ABSTRACT: Weevils (Coleoptera: Curculionidae) may play a role in the reduced regenerative ability of oak (Quercus L.) species in the hardwood forests of eastern North America. Presently, because of biome-wide regeneration failure, silvicultural treatments of prescribed fire and mechanical thinning are being implemented as a means to enhance natural oak regeneration. The effect that these treatments may have on the diversity and population structure of non-target organisms like weevils (oak seed predators) remains unclear. This study provides an evaluation of the weevil populations of two experimentally managed, mixed-oak forests in southeastern Ohio. Each of the two sites used in this study was divided into four 20 ha treatment plots consisting of: (1) untreated control, (2) thin only, (3) thinning followed by prescribed burning, and (4) prescribed burning only plots. Pyramid style traps (N = 48) were placed in each treatment unit to sample weevils. Overall, we identified 26 species of Curculionid weevils representing nine genera from five different tribes and two subfamilies. Weevil communities were generally dominated by a few highly abundant species and a moderate number of uncommon to rare species. Generally, treatments increased overall weevil diversity and influenced the abundance of certain rare species. However, there was no significant effect on number of weevils or on occurrence of the two major acorn infesting genera (Curculio L. and Conotrachelus Dejean). Based upon our findings, prescribed spring burning had little effect on overall weevil populations and is not likely to substantively aid in silvicultural endeavors to promote oak regeneration; however, effects on rare species need to be carefully considered.

Index terms: Coleoptera, Curculionidae, fire, forest management, Quercus

INTRODUCTION

Forest management techniques, including applications of prescribed burning and mechanical thinning, are presently being explored as a means to enhance the natural regeneration of oak species (Quercus spp. L.) in the eastern and central hardwood forests of North America (Brose et al. 1999; Franklin et al. 2003; Hutchinson et al. 2005; Albrecht and McCarthy 2006). One mode of action by which silvicultural treatments are thought to improve regeneration is through a reduction in the occurrence of invertebrate seed predators, particularly acorn weevils (Coleoptera: Curculionidae). It is hypothesized that a spring burn might destroy weevils emerging from the soil as well as those residing near the soil surface. Additionally, by removing the leaf litter, prescribed burning may also increase susceptibility of weevils to predation by vertebrate predators such as the white-footed mouse (Peromyscus leucopus) and the short-tailed shrew (Blarina sp.), both of which are common in the eastern deciduous forests (Anderson and Folk 1993; Semel and Anderson 1988).

Weevils, particularly those in the genus Curculio (L.), are the major seed predator of oak species in the eastern United States, and damage to seed crops can vary anywhere from 0-100% based on tree species and seed crop size (Christisen 1955; Gibson 1972, 1982; Riccardi et al. 2004; Miller and Schlarbaum 2005). Gibson (1969) lists 27 species of Curculio as occurring in America north of Mexico. Adult Curculio spp. can be found from April to November in southern states with a slightly lower active period farther to the north. Toward the end of the summer, females excavate a hole into developing acorns using their extended rostrum and deposit an egg. Eggs hatch in 5-14 days and larvae feed from within the pericarp for approximately two weeks. After seed drop, larvae exit the acorn and burrow into the ground to overwinter. Diapause may last from one to five years, depending upon the species; however, one or two years is common (Gibson 1969). Conotrachelus (Dejean), another major genus of seed-feeding weevils, generally emerges later in the summer and oviposits in acorns at the end of August and early September. Many species in this genus require pre-existing damage to the nut as they are unable to chew through the pericarp on their own. Not all weevil species breed in seeds; many simply oviposit in or on the soil surface, or on the surface of leaves or other parts of a tree, and may feed either on the roots or the inner bark (Blatchley and Leng 1916; Evans 1959).

The purpose of this study is to determine if stand level treatments affect the diversity and abundance of adult weevils in two man-

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Natural Areas Journal 28:363–369
Effects of stand level silvicultural treatments on weevil abundance were analyzed with a mixed model Analysis of Variance (ANOVA) using the NCSS statistical software package (Number Cruncher Statistical System 2004). All Curculionids captured over the 15-week period were combined into four treatments and two replicates (sites), where treatment (control, thin, prescribed burn, and thin + prescribed burn) was a fixed effect, and site (Zaleski, REMA) was a random block effect. F-tests were considered significant at a critical value of $P = 0.05$ or below.

**RESULTS**

Overall, we identified 833 individual Curculionid weevils belonging to 26 different species and representing nine genera from five different tribes and two subfamilies (Table 1). The Asiatic oak weevil (*Cyrtaspistomus castaneus* Roelofs) was the most abundant species at both study sites, comprising 63% of the weevils caught at Zaleski and 64% at REMA. *Conotrachelus* spp. comprised a large proportion of the remainder. Many of the species (22) were very uncommon and found at either low abundance or in only a single stand. Overall, a greater number of weevils were caught at Zaleski (446) than at REMA (387).

Diversity analysis reveals that by most measures, the Zaleski site had slightly greater diversity than the REMA site, regardless of treatment (Table 2). Species richness ($S$) ranged from 7 to 14, with the lowest richness occurring in control stands. Stand level disturbance from the prescribed burning and thinning treatments increased diversity by almost all measures ($S, H', 1/D$). The ACE estimator of species richness shows that there are 2-2.5 times more species likely to be present than we recovered in sampling. This was due to the large number of singletons that were recovered, and indicates that sampling intensity probably needed to be greater.

The NMDS ordination results suggest that there is a moderately strong effect on weevil community composition (Figure 1).
Table 1. List of species and number of individuals of Curculionid weevils captured at two study locations, the Zaleski State Forest (Z) and the Raccoon Ecological Management Area (R), in Vinton Co. southeastern Ohio, USA.

<table>
<thead>
<tr>
<th>Species</th>
<th>Control</th>
<th>Thin</th>
<th>T &amp; B</th>
<th>Burn</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z  R</td>
<td>Z  R</td>
<td>Z  R</td>
<td>Z  R</td>
<td>Z  R</td>
</tr>
<tr>
<td>Subfamily: Curculioninae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tribe: Cryptorhynchini</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conotrachelus anaglypticus</em></td>
<td>16 4</td>
<td>9 7</td>
<td>16 9</td>
<td>26 4</td>
<td>67 24</td>
</tr>
<tr>
<td><em>Conotrachelus falli</em></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
<td></td>
<td>0 3</td>
</tr>
<tr>
<td><em>Conotrachelus geminatus</em></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
<td></td>
<td>2 0</td>
</tr>
<tr>
<td><em>Conotrachelus juglandis</em></td>
<td>1 1</td>
<td>5 28</td>
<td>6 6</td>
<td>5 7</td>
<td>18 46</td>
</tr>
<tr>
<td><em>Conotrachelus naso</em></td>
<td>1 1</td>
<td>2</td>
<td>0</td>
<td></td>
<td>3 4</td>
</tr>
<tr>
<td><em>Conotrachelus posticatus</em></td>
<td>21 22</td>
<td>4 7</td>
<td>1 5</td>
<td>3 3</td>
<td>39 37</td>
</tr>
<tr>
<td><em>Cryptorhynchus bisignatus</em></td>
<td>1 1</td>
<td></td>
<td>1 0</td>
<td></td>
<td>1 0</td>
</tr>
<tr>
<td><em>Cryptorhynchus failax</em></td>
<td>1 1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>0 1</td>
</tr>
<tr>
<td><em>Cryptorhynchus lapthi</em></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
<td></td>
<td>0 1</td>
</tr>
<tr>
<td><em>Cryptorhynchus parochus</em></td>
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<td>1</td>
<td>1</td>
<td></td>
<td>1 0</td>
</tr>
<tr>
<td><em>Micromastus spp.</em></td>
<td>3 1</td>
<td></td>
<td>1 1</td>
<td></td>
<td>0 1</td>
</tr>
<tr>
<td>Tribe: Curculionini</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Curculio caryae</em></td>
<td>1 1</td>
<td>1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Curculio confusor</em></td>
<td>1 1</td>
<td>1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Curculio humeralis</em></td>
<td>1 1</td>
<td>1 2</td>
<td>3 2</td>
<td>1 3</td>
<td>4 4</td>
</tr>
<tr>
<td><em>Curculio iowensis</em></td>
<td>1 1</td>
<td>1 2</td>
<td>1 3</td>
<td></td>
<td>2 3</td>
</tr>
<tr>
<td><em>Curculio neocorithus</em></td>
<td>1 1</td>
<td>1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Curculio pardalis</em></td>
<td>1 1</td>
<td>1 2</td>
<td>3 2</td>
<td>1 3</td>
<td>3 4</td>
</tr>
<tr>
<td><em>Curculio sulcatulus</em></td>
<td>1 1</td>
<td>1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Curculio timidis</em></td>
<td>1 1</td>
<td>1 2</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Curculio spp.</em></td>
<td>2 1</td>
<td>2</td>
<td>1</td>
<td></td>
<td>0 1</td>
</tr>
<tr>
<td>Tribe: Otidocephalini</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Otidocephalus chevrolatii</em></td>
<td>1 1</td>
<td>1 1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Otidocephalus spp.</em></td>
<td>1 1</td>
<td>1 1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td>Tribe: Prionomerini</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Piazorhinus scutellaris</em></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td>Tribe: Zygopini</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Eulechriops minutus</em></td>
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<td></td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td><em>Psomus spp.</em></td>
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<td>1 1</td>
<td>1 1</td>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td>Subfamily: Entiminae</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cyrtepistomus castaneus</em></td>
<td>56 61</td>
<td>45 42</td>
<td>112 49</td>
<td>71 96</td>
<td>284 248</td>
</tr>
<tr>
<td>Totals</td>
<td>103 95</td>
<td>72 91</td>
<td>146 82</td>
<td>125 119</td>
<td>446 387</td>
</tr>
</tbody>
</table>

*Indicates species not previously recorded in this area.
There was no effect of silvicultural
ations by implementing stand-level
interaction, indicating that both genera
in the spring would reduce abundance.
However, the prescribed burning and me-
ments on occurrence of either genus
treatment plots at both study sites, and
rejects our hypothesis that prescribed fire
attempts to promote oak regeneration.
Controlling seed-destroying insect
composition. In fact, stand level treatment
observed no significant treatment x genus
treatment effects are relevant to community
the nine genera indentified in this study,
number of weevils
were similarly unaffected
6, Natural Areas Journal

**DISCUSSION**

Controlling seed-destroying insect popu-
lations by implementing stand-level
treatments would benefit land managers
attempting to promote oak regeneration.
However, the prescribed burning and me-

<table>
<thead>
<tr>
<th>Measure</th>
<th>C</th>
<th>T</th>
<th>B</th>
<th>TB</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Z</td>
<td>R</td>
<td>Z</td>
<td>R</td>
</tr>
<tr>
<td>J</td>
<td>9</td>
<td>7</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>H'</td>
<td>0.72</td>
<td>0.63</td>
<td>0.84</td>
<td>0.66</td>
</tr>
<tr>
<td>D</td>
<td>1.59</td>
<td>1.22</td>
<td>2.15</td>
<td>1.58</td>
</tr>
<tr>
<td>I/D</td>
<td>0.74</td>
<td>0.57</td>
<td>0.84</td>
<td>0.67</td>
</tr>
<tr>
<td>ACE S</td>
<td>3.85</td>
<td>2.32</td>
<td>6.16</td>
<td>3.02</td>
</tr>
<tr>
<td>ACE SE</td>
<td>18.67</td>
<td>14.16</td>
<td>37.55</td>
<td>23.34</td>
</tr>
</tbody>
</table>

Overall, there was no significant effect of
the silvicultural treatments on total
number of weevils \( F = 1.04, df = 3, P
= 0.4886 \) found in a stand. This finding
rejects our hypothesis that prescribed fire
in the spring would reduce abundance. Of
the nine genera indentified in this study, two – *Conotrachelus* and *Curculio* – are
considered to be major predators of oak
acorns. Both genera were found in all
treatment plots at both study sites, and sta-
tistically the two locations were similar in
their numbers, though *Conotrachelus* was
more abundant than *Curculio* (Figure 2).
There was no effect of silvicultural treat-
ments on occurrence of either genus \( F =
0.06, df = 3, P = 0.9767 \). Likewise, we
observed no significant treatment x genus
interaction, indicating that both genera
were similarly unaffected \( F = 0.41, df =
3, P = 0.7557 \).

Species in the genus *Curculio* are regarded
as primary seed infesting weevils of oaks as
well as other nut tree species, since they do
not require previous insect or other damage
to a seed for oviposition. *Curculio* weevils
are host specific, and of the more than nine
species captured in our study, at least five
are known to feed on oaks common to the
central hardwood forest. Two of the species
found in our study were not previously
reported in this region. *Curculio* is listed by
Gibson (1969) as occurring only in the
southwestern states, particularly New
Mexico, Arizona, and Texas. This species
breeds in oaks, though no information
is given as to particular host species.
It is possible that a prescribed burn con-
ducted early in the fall, during the period
of acorn drop, may be more effective in
reducing weevil occurrence by destroying
larvae residing within the acorns.

*Curtepistomus castaneus*, the non-native
Asian oak weevil, was the most abundant
weevil encountered in our study. This
species was introduced to North America
from Japan and first detected in New Jer-
sy in 1933. Fergenson et al. (1991) found
black, white, and red oak, along with
sugar maple (*Acer saccharum* Marsh.),
to be the preferred host trees of this spec-
ies; and additional studies by Frederick
and Gering (2006) substantiate this claim.
*Curtepistomus castaneus* weevil larvae
have been reported to impact oak seedling
growth by feeding on the fine roots and
leaves (Sander 1990).

**DISCUSSION**

Controlling seed-destroying insect popu-
lations by implementing stand-level
treatments would benefit land managers
attempting to promote oak regeneration.
However, the prescribed burning and me-

The most abundant species, *C. naso*, is known to oviposit in acorns, particularly those of the white oak subgroup (*Leucobalanus*), in addition to *Crataegus* and *Malus* species. Larvae of the genus *Cryptorhynchus* are bark borers and adults are generally found on the bark and dead twigs of oaks, hickory, birch (*Betula* spp. L.), and others. Weevils in the genus *Oidocnephus* primarily breed in galls found on oaks and other tree species. *Piazorhinus scutellaris* is found on oaks where it is thought to mine the leaves. *Eulechriops minutus*, *Piazorhinus scutellaris*, and *Psomus* spp. are known to occur on oak as well as hickory and ash; however, it is not clear whether or not they breed within the seeds of any of these species (Blatchley and Leng 1916). While the purpose of this study was not to provide a comprehensive list of all Curculionids in the region, it does give us a glimpse into the major species inhabiting oak forests and how their populations are structured and influenced by forest management activities. Species richness indicators suggest that considerably more sampling needs to be conducted to better clarify community composition. The apparent ineffectiveness of silvicultural treatments, particularly prescribed burning in the spring, in reducing seed weevil occurrence is an important preliminary finding. Additional research should examine the effect of fall burns on weevil abundance and the relationship of burn time to mast cycles. The effect of burning on rare species requires additional consideration.

**ACKNOWLEDGMENTS**

We would like to thank the USDA Forest Service for site access, logistical support, and data collection. We especially wish to thank Dr. Robert P. Long, USFS, Delaware, OH, for his support and assistance. While not receiving direct support, this project would not have been possible without the infrastructure supplied by the Fire and Fire Surrogates (FFS) research project funded by the Joint Fire Science Program. Direct funding was supplied to JAL by a grant from the Ohio University Graduate Student Senate. Thanks to Dr. Kelly Johnson for help in developing this research and for assistance in weevil identification. Thanks also to Drs. Harvey Ballard and Kim Brown for their assistance and comments throughout.

Jeffrey Lombardo was a graduate student in the Department of Environmental and Plant Biology at Ohio University. He completed this work as part of his M.S. thesis research examining the effects of fire and thinning on oak seed production and predation.

Brian McCarthy is a Professor of Forest Ecology in the Department of Environmental and Plant Biology at Ohio University. His research focus is on the diversity, ecology, and disturbance dynamics of eastern deciduous forests.
Figure 2. Mean (± SD) number of weevils in the genus Curculio and Conotrachelus captured in each of the four silvicultural treatments at the Zaleski and REMA experimental forests in southeastern Ohio.

LITERATURE CITED


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