Comparison of arthropod prey of red-cockaded woodpeckers on the boles of long-leaf and loblolly pines

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Abstract Red-cockaded woodpeckers (*Picoides* ***borealis)*** forage on the boles of most southern pines. Woodpeckers may select trees based on arthropod availability, yet no published studies have evaluated differences in arthropod abundance on different species of pines. We used knockdown insecticides to sample arthropods on longleaf (*Pinus palustris*) and loblolly pine (*P. taeda*) to determine which harbored the greater abundance of potential prey. Longleaf pine had significantly greater arthropod abundance (278±44.4/tree, $P=$ 0.013) and biomass (945±28 mg/tree, $P=0.007$) than loblolly pine (132±13.2/tree and 395±28 mg/tree). Certain groups were found in significantly higher numbers on longleaf, including Thysanura ($P=$ 0.0004), Hemiptera ($P=$ 0.0209), and Pseudoscorpiones ($P=$ 0.0277). Biomass of woodroaches (Blattaria: Blattellidae) also was greater on longleaf boles, but number of individuals did not differ significantly, suggesting that larger arthropods may prefer the bark structure of longleaf pine. We altered the bark surface of longleaf pine to determine whether bark structure may affect arthropods residing on a tree's bole. When the loose bark was removed by scraping, we recovered fewer arthropods from scraped than from unscraped control trees 8 weeks after scraping. We also lightly scraped the outer bark of both tree species and found that longleaf pine had significantly more loose, flaking bark scales than loblolly ($P=0.0012$). These results suggest that bark structure and not the chemical nature of the bark is responsible for differences in arthropod abundance and biomass observed on the 2 tree species. Retaining or restoring longleaf pine in red-cockaded woodpecker habitats should increase arthropod availability for this endangered bird and other bark-foraging species.

Key words arthropods, bark, loblolly pine, longleaf pine, red-cockaded woodpecker

Many birds obtain most of their arthropod diet from the boles of live trees. One that occurs in the southern United States, the endangered red-cockaded woodpecker ***(Picoides borealis),*** forages almost exclusively on live pines (Repasky 1984, Porter and Labisky 1986, Walters 1990, Jackson 1994). This woodpecker has been observed foraging on pines as small as 5 cm diameter at breast height (dbh), although it prefers trees larger than 25 cm dbh (Hooper and Lennartz 1981, DeLotelle et al. 1983, Repasky 1984, Porter and Labisky 1986) or the largest and oldest trees in an area (Engstrom and Sanders 1997, Zwicker and Walters 1999). Because red-cockaded woodpeckers are nonmigratory, their survival is influenced directly by the quality of foraging habitats surrounding roosting and nesting cavities (James et al. 1997, Davenport et al. 2000).

Despite efforts to increase red-cockaded woodpecker numbers, populations are fragmented and continue to decline throughout the species' range (James 1995). Declines appear to be associated with losses of mature longleaf pine (*Pinus palustris*) stands from timber harvesting, clearing for agriculture, urban development, and conversion to

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Longleaf pine stand located within a red-cockaded woodpecker foraging area on the Savannah River Site, South Carolina. Photo by S. Horn.

faster-growing species (e.g., loblolly pine [*P. taeda*]; Jackson 1971). Longleaf pine once covered roughly 24 million ha in the southeastern United States, but remaining forests constitute less than 1.3 million ha (Outcalt and Sheffield 1996). The effect of converting longleaf pine forests to loblolly pine on arthropod availability for bole-foraging bird species has not been investigated.

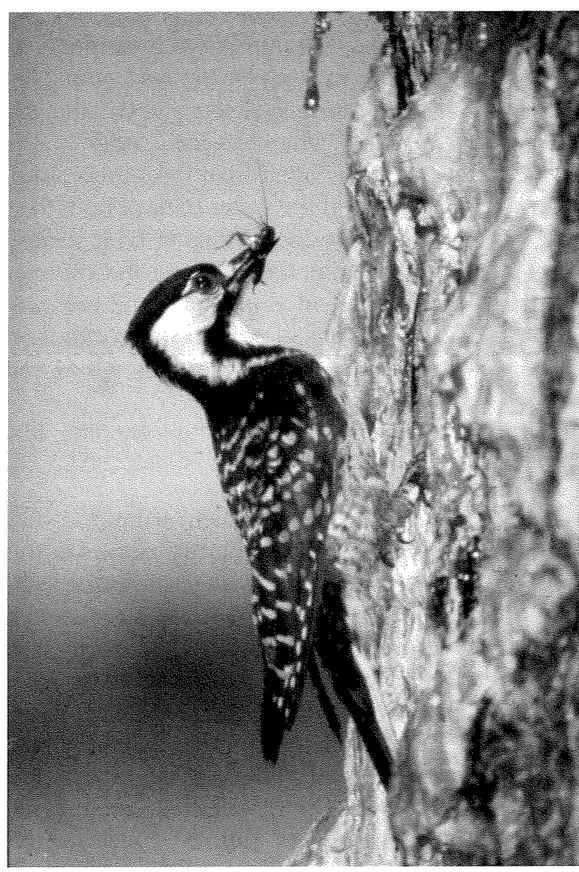
Bark is an important habitat for many arthropods, and bark structure may influence their diversity and abundance. Studies suggest that rough bark with deeper crevices provides better habitat for arthropods (Jackson 1979, Nicholai 1986, Mariani and Manuwal 1990).

Red-cockaded woodpeckers prefer to forage on larger or older trees (Porter and Labisky 1986, Hooper 1996, Engstrom and Sanders 1997, Zwicker and Walters 2000) that have thicker bark (Hooper 1996, Hanula et al. 2000*a*). Arthropod biomass on longleaf pines increased on trees up to age 60-80 years and then remained similar on trees up to 120 years of age (Hooper 1996, Hamila et al. 2000*a*). Arthropod biomass also increased with bark thickness up to a point, but once the bark reached a certain thickness, arthropod biomass remained the same. Because bark thickness and tree age were correlated, Hanula et al. (2000*a*) suggested that bark thickness might be the underlying reason longleaf pine 60-90 years old had more arthropods than younger trees.

If bark thickness or structure were an important tree characteristic resulting in more arthropods on tree boles, then management that favors planting or retaining species with desirable bark characteristics would benefit red-cockaded woodpeckers. Based on preliminary observations, we hypothesized that longleaf pines would harbor more arthropods than loblolly pines of similar size and age because the bark of longleaf appeared to have more hiding places for arthropods. We compared arthropod abundance and biomass on loblolly and longleaf pines, common species within foraging habitats of red-cockaded woodpeckers, and examined how bark structure influenced their abundance.

Study site

We conducted this study at the Savannah River Site (SRS), an 80,270-ha United States Department of Energy nuclear production facility located in the upper Atlantic Coastal Plain Physiographic Province. Both longleaf and loblolly pine forests are prevalent on the site, covering approximately 14,924 ha and 25,677 ha, respectively (Knox and Sharitz 1990). Historically, longleaf pine dominated the dry sandhill habitats, whereas loblolly pine



Female red-cockaded woodpecker delivering a woodroach to nestlings. Woodroaches are common bark inhabitants and often comprise a substantial bulk of the RCW nestling diet. Photo by J. Hanula.

Hydraulic lift truck used to access the canopy for insecticide application. Notice the insect collection tarp located at the base of the tree being sprayed. Photo by S. Horn.

were found mostly in riparian areas. The site now contains artificially regenerated, even-aged stands of loblolly, longleaf, and slash pines, but managers are working to restore species to their original habitats. The stands we selected for our study were similar in age (40-45 yr old based on stand establishment data), appearance, and understory plant composition. Common understory species included wax myrtle (*Myrica cerifera*), American beautyberry (*Callicarpa americana*), black cherry (*Prunus serotina*), yellow jessamine (*Gelsimium sempervirens*), poison ivy (*Rhus radicans*), and sassafras (*Sassafras albidum*).

Methods

Arthropod sampling

To remove arthropods from the tree bole, we sprayed Pounce 5.2EC® (FMC), a synthetic pyrethroid insecticide that provides quick knockdown of most arthropods. We used a 7.6-L handheld sprayer rather than a fogging device to ensure that arthropods were sampled only from the tree bole and not the canopy.

We selected 2 stands of each species based on similarities in age, stand structure, and vegetation. To minimize the likelihood that factors other than tree-bole characteristics would influence the results, we selected stands in close proximity. Treated trees occupied dominant or codominant positions in the canopy, so we used a hydraulic lift truck to access tree boles up to the lower canopy. We applied insecticide to entire boles, starting at the base of the crown, on days with light to no wind and partly cloudy skies. We collected arthropods that fell from tree boles on 2 tarps (3 x 3.5 m) placed at the base of trees so that they covered the ground surrounding the tree boles. Each tree bole received approximately 5 L of insecticide solution (1% AI). Insecticides affect arthropods at different rates, so we collected arthropods from the tarps for 2 hr and immediately placed them in 70% alcohol.

We sprayed 8 loblolly and 8 longleaf pine trees (4 trees/stand) in July and August 1999. We treated tree species on successive days (i.e., a loblolly pine was sprayed one day, and the next day a longleaf pine was sprayed at the same time of day). To reduce differences in arthropod diversity or abundance resulting from time of collection, we sprayed trees and collected during the same time intervals each day. We also recorded total tree height, height to the base of the living crown, and dbh for each treated tree.

Bark structure

We conducted a second experiment on 10 longleaf pine trees in the same habitat as above to determine whether bark structure affected tree-bole arthropod communities. In August 1999, we used bark-scraping tools to scrape 3-m sections of the boles of 5 trees until the outer bark was smooth. We avoided injuring trees to reduce the possibility of attracting insects to the wounds. No bark was removed from the remaining 5 trees. We waited one month and then applied insecticide to the 3-m scraped sections of trees and a similar area on unscraped control trees for collection of arthropods as described above.

There is little quantitative evidence regarding differences in southern pine bark structure, weight, moisture content, or exfoliation rates, which might be important indicators of arthropod abundance.

Howard (1971) stated that the manner and ease of scale exfoliation are related to structure and may have some species significance. To compare the outer bark of loblolly and longleaf pine, we marked off 0.5-m^2 areas on 10 previously unscraped trees of each species and lightly scraped to remove bark that was loose and flaked off easily. Care was taken to apply similar force to the scraping tool on each tree. We oven-dried (40°C for 72 hr) and weighed the bark, and calculated the percentage moisture to determine whether bark moisture influenced tree selection by arthropods. We also measured bark thickness using a bark gauge to determine whether this characteristic affected presence of arthropods.

Statistical analysis

We identified arthropods to morphospecies using a reference collection and then oven-dried (40°C for 48 hr) and weighed them to estimate biomass. We used a t-test (SAS 1985) to test for differences in arthropod and bark variables between the 2 tree species and between scraped and unscraped trees. For some taxa, we transformed the data using log,, $(x+1)$ or $\sqrt{x+0.5}$ transformation to stabilize the variance. All estimates are presented ±1 SE.

Results

Both loblolly and longleaf trees averaged 38.1 cm dbh, but we sprayed slightly higher on loblolly trees (13.1±0.11 m) than on longleaf (12.2±0.10 m) because the loblolly trees were taller. We collected 3,279 arthropods from 15 orders (Table 1). Hymenoptera (mostly ants) were the most common, followed by Blattaria (roaches), Coleoptera (beetles), Hemiptera (true bugs), Araneae (spiders), and Thysanura (silverfish), respectively. Other groups collected included Diptera (flies), Psocoptera (bark lice), Orthoptera (crickets), Homoptera (aphids), and Pseudoscorpiones (pseudoscorpions). Biomass was greatest in the Blattaria and Hemiptera due to large woodroaches in the genus *Parcoblatta* and large bugs in the genus *Largus*. Tree species were paired by time of day, and at no time did a loblolly yield more arthropods than its paired longleaf.

Although the same morphospecies of arthropods were collected from both tree species, longleaf tree boles had twice the number of arthropods and nearly 3 times the arthropod biomass as loblolly pine. We collected 278 arthropods/tree (SE= 44) from longleaf pine, significantly more ($P=0.013$) than the 132 (SE= 13) collected from loblolly pine. Likewise, arthropod biomass was significantly greater on longleaf pine ($\bar{x}=0.946$ g/tree, SE=0.145, $P=0.007$) than on loblolly tree boles (a?= 0.395 g/tree, SE = 0.028).

Three orders, Thysanura, Hemiptera, and the Pseudoscorpiones, were recorded in significantly higher numbers on longleaf pine (Figure 1). Although mean biomass of 5 of the 6 most commonly collected orders was greater on longleaf pine (Figure 2), only Thysanura, Hemiptera, and Blattaria were significantly greater.

We collected 230 different arthropods, including 47 genera from 41 families and 11 orders, from scraped and unscraped sections of longleaf pine boles. Unscraped trees yielded twice as many arthropods and 40 times the arthropod biomass as that recovered from scraped trees (Table 2). Silverfish (Thysanura), spiders (Araneae), and roaches (Blattaria) were more abundant on trees that had no bark removed, but only beetles (Coleoptera) and

Table 1. Total number and biomass of arthropods collected from the boles of 8 longleaf and 8 loblolly pine trees on the Savannah River Site (Aiken County, S.C.) using Pounce 5.2EC, a quick knockdown insecticide.

	Longleaf			Loblolly		
Arthropod Order	No. genera	Number	Biomass (g)	No. genera	Number	Biomass (g)
Araneae	19	190	0.767	19	124	0.503
Blattaria	3	332	2.246	2	189	0.396
Coleoptera	31	226	1.055	22	159	0.448
Diptera	4	43	0.007	7	21	0.014
Geophilomorpha	1	9	0.027	1	7	0.015
Hemiptera	16	264	1.474	3	67	0.654
Homoptera	3	4	0.001	5	12	0.050
Hymenoptera	19	717	0.316	14	269	0.318
Isoptera	0	0	0	1	1	0.0001
Lepidoptera	2	7	0.004	4	10	0.217
Opiliones	1	1	0.024	1	3	0.054
Orthoptera	3	94	0.162	1	57	0.091
Pseudoscorpiones	1	52	0.024	1	55	0.006
Scolopendromorpha	1	5	0.401	1	5	0.189
Thysanura	1	251	1.049	1	55	0.196

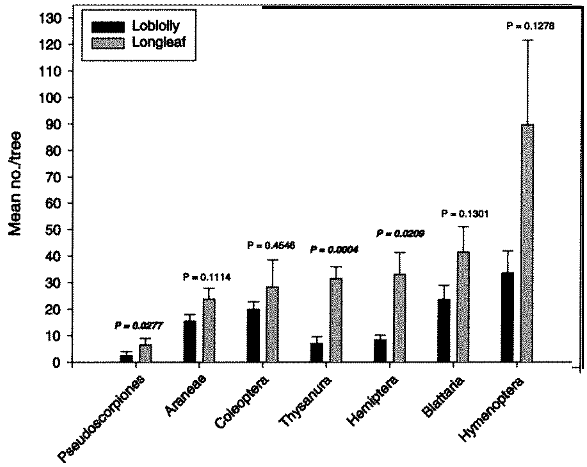


Figure 1. Mean number ($\bar{x}$ ± SE) of the most common orders of arthropods collected from the holes of 8 longleaf and 8 loblolly pine tree by spraying them with a quick knockdown insecticide (Pounce 5.2EC) and collecting the arthropods that fell on tarps on the ground. The P-value is listed above each arthropod order; those showing significant differences are hold and italicized (based on t-tests $P < 0.05$).

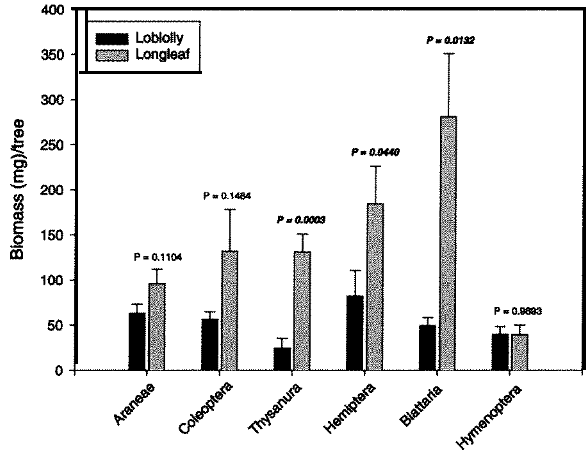


Figure 2. Mean oven-dried biomass ($\bar{x}$ ± SE) of arthropods collected from the holes of 8 longleaf and 8 loblolly pine trees by spraying them with a quick knockdown insecticide (Pounce 5.2EC) and collecting arthropods that fell on tarps on the ground. The P-value is listed above each arthropod order; those showing significant differences are bold and italicized (based on f-tests $P < 0.05$).

spiders (Araneae) had greater biomasses on unscraped trees at $\alpha<0.05$. In addition, biomasses of Thysanura and Blattaria were significantly greater on unscraped trees at $\alpha<0.09$.

We removed significantly more (P=0.0012) outer bark from longleaf pines (164 ± 16 g/0.5-m^2) than loblolly (89±8 g/0.5-m^2) by lightly scraping them. Bark moisture content (longleaf=6.8±0.24%; loblolly pine=6.0±0.35%), and thickness (longleaf=2.25 ±0. 16 cm; loblolly= 2.28±0.16 cm) were similar for the 2 pine species.

Discussion

The bark of longleaf pine hosts a large and diverse arthropod community (Hooper 1996, Hanula and Franzreb 1998, Hanula et al. 2000*a*). This study suggests that longleaf pine may be particularly

Table 2. Mean (±SE) number and biomass (g oven-dried weight) of the common arthropod orders collected from scraped or unscraped 3-m long sections of longleaf pine tree boles (n = 5). Scraped trees had only the loose outer bark removed. Arthropods were collected 8 weeks after scraping by treating the 3-m scraped area and the same size area of unscraped trees with Pounce 5.2EC insecticide and collecting the arthropods that fell from the trees.

	Number (Mean±SE)[a]			Biomass (g) (Mean±SE)[a]		
Order	Scraped	Unscraped	P	Scraped	Unscraped	P
Araneae	4.2 ± 0.80	8.6 ± 1.53	0.02	0.0013 ± 0.0007	0.0965 IO.0379	0.05
Blattaria	0.0 ± 0.00	0.8 ± 0.40	0.05	0	0.0046 ± 0.0023	0.08
Coleoptera	2.8 ± 0.58	3.8 ± 0.80	0.26	0.0051 ± 0.0035	0.0228 ± 0.0040	0.01
Diptera	3.8 ± 1.52	1.0 ± 0.31	0.14	0.0007 ± 0.0003	0.0001 ± 0.0000	0.13
Herniptera	0.2 ± 0.20	1.2 ± 0.58	0.14	0	0.1997 ± 0.1737	0.28
Hymenoptera	3.0 ± 0.77	5.2 ± 3.24	0.54	0.0008 ± 0.0003	0.0076 ± 0.0056	0.30
Orthoptera	0.0 ± 0.00	4.0 ± 2.44	0.14	0	0.0019 ± 0.0012	0.15
Psuedoscorpiones	0.8 ± 0.37	0.6 ± 0.40	0.65	0.0002 ± 0.0001	0.0002 ± 0.0001	0.84
Psocoptera	0.6 ± 0.40	1.8 ± 0.96	0.28	0	0.0004 IO.0002	0.19
Scolopendromorpha	0.2 ± 0.20	1 .0 ± 0.63	0.28	0.0002 ± 0.0002	0.0023 ± 0.0014	0.22
Thysanura	0.2 ± 0.20	5.8 ± 2.10	0.001	0.0005 ± 0.0005	0.0313 ± 0.0132	0.07
Total	15.8 ± 1.39	30.2 ± 5.41	0.01	0.0091 ± 0.0036	0.3676 ± 0.1645	0.01

[a] Mean number or biomass of arthropods on scraped trees were compared to unscraped trees using a t-test (SAS 1985). $\log_{10}(x+1)$ or $\sqrt{x+0.5}$ transformations were used to stabilize variance.

important to the foraging ecology of the red-cockaded woodpecker. Overall, we found that longleaf pines harbor twice the number of arthropods and almost 3 times the biomass compared to similar-sized loblolly pine. Comparing loblolly to shortleaf pine (*P. echinata*), Collins (1998) captured higher numbers of arthropods on sticky traps 3 m above the ground on loblolly trees. Over 89% of his captures on loblolly pine were springtails (Collembola), flies (Diptera), and ants; but only true bugs (Hemiptera) and ants were captured in significantly higher numbers on loblolly pine and moths or butterflies (Lepidoptera) on shortleaf pine. We saw no evidence of differences in the taxonomic composition of arthropod communities on the 2 species of trees we studied. Likewise, Nicholai (1986) demonstrated that the dominant communities found on bark are similar in a given area regardless of tree species, and Hanula et al. (2000b) reported that prey fed to nestling red-cockaded woodpeckers was similar regardless of foraging substrate (i.e., longleaf pine or loblolly pine). Although these pines harbor similar prey, our findings show that longleaf pine has more arthropods than loblolly pine of comparable age and size. Arthropods may remain on longleaf tree boles because the structure of longleaf bark provides more hiding places or a more suitable microclimate.

Despite having a similar community composition, abundance and biomass of Thysanura and Hemiptera was greater on longleaf pine, as was the biomass of Blattaria and abundance of Pseudoscorpiones. We collected silverfish (Thysanura) from both pine species. However, 82% were collected from longleaf pine; silverfish either prefer or survive better in the microhabitats associated with longleaf bark.

We recovered significantly more Hemiptera, primarily *Largus* sp., from longleaf pine. Despite being diurnal and common, *Largus* sp. have not been reported as prey (Hanula and Franzreb 1995, Hess and James 1998, Hanula et al. 2000*b*, Hanula and Engstrom 2000), which could be a result of distastefulness. Although they are more abundant on longleaf pine trees, it is not clear what they do in that habitat.

Hymenoptera was the most abundant group on both species of pine, primarily because of 2 genera of ants, ***Crematoguster*** and ***Camponotus.*** Both have been reported as prey of red-cockaded woodpeckers (e.g., Hanula and Franzreb 1995, Hess and James 1998). Ant abundance did not differ significantly on the 2 tree species, although variation in numbers of ants was high. Likewise, biomass of ants captured was about the same, but ***Crematoguster*** spp. were more common on longleaf pine and the larger *Camponotus* spp. were more common on loblolly pine. Despite high numbers of ants collected from longleaf pine trees, ant biomass was less than the 5 other common groups of arthropods.

Woodroaches were reported to be the most common prey item fed to nestling red-cockaded woodpeckers on the Savannah River Site and at 3 other locations in South Carolina and Georgia (Hanula and Franzreb 1995, Hanula et al. 2000*b*, Hanula and Engstrom 2000). In our study, they were the most commonly collected group after Hymenoptera and they had the greatest overall biomass. Woodroach biomass was significantly greater on longleaf pine, although numbers were similar on the 2 tree species, suggesting that larger woodroaches preferred habitats associated with the bark of longleaf pine.

Pseudoscorpions also were collected more frequently from longleaf pine. Pseudoscorpions are common inhabitants of pine bark, where they feed on Collembola (springtails) and small Acarina (mites) (Ruppert and Barnes 1991). Due to their general habits and very small size, pseudoscorpions probably play a minor role as a red-cockaded woodpecker food resource.

Our findings are similar to those of other researchers who attributed increases in arthropod abundance to differences in bark structure. In Europe, Nicholai (1986) found that trees with smooth bark had fewer arthropods than trees with fissured bark and suggested that bark microclimate was better on scaly-barked trees. He suggested that many bark-inhabiting arthropods might be negatively affected by converting from one forest tree species to another. Mariani and Manuwal (1990) captured more spiders from trees with deeper bark crevices. They found that an increase in brown creepers (*Certhia americana*) was correlated with larger numbers of spiders, suggesting that bark structure may influence prey and therefore numbers of bark-foraging birds.

Despite the differences we found in abundance and biomass of potential prey of red-cockaded woodpeckers, no one has observed a clear preference by this woodpecker for foraging on longleaf pine (Zwicker and Walters 1999 and references therein). Zwicker and Walters (1999) found no evidence of preferential foraging on one species of pine in mixed pine stands and suggested that red-cockaded woodpeckers select longleaf pines at the stand level and not at the individual tree level.

Our experiment showed that unscraped trees had significantly more arthropods, suggesting that the loose, flaky, outer bark of longleaf pine is important to arthropods and not other characteristics, such as host odors. Externally, the bark of southern pine is highly variable within a species, while samples from trees of different species may be quite similar (Howard 1971). Bark densities of loblolly and longleaf pines are similar (Martin and Crist 1968), so the structural differences of longleaf bark accounted for the difference in amount of bark removed. Bark thickness and moisture content were similar for both tree species in our study, so these variables were not likely to account for the differences in arthropod abundance we observed. Our study showed that longleaf pine had more loose, flaky bark than loblolly, and it is likely that this characteristic of longleaf pine resulted in more and larger arthropods remaining on their boles during the day.

Management implications

Beyer et al. (1996) called for research that identifies which habitat components affect red-cockaded woodpecker survival and how these components can be manipulated through management. If red-cockaded woodpeckers selectively forage on trees that support more arthropods, then our data show that retention and regeneration of longleaf pine in red-cockaded woodpecker foraging territories should be beneficial. Although our results are limited to one area and one age class of trees, this research provides valuable new information that will help in defining habitat features important to this endangered species. Forest management that provides good arthropod habitat on live tree boles should help optimize red-cockaded woodpecker foraging habitat, increase prey abundance for this and other bark-foraging species, and possibly reduce the amount of land needed to sustain individual red-cockaded woodpecker groups.

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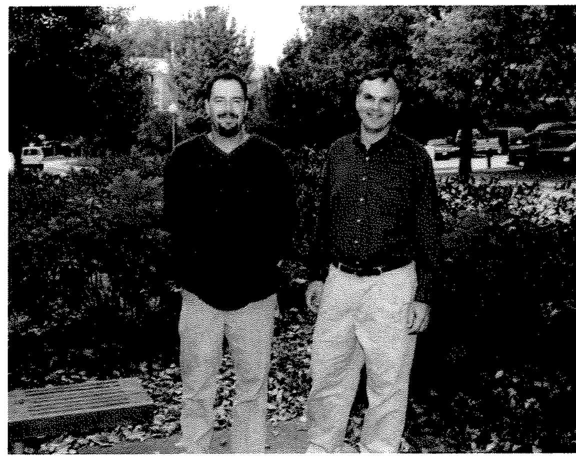

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