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FUNGI AND RED-COCKADED WOODPECKER CAVITY TREES

RICHARD N. CONNER AND BRIAN A. LOCKE

It is widely thought that red heart fungus (*Phellinus pini* [Thore ex. Fr.]), syn. *Fomes pini*, must decay the heartwood of living pine trees (*Pinus* spp.) before Red-cockaded Woodpeckers (*Picoides borealis*) can excavate a cavity into the tree (Steirly 1957, Ligon 1971). Jackson (1977) reported that 20% of the red-cockaded cavity trees in the shortleaf (*P. echinata*) and loblolly (*P. taeda*) pines he sampled with an increment borer did not have visually detectable signs of red heart disease. He suspected, however, that the decay may have been in early stages or completely removed when the cavity was made.

P. pini has been the only fungus known to be found in red-cockaded cavity trees. Woodpeckers other than red-cockaded are dependent on trees with decayed heartwood, a condition that softens the heartwood and facilitates nest cavity excavation (Conner et al. 1976). In this instance, oaks (*Quercus* spp.) and hickories (*Carya* spp.) were the predominant tree species and the heart rot usually associated with them was *Spongipellis pachyodon* (Pers.) Kotl and Pouz.

The objectives of this study were to examine the internal conditions of red-cockaded cavity trees and determine presence or absence of decay, species of fungi involved and mode of entry of heartwood-decaying fungi into the trees.

METHODS

From 1977–1980, we examined 34 Red-cockaded Woodpecker cavity trees from the Angelina and Davy Crockett national forests and the I. D. Fairchild State Forest in east Texas. We searched these forests for recently killed cavity trees. Many trees had died from fire damage during prescribed burns (Conner and Locke 1979). Other causes of mortality were southern pine beetles (*Dendroctonus frontalis* Zimm.) and wind throw.

The trees we examined were either on the ground (N = 6) or standing (N = 28) in areas where many other cavity trees were present for red-cockadeds and their competitors. Since dead trees are typically not used by red-cockadeds for nesting or roosting (Ligon 1970), our impact on the woodpecker population was negligible.

Eighteen longleaf pines (*P. palustris*) (mean age = 108 years), 13 shortleaf pines (mean age = 90 years), and three loblolly pines (mean age = 90 years) were examined. Sections of trees with cavities or cavity starts were cut out, vertically sectioned and taken into the laboratory where chips of heartwood were aseptically extracted at 2–3 cm and 10–13 cm above and below cavities and cavity starts. The chips were cultured on malt agar at 25°C (see Conner et al. 1976 for technique). Heartwood from regions where decayed wood was adjacent to undecayed wood also cultured. Species of cultured fungi were determined by macroscopic and microscopic examination of the mycelial cultures (Davidson et al. 1942, Nobles 1965).

Presence or absence of decay prior to cavity excavation was estimated by careful visual examination of vertical sections of nest trees at each cavity site. *P. pini* grows in typical, thin, vertical columns of decay (2–10 mm in diameter). The older the infection within the tree, the more numerous the vertical columns and the larger their diameters. Often these columns are filled with thick masses of reddish-brown hyphal tissue. If a woodpecker excavated a cavity into a region of the tree where these decay columns were present in the heartwood, a vertical section of the cavity would show decay columns extending above and below the cavity. If decay occurred after the cavity was excavated, the cavity in effect would serve as a barrier and prevent spread of the decay. In the trees we examined, visual signs of decay at each cavity site were either totally lacking or present both above and below the excavated cavity.

RESULTS AND DISCUSSION

Heartwood decay was probably not an absolute prerequisite for Red-cockaded Woodpeckers to make a fully excavated cavity. Only 7 (39%) of the 18 longleaf pines examined were infected by heartwood decaying fungi; we detected no decay in 11 trees. Eleven (85%) of 13 shortleaf pines and all three loblolly pines examined had heartwood decay somewhere within the boles of the trees. If shortleaf and loblolly cavity trees are combined, 2 (12%) of these 16 trees did not have decayed heartwood. This is similar to the 20% figure observed by Jackson (1977) for the same tree species in Mississippi.

Presence of decay in the heartwood of a tree at one place in the bole did not necessarily mean that decay was present at all cavity sites within that tree. Examination of each cavity site revealed that 15 (47%) of 32 cavities in longleaf pines, 13 (87%) of 15 cavities in shortleaf pines, and 4 (100%) of 4 cavities in loblolly pines had decayed heartwood prior to cavity excavation (Table 1). Nineteen (37%) of the 51 cavities examined apparently were excavated into undecayed wood. Observations that Red-cockaded Woodpeckers can take a year or more to excavate a cavity (Baker 1971, Jackson 1977, Jackson et al. 1979) does not seem unreasonable in view of the firmness of healthy xylem tissue.

Four (31%) of 13 red-cockaded cavity starts were being excavated into longleaf pines with heart rots (Table 1); the remaining nine starts were being excavated into firm, undecayed wood. All three cavity starts in loblolly and shortleaf pines were being excavated into decayed heartwood.

A higher percentage of all cavities was excavated into decayed wood than were total cavity starts (Table 1). This suggests that some cavity starts that fail to hit decayed heartwood are aborted. However, this difference was not significant ($\chi^2 = 1.81, P > 0.26$) when tested with a 2×2 contingency table.

Although *P. pini* was the most common fungus (found in four longleaf, 10 shortleaf and two loblolly pines) *Phaeolus schweinitzii* (Fr.) Pat. (in one longleaf pine), *Lenzites saepiaria* (Wulf. ex. Fr.) Fr. (in one shortleaf pine),

TABLE 1
OCCURRENCE OF HEARTWOOD DECAY AT RED-COCKADED CAVITIES AND CAVITY STARTS IN EAST TEXAS PINE TREES

	Longleaf		Shortleaf		Loblolly		Total	
Cavity condition	N	%	N	%	N	%	N	%
Cavities								
Rot present	15	47	13	87	4	100	32	63
Rot absent	17	53	2	13	0	0	19	37
Cavity starts								
Rot present	4	31	1	100	2	100	7	44
Rot absent	9	69	0	0	0	0	9	56

Lentinus lepideus Fr. (in one loblolly pine), and *Phlebia radiata* Fr. (in one shortleaf pine) were also found in cavity trees. These four species of fungi were found in recently killed, standing cavity trees. *P. schweinitzii* is a common butt rot in pines that on occasion will spread several meters up the heartwood in the bole of a tree. The other fungi are thought to be dead wood and root decaying fungi (Overholts 1953). Obviously, decay of heartwood by these species can start before the tree is dead and has fallen. Two unidentified basidiomycetes were found in the heartwood of two longleaf pine cavity trees. One cavity tree contained two different species of fungi.

Researchers have suspected that Red-cockaded Woodpeckers introduce fungi (any species) as they begin to excavate a cavity and, as decay softens the sapwood, that the woodpeckers excavate the cavity entrance (Jackson 1977). Our results showed no indication of this sequence. As red-cockadeds excavated into sapwood tissue, pine gum (oleoresins) flowed to or was retained in the area of injury in apparently increased amounts, especially in longleaf pines. Pine gum had saturated the sapwood tissue surrounding the 67 cavity entrance tubes and cavity starts we examined. No fungus was ever detected in these saturated areas. Five cavity trees not included in our sample had lain on the ground for at least 3 years and had extensive decay in all other sapwood tissue except the areas around entrance tubes and starts that had been saturated with gum.

The heartwood of healthy, living pines is dead and thus does not saturate with oleoresins as does injured sapwood. Thus, woodpeckers may introduce *P. pini* or other basidiomycetes as they begin to excavate heartwood tissue in potential cavity trees (Jackson 1977). However, this was not apparent in our visual examinations of 32 cavities that had been vertically sectioned. At all the cavity sites where *P. pini* was present, columns of decay were present in the heartwood throughout the entire cavity-site area prior to cavity excavation.

When *P. pini* grows within pines, it grows more rapidly vertically than horizontally due to the structure of the wood. Thus, a column of vertical decay (e.g., 25 cm) may include about 1 cm^2 of horizontal decay (pers. obs.). Compartmentalization of decay is a well-known phenomenon (Shigo and Marx 1977). A woodpecker's excavation through an existing pattern of decay columns can be detected with relative ease if the tree can be cut down and vertically sectioned.

We also examined the vertical sections of cavity trees to see whether Red-cockaded Woodpeckers had detected a small pocket of decay and subsequently excavated all of the decay in the shape of a cavity. If this occurred, it might appear that the birds had excavated a cavity in a tree without heartwood decay. Our observations on the growth pattern of *P. pini* within trees suggest this is not the case. In order for decay to have spread sufficiently to provide for the horizontal diameter of a cavity, it would have had to grow very extensively in both vertical directions, well beyond the vertical dimensions of a red-cockaded cavity.

When it was possible to determine the mode of entry of heartwood decay, the entry was through a broken branch stub. This supports Affeltranger's (1971) speculation that entry of decay in red-cockaded cavity trees was through branch stubs with exposed heartwood or through large wounds. Entry through large wounds would probably be less common; 10–12 cm of sapwood would have to be gouged out to expose the heartwood.

If basidiomycetes were present, they were usually found at both 2–3 cm and 10–13 cm below nest cavities. In many trees, we also cultured numerous species of imperfect fungi (species that do not reproduce sexually) and bacteria. When present, imperfect fungi and bacteria were always found in the zone closest to the bottom of the nest cavity. We doubt that Red-cockaded Woodpeckers rely on imperfect fungi to decay wood tissue and thus ease their task of cavity excavation. Imperfect fungi were more prevalent in older nest cavities and typically absent in freshly excavated ones. We suggest that imperfect fungi begin to infect the wood tissue on all surfaces of the inside of the cavity, but only after the cavity is complete. This is similar to what was observed in woodpecker nest cavities in hardwood trees (Conner et al. 1976) where a succession of different imperfect fungi and bacteria infected all the wood tissue around the completed nest cavities.

It is difficult for us to conclude how much Red-cockaded Woodpeckers depend on decay to soften the heartwood of living pines. The presence of heart rot prior to excavation was not required for all cavities. The rate of occurrence of heart rot within cavity trees may just reflect the natural rate of occurrence of the fungi in the older trees within each forest community. Lay and Russell (1970) speculated that red heart is common in older stands and that woodpeckers could hardly avoid the fungus if they select older trees as cavity trees for reasons of tree size, wood density, or gum quality. Beckett (1971) also suspected that red heart was incidental to Red-cockaded Woodpecker selection of cavity trees.

We were not able to obtain current, accurate estimates of the frequency of heartwood decay in the longleaf stands and loblolly-shortleaf stands we examined. However, rough estimates of heartwood decay in loblolly and shortleaf pines in the Angelina and Davy Crockett national forests indicated a "moderate" infection rate (20–40%) for mature trees (G. E. Hartman, pers. comm.). Past estimates of the frequency of decay in Texas shortleaf pines, averaging 122 years of age, was 37% (Hepting and Chapman 1938). These frequencies are much lower than the frequency observed in our red-cockaded cavity trees (85%) in shortleaf pines. Frequency of decay in pine stands is variable and, in addition to age, is heavily dependent on stress factors such as excessive moisture and crowding (Wahlenberg 1946). Past frequencies of heartwood decay in other geographic areas were also lower than what we observed in shortleaf and loblolly pines: Arkansas loblolly—51% (mean age = 58 years), Arkansas shortleaf—11% (mean age = 120 years) (Mattoon 1915), Virginia Coastal Plain loblolly—19% (mean age = 110 years) (Nelson 1931), and North Carolina Coastal Plain loblolly—21% (mean age = 60 years) (Gruschow and Trousdell 1958). While this contrast tends to support the long held belief that Red-cockaded Woodpeckers prefer trees with decayed heartwood, it is still quite speculative because current frequencies of decay are needed to provide meaningful comparisons. Detection of heart rots by culture techniques is more efficient than simple visual examinations; thus, studies of decay frequencies from the past may have underestimated the actual presence of heart rots.

The frequency of decay in longleaf cavity trees was much lower than that in shortleaf or loblolly cavity trees (Table 1). Longleaf pines are well known for their copious production of gum, while shortleaf and loblolly pines produce much less (Wahlenberg 1946, Hodges et al. 1977). Because of the higher production of gum, longleaf pines have a higher resistance to invasion of fungi and bark beetles (Hodges et al. 1979). Gum can flow into injured tissue and slow or halt invasions. In fact, longleaf pine cavity trees have one-half the annual mortality rate of shortleaf and loblolly pine cavity trees (Lay 1973). Decay is not normally considered a problem in longleaf pines less than 100 years old (Wahlenberg 1946).

Mature stands of shortleaf and loblolly pines (70 years) would be expected to have a higher incidence of heart rot than similarly-aged stands of longleaf pines. Loblolly-shortleaf stands that are 70–80 years old should provide sufficient suitable cavity sites for Red-cockaded Woodpeckers. If red-cockadeds preferred longleaf pines with heart rot, a low frequency of suitably decayed longleaf pines may force some woodpeckers to use non-infected trees. Timber rotation ages (frequency of clearcutting) in longleaf pine forests (80 years in national forests) may not allow sufficient time for heart rot to develop to the extent and frequency necessary to be of most benefit to Red-cockaded Woodpeckers. It would require more time and energy to make cavities in nondecayed pines than in decayed pines. This may reduce the overall reproductive success of such birds and cause a gradual decline of populations in longleaf timber stands (see Conner 1979).

SUMMARY

Recently killed Red-cockaded Woodpecker (*Picoides borealis*) cavity trees were located during 1977–1980 in east Texas. Fungi from heartwood tissue at cavity sites and cavity starts was cultured on agar and identified. Heartwood decay was found in 63% of the cavity sites and 44% of the cavity-start sites examined. Longleaf pine cavity trees had a lower frequency of decay than did shortleaf and loblolly pine cavity trees. *Phellinus pini* was the most frequently detected fungus to be associated with red-cockaded cavity trees, but six other fungi species were detected. Our observations indicate that heartwood decaying fungi were not inoculated into the tree by the woodpeckers, but entered through broken branch stubs and were present prior to cavity excavation.

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WILDLIFE HABITAT AND SILVICULTURE LAB, SOUTHERN FOREST EXPERIMENT STATION, U.S. DEPT. AGRIC. FOR. SERV., NACOGDOCHES, TEXAS 75962 AND SCHOOL OF FORESTRY, STEPHEN F. AUSTIN STATE UNIV., NACOGDOCHES, TEXAS 75962. (PRESENT ADDRESS BAL: DEPT. BIOLOGY, NEW MEXICO STATE UNIV., LAS CRUCES, NEW MEXICO 88001.) ACEPTED 30 JUNE 1981.