

Resin Flow in Loblolly and Shortleaf Pines Used by Red-cockaded Woodpeckers

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ABSTRACT

We measured resin flow in loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pines in stands used by red-cockaded woodpecker, *Picoides borealis* (Viellot), in the Angelina and Davy Crockett National Forests in eastern Texas. We also measured resin flow in a mature loblolly pine stand not used by the woodpeckers. Resin flow varied by study area, species, and stand position. In woodpecker stands, pines experiencing low levels of competition seemed better able to tolerate the continual resin drainage associated with red-cockaded woodpecker resin well pecking. In the Angelina National Forest, all new cavity trees excavated during the study were on forest edges. In the non-woodpecker stand, edge trees had significantly better resin flow. These results indicate that the woodpeckers choose trees most likely to be good resin producers. They also indicate that silviculture in loblolly and shortleaf pine stands should favor edge and an open stand habit when red-cockaded woodpeckers are a major management consideration and that potential resin production can be measured in both cavity pines, and pines being considered for red-cockaded woodpecker introduction.

Key Words: Endangered Species; Edge Effect; National Forests; Forest Management

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Introduction

Red-cockaded woodpeckers, federally listed as an endangered species [1], are unique among North American woodpeckers in that nesting and roosting cavities are excavated in living pine trees. Populations occur from Texas and Oklahoma, east to Florida and north to Virginia, but have declined or been extirpated because of habitat loss and fragmentation [2-5]. Population declines have been reversed in some areas with the use of artificial cavities, translocation of non-breeding birds from large populations to needy populations, aggressive hardwood control and basal area reduction [6-7].

Although longleaf pine (*Pinus palustris* Mill.) in relatively open stands is considered optimal habitat [8], shortleaf (*P. echinata* Mill.) and pitch pines (*P. rigida* Mill.) also are readily used [9,10]. In Texas the majority of red-cockaded woodpecker clusters (called colonies in older literature) occur in loblolly (*P. taeda*) and shortleaf pine stands [3,11].

Attack by southern pine beetles (*Dendroctonus frontalis* Zimmermann) is the primary cause of cavity tree mortality in Texas loblolly and shortleaf pine stands [12,13]. Trees favored by the woodpeckers tend to be the oldest in the stand, ranging from 60-130 years old among loblolly and shortleaf pines, and are characterized by slow radial growth, disintegrating crowns and red-heart rot (*Phellinus pini*) infection [3,14,15]. Such characteristics may place southern pine trees at high risk of attack by southern pine beetles and other phloem boring insects even when bark beetle populations are relatively low [16].

A potentially important area of interaction among red-cockaded woodpeckers, southern pine beetles and southern pines is the resin system of pine trees used as hosts by both the woodpeckers and beetles [17-20]. Red-cockaded woodpeckers peck small holes, called resin wells, around cavity entrances that create a cascade of pine resin on the bole around and beneath cavity entrances. This flow of fresh, sticky resin serves as a barrier against rat snakes, *Elaphe* sp., a major nest predator [21,22]

A primary pine tree defense against bark beetle attack is resin in preformed resin flow [12, 16-20,23-29]. Bark beetles, particularly during endemic periods, are often unable to invade and kill southern pines with high resin flow [29]. Severe trauma, such as a lightning strike may temporarily immobilize resin production and flow and at the same time release host odors, particular alpha-pinene, an important component of pine resin [24]. Freshly excavated red-cockaded woodpecker cavity trees suffer disproportionate bark beetle attacks [12,13]. It is hypothesized that extensive resin-well pecking may cause the trees to resemble lightning struck trees under some circumstances [12] and may negatively affect resin production and flow in concert with other stresses [14,24].

Little research has focused on resin flow, an important defense in red-cockaded woodpecker cavity trees or mature to senescent trees in quasi old-growth stands. A better understanding of resin flow on the relative susceptibility of loblolly and shortleaf pine cavity trees can aid in developing more effective long-term management that incorporates red-cockaded woodpecker recovery into multiple use forestry. This study focuses on mature loblolly and shortleaf pine stands in Texas National Forests that are used or may potentially be used by red-cockaded woodpeckers.

Methods

Study Sites

Resin data from red-cockaded woodpecker clusters dominated by loblolly and shortleaf pine were collected in 1991-1993 from the Bannister Wildlife Management Area of the Angelina National Forest and from the Davy Crockett National Forest. Both forests are located in eastern Texas. Data were also collected in the Angelina National Forest from a mature loblolly stand with no evidence of red-cockaded woodpecker nesting, roosting or foraging.

The Angelina National Forest (31° 15' N, 94° 15' W, 50 m elevation MSL) is about 45 km east of Lufkin, Texas in Angelina, Jasper, Nacogdoches, and San Augustine counties. Its 62,423 ha are divided by Sam Rayburn reservoir into northern and southern portions of roughly equal size. The Bannister Wildlife Management Area is on the northern portion. Red-cockaded woodpecker clusters in this area are on shrink-swell soils of the Woodtell (fine, montmorillonitic, thermic, Vertic Hapludalf) and Lacerda (very-fine, montmorillonitic, thermic Aquentic Chromudert) series. Loblolly and shortleaf pines dominate the overstory, with a small overstory hardwood component. Substantial hardwood midstory and medium to high pine basal area (19-22 m² ha⁻¹) existed at the time of the study. Midstory has since been controlled and pine basal area reduced.

The Davy Crockett National Forest (31.30 N, 95.10 W, 95 m elevation MSL) has 65,599 ha, and is situated in Houston and Trinity counties about 45 km west of Lufkin, Texas. Moswell series soils (very-fine, montmorillonitic, thermic, Vertic Hapludalf) were predominant in the study areas. The forest canopy was composed of loblolly and shortleaf pines at basal areas ranging from 19 to 28 m² ha⁻¹. Hardwood midstory was substantial in all stands surveyed. As in the Angelina National Forest, pine basal area was subsequently reduced and hardwood midstory controlled in compliance with court-ordered management.

To study the edge effect on resin production without woodpecker influence, a non-woodpecker stand in the Angelina National Forest was also selected. It was dominated by loblolly pine at an interior basal area exceeding 24 m² ha⁻¹. A substantial mature white oak (*Quercus alba* L.) component also was present in the canopy at about 7 m² ha⁻¹ basal area. Midstory was sparse because of low light. The understory consisted primarily of American beech (*Fagus grandifolia* Ehrh.) and Florida maple (*Acer barbatum* Michx.).

Sample Trees

Trees in the red-cockaded woodpecker clusters used for sampling were categorized as forest edge or forest interior trees (Table 1). Edge trees were 20 m or closer to a significant forest opening (0.25 ha or greater) with little or no crown competition. Other trees were considered to be interior trees.

Table 1: Sample sizes for resin sampling on stands with red-cockaded woodpecker activity in the Angelina and Davy Crockett National Forests in eastern Texas.

Cavity Tree	Edge Loblolly	Interior	Edge Shortleaf	Interior
Angelina National Forest				
Active	5	4	5	4
Inactive	5	4	2	3
Control	4	9	2	3
New	3	0	3	0
Davy Crockett National Forest				
Active	2	0	4	5
Inactive	2	3	8	4
Control	4	2	6	9

In addition to stand position, the following red-cockaded woodpecker activity categories were assigned: 1) active trees were currently used for nesting and roosting; 2) inactive trees were formerly used, but currently not used; and 3) control trees had no evidence of ever being used for woodpecker nesting or roosting, but did have external characteristics associated with cavity trees such as age, size, crown condition and evidence of heart rot. In the Angelina National Forest only, cavity trees excavated during the course of the study were added to those being samples and classified separately as new trees.

For the edge effect study without woodpecker influence, a total of 40 sample trees in the non-woodpecker stand in the Angelina National Forest were divided equally into two categories: edge trees were a distance of 20 m or less from a large, sharply delineated forest edge formed by a highway right-of-way and interior trees were 40 m or farther from this edge.

A number of sample trees in all of the study areas could not be aged with an increment borer because of heartwood decay. In the red-cockaded woodpecker stands, trees that could be aged ranged from 60 to 120 years, with most over 80. The trees that could be aged in the non-woodpecker area averaged 70 years.

Tree Measurements

Tree measurements taken in all study areas included tree height (HT) measured with a clinometer, height to lowest live branches, crown width and diameter measured with a diameter tape at breast height (DBH, 1.4 m). Live-crown ratio (LCR) was computed as the percentage of the total height of the tree covered with live branches.

Resin Flow

Resin flow was measured by driving a 2.54 cm diameter circular arch punch to the interface of xylem and phloem about 1.4 m above the ground on the bole. This is the depth of red-cockaded woodpecker pecking to produce resin from resin ducts. Sampling holes were punched between 07:00 and 10:00 hrs to minimize diurnal variation effects [30]. Triangular metal funnels were placed under the wounds to divert exuded resin into clear plastic graduated tubes. Resin flow was recorded in ml 8 and 24 hours after wounding. After 24-hour readings were completed, funnels and tubes were removed, and bark plugs replaced. At the non-woodpecker area, samples were taken at 1.4 m on all trees, and about 3.5 m on 10 edge and 10 interior trees.

Analyses

Data sets from each study area and each tree species were analyzed separately. For stands involving woodpecker activities, a series of analysis of variance (ANOVA) were performed to determine if there is any significant difference among the cavity tree types (active, inactive, control, and new) on HT, DBH, LCR, as well as resin production. These variables were also compared between the group of edge trees and interior trees.

For the non-woodpecker stands, the ANOVA was performed using a repeated measures approach because the same trees were used throughout the study for resin flow measurements [30]. ANOVA with $\alpha=0.05$ was used to test the null hypothesis of no differences among cavity trees types and stand position with respect to resin flow, while $\alpha=0.10$ was used to evaluate HT, DBH and LCR because of restricted sample size. The Least Significant Difference (LSD) method of means separation was used when the results of ANOVA were found statistically significant.

Results

Tree Measurements

Among loblolly pines with woodpecker activities in the Angelina National Forest, active cavity trees in the forest interiors had significantly higher live-crown ratio than other interior trees (Table 2). Shortleaf pines in the forest interiors showed a similar relationship, with active and inactive woodpecker trees having higher live-crown ratios than the control trees (Table 2).

Table 2: Average height (HT), diameter at breast height (DBH) and live-crown ratio (LCR) of loblolly and shortleaf pine sample trees by cavity tree type and stand position, Angelina National Forest, Texas.

Among the Davy Crockett National Forest sample trees, edge trees of both species had significantly larger crowns ($P<0.10$) than corresponding interior trees (Table 3). No other significant differences were found. It is notable, however, that all new cavity trees excavated by woodpeckers during the course of this investigation were on forest edges of the Angelina National Forest and had relatively high live-crown ratios (Table 2). These new cavity tree also exhibited high initial resin flow rates (Table 4).

Loblolly Pine								
Edge					Interior			
Cavity		HT	DBH	LCR		HT	DBH	LCR
Tree		m	cm	%		m	cm	%
Type	N	(SD)	(SD)	(SD)	N	(SD)	(SD)	(SD)
Active	5	28	59.9	52.7	4	25.7	56.1	59.4a
		-2.3	-4.8	-7.6		-2	-6.8	-9.9
Inactive	5	28	58.9	54.8	4	30.5	54.4	44.4b
		-1.9	-4.3	-5.6		-2.7	-5.8	-9.9
Control	4	29	62.2	48.7	9	27.9	58.9	43.4b
		-3.3	-10	-10		-2.6	-4.6	-7.2
New	3	28	56.9	56.6	0			
		-3.1	-9.1	-9				
Shortleaf Pine								
Edge					Interior			
Cavity		HT	DBH	LCR		HT	DBH	LCR

Tree		m	cm	%		m	cm	%
Type	N	(SD)	(SD)	(SD)	N	(SD)	(SD)	(SD)
Active	5	27	45.7	43.8	4	27.6	53.3	49.4a
		-2.2	-8.1	-2.6		-3.1	-4.1	-5.2
Inactive	2	27	49.3	42.1	3	24.4	52.3	50.2a
		-2.6	-3.3	-2.4		-4.8	-13	-4.2
Control	2	26	45.7	53	3	26.8	51	43.1b
		-3.2	-5.8	-5		-1	-5.8	-1.1
New	3	31	53.6	48.2	0			
		-2.5	-4.6	-13				

Nothing was significant unless annotation within a column where means followed by same letter do not differ significantly ($\alpha = 0.10$).

Table 3: Average height (HT), diameter at breast height (DBH) and live-crown ratio (LCR) of loblolly and shortleaf pine sample trees by cavity tree type and stand position, Davy Crockett National Forest, Texas.

Loblolly Pine								
Edge					Interior			
Cavity		HT	DBH	LCR		HT	DBH	LCR
Tree		m	cm	%		m	cm	%
Type	N	(SD)	(SD)	(SD)	N	(SD)	(SD)	(SD)
Active	2	28.2	58	37.8	0			
		-0.8	-0.6	-1				
Inactive	2	29	64	40.5*	3	30	55.1	31.5
		0	-7.6	-0.7		-2.1	-17	-2.6
Control	4	26.9	58	49.0*	2	27	62	33.9
		-4.7	-9.9	-6.9		0	-6.1	-2.4
Shortleaf Pine								
Edge					Interior			
Cavity		HT	DBH	LCR		HT	DBH	LCR
Tree		m	cm	%		m	cm	%
Type	N	(SD)	(SD)	(SD)	N	(SD)	(SD)	(SD)
Active	4	26.6	50	46.5*	5	25	43.2	34
		-2.7	-8.1	-6.9		-3	-6.1	-5.5

Inactive	8	26.4	52	36.6*	4	28	47	29.2
		-1.3	-8.9	-7.9		-3	-6.8	-6.9
Control	6	25.2	47	40.1*	9	27	51	35.9
		-2	-4.3	-7.8		-2.6	-4.3	-11
Nothing was significant expect the annotation * where the mean of edge trees significantly differs from that of corresponding interior trees ($\alpha = 0.10$).								

Resin Yield

Resin flow varied by forest, pine species, cavity tree type and stand position. Among loblolly pines in the Angelina National Forest, new cavity trees and inactive trees had the highest resin flow on the edges, whereas active trees were the highest resin producers among interior trees (Table 4). Edge active and control trees had lower resin flow than corresponding interior trees, but inactive edge trees had significantly higher resin flow than the corresponding interior trees.

Among the Angelina National Forest shortleaf pines, the only similarity was that new trees also were among the highest resin producers (Table 4). The only significant edge versus interior comparison was with inactive cavity trees, where the interior sample trees exhibited higher resin flow.

Table 4: Average eight and twenty-four-hour resin flow (ml) for loblolly and shortleaf pine sample trees in northern Angelina National Forest, 1986 - 1989.

Loblolly Pine						
Edge				Interior		
Cavity			24			24
Tree		8 hours	hours		8 hours	hours
Type	N	(SD)	(SD)	N	(SD)	(SD)
Active	5	2.2b*	3.2b*	4	5.3a	7.2a
		-1.9	-3		-4.7	-6.9
Inactive	5	5.7a*	7.8a*	4	3.1b	4.2b
		-6.6	-8.5		-2.9	-4.3
Control	4	2.3b*	3.5b*	9	3.6b	5.3ab
		-2.7	-3.8		-3.4	-4.9
New	3	4.7a	7.6a	0		
		-3.4	-6.1			
Shortleaf Pine						
Edge				Interior		
Cavity			24			24
Tree		8 hours	hours		8 hours	hours

Type	N	(SD)	(SD)	N	(SD)	(SD)
Active	5	2.9b	4.4b	4	3.3b	4.5b
		-2.7	-4		-3.1	-4.3
Inactive	2	3.1b*	5.3b*	3	6.4a	8.7a
		-.3	-4.9		-6.3	-8.8
Control	2	4.9b	8.2ab	3	3.6b	6.1ab
		-4.9	-9.1		-3.6	-6.3
New	3	7.9a	11.4a	0		
		-5	-7.5			

Inactive trees in the forest interior had higher resin flow than control trees among loblolly pines in the Davy Crockett National Forest (Table 5). Inactive edge trees had higher resin flow than inactive interior cavity trees. The only other significant comparison was for control trees at 24 hours, with edge trees having the higher resin flow. Highest resin flow among shortleaf pines in the Davy Crockett National Forest was observed in interior active and control trees (Table 5). Interior active trees had significantly higher resin flow than edge active trees.

Edge Effect

Forty trees without woodpecker activities were selected and categorized into edge tree or interior tree in order to determine edge effect influenced solely by forestry practices. No differences in any tree measurements were seen in this non-woodpecker stand in the Angelina National Forest (Table 6). For resin flow, edge trees consistently produced significantly higher resin than interior trees at both 1.4 and 3-5 m, with the single exception of 1.4 m results on September 18, 1992 (Tables 7). When multiple date data were combined, it reconfirmed that edge trees produced more resin than interior trees significantly (Table 8).

Discussion

A copious resin flow, particularly during the breeding season, in the face of environmental stresses, including resin-well pecking, may be a viable indicator of health for red-cockaded woodpecker cavity trees [19,20,28]. Red-cockaded woodpeckers select cavity trees if there is sufficient resin production from resin well pecking [11]. This may be particularly true in shortleaf and loblolly pine stands, species that usually exhibit lower resin flow than longleaf pine [19] and are more susceptible to bark beetle mortality [12,13,28]. Theoretically, trees with large crowns should be better able to support a larger volume of sustained resin flow than trees with smaller crowns, and thinning has been associated with higher resin flow in younger trees [31,32], but this was not true in our study.

In the Davy Crockett National Forest, interior shortleaf pine trees had significantly smaller crowns than corresponding edge trees, but active and inactive cavity trees had significantly higher resin flow. Loblolly pines in the same forest also had larger crowns on edges, but these also had higher resin flow. Crown size did not vary by stand position in the Angelina National Forest, but resin flow did. Among loblolly pines, active and control edge trees had lower resin flow. Interior active loblolly pines had both larger crowns and higher resin flow. No such trends were seen in the shortleaf pine trees. New cavities established during the study were on forest edges, had live-crown ratios averaging above 45 percent and had the highest mean resin flow during the study. These observations indicate that red-cockaded woodpeckers actively choose trees that are likely to be high resin producers in a given stand [11,15,20,22].

Some of the variation in resin flow may be explained by the growth-differentiation balance [33,34] as a generalized way of understanding and predicting plant development and behavior. According to this concept, growth predominates when all internal and external factors are favorable. Water availability is seen as crucial in the growth-

differentiation balance [33,34]. When water is slightly limiting but other factors such as light, temperature and photosynthate supply are not, then differentiation is favored.

Red-cockaded woodpeckers are known to select pines for cavity trees that yield high volumes of resin [11]. Generally live-crown ratio of 40 percent or greater is associated with satisfactory growth and vigor, whereas live-crown ratio of less than 30 percent results in a loss of vigor from which trees may not recover even after thinning [35]. Such a reduction of vigor may lead to increased risk of death from insects, diseases and fire.

Resin flow in all study areas varied by tree species, stand position and red-cockaded woodpecker activity. Seasonal factors such as soil moisture deficits, photoperiod and cold-hardening; competitive stresses related to stand position; and a response to continual wounding by the woodpeckers are environmental factors known to influence resin flow [36] that may have influenced resin flow in this study. Genetic factors in loblolly pine act within individual pines to increase (or decrease) growth. In our study we found high (or low) resin producers remained in these categories [37].

In the non red-cockaded woodpecker study area, a more rigorous sampling of mature loblolly pines were categorized as edge or interior. Edge trees in the non-woodpecker stand clearly had significantly higher resin flow than the interior trees where stand position was clearly defined and was the only difference between the two tree categories. Especially interesting was the magnitude of sample differences 3 to 5 m up the bole from April through August 1992, a time for red-cockaded woodpecker nesting and fledging and when southern pine beetles may be particularly active. These substantial differences at 3 to 5 m up the bole (where most southern pine beetle attacks are initiated) indicate that the edge trees in this case are more beetle resistant [38]. These trees also would be superior from the perspective of the red-cockaded woodpeckers.

The added stress associated with red-cockaded woodpecker resin well maintenance may trigger additional resin flow, or ultimately result in lowered resin flow if moisture availability, photosynthetic surface, light availability and carbon demand created by continual resin drainage becomes non-sustainable. Edge trees typically have more resources available, enabling a sustained and higher resin flow for a greater period of time, with increased wounding having significantly higher resin flow in loblolly pine [37,38]. Resin well pecking in relatively dense stands may result in a diminished ability of the tree to resist insect attack and disease spread [13, 23, 37]. Loblolly pine responded with an increase in resin flow after mechanical wounding. This increased resin flow reflects translocation of resin and also an induced response of resin synthesis [32]. Newly excavated red-cockaded woodpecker cavity trees in our study exhibited higher resin flows on stand edges indicating an initial effect on resin allocation. These results may partially explain the red-cockaded woodpecker's observed preference for edge trees and low basal area. Resin well pecking in relatively dense stands may result in a diminished ability of the tree to resist insect attack and disease spread [12,26,28].

In all of the study areas, the gross seasonal trends in resin flow were exemplified by the non-woodpecker area. Resin flow at the beginning of the year is at a seasonal low. It begins to rise notably at about mid-March reaching seasonal highs in July and August. After September it declined quickly to seasonal lows. Relationships among sample tree categories tended to remain the same for each sampling period.

Management to favor red-cockaded woodpeckers in loblolly and shortleaf pine stands should be site specific, and produce and maintain an adequate number of high resin producing trees. Potential and active red-cockaded woodpecker trees can be sampled for resin production following the sampling methods used in this study. The sampling can follow the projected resin production over the season and recommendations made for resin status of each tree for potential for both future status of the tree and for installation of artificial cavities. Maintaining an open park-like stand, or providing some edge habitat should enhance resin production in pines potentially used by red-cockaded woodpeckers. Long-term management should emphasize windfirmness and a relatively open stand habit early in a pine stand's history. Silvicultural options for red-cockaded woodpecker management may include irregular seed-tree regeneration that may help to create two-age stand structures similar to some of the study areas [39, 40]. Attempts at uneven-age management also must take the species' lack of shade tolerance past the sapling stage into account as well.

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