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ASSOCIATION BETWEEN BARK BEETLE POPULATION DYNAMICS AND SILVICULTURE DISTURBANCES IN DECLINE-IMPACTED LOBLOLLY PINE STANDS: YEAR ONE DATA

by
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ABSTRACT
Annually, bark beetles (Coleoptera: Scolytinae and Molytinae) cause extensive destruction in industrial pine plantations in the southeastern United States. Elevated bark beetle populations induce stress resulting in degraded crown conditions and therefore, contribute to pine mortalities. The present article discusses the population trends of the root-feeding *Hylastes* spp., using the sampling of insects captured in central Alabama and Georgia. Preliminary results indicate that the population *of H. porculus* and *H. salebrosus* illustrate a spring and fall peak. However, the population of *H. tenuis* appears to change frequently during a year.

INTRODUCTION
Loblolly pine (*Pinus taeda*) is a native pine species to the southern U.S., whose native range extends through 14 states from southern New Jersey south to central Florida and west to eastern Texas. Recently, loblolly pine decline (LPD) with symptoms of thinning and yellowing crowns, fine root deterioration and reduced radial growth, has become a serious problem in the southern U. S. It has been present in upland sites of central Alabama (first observed on the Talladega National Forest) since the 1960s (Brown and McDowell, 1968). Other areas of central Alabama have reported LPD, including National Forest lands in the Anniston, Heflin, Tuscaloosa and Bibb Counties (Hess, 1997; Allen, 1994).

LPD is associated with interaction of environmental, insect, and pathogen agents. Loblolly pines in predominately loam, sandy loam or sandy clay loam are quite susceptible to LPD. Also, tree age, topography as increased slope with S/SW aspect and organic matter content in the soil are primary predisposing factors for initiation of loblolly pine decline. For example, growth rates of loblolly pine will rapidly decline after age 40, if environmental factors such as drought, wind, and nutrient availability reduction happen, pines cannot suffer and those factors would increase the potential to infest LPD. Studies reported there is a high correlation between root decline and LPD, so root mortality is considered to be an associated factor. *Hylastes* spp. are root feeding bark beetles to typically attack weakened pines and have been associated with ophiostomatoid fungi, such as *L. terebrantis*, *L. procerum* and *L. serpens*. Those root pathogens including *Leptographium* spp. and *Ophiostoma* spp. have been consisitently found on sites suffering from LPD in central Alabama (Hess, N.J. et al., 1999, Eckhardt and Menard 2005).

High numbers of *Hylastes* spp. can significantly reduce host vigor by carrying spores of blue stain fungus to pine roots which blocks the movement of water and nutrients further weakening the tree, thus mass of root-feeding bark beetle attack may predispose trees to other pine bark beetle attack. The root-feeding beetles are attracted to trees that are under stress from natural and or anthropogenic causes (Eckhardt *et al.*, 2007) Ostrosina *et al.* (2002) reported longleaf pine decline associated with *L. terebrantis* and *L. procerum*. Zanzot *et al.* (2010) also have found *Grosmannia huntii* associated with longleaf pine (*P. palustris*) and the insect vectors *H. salebrosus* and *H. tenuis*. *Leptographium serpens* and *G. huntii* are newly reported to the U.S., are pathogenic, and *L. serpens* has been added as a candidate for Southern Region Priority Invasive Species list. Otrosina *et al.* (1997) and Hess *et al.* (1999) have found that declining loblolly pines appear to be more vulnerable to attack by SPB than healthy trees in the southeastern U.S. Campbell *et al.* (2008) reported species richness of Scolytidae (Coleoptera: Curculionidae) was higher following anthropological disturbances such as thin plus burn plots and thin only plots when compared to untreated controls in longleaf pine stands on the Coastal Plain of Alabama.

Consequences of treatments should be well understood prior to implementation, because knowledge of bark beetle trends and population level responses to common silvicultural disturbances proves vital to forest managers in making management decisions. This study was developed to quantify fluctuations in pathogen-vectoring beetle populations as a response to harvest and thinning disturbances and the interrelatedness of trends among beetle species. The objectives of this project are:

(1) Quantify the populations of *Hylastes* spp. and other pine bark beetles in stressed and healthy loblolly pine stands through 3 different periods (spring, summer, and fall) before and after treatments;
(2) Compare bark beetle population changes one year following traditional thinning, clear-cut, and control treatments;
(3) Estimate aspects of tree vigor prior to and one year following treatments;
(4) Relate all managements and site characteristics to changes in populations of bark beetles

MATERIALS AND METHODS

Study Sites and Plot Descriptions

Five study sites have been installed on Forest Health Cooperative Member property in central Alabama and Georgia: SS (Sizemore & Sizemore locations in AL), RAY (Rayonier locations in GA), WEY (Weyerhaeuser locations in AL), WV (Westervelt locations in AL) and F&W (F&W locations in

GA) study sites (Table 1). In each study site, nine Forest Health Monitoring (FHM) plots with three treatments were established, including three plots for thinning, three plots for clear cutting, and three plots for control (no treatment) (Table 2). Loblolly pine on all plots exhibited decline symptoms. Forest Health Monitoring plots were established at each research site (Fig. 1). These plots consist of one central plot and three subplots identical to the central plot. The subplots are located 120 ft away from the central plot at a bearing of 120°, 240°, and 360° (Dunn, 1999). Research sites were established in January 2009 and are being monitored 1 year pre- and post-treatment (dates dependent upon when members completed treatment on plots).

Table 1. Locations and characteristics of sites used in the study of loblolly pine decline in central Alabama and Georgia.

Plot	County	Location	Stand Age	Pine Basal Area	Total Basal Area	Slope	Aspect[a]	Land Form	Topographic Position
Ray 1	Lumpkin	N 32.002 W 84.977	15	110	110	14	N/NW	v	Side-slope
Ray 2	Lumpkin	N 31.997 W 84.860	17	140	160	4	E/NE	v	Ridge-top
Ray 3	Lumpkin	N 31.992 W 84.904	15	210	210	0	NA	f	Ridge-top
Ray 4	Lumpkin	N 32.014 W 84.970	15	100	100	8	SW	c	Side-slope
Ray 5	Lumpkin	N 32.009 W 84.969	15	100	100	6	S/SW	f	Side-slope
Ray 6	Lumpkin	N 31.992 W 84.866	17	200	200	1	NA	f	Ridge-top
Ray 7	Lumpkin	N 31.890 W 84.956	21	140	150	2	NW	f	Ridge-top
Ray 8	Lumpkin	N 31.893 W 84.950	21	140	150	8	SE	v	Side-slope
Ray 9	Lumpkin	N 32.003 W 84.981	15	120	130	10	E/NE	v	Side-slope
SS 1	Dadeville	N 33.087 W 85.879	17	160	170	19	E	v	Toe-slope
SS 2	Dadeville	N 33.090 W 85.884	17	170	170	4	NW	c	Toe-slope
SS 3	Dadeville	N 33.085 W 85.880	17	140	140	19	NW	v	Nose-slope
SS 4	Dadeville	N 32.913 W 85.709	25	110	110	3	SE	v	Nose-slope
SS 5	Dadeville	N 32.9126 W 85.699	25	130	140	4	E	v	Toe-slope
SS 6	Dadeville	N 32.9119 W 85.695	25	130	150	3	NW	f	Ridge-top

Table 1. (Continued)

Site	County	Location	Stand Age	Pine Basal Area	Total Basal Area	Slope	Aspect	Land Form	Topographic Position
SS 7	Dadeville	N 32.9110 W 85.714	25	70	90	2	SW	f	Toe-slope
SS 8	Dadeville	N 32.913 W 85.715	25	120	140	5	NE	c	Toe-slope
SS 9	Dadeville	N 32.916 W 85.713	25	110	110	1	NW	f	Side-slope
FW 2	Cusseta	N 32.189 W 84.858	16	150	150	6	S/SW	v	Side-slope
FW 3	Cusseta	N 32.185 W 84.860	16	170	170	8	N/NW	v	Side-slope
FW 4	Cusseta	N 32.191 W 84.859	23	140	160	6	NW	v	Ridge-top
FW 5	Cusseta	N 32.174 W 84.839	19	150	180	11	N/NE	v	Toe-slope
FW 6	Cusseta	N 32.156 W 84.942	22	100	130	19	SE	v	Side-slope
FW 7	Cusseta	N 32.150 W 84.934	31	120	160	1	NA	f	NA
FW 8	Cusseta	N 32.154 W 84.932	22	90	140	8	S/SE	v	Side-slope
FW 9	Cusseta	N 32.152 W 84.930	31	80	120	1	NA	f	Ridge-top
WEY 1	Marion	N 32.755 W 87.4126	12	140	140	13	NW	v	Toe-slope
WEY 2	Marion	N 32.750 W 87.4128	12	140	140	2	N	v	Ridge-top
WEY 3	Marion	N 32.759 W 87.4121	12	150	160	13	W/SW	v	Ridge-top
WEY 4	Marion	N 32.796 W 87.4357	27	100	110	30	SW	v	Side-slope
WEY 5	Marion	N 32.794 W 87.4353	27	80	110	6	W	v	Side-slope
WEY 6	Marion	N 32.743 W 87.401	12	140	150	3	N	v	Ridge-top
WEY 7	Marion	N 32.655 W 87.280	29	80	90	6	W/SW	v	Ridge-top
WEY 8	Marion	N 32.658 W 87.277	29	70	110	18	N/NW	v	Side-slope
WEY 9	Marion	N 32.661 W 87.276	29	100	110	10	N	v	Side-slope

Table 1. (Continued)

Site	County	Location	Stand Age	Pine Basal Area	Total Basal Area	Slope	Aspect	Land Form	Topographic Position
WV 1	Tuscaloosa	N 33.217 W 87.891	15	170	180	22	N/NW	v	Side-slope
WV 2	Tuscaloosa	N 33.214 W 87.893	15	180	190	18	W	v	Side-slope
WV 4	Tuscaloosa	N 33.2057 W 87.949	18	150	170	14	NW	v	Side-slope
WV 5	Tuscaloosa	N 33.2058 W 87.948	17	160	180	8	NW	c	Side-slope
WV 6	Tuscaloosa	N 33.206 W 87.949	17	120	120	26	E/NE	v	Ridge-top
WV 7	Tuscaloosa	N 33.181 W 87.928	50	40	40	5	NE	v	Ridge-top
WV 8	Tuscaloosa	N 33.1814 W 87.927	51	40	40	9	E/NE	v	Ridge-top
WV 9	Tuscaloosa	N 33.191 W 87.904	50	80	100	28	SW	v	Side-slope

[a] NA: no aspect.

Table 2. Treatment Schedule

Study Sites	Traditional Thinning	Clearcut
F&W	No current schedule for completion	Nov. 19th, 2009-Jan.29th, 2010
SS	Nov. 20th, 2009-Feb. 24th, 2010; Oct. 9th,2010-present	Feb.2010(plot 9 only)*; Restarted Oct.7th-present
RAY	Nov.19th, 2009-Dec.4th,2009	Nov. 19th, 2009-Dec.4th, 2009
WEY	July 25th, 2010-Aug. 10th, 2010 (Plot 2 has not been thinned)	Dec.16th,2009-Feb.28th,2010
WV	July 21st, 2010-Aug.5th, 2010	Dec.9th,2009(WV9); Jan.7th,2010 (WV7,8)-Jan,22nd, 2010

N/S: not started; *: not finish.

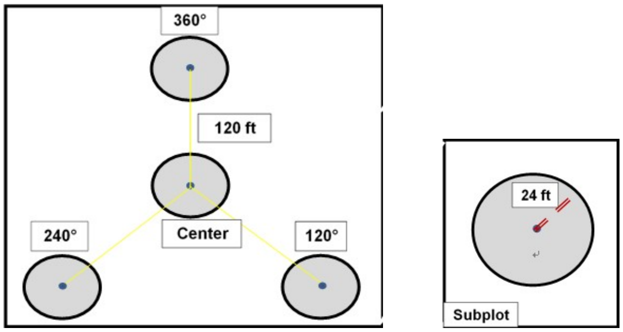

Figure 1. Plot Layout in Each Selected Site

Plot Monitoring

Loblolly pines on each subplot within a 24 feet radius were rated based on FHM standards to determine crown condition as a vigor and disease indication. Several vigor parameters such as DBH, live crown ratio, crown light, crown position, crown density as well as crown dieback and foliage transparency were measured and recorded pre-treatment. Five- and ten-year radial growth will be assessed along with the growth parameters of DBH and height. Stand conditions including basal area, slope inclination (%), slope aspect (NW, W, SW, S, SE, E, NE, N), and convexity of each plot will be obtained.

Insect Sampling

Three types of insect traps (panel, flight intercept (FIT), and pitfall trap) were installed on each plot to capture bark beetles and their predators, root and lower stem colonizing beetles and adult root colonizing insects. Panel traps are made of black colored corrugated plastic, and it is designed for monitoring forest Coleoptera. A plastic cup with anti-freeze is hung on the bottom of the panel trap in order to store captured insects. Pitfall traps consist of 20-cm sections of 10-cm-diameter polyvinyl chloride plastic drainpipe with eight entrance holes equally spaced around the pipe circumference at one end. The interior of each trap is coated with a thin layer of liquid Teflon to prevent the escape of the captured insects. Both ends were capped with removable plastic lids, and two holes were drilled in the bottom lid for drainage. The traps were buried, leaving entrance holes slightly above ground level. Flight intercept traps (FIT) are made of plastic milk jugs fitted with a small cup at the bottom. Two 8 ml glass vials filled with southern pine turpentine and 95% ethanol are installed in every trap. In addition, fresh loblolly pine twigs, which were approximately 3 cm long by 1cm diameter, were put into pitfall and FIT traps in order to keep captured insects. Traps would be monitored and sampled every two weeks year-round for two consecutive years (one year pre- and one year post-treatment). Captured insects were placed in sterile polyethylene transported back to the laboratory for sorting and identification.

Root Sampling

Lateral roots (> 2cm) from three dominant/codominant loblolly pines per subplot were sampled pre-treatment from October 2009 to March 2010 by using the two-root excavation method modified from Otrosina *et al.* (1997). From each tree, two lateral roots were excavated up to 1 m from the tree base (horizontal). From each root, three root cores (5 mm in diameter and approximately 30mm in length) were collected using an increment hammer (Suunto USA, Inc., Ogden, UT). The hammer was sterilized by spraying 95% ethanol after sampling each tree and allowed to air-dry to preclude contamination. Samples were placed in plastic bags, transported back to the laboratory in a cool ice chest, and kept at 4 °C until processed.

To determine the presence of *Leptographium* spp., surfaces of root tissues were sterilized with commercial bleach, ethanol, and distilled water (10:10:80 v/v/v), and were cultured in CSMA media (3 per plate, 2 plates per tree) for isolating blue-stain fungi. After 2 weeks, the plates were examined for fungal growth and putative *Leptographium* spp. isolates were ultimately cultured to slants for storage.

RESULTS

Description of study area

Since all data has not been collected, many differences cannot currently be assessed. Plots were distributed across most slopes and aspects. Pre-treatment data of crown conditions (Table 3) showed loblolly pine plantations at SS sites appear more vigorous (Avg. DBH=8 in, Crown density=40) than the other three sites, although all plots are exhibiting symptomology (thinning crowns and short chlorotic needles). Stand conditions including basal area, slope inclination (%), slope aspect (NW, W, SW, S, SE, E, NE, N), and convexity of each plot will be obtained (Table 1).

Table 3. Average values of pre-treatment data on crown conditions.

Study Site	DBH (in)	Crown Ratio (%)	Crown Light	Crown Position	Crown Density (%)	Crown Dieback (%)	Foliage Transparency (%)
F&W	6.4	30	1	2	30	0	30
RAY	6.2	30	1	2	30	0	30
SS	8	35	1	2	40	0	35
WV	7.5	35	1	2	35	0	35
WEY	7.8	35	1	2	35	0	35

Insect Activity

A total of 15,785 beetles and weevils from 25 species in family Curculionidae were captured from March 2009 to February 2010 (Figs.2 and 3). Four species of scolytine bark beetles (*Hylastes porculus*, *H. salebrosus*, *H. tenuis*, and *Ips grandicollis*), two species of molytine weevils (*Hylobius pales* and *Pachylobus picivorus*) and four scolytine ambrosia beetles (*Gnathotrichus materiarius*, *Xyleborus pubescens*, *Xyleborinus saxesenii*, *Xylosandrus crassiusculus*) were captured most frequently. Other scolytines and curculionidae captured included *Dendroctonus terebrans* (n=129), *D. frontalis* (n=7), *I. avulsus* (n=51), *Xylosandrus compactus* (n=138), *Monarthrum mali* (n=113), *M. fasciatum* (n=47), *Xyleborus atratus* (n=88), *Xylosandrus germanus* (n=46), *Pissodes nemorensis* (n=128), *Orthotomicus caelatus* (n=37), *Xylosandrus mutilatus* (n=709), *Xyleborus ferrugineus* (n=7), *Trypodendron scabricollis* (n=33), *Pitybonus comatus* (n=102), and *Dryoxylon onoharaensum* (n=141).

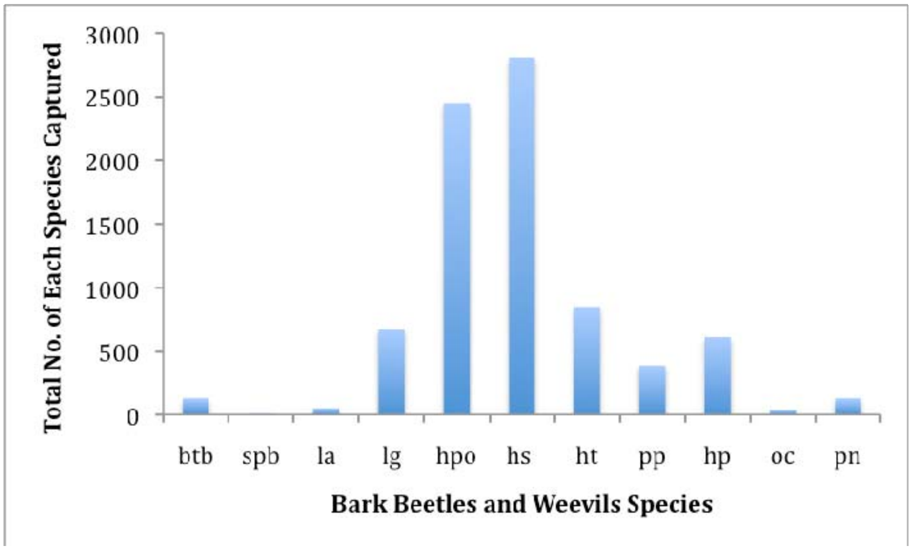

Figure 2. Total number captured of bark beetles and weevils in loblolly pine stands in central Alabama and Georgia, from 12 March 2009 to 24 February 2010.

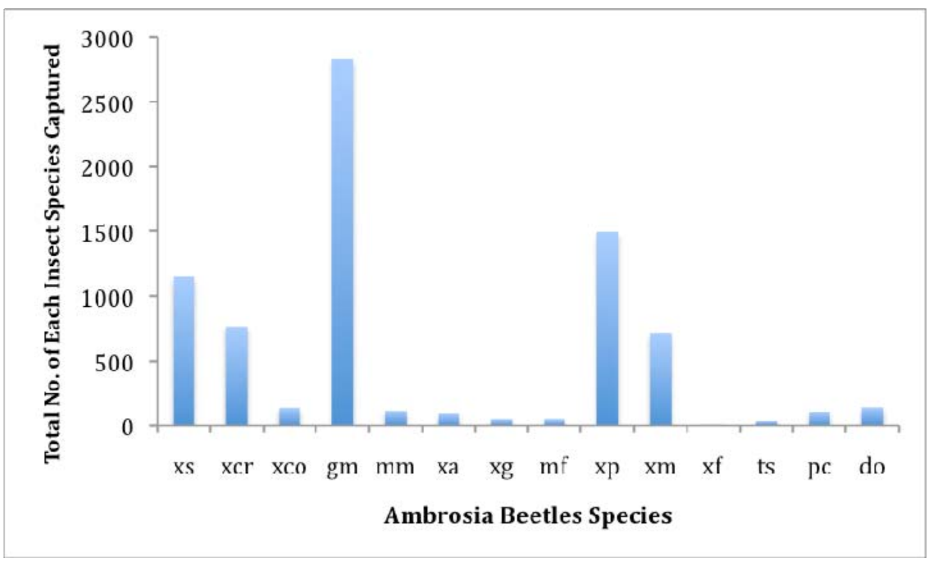

Figure 3. Total number captured of ambrosia beetles in loblolly pine stands in central Alabama and Georgia, from 12 March 2009 to 24 February 2010.

Hylastes salebrosus, the most frequently captured insect, and two other *Hylastes* spp. as well as those two molytine weevils are root-feeding beetles. Since some plots are still under treatment (blue arrows labeled in Figs 4, 5 and 6 are time of clearcut, and green arrows labeled are time of thinning in different sites), it is hard to compare differences of population response among plots. However, trends of insect populations in the first year can help us understand root-feeding *Hylastes* spp. Numbers of captured *H. salebrosus* and *H. porculus* peaked in spring and fall (Figs. 4 and 5), however, *H. tenuis* did not show an apparent peak (Fig. 6). During December 2009 to January 2010, the number of *Hylastes* spp. captured dropped to zero, which corresponds to a period of low temperature. Comparisons among the numbers of *Hylastes* spp. captured in the five study sites, the number of *H.*

salebrosus and *H. porculus* were higher at the WV and SS sites, especially in spring and fall (Figs. 3 and 4). The *H. tenuis* population fluctuated frequently from spring to fall, but dropped to zero during winter season (Fig.5).

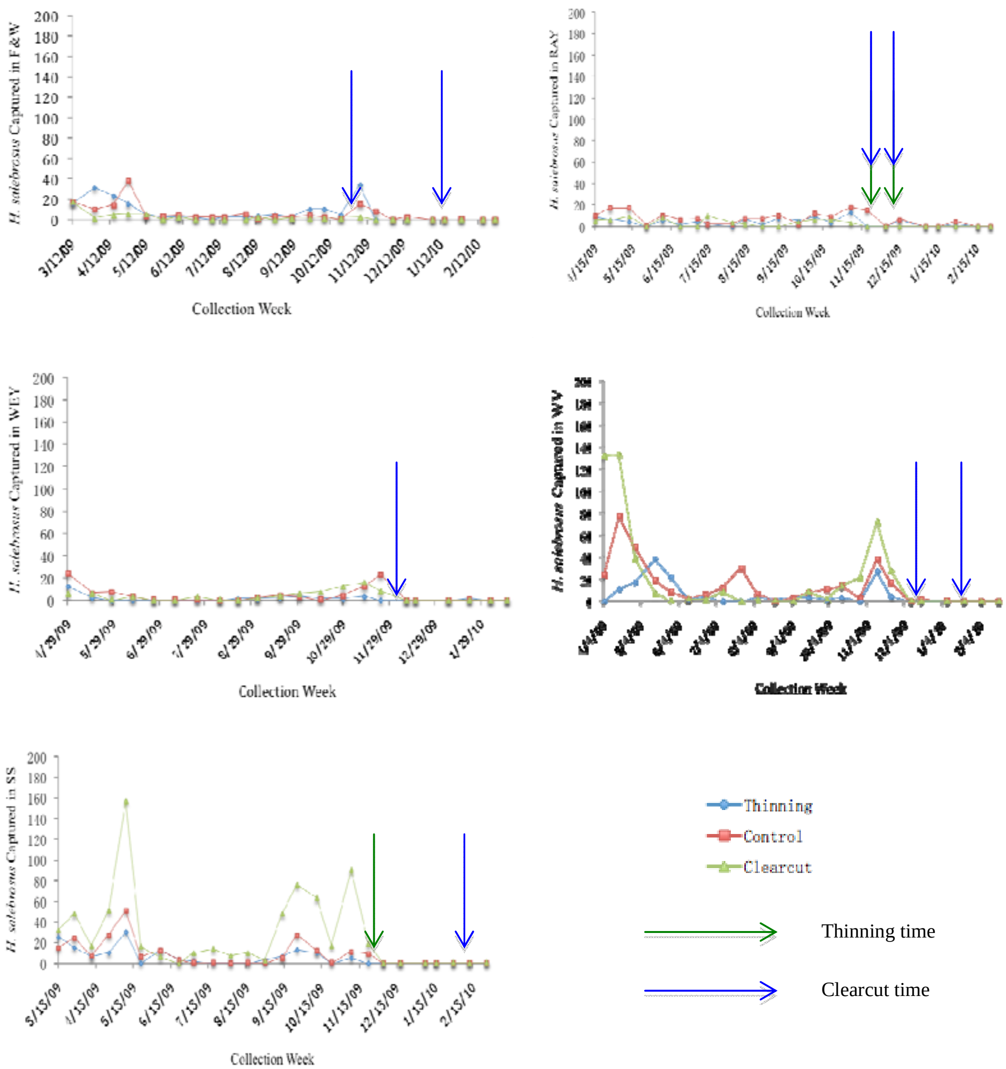

Figure 4. Bi-weekly captured *H. salebrosus* in central Alabama and Georgia, from 12 March 2009 to 24 February 2010, showing when treatments were applied.

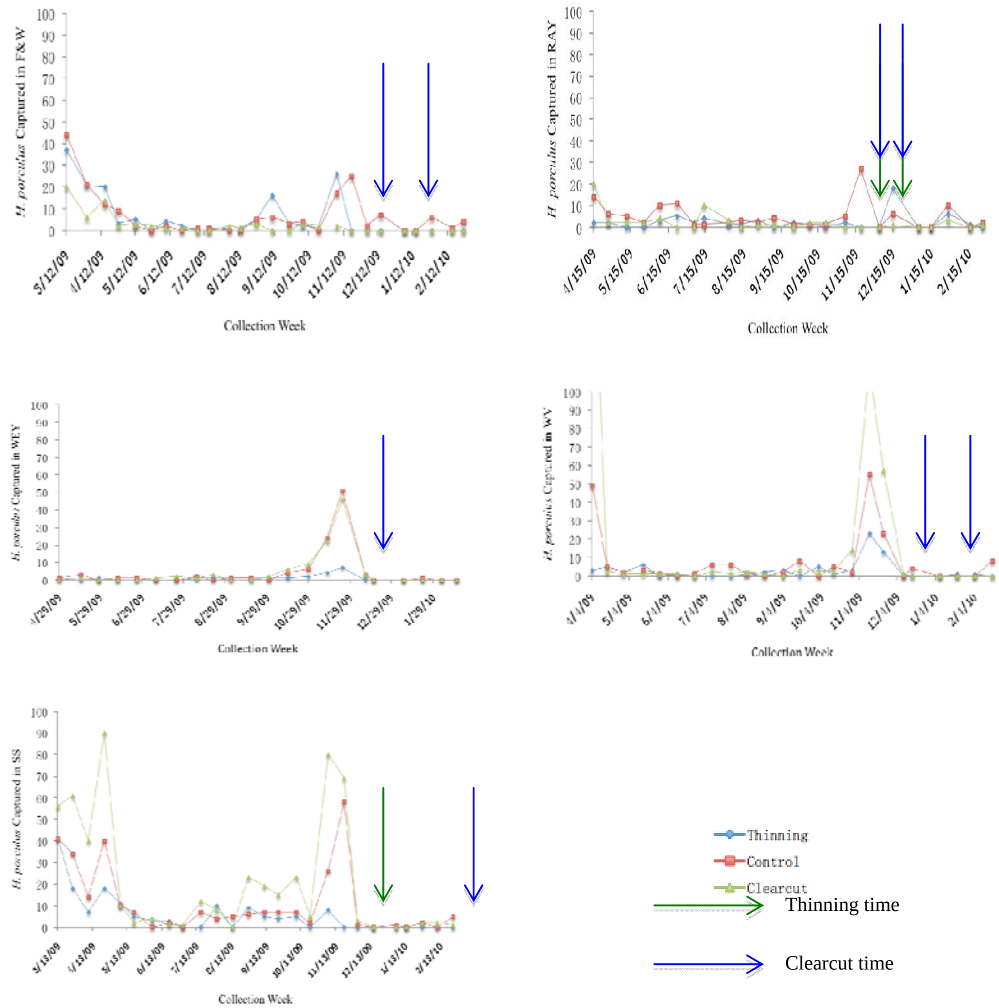

Figure 5. Bi-weekly captured *H. porculus* in central Alabama and Georgia, from 12 March 2009 to 24 February 2010, showing when treatments were applied.

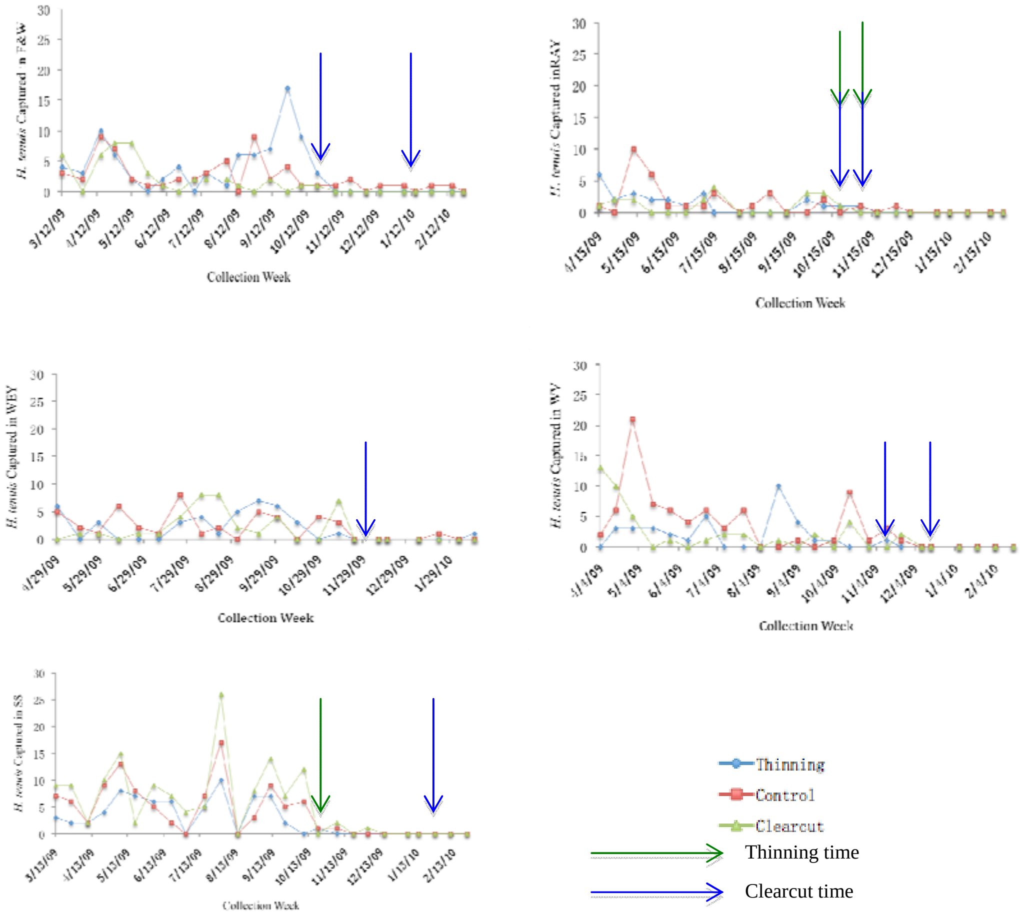

Figure 6. Bi-weekly captured *H. tenuis* in central Alabama and Georgia, from 12 March 2009 to 24 Februray 2010, showing when treatments were applied.

Root Condition

Leptographium terebrantis, *L. serpens*, *G. huntii*, *L. procerum* and *O. ips* were consistently isolated from lateral roots. *Leptographium procerum* and *L. terebrantis* were consistently isolated from lateral roots and more common among different sites, while *L. serpens* and *O. ips* were isolated from plots with severe pine decline symptoms.

Table 4. Percentage of ophiostomatoid fungal isolations (pre-treatment)

	L. terebrantis	*L. serpens*	*G. huntii*	*L. procerum*	*O. ips*
F&W	4.6	0.92	12.04	12.04	0
RAY	3.7	3.7	4.6	13.9	0
WEY	1.9	10.2	9.3	19.4	0.93
WV	14.8	4.6	5.6	22.2	7.4
SS	7.4	0	0.93	5.6	0.93

In F&W, RAY, WEY and WV sites, *L. procerum* was isolated more often than the other fungi (12.04%, 13.9%, 19.4% and 22.2%, respectively). *Grosmannia huntii* was isolated more often at F&W (12%)

than at RAY, WEY and WV sites (5%, 9% and 6%, respectively). The SS sites had the lowest isolation rates of all other locations (Table 3).

DISCUSSION

The Year 1 results presented here show that root-feeding beetles are active throughout most of the year, which is similar to the findings of Zanzot and Eckhardt (2010). This study also indicates that year-round sampling is necessary to monitor insect population peaks as they do not always fall during spring when southern pine beetle is traditionally trapped. The number of *H. salebrosus* captured was greater than the other two *Hylastes* spp., in contract with another study where *H. tenuis* was the dominant species (Zanzot and Eckhardt, 2010), but similar with those studies where *H. porculus* and *H. salebrosus* were predominant (Eckhardt *et al.* 2007, Sullivan *et al.* 2003). Loblolly pine decline was found to be associated with interaction factors such as host, insect, pathogen and site characters. These root-feeding beetles have been found associated with *L. procerum*, *L terebrantis*, *L. serpens* and *G. huntii* and as vectors (Eckhardt *et al.* 2004, Zanzot *et al.* 2010) and are attracted to trees that are under stress from natural or anthropogenic causes (Eckhardt *et al.*, 2007).

Since treatments are still underway, we cannot make definite statements about insect population responses to management. However, understanding the temporal effects of forest management in plantations on the diversity and abundance of arthropods and plants, and the presence of fungi is important. These comparisons will become available when Year 2 data is completed.

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