ASSESSMENT OF LOBLOLLY PINE DECLINE AND SITE CONDITIONS ON FORT BENNING MILITARY RESERVATION, GA

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Abstract—A decline of loblolly pine (*Pinus taeda* L.), characterized by expanding areas of declining and dead trees, has become prevalent at Fort Benning, GA. A 3-year study was conducted to determine the kinds of fungi, insects, and site disturbances associated with this problem. The insects *Dendroctonus terebrans*, *Hylastes salebrosus*, *H. tenuis*, *Pachylobius picivorus* and *Hylobius pales* were significantly more abundant in symptomatic than in asymptomatic loblolly pine plots. These root and lower stem-infesting insects consistently carried the fungi *Leptographium terebrantis*, *L. procerum*, and *L. serpens*. Root sampling revealed high levels of root damage and mortality, staining and infection with *Leptographium* species. This belowground damage and mortality preceded the expression of aboveground symptoms, such as short chlorotic needles, sparse crowns, and reduced radial growth. A sequence of interactions among this complex of organisms and abiotic factors is proposed as the cause of 'loblolly pine decline.' This study confirms the findings for loblolly pine decline at other geographic locations and validates the Loblolly Pine Decline Risk Map.

INTRODUCTION

Loblolly pine decline is a syndrome associated with loblolly pine (*Pinus taeda* L.) in the Southeastern United States that is reported to occur from eastern MS to central AL, and GA to SC and NC. This decline is similar in symptomology to other pine diseases, such as littleleaf disease of shortleaf pine (*P. echinata* P Mill.) (Campbell and Copeland 1954), and has approximately the same geographic range. The cause of littleleaf disease is usually attributed to a combination of soils that have poor drainage and to the presence of *Phytophthora cinnamomi* Rands (Campbell and Copeland 1954, Oak and Tainter 1988, Roth 1954). Loblolly pine decline complex is characterized by lateral root deterioration prior to crown symptoms, loss of fine roots before mortality, and heavy cone crops. The declining crowns occur within the 30 to 50 year age class when trees express decline symptoms and die prematurely. There is no evidence of bark beetle activity, foliage disease, or heart rot disease to account for the mortality. Loblolly pine decline occurred on sites with abiotic or biotic stress factors that may cause changes in the host chemical profile. These changes are attractive to root feeding insects that vector the fungal pathogen *Leptographium*. The stress conditions affecting host vigor on these sites favor an increase in root-feeding insect populations and associated vector activity (Eckhardt and others 2007, Otrosina and others 1997). *Leptographium* species are vectored by at least 16 different species of Coleoptera. Although an increase in root-feeding insect activity is necessary for the decline to develop, these insect vectors by themselves, do not account for tree mortality. The increase in root-feeding insects does correspond to increased *Leptographium* colonization in roots and contributes to mortality (Eckhardt and others 2007). The primary predisposing factor for initiation of decline apparently relates to site topography parameters found in association with the presence of decline. Loblolly pine decline is generally associated with well-drained convex site features located on moderate to steep slopes with a southerly aspect, and trees in a state of low vigor. A nondecline site tends to have relatively flat to concave site features with a northerly aspect and is associated with trees in a high state of vigor (Eckhardt 2003).

The spatial patterns of abiotic factors in loblolly pine decline identified by Eckhardt (2003) were used in a Geographical Information System (GIS) to delineate loblolly pine decline at a landscape level. In that study the biological data corresponding with the presence of decline was used to identify abiotic parameters and produce a Loblolly Pine Decline Risk Map (LPDRM). The primary question is whether this mapping technique is applicable in delineating loblolly pine decline in other geographic regions with symptoms of loblolly pine decline? This study addresses this question by using the LPDRM in another geographic area and tests the map efficacy in delineation of the biological parameters corresponding to decline.

MATERIALS AND METHODS

The LPDRM was created for the study area Fort Benning Military Reservation (FBMR) which is located in the midwestern portion of GA's Muscogee and Chattahoochee counties that are mid-state on the eastern AL border. The predominant land base is Upper Coastal Plain with some Piedmont transition zone along the Fall Line. FBMR personnel provided the topographic and geographical data from their geospatial database. Topographic data were derived from the 10m Digital Elevation Model (DEM), which is based on contours obtained from the U.S. Geological Survey (USGS) 7.5 minute (1:24,000) topographic quadrangles. Slope and aspect were derived from multiple DEM coverages of the FBMR area. The shape file coverage for FBMR was used to delineate reservation boundaries, stands, compartments, roads, and streams for the pine decline risk map assessment. All data gathered were georeferenced and projected in Universal Transverse Mercator 83 (UTM83) and thus constitute a geographic database of FBMR, Georgia.

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ArcView 3.2 (ESRI 1996), along with the Spatial Analyst extension (ESRI 1996), was used to combine and analyze the different maps created by a series of ArcView 3.2 functions containing multiple steps that create, merge, and intersect parameters of loblolly pine decline. The resulting product spatially presents the topological parameters in a multicolored polygon map (green = minimal, yellow = low, magenta = moderate, and red = high) to classify the level of loblolly pine decline. The reclassified data from the aspect and slope maps have polygons that contain combinations of unique topological parameters associated to decline and represent the occurrence of some level of loblolly pine decline as described by Eckhardt (2003).

Thirty-six 0.07-ha plots were located using a Global Positioning System (GPS) and established using Forest Health Monitoring (FHM) protocols (Dunn 1999). The location of the plots was determined using LPDRM to designate a site as either symptomatic (decline) or asymptomatic (healthy). There were 15 asymptomatic and 21 symptomatic plots established. The symptom categories were divided into four loblolly pine age/size classes: seedlings/saplings < 10-year age class (< 10.0 cm diameter), pulpwood 10- to 19-year age class [> 10.0 cm but < 29.75 cm d.b.h.], 20- to 40-year age class (>29.75 cm d.b.h.), and greater than 40-year age class (>29.75 cm d.b.h.). Pine decline study plots consisted of a 0.02-ha central permanent plot and three 0.02-ha subplots. The subplots were marked off 120 m from the central plot at bearings of 120, 240, and 360 degrees (Dunn 1999).

At each location, a root health assessment was performed on three dominant or codominant pines nearest to the center plot location. Tree species, diameter at breast height (d.b.h., approximately 137 cm aboveground), age, and 5- and 10-year radial growth increments were recorded from each of the root-sampled trees. Roots were collected from the 36 research plots during the summers (May, June, and July) of 2004 and 2005, with 18 plots sampled the first summer and 18 the second. The two-root excavation method was used in which three dominant/codominant trees nearest to the plot center were selected for sampling (modified from Otrosina and others 1997). Two primary lateral roots extending away from the tree base were excavated with hand tools from the root collar out to the approximate crown drip line for each selected tree. Root depth was also recorded at this time. Roots were visually examined for primary root damage and fine root presence or absence, damage, and/or death before removal from soil. Primary roots were defined as the major lateral roots extending from the base of the tree to the drip line. All secondary and feeder roots were categorized as fine roots. Roots that were shriveled and dried were tallied as dead. Trees with primary roots but no secondary root growth were tallied as having their fine roots absent. Damage caused by insects was determined by direct observation at the time of root sampling on every pine on all center and sub-plots. Infestation and damage caused by *Hylastes salebrosus* Eichoff, *H. tenuis* Eichoff, *Hylobius pales* Herbst., and *Pachylobius picivorus* (Germar) (all Coleoptera: Curculionidae) were estimated by sweeping soil away from the root collar and lateral roots, and looking for entrance/exit holes and pitch formation on the bark. Damage was also assessed in the laboratory by peeling the bark from the roots and looking for the presence of insect galleries. Root wedge samples were cut from primary roots at 16-cm intervals, beginning at 16 cm from the root collar. Also, random samples of 2- to 8-cm fine root samples were collected between primary root sample intervals. All root samples were placed in plastic bags and kept chilled in ice chests for transport to the laboratory. Fungal isolations from sampled roots were conducted as previously described by Eckhardt and others (2007). Logistic regression methods using PROCLOGIST (SAS Institute Inc. 2001) were used to analyze the incidence of staining fungi, root damage type, and root health in symptomatic versus asymptomatic plots.

Soil samples were collected from all root-sampled plots in 2004 and 2005. A soil auger was used to collect soil near the lateral roots of three dominant or codominant loblolly pine trees closest to the plot center using a collection pattern that followed Lewis and others (1987). The soil samples collected near each root were placed in individual plastic bags, kept on ice, transported to the laboratory and stored at 4 °C for no more than 3 days. Fungal isolations from sampled soils were conducted as previously described by Eckhardt and others (2007).

Insect activity on plots was determined using pitfall traps (adapted from Klepzig and others 1991) to capture root-feeding insects on the subplots of 31 center plots (three subplots per plot, 93 total pitfall traps) from March to May for the 2003 and 2004 trap year to allow for the best chance of bracketing the emergence period of most bark beetles (Drooz 1985). Insects were collected on a biweekly basis and transported to the laboratory for identification and isolation of associated fungi as described in Eckhardt and others (2007). Data were analyzed using generalized linear procedure models with repeated measures analysis in Proc GLM (SAS Institute, Inc. 2001). The model was Y = m + treatment, where m is the mean and treatment was the treatment effect. When significant treatment differences were indicated, means were separated by Fisher's Protected LSD test (P = 0.05).

Plot measurements taken on all center and subplots included tree species composition (pines and hardwoods), tree d.b.h., basal area (tree count using 10 factor prism 0.04-ha plot) for the loblolly pines, and total trees present (Dunn 1999). Additional measurements of sampled trees included age and growth increment (5 and 10 yr) (Dunn 1999). Other site data collected were aspect of slope, percent slope, elevation, topographic position, land form, and percent slope. These data provided a measure of site conditions, stand density, and influence of external stresses. Crown ratings of live crown ratio (comparison of crown length with total tree height), crown light (a measure of light impacting the crown from all sides and the top exposure), crown position (superstory, overstory, midstory, or understory), crown density (percent of crown outlined with living branches and foliage), crown dieback (the ratio of recent fine twig dieback to total live crown), and foliage transparency (percent sunlight transmitted through the living crown) were recorded for all loblolly pines with d.b.h. 12.7 cm or greater to describe relative tree health (FHM protocols, USDA 2001). Trees with high scores for live crown ratio, density and diameter and low scores for dieback and foliage transparency have increased potential for carbon fixation, nutrient storage and increased potential for survival and reproduction (USDA 2001). Crown evaluations quantitatively assessed current tree conditions and provided an integrated measure of site conditions, stand density and influence of external stresses. Resin sampling for vigor of hundred ninety eight trees were sampled (33/decline/age class) on the south side of each tree by punching a hole approximately 137 cm above ground with a 1.9 cm diameter arch punch (No. 149 Osbourne). A plastic resin sampler (Missoula Technology Development Center, Montana) was screwed in place over the punch hole with two wood screws. A pre-weighed polyethylene terephthalate (PET) Corning® 15 ml centrifuge tube was screwed into the resin sampler and left for 24 hours. Centrifuge tubes with resin were then collected, capped, and put on ice for transport to laboratory. Resin weights were determined. Plot measurements were analyzed using ANOVA. Data collections on study plots involving forestry mensurations, resin sampling, and crown conditions were conducted by Forest Service and University personnel trained and certified in the respective forestry practices and completed on a blind treatment basis (USDA 2001).

RESULTS

Topography

Plots had elevation ranges from 98 to 175 m and a 139 m mean, and aspect ranges from 5° to 360° and a 234° mean, with a slope range from 1 to 12 percent and a 6 percent mean. The assessment of the LPDRM for the 36 plots indicated accurate identification for 13 of 15 (86 percent) asymptomatic and 21 of 21 (100 percent) symptomatic plots. Slope greater than 5 percent was the only topographic factor that was statistically significant ($F_{1, 36}$=10.1, p=0.0031) by treatment. At slope greater than 5 percent, decline incidence increased. No other site topography factors had statistical significance when compared to treatment and when alone, appear to have only minor effects. Although the LPDRM was still highly accurate at identifying sites by symptom category and was used effectively to do so, other biological parameters associated with symptom categories were used to verify this as well (e.g., radial growth, crown condition, resin weight, root condition, and insect activity).

Growth Variables

Tree ages ranged from 6 to 84 years in the study plots. The range of d.b.h. measurements for loblolly trees sampled for growth and vigor was 10.4 to 53.3 cm. Higher mean d.b.h. was to be shown significant in symptomatic trees when correlated to radial growth ($F_{1, 49}$=5.42, p=0.0241) in the 10- to 19-year age category. The 5-year radial growth ranged from 4.5 to 31.4 mm, and 10-year radial growth was 9.8 to 58.45 mm. Asymptomatic plots had trees with increased radial growth in 5- and 10-year measurements. The increased 5- and 10-year radial growth was statistically significant in asymptomatic plots compared to symptomatic for the tree age categories 10 to 19, 20 to 40, and 40+ (table 1). The range of height for trees on the study plots was 16 to 88 feet. There was no significant difference in the mean d.b.h. and tree height measurements when overall means for symptomatic vs. asymptomatic trees were compared by age category. A response trend indicating reduced d.b.h. and tree height means for symptomatic plots began in the 30- to 39-year age category and continued through 40+ years.

Crown Condition

Three crown conditions (crown density, crown ratio, and foliar transparency) were found to be statistically significant when compared to symptom category. The age category for pulpwood (10 to 19) had foliage transparency reported as significant ($F_{1, 437}$ =14.27, p=0.0002) and in age category 20-40 crown ratio ($F_{1, 451}$=9.52, p=0.0002) was significant for symptomatic categories (table 2). This may be a result of crown rating tree locations, as not all crown rated trees were on the center plot where the plot is risk rated.

Resin Analysis

Mean resin weights were 10.8 g for asymptomatic and 6.1 g for symptomatic sampled trees. Resin weights on asymptomatic plots were statistically significant when compared to symptomatic plots and by age 10 to 19 years ($F_{1, 65}$=19.59, p<.0001), 20 to 40 years ($F_{1, 65}$=26.33, p<.0001), and 40+ years ($F_{1, 65}$=23.28, p<0.0001).

Root Condition/Isolations and Soil Isolations

Leptographium species were isolated from the primary and fine root samples from 23 of the 36 plots and from the soil in 5 of the 36 plots. *Leptographium* species isolated from the primary root samples were *L. terebrantis* Barras & Perry, L. *procerum* (Kendr.) Wingfield, *L. serpens* (Goid.) Wingfield, and an unidentified *Ophiostoma* sp. Only *L. procerum* was isolated from the fine roots. The overall proportion of *Leptographium* species isolated was higher from roots of trees on symptomatic plots (91 percent) than those from asymptomatic plots (0.08 percent). In addition, only *L. procerum* was isolated from the soil samples and was generally more common in soil from symptomatic (80 percent) vs. asymptomatic (20 percent) plots. Root system deterioration was significantly higher in symptomatic than in asymptomatic trees. Symptomatic trees consistently had more dead and fewer fine roots present, more physical damage from insects and fire, more staining of the primary roots, and a higher percentage of *Leptographium* species per root system.

Insect Variables

The total number of root-feeding insects (*Hylastes* spp.) and reproduction weevils (*Hylobius pales* and *Pachylobius picivourus*) captured in pitfall traps increased annually during the 3 years of trapping (1117 in 2003, 1253 in 2004 and 2423 in 2005). The mean pest insect abundance for all plots and years increased from 82.78 to 127.33. Mean insect numbers were significantly higher on symptomatic plots than asymptomatic plots for study years 2003 ($F_{1, 30}$=4.22, p=0.0495) and 2004 ($F_{1, 30}$=4.33, p=0.0468) (fig. 1). Mean insect abundance increased when plots had a history of disturbance (burning, thinning, or feral hog rooting) and when multiple disturbances occurred (fig. 2). Insect abundance by age category was statistically significant ($F_{3, 123}$ =10.52, p<0.0001) with higher abundance in precommerical (< 10 years) and 40+ years (fig. 3). Mean insect abundance of different root feeders was similar; symptomatic

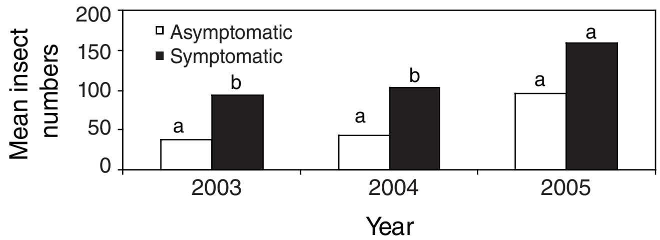

Figure 1—Mean insect abundance by plot treatment for all trap years on Fort Benning Military Reservation. Bars with the same letter at each treatment are not significantly different (P> 0.05).

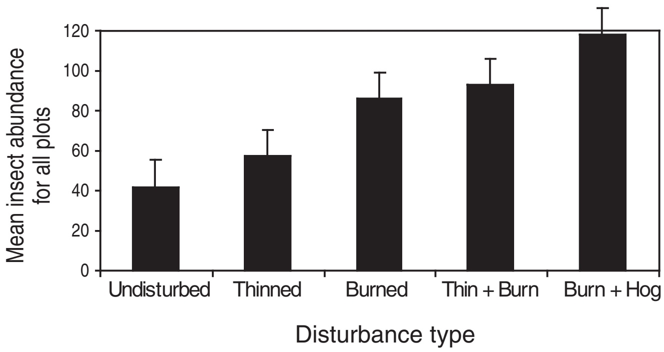

Figure 2—Mean abundance of insects captured at Fort Benning Military Reservation for all plots, all years, and segregated by the type of disturbance on plots.

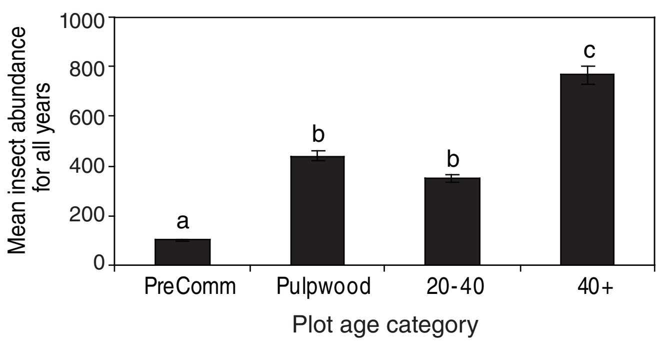

Figure 3—Mean insect abundance per plot for all trapping years (2003 to 2005) segregated by age category (PreComm <10 years, Pulpwood 10 to 19 years) of the plots on Fort Benning Military Reservation. Bars with same letter for each age category are not significantly different (p > 0.05).

plots had greater numbers than asymptomatic plots, and insects were more abundant in older tree age categories.

DISCUSSION

The abiotic factors that predispose trees to decline may be the result of changes in the pine physiology that provides an environment favorable to predisposing biotic factors (Hodge and others 1979). Decline symptoms appeared to be more pronounced in areas that had steeper slopes and a south-facing aspect. These microsite conditions are primarily associated with minor changes in topography that create distinctive environmental conditions and appear to be the essential elements correlating to the biology of decline. Microsite differences are often strongly correlated with whether the site is symptomatic or not, the presence of an association of root-feeding insects and *Leptographium* fungi, and loblolly pine vigor. The topography of microsites was correlated with abiotic conditions (positive or negative) to which loblolly pine responded physiologically with changes in growth parameters, vigor, insect abundance, isolation rates of *Leptographium* species, and root condition of the trees. Physiographic factors exert a general influence on stand quality, but microsite variation in percent slope and aspect are critical components in the distribution of either symptomatic or asymptomatic trees within a given stand. These findings are similar to results reported by Shoulders and Walker (1979) and Zahner (1958). Slope percentage may have an effect on soil moisture where a gentle slope of less than 5 percent is optimal. A slope of 1 to 2 percent is optimal for tree growth and vigor; and a slope in excess of 5 percent causes a reduction in tree growth and vigor (Lorio and Hodges 1968, 1971, Lorio and others 1972). The data reported here support these findings and are the essential elements to the validation of LPDRM accuracy. The strong association with a vigor condition led to an accurate identification of microsite locations for selecting plots within the proper symptom treatment. Aspect appears to affect the soil temperature (Marshall and Holmes 1988) and soil water balance in high latitude regions (Hanna and others 1982), and was correlated with loblolly pine decline (Eckhardt and others 2007). The effects of slope and aspect may combine to create microclimates within microsites. Adverse (symptomatic) microclimates act as a predisposing disturbance that alone or in combination with other inciting disturbances reduce tree vigor. Accurate delineation of microsites using the LPDRM provided by this study can provide managers with the opportunity to mitigate some inciting disturbances and lower the risk of decline.

The accurate delineation of microsites and their predisposing effect on loblolly pine and commensurate vigor response provided the study with a biological association (growth parameters) for assessing the LPDRM. Evidence for pine growth decline in the Southeastern U.S. has been reported by the U.S. Forest Service, Forest Inventory Analysis (FIA) to have occurred over the last decade (Bechtold and others 1991, Gadbury and others 2004), although no casual factors where identified. Other studies investigating southern pine decline complexes have also reported reduction in growth parameters that can be associated with abiotic and biotic stress factors (Eckhardt and others 2007, Hess and others 1999, Otrosina and others 1999, 2002). These studies suggest that southern pines exhibiting reduced growth parameters are associated with a reduced vigor condition. The past decade has experienced extremely high southern pine beetle activity that can be associated with pines of reduced vigor (Blanche and others 1983, Hicks and others 1980, Schultz 1997). This suggests that there may be predisposing ecological conditions that reduce the health and vigor of pines across the Southeastern U.S. This study may have provided some elucidation of possible factors affecting reduced growth and vigor of pines. Reduced growth reported in this study was consistently associated with predisposing physiographic factors associated with varied tree vigor. Symptomatic plots that exhibited lower stem growth values appeared to be similar to other Southeastern U.S. sites that had reduced growth. Reduced growth and vigor were physiological conditions that were used to assess the presence of an abiotic site stress brought on by microsite factors. Poor crown conditions and lower resin production were significant factors in association with loblolly pine decline. Trees with large, dense crowns, and high resin production were associated with asymptomatic sites. In contrast, trees with small, thin crowns, and low resin production were associated with symptomatic sites.

Resin flow is the primary defense of pines against insect attack and fungal invasion (Bridges 1987, Hodges and Lorio 1975). Relative vigor can be associated with the amount of resin production by loblolly pine. Trees that produced more resin for a given measured time period had greater vigor at asymptomatic microsite locations. The trees on symptomatic plots showed lower resin production when compared with trees on asymptomatic plots (fig. 1). The aboveground symptoms of reduced radial growth, increased foliar transparency, decreased crown density, and reduced resin production (low vigor), were displayed by trees in the symptomatic plots but not in the asymptomatic plots. Trees in symptomatic plots also had deteriorated root systems. These results are consistent with results from studies of other pines associated with *Leptographium* species (Leaphart and Gill 1959, Wagener and Mielke 1961).

The decline of loblolly pine at FBMR appears to have resulted from the debilitation of root systems infected with *Leptographium* species associated with root-feeding insects attracted by the weakened condition of potential host trees influenced by stress or onsite disturbances. This finding is consistent with the findings in similar pine decline studies (Eckhardt and others 2007, Hess and others 2005, Klepzig and others 1991). *Leptographium* species and root-feeding insects were consistently associated with declining trees, and the damage apparent in the root systems was typically higher in symptomatic trees (table 4). This is consistent with observations made for other pines with *Leptographium* species activity in their roots (Eckhardt and others 2004, Klepzig and others 1991).

Total pest insect numbers showed a greater than two-fold increase over the 3-year study. The average daily catch per trap of 30 for southern pine beetle is considered epizootic, and in 2005 an average of 43 root-feeding beetles were collected per day per trap. This association indicates that root-feeding beetles may be at abnormally high populations (epizootic) and spreading infection by *Leptographium* fungi. These insects were found to be a significant contributing factor in the occurrence of loblolly pine decline on symptomatic plots. The overall average number of insects and the average number of insects associated with some type of plot disturbance (i.e. thinning, burning, and feral hog rooting) were higher in all symptomatic plots compared to the asymptomatic plots. The same pattern occurred when counts made from undisturbed plots were compared to single disturbance plots. Multiple disturbance plots had consistently higher average insect catches than single disturbance plots. These data indicate that higher numbers of root-feeding insects are significantly associated with a disturbance and further suggest that any increase in the number of disturbances to which a site is subjected favors further increases in the population of root-feeding insects. The association of root-feeding insects and *Leptographium* species on disturbed sites and the occurrence of loblolly decline suggest that disturbance mitigation may be a management option.

Five insect species (*H. picivorus*, *H. pales*, *H. salebrosus*, *H. tenuis*, and *D. terebrans*) occurred in higher numbers in symptomatic than in asymptomatic plots. This corresponds to the increased levels of associated beetle activity within stands having an elevated incidence of *Leptographium* species reported for declining loblolly pine in Alabama (Eckhardt and others 2007), for stands showing red pine decline in Wisconsin (Klepzig and others 1991), and for stands exhibiting black stain root disease caused by *L. wageneri* (Hansen 1978, Harrington and others 1985). These root-feeding insects were consistently associated with *L. terebrantis*, *L. procerum*, and *L. serpens* and may be serving as vectors of these, as well as similar, fungi in other disease complexes (Klepzig and others 1991, Rane and Tattar 1987). Insect damage alone was not found to seriously affect the trees, but the resulting colonization by the introduced *Leptographium* species was extensive. All of the pestiferous insects (five root-feeding bark beetle and weevil species) and other bark beetles and fungus-feeding insects have had *Leptographium* fungi isolated from them. Conidia are produced in sticky drops on the heads of conidiophores growing from fungal hypae within beetle galleries. New infections are initiated when contaminated beetles (from broods developing in diseased roots) are attracted to disturbed or stressed stands, dig through the soil in search of suitable roots for breeding and feeding, and bore into roots of living trees. The weakening and killing of root systems can provide enough susceptible hosts (brood substrate) to maintain high bark beetle populations over time (Eckhardt and others 2004). *Leptographium* isolates from root samples were collected on plots with high populations of root-feeding bark beetles and weevils that are aggressive in their feeding habits, thus creating new wound courts and opportunities for fungal invasion. At high population levels, the aggressive feeding activity of these bark beetles and weevils appears to have a major role in the occurrence of *Leptographium* species within areas of decline, as demonstrated by high insect numbers trapped with consistent *Leptographium* isolations from these insects (Eckhardt and others 2007). The insect numbers trapped were also significantly correlated with the degree of decline and root disease (Eckhardt and others 2007). The high pestiferous insect population and their association with *Leptographium* species were correlated with *Leptographium* pine root disease (Eckhardt and others 2007). This study confirms the similar findings for loblolly pine decline reported by Eckhardt and others (2007) and Hess and others (2005) and thus validated the potential of the LPDRM system as a useful tool for identifying and managing this disease.

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