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PHYSIOLOGY OF RED-COCKADED WOODPECKER CAVITY TREES: IMPLICATIONS FOR MANAGEMENT [1]

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Abstract. Resin flow and tree moisture stress, frequently used as indicators of pine susceptibility to pine bark beetle (Dendroctonus frontalis Zimm.) attack, were measured in loblolly (Pinus taeda L.) and shortleaf (P. echinata Mill.) pines red-cockaded woodpecker [Picoides borealis (Vieillot)] cavity trees in the Angelina and Davy Crockett National Forests in eastern Texas. No differences in moisture stress were found, whereas resin flow between different types of cavity trees and control or potential trees varied by site and species. It was concluded that effects of red-cockaded woodpecker activity on host tree susceptibility to southern pine beetle will vary by site, tree species, and host tree condition. Forest management activities and general forest health are much more important for the bird's long-term survival.

Introduction

The red-cockaded woodnecker, [Picoides borealis (Vieillot)] (RCW) has been listed as an endangered species since 1970. Endemic to the pine ecosystems of the South and Southeastern United States, the RCW is unique in that it excavates its nest cavity exclusively in living pine trees. Old-growth longleaf (Pinus palustris Mill.), loblolly (P. taeda L.), and shortleaf (P. echinata Mill.) pines are primarily utilized. RCW populations in Texas (Conner and Rudolph 1989) and southwide (Costa and Escano 1989) are generally declining due in large measure to loss of old-growth southern pine habitat (U.S. Fish and Wildlife Service 1985).

In addition to excavating its nest cavities in living pines, RCWs peck small holes, called resin wells, around the entrance to their cavities that cause a copious flow of pine resin down and around the boles of their cavity trees. The resin serves primarily as a barrier against rat snakes [Ela he obsoleta (Say)], a major RCW pre ator (Jackson 1974; Rudolph et al., 1990b), but has little effect on cavity competitors (Rudolph et al., 1990a).

The major cause of RCW nest cavity tree loss in Texas loblolly and shortleaf pine stands is attack by southern pine beetle (Dendroctonus frontalis Zimm.) (Conner et al., in press; Kulhavy et al. , in press). Trees favored by the RCW for nest cavities tend to be old, ranging from approximately 60 to 130 years

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of age in loblolly and shortleaf pine, with slow radial growth, and infection with red-heart rot (Phellinus pini) (Lennartz et al., 1983; Conner and O'Halloran 1987). These characteristics tend to place pine trees at high risk of attack by southern pine beetle and associated phloem-boring beetles, even when bark beetle populations are generally at endemic levels.

A primary host defense against bark beetles is preformed resin flow (Hodges et al., 1979; Payne 1980; Paine et al., 1985). Preformed resin is resin present in the resin ducts at the time of wounding or insect attack, rather than resin produced as a response to these stimuli. Bark beetles, particularly during endemic population levels, are frequently unable to effectively colonize and kill pines with high resin flow. An important factor in predisposing trees to successful attack by phytophagus insects is moisture stress (Kozlowski 1969). Lorio and Hodges (1977) found that stressed pines were much less able to resist southern pine beetle attack than unstressed trees.

The purpose of this investigation was to examine the effects of RCW cavity excavation and resin-well pecking on preformed resin flow and tree moisture stress. Implications for management based on these and other characteristics of RCW cavity trees are also explored.

Methods And Materials

Study Area

Data were collected in the Bannister Wildlife Management Area of the Angelina National Forest (ANF), Texas, periodically during the growing seasons of 1988 and 1989. Data were also collected in 1989 and 1990 from the Neches district in the Davy Crockett National Forest (DCNF), Texas, approximately 100 km west of the ANF. Sampling dates in the ANF were June 3, July 15, September 1, and October 21 of 1988; and May 24, July 21, August 16, and September 29 of 1989. In the DCNF sampling times were June 6, July 20, August 22, and October 14 in 1989; and March 10, June 5, July 23, and September 7 in 1990.

Red-cockaded woodpecker cavity trees evaluated in this study were either loblolly or shortleaf pines. Sample trees in the ANF were divided into four categories:

1. Trees currently used for RCW nesting and roosting that had been established prior to 1987 (old active);
2. Trees previously used for nesting and roosting, but currently not used by RCW (inactive);
3. Trees having external characteristics associated with RCW trees, such as age, evidence of heart-rot, etc., but no history of RCW utilization (potential); and
4. Cavity trees activated after 1987 (new active).

In the DCNF, only the first three categories were sampled. Approximately 60 trees, divided into appropriate categories, were sampled in each forest. The same trees were used in each sampling interval.

Resin Flow

Resin flow was measured by driving a 2.54-cm diameter circular arch punch to the interface of xylem and phloem at approximately 1.4 m (dbh) on the bole. All holes were punched between the hours 1900 and 2200 to minimize effects of diurnal variation in resin flow (Nebeker et al., 1988). Triangular metal funnels were then placed under the wounds to divert exuded oleoresin into a clear plastic graduated tube. Resin flow was recorded at 8 and 24 hr after wounding. After recording 24-hr values, funnels and tubes were removed, and the bark plug replaced. To avoid placing undue additional stress on the trees, only one sample/tree was taken during any one sampling period.

Tree Moisture Stress

Tree moisture stress was evaluated by using the pressure chamber technique (Scholander et al. , 1965)) . Twig samples were taken from the upper crowns of cavity and non-cavity trees selected from among the trees samples for resin flow. Sampling took place during peak stress periods of 1300 to 1500 hr at the same times as resin sampling. Only established active RCW trees, inactive trees, and potential trees were evaluated. Newly excavated cavity trees were too few in number to provide valid comparisons. Twigs were removed by a blast from a 12-gauge shotgun, and moisture status evaluated within 60 sec of removal.

Analysis

Data were analyzed on the Honeywell™ CP-6 mainframe computer at Step-? hen F. Austin State University using the SPSS^x statistical software package (Norusis 1985). Resin flow at 8 and 24 hr was analyzed separately for each species and by each forest. Resin flow by species was analyzed using the Mann-Whitney U-Wilcoxon Rank Sum test (Norusis 1985). Kruskal-Wallis non-parametric rank analysis was used to evaluate resin flow by cavity tree type. When differences were significant at $P \leq 0.05$, ranked means were separated using the non-parametric multiple comparison procedure described by Daniel (1990). The same procedures were used to analyze tree moisture stress.

Results

Resin flow did not vary significantly by sample date in either forest, most likely because sampling was done only during the growing season of spring, summer, and early fall. Samples were therefore pooled for analysis into their respective species and cavity tree types for each forest, without reference to sample date.

Overall, 8- and 24-hr resin flow, combining all cavity tree types, showed significant differences in resin flow by species (Table 1), but with the species exhibiting highest resin flow differing by forest. In the ANF, shortleaf pine had higher resin flow, while loblolly pine had the highest resin flow in the DCNF.

Analysis of sample trees by cavity tree type showed similar difference by species. In the ANF there were no significant differences in resin flow

Table 1. Overall resin flow at 8 and 24 hr by species and forest.

Species	N	Angelina NF 8 hr	Angelina NF 24 hr	N	Davy Crockett NF 8 hr	Davy Crockett NF 24 hr
		--- (ml) ----			--- (ml) -----	
Loblolly	267	4.23 a[1] (3.98)[2]	6.12 a (5.97)	126	5.89 b (5.21)	9.21 b (8.66)
Shortleaf	181	5.59 b (4.82)	8.14 b (7.25)	331	3.53 a (3.89)	5.93 a (6.31)

[1] Resin flow differs significantly between species for 8- and 24-hr measurements [α = 0.05, Mann-Whitney U-Wilcoxon Rank Sum Test (Norusis 1985)].

[2] Standard deviation.

Table 2. Eight- and twenty-four hr resin flow by cavity tree type, Angelina National Forest, 1989 and 1990.

Cavity tree type	N	Loblolly pine 8 hr	Loblolly pine 24 hr	N	Shortleaf pine 8 hr	Shortleaf pine 24 hr
		--- (ml) ----			---- (ml) -----	
Active	81	4.23 a[1] (4.15)[2]	6.12 a (6.58)	68	4.27 a[1] (3.44)	6.04 a (5.20)
Inactive	65	4.78 a (4.08)	6.20 a (5.60)	23	5.64 a (5.88)	8.03 a (8.48)
Potential	95	3.75 a (3.81)	5.59 a (5.57)	40	4.59 a (4.06)	7.09 a (6.77)
New active	29	4.57 a (3.84)	7.64 a (6.26)	29	10.07 b (4.50)	14.70 b (6.68)

[1] Within columns, means followed by the same letter are not significantly different [α = 0.05; Kruskal-Wallis non-parametric rank analysis (Norusis 1985); non-parametric multiple comparison procedure (Daniel 1990)].

[2] Standard deviation.

by cavity tree type in loblolly pine (Table 2). In shortleaf pine, however, newly activated cavity trees had much higher resin flow than old active, inactive or potential.

Table 3. Eight- and twenty-four hr resin flow by cavity tree type, Davy Crockett National Forest, 1989 and 1990.

Cavity tree type	N	Loblolly pine 8 hr	Loblolly pine 24 hr	N	Shortleaf pine 8 hr	Shortleaf pine 24 hr
		---- (ml) ----			----- (ml) -----	
Active	22	9.27 b[1]	13.82 b[1]	82	3.70 ab	5.90 ab
		(5.38)[2]	(9.21)		(4.50)	(7.28)
Inactive	48	5.67 ab	9.21 ab	111	2.59 a	4.27 a
		(4.89)	(8.27)		(3.11)	(4.78)
Potential	56	4.75 a	7.39 a	136	4.25 b	7.39 b
		(4.97)	(8.24)		(3.85)	(6.49)

[1] Within columns, means followed by the same letter are not significantly different [$\alpha = 0.05$; Kruskal-Wallis non-parametric rank analysis (Norusis 1985); non-parametric multiple comparison procedure [Daniel 1990)].

[2] Standard deviation.

Table 4. Tree moisture stress by species and cavity tree type, Angelina National Forest, 1988 and 1989.

Cavity tree type	N	Loblolly pine	N	Shortleaf pine
		---- (MPa) ----		----- (MPa) -----
Active	17	1.77	16	1.70
		(0.14)'		(0.19)
Inactive	6	1.76	11	1.78
		(0.18)		(0.14)
Potential	25	1.78	10	1.68
		(0.17)		(0.19)

[1] Standard deviation.

Results from the Davy Crockett National Forest were different (Table 3). Active loblolly pine cavity-trees had significantly higher resin flow than the potential trees. For shortleaf cavity trees, resin flow was highest in the potential trees and lowest in inactive trees.

No significant differences were found in tree moisture stress between cavity tree types in either forest (Tables 4 and 5). It should be emphasized, however, that these are results taken only during hours of peak stress and do not include newly activated cavity trees.

Table 5. Tree moisture stress by species and cavity tree type, Davy Crockett National Forest, 1989 and 1990.

Cavity tree type		Loblolly pine		Shortleaf pine
		---- (MPa) ----		---- (MPa) ----
Active	10	1.77 (0.15)[1]	16	1.82 (0.15)
Inactive	8	1.69 (0.30)	11	1.78 (0.10)
Potential	18	1.73 (0.22)	10	1.74 (0.17)

[1] Standard deviation.

Discussion

Resin-well pecking by RCWs on active cavity trees is a continual wounding of the tree, resulting in a sustained flow of resin at the wound site. Results indicate that this pecking activity can affect preformed resin flow in some cases, but the direction and magnitude of the effects are interactive with tree species and site factors. Effects may also be transient.

In the ANF only newly excavated shortleaf pine cavity trees had resin flow significantly different (in this case higher) than other cavity and potential tree types. That the older active trees were at the same levels as inactive and potential trees indicates the effect is temporary. The loblolly sample trees in the ANF, with no differences in resin flow between any of the cavity-tree types, are apparently unaffected in this respect by RCW cavity excavation and resin-well pecking.

Results from the DCNF indicate that loblolly cavity trees may respond to woodpecker activity by increased resin flow, with the opposite being the case for shortleaf pine. These results, however, may be complicated by site differences. In the ANF, both shortleaf and loblolly pine cavity trees occurred in all colonies, though loblolly predominated. In the DCNF , where annual rainfall tends to be lower, loblolly pine was more restricted to bot tomland and moist areas, while trees on ridges tended to be relatively pure stands of shortleaf. Blanche et al. (1985) found that bottomland pines responded to wounding by increased resin flow, while trees on ridges did not.

Essentially uniform tree moisture stress data, regardless of cavity-tree type or species indicates that RCW activity is not having an effect on moisture stress during the peak stress hours. This does not necessarily mean that it is the same at all hours of the day for all sites. Diurnal measurements, beginning during the predawn period and ending in early evening, would give more complete results, but are highly problematic due to the size of the trees, potential impact on the crown from repeated sampling with a shotgun, and the presence of the birds in close proximity to the cavity trees early and late in the day.

It is difficult to generalize about the effect of RCW activity on the relative susceptibility of its host to bark beetle attack. The effect, if any, is variable by site and species (and also probably by initial host condition). Its importance is probably minor compared with effects of forest management activities on the site, such as prescribed burning, thinning, and midstory removal. RCW cavity trees, particularly loblolly and shortleaf, are naturally at a stage in life where vulnerability to mortality from pine bark beetles is high.

Long-term, proactive management strategies to favor the RCW in the loblolly/shortleaf forests of Texas should be aimed at reducing risk of bark beetle attack by increasing overall forest health. Increasing tree species diversity, increasing age class diversity, and favoring native species are a few general suggestions frequently made for reducing bark beetle risk (Hicks et al., 1979). Management guidelines should be flexible enough to allow for site specificity in optimizing general forest health in a particular region.

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