longleaf pine (*Pinus palustris* Mill.), a majority of the Ft. Benning nest cavities are found in the generally smaller and shorter-lived loblolly pine (*Pinus taeda* L.). Although forest management operations that are conducive for the woodpecker populations have been proceeding as mandated, mortality of essential loblolly pine stems seems to occur at a rate much greater than the rate at which stand conversion to longleaf pine is proceeding. In addition, some of the causes and factors postulated as causative might also result in slow or poor longleaf pine stand establishment through the region. This paper explores a set of possible causes and contributing factors in loblolly pine mortality on Ft. Benning and throughout the region, providing insight into pertinent researchable questions that should be posed to address this problem

Background

The forest history of Ft. Benning and the region is characterized by over a century of deforestation, followed by subsistence farming and consequent soil erosion. Indeed, most of the arable land in the southeastern United States has undergone similar degradation, and forest cover was reduced to about 20 percent during the last half of the 19th century (MacCleery 1992). Reforestation efforts after the 1920's and reversion of abandoned farm land to forest land were key in the development of the current forest vegetation in the southeast (MacCleery 1992). The western half of Ft. Benning was purchased in 1918, to support WWI mobilization and training. The eastern half was added in 1939-41 in preparation for WWII. In both cases, the lands 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). This pine species' natural range extends from east Texas across 14 southern states to southern New Jersey. In its original distribution, it is scarce on deep sandy soils of the lower Atlantic coastal plain, the sand hills of North Carolina and South Carolina, and was important in only localized areas of southeastern Georgia and Northern Florida (Little 1971, Baker and Langdon 1990). Due to its rapid growth, loblolly pine has become a very important commercial species, and is also aggressive in colonizing abandoned agricultural fields and other disturbed areas. This attribute has led to one common designation of this species as "old field pine". Despite its extensive range, 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 Ft. Benning are not inherently well suited to loblolly pine, although it was planted as a reforestation measure from the 1930s onward, and, as noted above, is an effective invader when fire is suppressed. Much of Ft. Benning was afforested by natural invasion in the 1930s through about 1950, and loblolly pine was then extensively planted as a best forestry practice from the mid 1950s 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 Red-cockaded Woodpecker (RCW) population and currently have become subject to current high mortality rates.

Characterization of symptoms and mortality

Widespread 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, trees exhibit symptoms not unlike littleleaf disease of shortleaf pine (Campbell and Copeland 1954), i.e., progressively thinning crowns, shortening needle length, and off color needles. Since

1968, there are two other reports dealing with this issue on National Forests in Alabama (Hess et al. 1999, Eckhardt et al. 2003). Crown symptoms generally appear about age 40 while stands older than 50 to 60 years sustain severe mortality. Trees apparently succumb within a few years after the initial onset of symptoms. The affected Ft. Benning trees generally meet these age and condition criteria.

Possible causes and associated influences

Loblolly pine presently has a broad geographic range and is a prolific seed producer; readily colonizing abandoned agricultural fields. It is a highly productive species on a wide variety of sites when managed properly, especially during the initial 30 to 40 years. On the other hand, when planted in so called “off site” situations, such as deep, nutrient poor upland sand hills, coastal plain deep sandy soils, or other soils of rapid internal drainage, stands of this age may be considered close to maximum age for optimal production (Schultz 1997).

Loblolly pine historically occupied a much narrower range of sites and soil types than where it is presently found. The tree species was a minor component of the original Piedmont forests and, in Coastal Plain sites, it does not compete well with longleaf pine when subjected to frequent fires (Schultz 1997).

Soils

In general, best growth for this tree species is achieved on moderately acid soils having imperfect to poor surface drainage, thick medium textured surface layers, and fine textured sub soils (Baker and Langdon 1990). Many, or possibly most, sites on Ft. Benning supporting stands of loblolly pine may not have suitable, much less optimal, soils for long-term productivity of this species.

Soil type and soil condition have long been recognized as a basic foundation of silviculture and site productivity (Smith 1962). Most soils on the southeastern upper

coastal plain and piedmont have undergone extensive erosion and disturbance caused by farming practices from the 19th to the mid 20th century (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, although not necessarily that amount at the Ft. Benning site. There is evidence that past land use legacies can have far-reaching consequences regarding forest soil nutrient levels. Nutrients and organic matter removed by repeated cropping, particularly organic carbon and nitrogen, can result in complex legacies affecting current and future forest nutrient status and productivity dynamics (Richter et al. 2000, Foster et al. 2003). Legacies resulting from somewhat distant past land use often are discernable and persistent imprints on ecosystems that affecting site productivity (Richter et al. 2000). The resulting changes continue to interact over time creating future complexities in soil conditions and productivity (Foster et al. 2003). In turn, changes in soil characteristics and nutrient balance can affect a suite of factors influencing physiological characteristics, such as growth efficiency, root architecture, or duff layer characteristics creating a complex mosaic over varying landscapes. Ft. Benning soils certainly meet these conditions.

We must note, however, that a major emphasis of the originally defined symptoms and causes of littleleaf disease (Brown, 1968; Coder, 1997; Hoffard et al. 1995) specified heavy clay soil which restricts drainage as a causal factor. The sites in question at Ft. Benning generally are of the opposite condition, i.e., fast-draining sands. Three of the five sites reported by Brown, however, were growing on Troup and Wagram soils, which are major soil series on Ft. Benning. Thus, in spite of the association of this syndrome with clay soils, it clearly was reported from soils similar to those on Ft. Benning.

Other factors also influence soil conditions, and the physical demands placed on soils by military use at Ft. Benning are surely contributing factors. While the effects of training activities have often been compared to forestry or agricultural practices, they differ in significant ways. Intensive training use may cause large areas to remain indefinitely in a “tilled” state, or a state lacking any vegetative cover, even short term growth. When revegetation is performed, growth of the plants on such sites may be much less than

anticipated. This has been attributed to the loss of nutrients and almost total absence of organic matter, the soil surface being the subsoil (B or C horizon) of the original soil. When the areas are used for tracked vehicle training, these surface layers are continually churned and mixed. While such areas do not cover the entire installation, and show this extreme disturbance only in localized zones, the situation represented is not conducive to successful reforestation even when training is shifted to another area...

Fire and other silvicultural treatments

Use of prescribed fire is an important silvicultural tool for management and control of hardwood competition in loblolly pine stands (Schultz 1997). A majority of the pine and mixed forests on Ft. Benning have been prescribed burned for 15 or more years, largely on a three year return cycle. The role of fire is unknown in the present discussion of decline, 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 (*Pinus palustris* Mill.) They hypothesize duff buildup in a longleaf pine stand after at least seven years of fire absence contributes to excessive tree 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 *Heterobasidion annosum* (Fr.) Bref. was also a factor in the decline of longleaf pine on these sites. They also observed a relationship between fire severity and amount of root feeding bark beetles within the first weeks post burn (Sullivan et al. 2003). In addition, direct heat effects such as cambial damage from excessive fire temperatures and heat pulse duration can also be a stressor. Some observers suggest that the three-year return cycle burn frequency on Ft. Benning may be too short for recovery from these stress effects. Duff conditions, however, are generally not similar to the condition described above, and ground-level fuel loads in Ft. Benning are normally not heavy.

Given the unique set of disturbances and management necessities or constraints in Ft. Benning and other bases, the connection between silvicultural treatments including fire, e.g., thinning regimes, herbicide use, etc. should be investigated in regards to decline of loblolly pine. Anecdotally, return of fire to longleaf stands has resulted in delayed tree mortality at several installations in the past 10 years.

Pathogens and insects

Root disease pathogens, particularly those affecting woody roots, are regarded as key drivers of forest ecosystems (Otrosina 2005). They may act as primary causes or secondary consequences of disturbance (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 silvicultural, ecological, and pathological factors that influence disease impact in these cases become very complex.

One characteristic of the *Leptographium* / Ophiostomatoid fungi is their association with root feeding bark beetles such as *Hylastes* sp. and *Hylurgops* sp. (Coleoptera:Scolytidae), which likely vector these fungi (Eckhardt et al. 2004). The beetles carry spores of the fungi presumably acquired from microscopic conidiophore's slime heads bearing sticky spore masses inside the insect galleries. Spores of these fungi are not suited to aerial dispersal so insects are a critical component of overland spread. Little is known of spore survival in soils or their longevity on insects.

Leptographium species have been associated with loblolly pine decline (Eckhardt et al. 2004, Eckhardt et al. 2007). This genus and associated genera of Ophiostomatoid fungi represent a spectrum of pathogenicity from non-pathogenic (blue-stain of lumber) to highly pathogenic (black stain root disease). The roles these fungi play are not clear, although several published studies discuss their occurrence and association with loblolly pine and other conifer mortality in the United States. There is evidence the pathogen species reported on longleaf pine and loblolly pine are associated with tree stress incited by complex interactions between silvicultural treatments, site conditions, insects, and tree

physiological status (Eckhardt et al. 2004a, Eckhardt et al. 2007, Sullivan et al. 2003, Otrosina et al. 2002). Generally, except for fungi like *Leptographium wageneri*, the cause of black stain root disease in the western United States, most of these fungi are opportunistic pathogens attacking already compromised trees (Harrington and Cobb 1988). Specific examples of *Leptographium* species associated with tree mortality following prescribed burning in longleaf pine (Otrosina et al. 2002, Sullivan et al., 2003), with loblolly pine decline in Alabama (Eckhardt et al. 2004a, Eckhardt et al. 2007), decline of longleaf pine (Otrosina et al. 1999), red pine decline (Klepzig et al. 1991), mortality in Scots pine (*Pinus sylvestris* L.) (Highley and Tattar 1985), and loblolly pine stands susceptible to southern pine beetle attack (Otrosina et al. 1997) illustrate the complexity of the present pathological situation in Ft. Benning. While these associations are suggestive of a possible causal relationship, they also involve interactions with other confounding factors, among them fire, soil conditions, ecological range, or silvicultural practice. Numerous other associations of *Leptographium* and other Ophiostomatoid genera and species with many other conifers worldwide have been reported. (Harrington and Cobb 1988, Jacobs and Wingfield 2001).

Although generally regarded as opportunistic, these Ophiostomatoid fungi may serve to hasten tree mortality. The infection process compromises the tree's ability to replace damaged roots, foliage, etc, which are a consequence of other stressors. Physiologically weakened trees, whether weakened by abiotic stressors such as drought, high temperatures, or nutrient deficiencies, or weakened by these fungi, are subsequently more susceptible to pathogens and insects. On the other hand, additional pathogens may be involved in loblolly pine mortality. *Heterobasidion annosum*, for example, is a destructive root rot pathogen that is prevalent in the region and root disease caused by this fungus is present region wide. The role of this and other pathogens in current mortality in Ft. Benning and other military installations (or other forested lands) in the region have not been investigated. Because root diseases are cryptic, and in many cases not identified without considerable effort, they are often overlooked in assessments of stand health. Also, growth losses by *H. annosum* infection can be significant (Tainter et al. 1989). Often, the additional stress resulting from root disease renders trees susceptible

to stem attacking bark beetles (Alexander et al. 1981, Cobb et al. 1974). In all these cases, the issue will always exist of whether the insects or fungi attack healthy, unstressed trees, or whether they require a previous incident of some weakening nature before they are able to gain entrance.

The question also exists as to whether we are dealing with introduced pathogens. The taxonomic and pathological relationships of the Ophiostomatoid complex fungi are poorly understood and it is important to understand precisely the pathogen(s) that are encountered in any study. Taxonomic positions of these organisms must be better defined; otherwise, their ecological and pathological roles will remain critically incomplete. Management regimes to mitigate effects of non-native pathogens can be different from those native to the ecosystem. Thus, a proactive approach to identify current and emerging threats is also a necessary strategy.

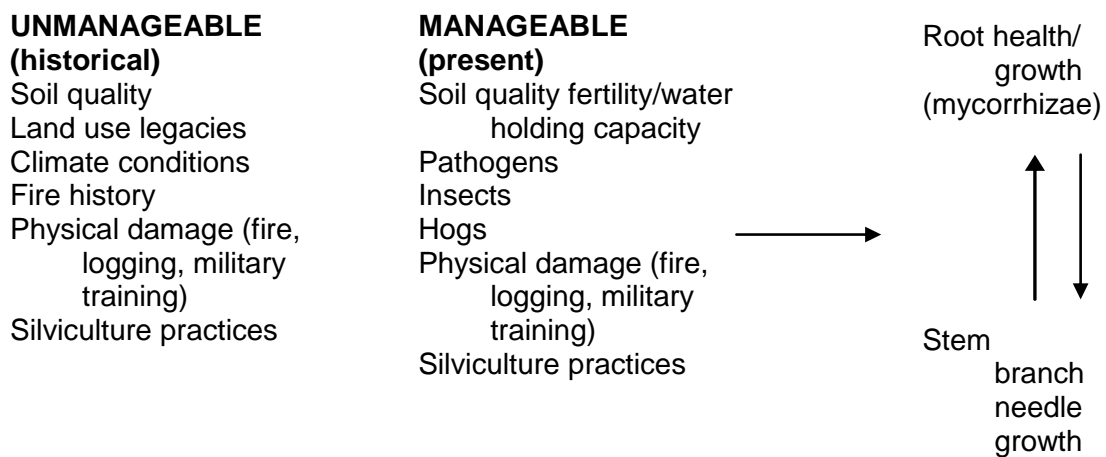
Weather and Climate

Several aspects of weather and climate may have a relationship to the present condition decline. It is known that this area suffered a period of high temperatures combined with low precipitation in the period 1999-2001 (Lozar, 2004). While not the most severe drought of record, it matched the most extreme moisture deficit of the 1920s. These conditions surely resulted in stress on all forest species to some degree. Is it possible that the stress and resultant loss of a substantial portion of the annual increment of root growth for 3 years in a row left many loblolly pine trees in a weakened condition? 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 in 2007 as well, given that the precipitation deficit appears similar and the region has been identified as being in extreme drought.

In the longer term, it is generally accepted that the climate of the region will become both somewhat warmer and have greater variability in extremes (Burkett et al. 2001). Only the degree of change is in question. Since diminished feeder root (rootlet) growth is

apparently one of the important underlying causes of littleleaf syndrome (Campbell and Copeland 1954, Hoffard et al. 1995), which has similarities to “loblolly pine decline”, these more extreme climatic swings suggest a decreased ability to maintain adequate root growth which, in turn, suggests a greater likelihood of decline and death for older trees on sites prone to drought stress.

All the above may be summarized in the flow diagram.



Embedded in the historical category is that the present modified ecosystem is the result of those past events and their consequences. These consequences can be far reaching and must be dealt with in the context of this current modified ecosystem (Foster et al. 2003, Richter et al. 2000). Indeed, loblolly pine stands on many sites in Ft. Benning may simply be approaching an age structure that is simply unsustainable given edaphic factors on which they occur, e.g. deep well drained sandy soils or old agricultural fields. Disease, insects, and other associated stressors acting on tree species presently on these sites may have unpredictable or more severe effects on ecosystem processes than existed prior to those disturbances. This concept has been defined as “exotic ecosystems”: A pathologically unstable ecosystem arising from changes brought about by past land use or current management practices (Otrosina 2005). Thus, it is important to determine whether decline (here meaning the set of symptoms outlined in the Introduction and Background, above) has always been present or are there novel conditions working at present.

Long Term Implications

It may be that the growing conditions for loblolly pine on Ft. Benning, and on similarly previously-abused sites across the region, are simply not sustainable for long-term successful growth to potential maturity of the species. The conditions are simply not those in which this growth potential was originally observed, but are a very different subset of conditions with respect to soil fertility, compaction, and disturbance. The growth conditions of the 18th, or even 19th, century no longer apply here. The ecology has become that of a permanently altered environment which could require centuries (or longer) to return to the conditions which supported growth originally.

Loblolly pines are also generally considered to be growing in sites different from those where they were originally found at the time of European settlement, the great spatial extent of loblolly growth notwithstanding. In regional forestry practice, the species is managed on a short rotation for smaller stem sizes, and only rarely is it anticipated that they will be maintained beyond 50 years, or 30-35 cm stem diameter. These sizes, however, are exactly those which are being used for RCW management. 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. 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.

More importantly for Ft. Benning, and all the military installations and others managing for the RCW, what does this imply for the success of the longleaf pine restoration/expansion which is taking place throughout the region? Are the sites which once did support longleaf pine still capable of doing so? And, are they capable of sustaining this growth to the 120 year age (and 50-60 cm diameter) being targeted in many locations? Or, will the same factors which appear to be causing decline of loblolly pine also affect longleaf pine plantings in the same manner? This must be asked, especially since recovery of the Red-cockaded Woodpecker appears to depend on such a

success in the long term. Is this still a sustainable goal? While we cannot reach a firm conclusion at this early stage in the longleaf pine restoration programs, we must caution that similar problems facing these efforts may well arise.

Researchable approach and questions

Stress is a common theme throughout this discussion, whether resulting from unmanageable historical events or to present and, in varying degrees, manageable processes. It is critical that the proper research questions be articulated to define the underlying causes, determine relevant approaches, and provide management with basic feasible solutions. Some of these critical questions are:

- 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 Red-cockaded Woodpecker? Reliable numbers of deaths must be acquired so that a loss rate may be calculated.
- Is longleaf also declining? If so, does the same pattern of decline exist as in loblolly pine? (Anecdotally, and partially supported by recent surveys, no).
- Did the drought of 1999-2001 affect root growth such that it left some trees weakened and more susceptible to other stresses?
- Are conifers becoming more susceptible to disease because increased stress due to global climate change?
- Is there something we can do to extend the life of RCW trees to avoid a bottleneck? (e.g. fertilize individual trees?) (Attempted earlier this decade, unsuccessfully)
- Is decline 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?
- Are the same root pathogens present in both regions? Are the same root feeding insects present in all regions? Profile root feeding insects in the region.
- 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?
- When do we consider a stand in decline? Is there some numeric threshold which should/could be applied? Both temporal and spatial patterns must be considered.
- Are the same sets of symptoms occurring on loblolly pine growing within its optimal site conditions as presently observed on “off site” pine?
- Do *Leptographium* populations have the same genetic diversity in different areas? Do they differ between areas?

More research is needed to determine causality of mortality, including mortality patterns both locally and regionally. It may be possible to use remote sensing technology to correlate declining trees with hyper-spectral signatures. In addition, tree coring on symptomatic and non-symptomatic trees may provide information on growth impact leading to mortality. This research is conducted ideally with other studies such as complete root system excavation to correlate tree symptoms, fungal infection, root feeding insects, and site conditions. 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. Certainly, longleaf pine ought to be studied in conjunction with loblolly pine to assess proactively the existence of future risk.

Some of these studies could logically be rather short term, and not require massive efforts to acquire relevant data. Funding of appropriate studies immediately, would assist to provide actual data for many of these factors.

Resolution of the problem in the long term will require a multi-disciplinary approach utilizing regional comparisons among ecosystems. In the interim, we should apply the fundamental principles stated by Smith (1962) “It is far better to base practice on available knowledge than to ignore it and proceed on a mystic philosophy founded on vaguely suspected influences of unknown agencies”.

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