FINAL REPORT

THE EFFECTS OF THE 1998 FLORIDA WILDFIRES ON PINE BARK BEETLES, REPRODUCTION WEEVILS, AND THEIR ASSOCIATES

USDA Forest Service
Southern Research Station
Study Plan No. FS-SRS-4505-34

James L. Hanula1, James R. Meeker2, Daniel R. Miller1, and Edward L. Barnard2

1USDA Forest Service, 320 Green St., Athens, GA 30602-2044
2 Florida Division of Forestry, P.O. Box 147100, Gainesville, FL 32614-7100
Introduction

The 1998 wildfires in Florida burned over 200,000 ha of forests creating a unique situation to study bark beetle and reproduction weevil population ecology. Such a large area of southern pine forests damaged by intense summer fires lasting several weeks is unique. Although the Buckhead wildfire burned nearly 46,000 ha of the Osceola National Forest in March 1956, it occurred in late winter when temperatures were low (45°F) and burned through the forest within two days (Storey and Merkel 1960). In contrast, the wildfires of 1998 occurred in June and July during an extended drought when Keetch-Byram drought indices were above 700 and temperatures were in the 90's most days. At the conclusion of the fires it was clear that they killed large numbers of trees. What was uncertain was how the remaining trees that still had some live crown would fare in subsequent years, and how the bark beetle and reproduction weevils that inhabit Southern pine forests would respond to this mosaic of dead, dying and damaged trees.

The pine bark beetle complex (Coleoptera: Scolytidae) in the South includes five common species that at times can cause tree mortality: the Southern pine beetle (SPB), *Dendroctonus frontalis* (Zimmermann); the pine engravers, *Ips grandicollis* (Eichhoff), *I. calligraphus* (Germar), and *I. avulsus* (Eichhoff); and the black turpentine beetle (BTB), *D. terebrans* (Olivier). Of these, SPB is the most aggressive, routinely killing relatively healthy trees over large areas across the South during outbreaks (Price et.al. 1991). *Ips* beetles are less aggressive than SPB with tree-killing attacks generally restricted to stressed or damaged trees. *Ips* populations often build up in logging slash, windthrown, drought-stressed or lightning struck trees. From these population foci, subsequent generations can emerge to attack apparently healthy trees nearby (Drooz 1985). Thatcher (1960) estimated that pine engravers were responsible for 3.7 million m³ of timber loss annually in the South while Baker (1972) reported 1.1 million m³ was killed annually in Florida alone. BTB is attracted to stumps and injured trees. Trees weakened by fire, old age, adverse weather, or damaged by storms and naval stores or harvesting operations are frequently attacked. Although BTB is primarily considered a secondary pest attacking weakened or damaged trees, outbreaks resulting in extensive tree mortality have occurred in all states along the Gulf coast (Drooz 1985).

Pine reproduction weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar) (Coleoptera: Curculionidae), differ from bark beetles in that they breed in the stumps and roots of recently cut, killed or severely damaged trees. Adults that emerge from the dead material feed on the phloem tissue of seedlings or small branches of larger trees. When feeding is concentrated on seedlings these weevils often cause severe reductions in pine reproduction in infested areas. Reproduction weevils are capable of flying over 2 miles to reach breeding sites and adults can live for nine months or longer in the field (Bullard and Fox 1969). Attraction to and subsequent increases in weevil populations in the burned areas might affect pine regeneration in and around such areas, and these weevils have been implicated in the transmission of *Leptographium procerum* (Kendrick) Wingfield, a root disease reportedly capable of killing larger, mature pine trees (Klepzig et.al. 1991, Nevill and Alexander 1992a).

The above insects may affect the long-term health of the forests in the vicinity of the
burns. One possibility is the number of dead trees is so large or they were so altered by the fire that these insect species will not be able to take full advantage of a seemingly abundant resource. Conversely, the large numbers of dead and damaged trees may result in a build up of bark beetles that could then kill weakened trees that might otherwise have survived the fires. In addition, the high populations could spill over into nearby unburned areas killing relatively healthy trees. The availability of severely weakened trees could allow engraver beetles and BTB to maintain high population levels over several years. Increases in regeneration weevil populations could substantially affect or delay natural or artificial forest regeneration. The combination of these events may start a prolonged cycle of forest decline, especially through the transmission of _L. procerum_.

We examined tree mortality, and relative abundance of bark beetles and wood borers along a gradient of fire intensity from no fire to high intensity using a variety of standard trapping and sampling techniques. Sampling devices included Lindgren funnel traps to determine the relative abundance of pine foraging species and their associated predators, and unbaited pitfall traps and crawl traps to sample reproduction weevil populations. In addition, we monitored tree mortality within study stands over a one year period and sampled roots of live trees to determine the prevalence of _Leptographium_ species one year after the wildfire.

**Methods**

We conducted the study on the Osceola National Forest in Baker and Columbia counties Florida where approximately 8,000 ha burned in July 1998. The burned area resulted from a single arson start and included a variety of stand conditions from slash pine (_Pinus elliottii_ Engelm.) plantations to mature longleaf pine (_Pinus palustris_ Mill.) stands with understories dominated by saw palmetto and gallberry. Previous stand treatments were well documented and a full range of fire intensities were available in a relatively small area. Also, very little salvage was done so the majority of stands were undisturbed except for the fires. A further advantage of using this area of the Osceola National Forest was that results from a previous wildfire on the forest were available for comparison (Storey and Merkel 1960).

We established study plots in October 1998 in three stands in each of the following fire intensity classes: 1) no burn; 2) low intensity fire (no crown damage); 3) moderate intensity fire (some crown damage and resin weeping near tree base) and; 4) high intensity (almost complete crown scorch plus resin weeping). Within each stand we established five plots spaced 50-100m apart. At each plot we chose the 10 closest living trees (some green foliage visible) to the plot center, measured their diameter, estimated fire severity (% crown scorch and height of stem char), and recorded the presence or absence of bark beetle or wood borer activity. Table 1 shows tree species and average diameter (cm) of the 50 trees selected in each stand. The trees were reexamined in January, May, July and October 1999, to estimate mortality and bark beetle activity. In addition to our initial visual assessment of fire intensity, we determined tree mortality in each stand by conducting a 10 or 20 m wide strip cruise through each stand along a line connecting our five plots in January, 1999. The width of the strips varied among stands depending on stand density. All living and dead trees within the strips were counted and
We monitored insect abundance in the stands with various insect traps. In each of the five plots/stand we installed one crawl trap (Hanula and New 1996) on the bole of a live tree to catch adult reproduction weevils crawling up the trees and a pitfall trap to sample weevils crawling on the ground. The pitfall traps consisted of a 480-ml capacity plastic cup with drain holes in the bottom buried in the soil so the top was even with the soil surface. A second collection cup filled with preservative solution (1% formaldehyde in a saturated NaCl solution) was placed inside the first and a funnel was set inside the mouth of the larger cup so that arthropods were directed into the smaller cup. The funnel was coated with Fluon (a Teflon-like material) to prevent arthropods from crawling out once they enter the trap. Following installation of the pitfall, four 1-m long pieces of aluminum sheet metal (20 cm wide) drift fence were inserted into the soil (15 cm above ground) so that the edges touched the pitfall cup and the pieces formed a +–pattern with the trap in the center. Each trap was covered by a 15- x 15-cm piece of aluminum sheet metal supported by 30-cm long plastic garden stakes to reduce trap flooding by rainfall. Both crawl traps and pitfalls were operated continuously and samples were collected once per month. Samples were sorted, stored in 70% ethanol, identified and counted.

Traps in the three control plots were relocated on 12 January, 1999 due to prescribed burns scheduled for the previously selected control plots. We included trap catches from the original plots since all of the control plots were in the same general area and they were comparable in tree species, size and understory composition. Traps were operated from October 1998 through June 1999, approximately one year after the fire.

On 26-29 October 1998, three Lindgren 8-unit multiple-funnel traps (Lindgren 1983) (Phero Tech Inc., Delta BC) were set in each stand, to sample other pine foraging species, for a total of 36 traps. Lindgren multiple-funnel traps are an effective tool for assessing the diversity and abundance of forest Coleoptera (Chénier and Philogène 1989a; Miller and Maclauchlan 1998). Within each stand, traps were suspended between two trees on a rope within 3 of the 5 plots such that the top funnel of each trap was 1.3-1.5 m above ground. No trap was within 2 m of any tree. Each collection cup contained a small square (5 cm²) of Vapona (a.i. dichlorvos) to kill captured insects and prevent predation. Trap catches were collected at intervals of 1-3 weeks until termination on 9 November 1999.

All traps were initially baited with (±)-α-pinene from Aldrich Chemical Company Inc. (Milwaukee WI), released from closed 30 ml Nalgene low-density polyethylene bottles (Fisher International, Atlanta GA) at a rate of about 0.1-0.2 g/d at 25°C and a longevity of about 120 days. (±)-α-Pinene is the most abundant monoterpen in the resin of longleaf pine (Mirov 1961). On 12 February 1999, the lure on one trap in each stand was replaced with a commercially produced (Phero Tech Inc.) high-release device consisting of a blue plastic pouch of (–)-α-pinene and a black plastic pouch of 95% ethanol, each with longevity of about 100 days. (–)-α-Pinene is the predominant monoterpen in slash pine (Mirov 1961) while ethanol is a common host attractant for bark and wood boring beetles (Fatzinger 1985; Fatzinger et al. 1987; Chénier and Philogène 1989b). The release rates of (–)-α-pinene (chemical purity >95%) and ethanol were about 1-3 g/d at 25°C. Lures on traps in plots A and E of each stand were replaced on 12 February. All lures were again replaced in May and August.
The addition of high-release devices to one trap per plot was done to increase trap competitiveness with the natural host tree attractants. The use of low-release devices of (±)-α-pinene was made to ensure consistency with longleaf pine monoterpane constituent, continuity with the previous period and as a contingency against trap saturation.

During the period August to October, 1999 we sampled roots of six living pine trees per stand using a modified two-root excavation method (Alexander et al. 1981). Segments (10-25 cm long) of two or sometimes three primary lateral roots were taken from each tree. Sampled root segments were held in plastic bags. In the laboratory, individual roots were brushed free of debris and visually examined for the presence of insects or evidence of insect infestation (e.g., galleries, etc.). Roots were then split, debarked and 1-1.5 cm² chips of resin-soaked, stained or clear wood tissue were excised. These were surface sterilized by dipping in 95% ethanol followed by brief flaming. Surfaced sterilized sections were plated onto cycloheximide-amended (500 ppm) malt extract medium (Hicks et al. 1980). Plates were incubated under ambient laboratory conditions for 7-10 days and then examined for fungal growth and conidiophores characteristic of *Leptographium* spp.

Because regeneration weevils have been implicated in the transmission of *Letographium procerum* (Nevill and Alexander 1992a), we isolated fungi from living *H. pales* and *P. picivorus*. Adult weevils were collected from the high and moderate fire intensity stands in August 1999, using fresh, split, slash pine billets baited with a 1:1 mix of turpentine:ethanol. Five billet traps were widely distributed among five of the study stands and live weevils found beneath them were collected six days later. Fungal isolates were made from 52 weevils by gently rolling them across the surface of cycloheximide-amended malt extract medium. Plates were held for 10 days at ambient laboratory conditions and examined for colonies of *Leptographium* spp.

Tree mortality, pitfall and crawl trap data were analyzed using the SAS (1985) ANOVA procedure and Fisher’s Least Significant Difference multiple comparison test (P≤0.05). Weevil count data were transformed using the √(Y+0.5) transformation to remove heteroscedasticity (Sokal and Rohlf 1981). The SYSTAT 8.0 statistical package (SPSS Inc., Chicago IL) was used for analyses of Lindgren funnel trap data and *Leptographium* spp. prevalence data. Beetle count data were transformed by ln(Y+1) to remove heteroscedasticity, and analyzed by ANOVA and Fisher’s Least Significant Difference (LSD) multiple-comparison test (P ≤ 0.05).

**Results and Discussion**

Estimates of fire-caused tree mortality from strip cruises showed that stand selection criteria were directly related to tree mortality five months after the fire. Control stands contained an average of 1.5% dead trees, low fire intensity stands averaged 8.8% dead trees, moderate fire intensity stands averaged 37.6% dead trees and high intensity stands averaged 63.6% dead trees. Between five and eight months after the fire, sample trees experienced an additional average mortality of 13.3% in the high intensity stands which was significantly higher than tree mortality in the control, low or moderate fire intensity stands for the same period (Table 2). Mortality
among sample trees in the stands experiencing high fire intensity continued beyond eight months, doubling to 27.3% by May, 1999. Mortality among sample trees in the stands that experienced low or moderate intensity fires also doubled between eight and 11 months after the fire but were still not significantly different from the controls. Almost all of the tree mortality occurred during the 11 months between the end of the fire and May, 1999. Subsequent measurements in July and October 1999 showed that increases in tree mortality were comparable to the normal mortality that occurred in the unburned control stands.

The direct cause(s) of tree mortality were not clear. We observed *Ips* bark beetle attacks on all trees that died during the study but since these beetles regularly attack dead trees it is impossible to know whether the trees died as a result of their activity. Storey and Merkel (1960) tried to protect fire damaged slash and longleaf pine trees by spraying them with insecticide. They saw no difference between mortality of sprayed and unsprayed trees suggesting that the trees died as a result of the fire. We saw no evidence of SPB attacks and we caught none in our traps baited with host attractants. We also saw very few BTB attacks in the stands. Only four trees had BTB attacks. Despite an abundance of dead and dying trees in the stands that experienced high fire intensity we did not see evidence of the bark beetle population build up that we originally speculated could occur. In fact, tree mortality increased very little after May, 1999, despite a relatively dry spring and summer that should have further stressed the already weakened trees.

A high proportion of remaining live trees in the high fire intensity stands had roots infected with *Leptographium* spp. (Fig. 1). Over 75% of the sampled trees had at least one root with *Leptographium* infection in high fire intensity stands and nearly 60% of the sampled roots were infected. No *Leptographium* spp. were recovered from roots of sampled trees in the control stands and less than 10% of the sampled roots and trees in stands that experienced low fire intensities were infected with *Leptographium* spp. fungi. These data show that the fires damaged a large proportion of the roots and that root damage was proportional to fire intensity. In addition, although not all of the roots we sampled had *Leptographium* spp. fungi in them, all exhibited signs of damage. We found no healthy roots at our sampling depth of 15-20 cm on the 18 trees sampled in the high fire intensity stands. Otrosina et al. (1997) suggested that tree response to infection (resinous lesions) required energy that would not be available for defense against other invaders. The role of *Leptographium* spp., as root or tree pathogens is not clear. For example, *L. procerum* and *L. terebrantis* have reportedly been implicated in red pine (*P. resinosa* Aiton) decline (Klepzig et al. 1991) in Wisconsin and are thought to be transmitted by reproduction weevils and other root- and lower stem-feeding insects (Klepzig et al. 1991, Nevill and Alexander 1992a,b). Trees in stands that experienced high to moderate intensity fires where 40-75% of the trees sampled had infected roots may be more susceptible to bark beetles capable of taking advantage of weakened trees.

We found that 15-20% of the sampled roots in stands where moderate to high intensity fires occurred had reproduction weevil larval galleries (Fig. 2). Stands with no or low intensity fires had 0-4% of the roots with weevils. We recovered *Leptographium* spp. from 50% of the pales weevils and 36% of the pitch-eating weevils collected from beneath pine billets in the moderate to high fire intensity stands.

Weevils were more abundant in stands where fire intensities reached moderate to high
levels. Significantly more pales and pitch-eating weevils were captured in pitfalls in the moderate and high fire intensity stands than in the controls (Fig. 3). Weevil abundance in unburned control stands and stands with low intensity fires were similar for both species. The higher abundance of weevils in stands experiencing hotter fires may be due to an attraction of weevils from surrounding areas due to an abundance of suitable host material (i.e., dead and dying trees) and increased brood production. In contrast, Lindgren traps that catch flying insects captured significantly fewer *P. picivorus* in the high fire intensity stands than in stands in the other three fire intensity classes (Fig. 4). It is unclear whether this is due to less flight activity by the weevils when breeding sites are abundant or if the volatiles from the dead and dying trees were competing with the traps and reducing their catches.

Bark and wood boring beetles were captured in Lindgren traps with both types of lures throughout the study. However, traps baited with low-release devices caught fewer beetles than those baited with high-release devices. Therefore, catches in traps baited with high-release devices were used in the following analyses. The catches were summed for the period of 8 – 26 February, 8 March – 2 April, and 12 April – 30 July due to the late deployment of the high-release devices and from animal damage to several traps that resulted in lost trap catches during the periods of 26 February – 8 March and 2 – 12 April.

Mean trap catches of bark beetles that breed in the phloem tissue of pines were less abundant in the fire-damaged areas than in the control stands (Fig. 5). Catches of *Dendroctonus terebrans*, *Hylastes salebrosus*, *H. tenuis* and *Ips grandicollis* (Coleoptera: Scolytidae) were highest in the control stands with other species showing a similar trend. The young of all these species feed only on phloem of high nutritional quality. Fire may have directly or indirectly changed the attractiveness and quality of trees resulting in less desirable habitats for brood production. In addition, it is possible that an abundance of naturally produced host and beetle attractants outcompeted the lures we used in the stands that experienced high fire intensities. Since sample trees that died during the study were all attacked by *Ips* bark beetles, we would have expected increased bark beetle activity in stands with high tree mortality. However, we have no data on initial attack densities or brood success in those trees, and no other indications that beetle populations were increasing.

In contrast, catches of ambrosia beetles that breed in the sapwood of pines and/or hardwoods seemed higher in traps in the fire-damaged area (Fig. 5). Catches of *Monarthrum mali*, *Xyleborus ferrugineus* (Coleoptera: Scolytidae) and *Platypus flavicornis* (Coleoptera: Platypodidae) were highest in the stands with moderate or high fire-damage. Adults of these species tunnel into the sap- and heartwood of trees, seeding the galleries with “ambrosia” fungus. The young feed only on ambrosia until they become adults. As such, they and their host material would have been insulated from direct damage by fire. The other ambrosia beetle species, *Xyleborinus saxeni* and *Xylosandrus crassiusculus* (Coleoptera: Scolytidae) showed similar patterns. In contrast, mean catches of two other species, *Xyleborus* spp, were more abundant in the control stands.

The longhorn beetles, *Acanthocinus obsoletus*, *Tylocera nodosus* and *Monochamus titillator* (Coleoptera: Cerambycidae), were most abundant in the stands with low or moderate fire intensity, and the longhorn beetles, *Xylotrechus sagittatus* and *Arophalus rusticus* (Coleoptera: Cerambycidae) and the flathead borer, *Chalcophora georgiana* (Coleoptera:
Buprestidae) were most abundant in the control and low intensity stands (Fig. 6). The larvae of these species start their development in the phloem tissue prior to initiation of feeding in the sapwood. High intensity fires may have altered their early larval habitat as with the bark beetles. Other species of beetles associated with bark and wood-boring beetles varied in abundances relative to fire intensity. One general predator of bark and ambrosia beetles, \textit{Temnochila virescens} (Coleoptera: Trogositidae), showed a strong positive correlation between abundance and fire intensity (Fig. 7). Another predator, \textit{Silvanus} sp (Coleoptera: Sylvanidae), was more abundant in the control stands. Population levels of other species including \textit{Lasconotus} sp (Coleoptera: Colydiidae) showed no difference among treatment categories.

At this time we have no explanations for these various patterns in bark and wood boring beetle trap catches. A better understanding of the impacts of the wildfire on Osceola National Forest will require additional monitoring in order to resolve some of these questions. It is possible that bark beetle populations and associated tree mortality will increase in the year ahead, particularly in stands that experienced moderate to high fire intensities, as the associated loss of tree vigor lowers tree resistance to attacks. Populations of ambrosia beetles should correspondingly increase as well.

Management Implications

Tree mortality that was a result of the fires appeared to end by May, 1999 which is consistent with the observations of Storey and Merkel (1960) who studied the aftermath of the Buckhead fire on the Osceola National Forest. However, the abundance of dead and dying roots and \textit{Leptogriapnum} spp. fungi in living trees and two of their vectors, pales and pitch-eating weevils, in stands that experienced moderate to high intensity fires raises the possibility that those stands may continue to undergo long-term delayed mortality similar to that observed by Ferguson et al. (1960) following a fire that caused extensive basal damage. Even without the weevils the current levels of \textit{Leptographium} show that the root systems suffered significant damage as a result of the fires. In addition, the trees suffered high levels of crown scorch in areas where the fires reached moderate to high levels of intensity. Therefore, those trees are likely to be under considerable stress for several more years and at increased risk of bark beetle attack. The absence of SPB in all stands and particularly in the controls is encouraging since it suggests that these more aggressive, tree-killing beetles are currently at low population levels throughout the forest. Based on these results we see no reason to take further actions in the wildfire area.

Future Studies

Because of our concern for the long-term health of the area impacted by the wildfire, we will continue to monitor the 50 study trees/stand for several more years to determine if the
combination of root damage, *Leptographium* spp., weevils and bark beetles pose a threat to the residual and adjoining forests. In addition, we will monitor bark beetle activity in the stands for one more year to determine if populations are building up.

References


Fatzinger, C.W. 1985. Attraction of the black turpentine beetle (Coleoptera: Scolytidae) and other forest Coleoptera to turpentine-baited traps. Environmental Entomology 14:768-775.


Table 1. Tree species and average diameters (cm) (n=50 trees/stand) for stands used in the study.

<table>
<thead>
<tr>
<th>Fire intensity</th>
<th>Compartment&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Stand Number</th>
<th>Tree Species</th>
<th>Mean (±SE) Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>88</td>
<td>2</td>
<td>Slash</td>
<td>24.4 ± 0.96</td>
</tr>
<tr>
<td>control</td>
<td>98</td>
<td>3</td>
<td>Longleaf</td>
<td>27.9 ± 0.78</td>
</tr>
<tr>
<td>control</td>
<td>98</td>
<td>4</td>
<td>Longleaf</td>
<td>31.5 ± 1.18</td>
</tr>
<tr>
<td>low</td>
<td>68</td>
<td>1</td>
<td>Slash</td>
<td>28.6 ± 0.86</td>
</tr>
<tr>
<td>low</td>
<td>66</td>
<td>5</td>
<td>Longleaf</td>
<td>31.7 ± 0.72</td>
</tr>
<tr>
<td>low</td>
<td>49</td>
<td>6</td>
<td>Slash</td>
<td>25.5 ± 0.81</td>
</tr>
<tr>
<td>moderate</td>
<td>42</td>
<td>8</td>
<td>Slash</td>
<td>23.8 ± 0.68</td>
</tr>
<tr>
<td>moderate</td>
<td>67</td>
<td>11</td>
<td>Slash</td>
<td>30.0 ± 0.73</td>
</tr>
<tr>
<td>moderate</td>
<td>65</td>
<td>12</td>
<td>Longleaf</td>
<td>31.4 ± 0.85</td>
</tr>
<tr>
<td>high</td>
<td>41</td>
<td>7</td>
<td>Slash</td>
<td>26.3 ± 0.93</td>
</tr>
<tr>
<td>high</td>
<td>42</td>
<td>9</td>
<td>Slash</td>
<td>22.2 ± 0.52</td>
</tr>
<tr>
<td>high</td>
<td>42</td>
<td>10</td>
<td>Slash</td>
<td>25.0 ± 0.64</td>
</tr>
</tbody>
</table>

<sup>1</sup> Compartment designations are those of the Osceola National Forest.
Table 2. Mortality of 50 slash and longleaf pine (*Pinus elliottii* and *P. palustris*) trees/stand that initially (i.e., 5 mo. post-fire) survived low, moderate or high intensity wildfires in July 1998 compared to unburned control stands during the period October 1998 to October 1999.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0±0 a</td>
<td>0±0 a</td>
<td>1.3±1.33 a</td>
<td>2.0±2.0 a</td>
</tr>
<tr>
<td>Low</td>
<td>0.7±0.67 a</td>
<td>2.0±1.15 a</td>
<td>2.0±1.15 a</td>
<td>2.0±1.15 a</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.3±2.4 a</td>
<td>6.7±4.67 a</td>
<td>8.0±4.16 a</td>
<td>9.3±4.67 a</td>
</tr>
<tr>
<td>High</td>
<td>13.3±4.67 b</td>
<td>27.3±5.93 b</td>
<td>30.0±4.62 b</td>
<td>30.7±5.21 b</td>
</tr>
</tbody>
</table>

1 Means followed by the same letter within columns are not significantly different (*P*=0.05) by Fisher’s Least Significant Difference multiple comparison.

**List of Figures**

Figure 1. Mean percentage of trees and roots infected with *Leptographium* spp. Two to three roots were sampled per tree in stands with low (L), moderate (M) and high (H) intensity fire as determined by bole and crown scorch and control (C) stands on the Osceola National Forest, Florida during the period August to October 1999. A tree was considered infected if *Leptographium* spp. were cultured from one root. Bars within a figure followed by different letters are significantly different at *P* = 0.05 (LSD test).

Figure 2. Mean percentage of roots that contained *Leptographium* spp., *H. pales* or *P. picivorus* damage or both. Two to three roots were sampled per tree in stands with low (L), moderate (M) and high (H) intensity fires, as determined by bole and crown scorch, and control (C) stands on the Osceola National Forest, Florida during the period August to October 1999.

Figure 3. Mean number of the reproduction weevils *Hylobius pales* and *Pachylobius picivorus* captured in crawl traps on the boles of live trees and pitfall traps in the soil of stands that experienced wildfire of varying intensities (low (L), moderate (M) and high (H) intensity fire and control (C) stands) during the summer of 1998. Traps were operated continuously from October, 1998 through June, 1999.

Figure 4. Mean catches of reproduction weevils (Curculionidae) in multiple-funnel traps baited with ethanol and (-)-α-pine in stands with low (L), moderate (M) and high (H) intensity of fire scorch and a control (C) stand on the Osceola National Forest in 1999. Bars within a figure followed by different letters are significantly different at *P* = 0.05 (LSD test).
Figure 5. Mean catches of bark (phloeophagous) and ambrosia (xylomycetophagous) beetles (Scolytidae and Platypodidae) in multiple-funnel traps baited with ethanol and (-)-\(\Delta\)-pinene in stands with low (L), moderate (M) and high (H) intensity of fire scorch and a control (C) stand on the Osceola National Forest in 1999. Bars within a figure followed by different letters are significantly different at \(P = 0.05\) (LSD test).

Figure 6. Mean catches of longhorn (Cerambycidae) and flatheaded (Buprestidae) beetles in multiple-funnel traps baited with ethanol and (-)-\(\Delta\)-pinene in stands with low (L), moderate (M) and high (H) intensity of fire scorch and a control (C) stand on the Osceola National Forest in 1999. Bars within a figure followed by different letters are significantly different at \(P = 0.05\) (LSD test).

Figure 7. Mean catches of bark beetle predators (Trogositidae, Silvanidae, and Colydiidae) in multiple-funnel traps baited with ethanol and (-)-\(\Delta\)-pinene in stands with low (L), moderate (M) and high (H) intensity of fire scorch and a control (C) stand on the Osceola National Forest in 1999. Bars within a figure followed by different letters are significantly different at \(P = 0.05\) (LSD test).
FIG. 1
FIG. 2
**FIG. 3**

Bar graphs showing the mean (+SE) number of weevils (n=3) for different species under varying intensities of fire impact on the stand.
**Hylobius pales**

Mean (+SE) number of captured beetles ($n=3$)

**Pachylobius picivorus**

**Other spp**

Intensity of fire impact on stand

FIG. 4
FIG. 6
FIG. 7

Mean (+SE) number of beetles (n=3)

Temnochila virescens
Silvanus sp
Other spp
Lasconotus sp

Intensity of fire impact on stand