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Nest Box and Natural Cavity Use by Wildlife in Mid-South Hardwoods as Related to Physical and Microclimatic Characteristics.

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NEST BOX AND NATURAL CAVITY USE BY WILDLIFE IN MID-SOUTH HARDWOODS AS RELATED TO PHYSICAL AND MICROCLIMATIC CHARACTERISTICS

A Dissertation

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by
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ABSTRACT

Nest boxes (235) of three sizes were erected in a bottomland hardwood stand, in a cottonwood plantation and in an upland pine-hardwood stand in densities similar to those of natural cavities in adjacent unmanaged stands. Most natural cavity-trees were removed from box-bearing plots. Natural cavities (163) were selected for comparative purposes in adjacent unmanaged plots. Comparisons were made of small mammal abundance, bird abundance and cavity characteristics among habitats and plots. Hourly and annual microclimate of seven nest boxes and six natural cavities in bottomland hardwoods were compared over 18 months. Weekly activity at ten natural cavities and ten nest boxes was monitored for 65 weeks in two bottomland plots. All boxes and natural cavities were inspected every four weeks for animal use from February 1977 to February 1979. Preference for a cavity type by cavity dependent wildlife was determined in light of physical and microclimatic characteristics of the nest boxes and natural cavities.

Differences were found in hourly internal temperature, monthly maximum and minimum internal temperature, hourly ambient relative humidity, monthly internal relative humidity and internal light and solar radiation between boxes and natural cavities ($p < 0.05$). The microclimate of natural cavities was more stable than the microclimate of nest boxes, but the microclimate of nest boxes was more stable than the mesoclimate (ambient climate). All differences were consistent over time. The presence of a nest or an animal may alter the microclimate of a cavity markedly.

All cavity characteristics were different among plots and habitats ($p < 0.05$) except the heights of forks in cavity-trees and the frequency of cavities under limbs ($p > 0.05$). Also, no differences among habitats were found in frequency of lianas on natural cavity-trees, height of the lowest live branch of natural cavity-trees, frequency of forks of natural cavity-trees, and number of trees surrounding each natural cavity-tree per 0.02 ha ($p > 0.05$). No differences among plots were found in percent bark cover, frequency of snags, angle of entrance from horizontal, and location on bole or limb when only box-bearing trees were considered in analysis ($p > 0.05$). Orientation of animal-made cavities was non-random and differed between bottomlands (south and west) and uplands (north and west).

Birds were more abundant in the bottomland hardwood plots than in the upland plots. Cavity-nesters made up a larger percentage of the bird populations in the upland pine-hardwood plots than in the bottomland plots.

Small mammals were more frequently captured in the upland pine-hardwoods than in the bottomland plots. Peak captures on all plots occurred in the winter and early spring, probably due to high post-breeding season populations.

The number of visits by cavity-using wildlife per week to natural cavities was not different from the number of visits per week to nest boxes ($p > 0.05$) ($\bar{\bar{x}}$ = 2.9 visits per week).

Nest boxes were used more frequently than natural cavities by 18 of the 26 vertebrate taxa using cavities ($p < 0.05$). Only barred owls (*Strix varia*) used natural cavities more frequently than nest

boxes ($p < 0.05$). Invertebrates were more frequently found in cavities than were vertebrates. Mean four-week box use by vertebrates was constant over box sizes and habitats after two years. Similarly natural cavity use by vertebrates was relatively constant over habitat types. Most birds and mammals selected cavities on the basis of one or several cavity characteristics. Cavities retained in residual trees following thinning operations and having desirable characteristics may increase the probability of seasonal wildlife use. Interspersion of nest boxes among natural cavities may aid species preferring natural cavities by reducing interspecific competition for natural cavities.

INTRODUCTION

Several forest inventory reports have indicated a steadily decreasing volume of bottomland hardwood growing stock (Sternitzke 1965, Van Sickle and Van Hooser 1969, Earles 1975, Sternitzke 1976). Sternitzke (1976) indicated that mid-South delta hardwoods decreased an average of 105,200 ha annually between 1960 and 1970. Most bottomlands are being cleared for agricultural crops -- primarily soybeans[1]. Still more bottomland areas are being converted to monoculture stands of cottonwood and sycamore. By 1975, 16,000 to 20,000 ha of cottonwood alone had been planted in the lower Mississippi River Valley (Krinard and Johnson 1975). Dutrow (1970) predicted a maximum of over 400,000 ha in cottonwood plantations by 1980. All indications are that mixed bottomland hardwoods will continue to be cleared for agricultural purposes and the establishment of large areas of intensively managed monoculture forest.

Sternitzke (1976) suggested that if the mid-South is to continue as a leading manufacturer of hardwood timber products, forest management in the brown loam bluffs and loess-mantled uplands must be intensified to compensate for clearing of prime delta hardwood land. Johnson (1958) and Sternitzke (1976) indicated that as much

[1] Botanical nomenclature after Radford et al. (1968) except where otherwise noted; scientific names are presented in Table 73 of the Appendix.

as 810,000 ha in the upland bluff area are suitable for hardwood timber production. More intensive management of white oak, cherrybark oak, Shumard oak, yellow-poplar, and white ash will be needed to maintain a sustained yield of hardwood products in the mid-South. Buckner (1977) called for accelerated wildlife management research in such intensively managed stands.

By definition, intensive silvicultural practices do not favor the retention of low quality trees suitable for wildlife dens and nests, yet intensive silvicultural practices will be needed if the South is to continue as a leader in hardwood timber products. Shorter rotations and preharvest cutting of low quality trees are inevitable. Artificial selection against low quality trees by genetic tree improvement will contribute to the decrease in availability of such trees to wildlife. Although no literature reports the results of studies designed to assess the impact of silvicultural practices upon cavity-dependent wildlife, several authors suggested that populations of cavity-dependent wildlife are adversely affected by intensive forest management (Goodrum 1937, Thomas et al. 1976, Hardin and Evans 1977, DeGraaf 1978, Scott 1979). Seemingly the only practical method of providing nesting and denning sites for cavity-dependent wildlife, yet managing hardwood forests for maximum cellulose production, is to provide nest boxes. These artificial cavities would be available to wildlife sooner after harvest than would natural cavities, and they may allow intensive management of forest stands without affecting cavity-dependent wildlife species. It seems inevitable that millions of hectares of mid-South bottomlands

will be in agriculture or monoculture forests in the near future, and that upland hardwoods must be intensively managed. It is important that we determine a means of maintaining our wildlife resource without inhibiting timber production. These were the objectives of this study:

1) monitor microclimates of nest boxes and natural cavities in bottomland hardwoods and compare cavity characteristics in bottomland hardwoods, a cottonwood plantation and upland pine-hardwoods to help determine why nest boxes are, or are not, acceptable replacements for natural cavities.

2) compare the use of three standard size nest boxes with use of natural cavities by wildlife in a bottomland hardwood stand, in a monoculture cottonwood stand and in an upland mixed pine-hardwood stand.

Climatic characterization of natural cavities and large nest boxes was conducted at three bottomland hardwood plots (Ben Hur). Temperature, relative humidity, solar radiation and light were monitored on both an hourly and monthly basis for 18 months. The physical characteristics of all natural cavities and nest boxes were quantified (Table 1).

Small mammals and birds were indexed on selected plots in each habitat type to determine what species were available for cavity use (Table 1).

Use of natural cavities in unmanaged bottomland hardwoods (Ben Hur), unmanaged riverfront hardwoods (Durango) and upland pine-

Table 1. Experimental design, nest box and natural cavity study, East Baton Rouge Parish, Louisiana and Jefferson County, Mississippi.

Treatments and comparisons	Ben Hur						Donohoe				Durango			
	control	large box	medium box	small box	large box uncut	box-cavity	control	large box	medium box	small box	control	large box	medium box	small box
Activity														
Cavity type	natural	large	medium	small	large	large & natural	natural	large	medium	small	natural	large	medium	small
Number of boxes or cavities	70	30	30	30	30	15 & 15	48	30	30	30	46	30	30	30
Cavity tree cut		X	X	X				X	X	X		(plantation)		
Cavity trees blocked					X	X (except 15)								
Microclimate	X	X			X									
Cavity characteristics	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Small mammal trapping	X	X	X	X	X	X	X	X			X	X		
Bird observation	X	X					X	X			X	X		
Activity counters	X	X												
Cavity use														
Box vs. natural	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Large vs. medium vs. small		X	X	X				X	X	X		X	X	X
Uncut vs. cut		X			X									
Interspersion vs. separated	X				X	X								

hardwoods (Donohoe) was compared to use of nest boxes of three standard sizes in improvement cut bottomland hardwoods, in a cottonwood plantation, and in improvement cut upland pine-hardwoods, respectively (Table 1). Two additional plots at Ben Hur were used to test the effect of cutting on box use and box-natural cavity interspersion on cavity use. Boxes and natural cavities were checked every four weeks (± one week) for two years. Activity counters were attached to the entrances of ten large nest boxes and ten natural cavities at Ben Hur. Counters were monitored for 65 weeks to determine the consistency of cavity use.

LITERATURE REVIEW

The microenvironment of a nest box or natural cavity may make it more or less desirable as a nesting or roosting site by certain wildlife species. Certain amphibians respond to light of different wavelengths (Anderson 1964:401). Krantz and Gauthreaux (1975) found that movement to roosting areas by brown-headed cowbirds[1] was associated with the daily amount of solar radiation. The quantity or quality of light or solar radiation could also affect use of nest boxes or natural cavities by wildlife. Indeed, Klein (1955) reported that the amount of light entering a nest box influenced use by wood ducks.

Relative humidity has an effect on the stability of body temperatures of some reptiles and amphibians (ectotherms) (Hall and Root 1930). Temperature, humidity and wind can affect heat loss in birds, causing them to seek more suitable microclimates (Shilov 1973:189). Rose (1967:438) and Precht et al. (1973:614) reported similar adaptive behavior in mammals and reptiles, respectively. Several investigators have measured temperatures inside nest boxes (Kendeigh 1961, Stains 1961, Norman and Riggert 1977, Havera 1979) but none of these studies compared box temperatures to temperatures inside natural

[1]Avian nomenclature after American Ornithologists' Union (1957); scientific names presented in Table 75 of the Appendix.

cavities. Differences in nest box or natural cavity use may, in some instances, be attributable to differences in microclimate.

Physical characteristics of a natural cavity or nest box, and characteristics of the surrounding area may also influence use by certain wildlife species. Conner (1975) and Inouye (1976) indicated that entrance orientation of woodpecker cavities is not random. McClelland and Frissell (1975) quantified characteristics of snags useful to certain cavity-nesters. Conner (1976) quantified the nesting habitat of red-bellied woodpeckers. I could find no studies which compared cavity characteristics among habitat types, or which correlated nest box or natural cavity characteristics with use by a variety of wildlife species.

Much information is available on the use of nest boxes in the management of several wildlife species (Hesselscherdt 1942, Bellrose et al. 1964, Barkalow 1965, Flyger and Cooper 1967, Sanderson 1975, and others), but to my knowledge no work of this type has been done on cavity-dependent wildlife species in mid-South hardwoods with the exception of wood ducks (Strange et al. 1971, Davis 1978) and southern flying squirrels[2] (Dawson 1967). Brown and Bellrose (1943) compared species utilization of wood duck boxes on bottomland and upland sites in Illinois and Mississippi, but 90 percent of their boxes were erected near or over water. Several investigators reported use of nest boxes by wildlife species other than the species for which

[2] Mammalian nomenclature after Lowery (1974); scientific names presented in Table 76 of the Appendix.

the box was designed (Bryan 1946, Flyger and Cooper 1967, Dawson 1967, Burger 1969, Strange et al. 1971).

The importance of natural cavities to several species of wildlife has been well documented (Brown and Yeager 1945, Gysel 1961, Conner et al. 1975, Sanderson 1975, Hardin and Evans 1977, Thomas et al. 1978, and others), but to my knowledge no comparison has been made in the deep South between natural cavities and nest boxes, to determine the acceptability of nest boxes, with the exception of wood duck use (Bellrose et al. 1964). Pinkowski (1976) compared use of nest boxes to use of natural cavities by eastern bluebirds in Michigan.

Wildlife use of nest boxes erected in areas where natural cavities already exist was reported by several authors (Hesselscherdt 1942, Brown and Bellrose 1943, Dawson 1967, Flyger and Cooper 1967, Strange et al. 1971). Burger (1969) reported an increase in carrying capacity for gray squirrels in an area where nest boxes were the exclusive form of cavity. Barkalow (1965) reported similar results from an area where both natural cavities and nest boxes were available to gray squirrels.

METHODS

Description of the Study Areas

Ben Hur A mixed bottomland hardwood stand located on the Louisiana State University (LSU) Ben Hur Research Farm, East Baton Rouge Parish, Louisiana was chosen to represent one habitat type (Figure 1). Ben Hur is located in the NW¼ of Section 74, T8S, R1W, at latitude 30°23'0" and longitude 91°11'15".

The soil of this area is a Dundee-Tensas-Sharkey complex. Dundee (40 percent) and Tensas (40 percent) soils are found on ridges with Sharkey (20 percent) found in the swales (Dance et al. 1968:21). Backwater flooding of Ben Hur is prevented by the Mississippi River levee system. Occasionally, heavy rain will innundate low lying areas. The average elevation is 7.6 cm above mean sea level.

The climate of the Ben Hur area is greatly influenced by the Gulf of Mexico to the south and by the continental land mass to the north. The monthly mean temperature was 19.8°C on the basis of data collected from 1941 to 1970 at the Ryan Airport weather station, East Baton Rouge Parish, Louisiana (U. S. Weather Bureau 1977a). The average annual precipitation at the Ben Hur area for the past 30 years was 137 cm annually. A total of 329 frost-free days were recorded at the LSU Ben Hur Farm Weather Station in 1977 and 321 frost-free days were recorded there in 1978. Monthly climatic data for the course of the study are presented in Table 2.

The overstory of Ben Hur is dominated by water oak, coast pignut

Figure 1. Location of Ben Hur, Durango and Donohoe study areas.

Table 2. Monthly climatic data, LSU Ben Hur Experiment Station, East Baton Rouge Parish, Louisiana, January 1977 to December 1978 (deviations from normal indicated parenthetically).[a]

Month	Year	Average temperature (°C) Daily maximum	Daily minimum	Monthly	Total precipitation (cm)	Number of days with a frost
January	1977	10.8	-0.9	4.9 (-5.1)	18.9 (4.8)	20
February		17.6	3.9	10.8 (-0.4)	6.6 (-6.5)	6
March		22.6	10.6	16.6 (1.7)	9.4 (-0.7)	0
April		25.9	13.4	19.7 (0.3)	28.0 (5.1)	0
May		30.3	17.4	23.8 (0.4)	5.5 (-1.1)	0
June		33.7	21.0	27.3 (1.2)	6.5 (-5.9)	0
July		33.9	22.6	28.2 (0.7)	18.0 (-0.4)	0
August		31.8	22.8	27.3 (0.2)	31.5 (22.0)	0
September		31.4	21.4	26.4 (1.2)	25.3 (25.8)	0
October		26.1	12.3	19.2 (0.9)	12.3 (1.0)	1
November		22.1	10.8	16.5 (1.6)	22.4 (16.5)	1
December		17.6	4.8	11.2 (0.1)	11.4 (-5.4)	8
Average	1977	25.3	13.3	19.3 (0.0)	Total 195.8 (60.1)	36
January	1978	10.3	1.4	5.9 (-4.7)	5.4 (5.5)	19
February		11.9	1.4	6.7 (-4.8)	5.9 (-6.4)	16
March		19.5	7.2	13.3 (-1.4)	5.4 (-8.3)	1
April		26.7	13.7	19.8 (-0.2)	8.5 (-5.5)	0
May		29.7	18.3	24.0 (1.0)	24.0 (7.7)	0
June		32.4	21.3	26.9 (0.8)	13.3 (-2.1)	0
July		33.5	22.4	28.0 (0.6)	17.8 (1.6)	0
August		33.1	21.7	27.4 (0.1)	38.4 (7.3)	0
September		31.2.	20.9	26.0 (0.7)	11.6 (o.1)	0
October		27.5	11.4	19.7 (-0.3)	0.0 (-6.7)	0
November		24.8	11.6	18.2 (2.7)	12.6 (2.8)	0
December		17.5	5.7	11.6 (-0.4)	5.7 (-7.9)	8
Average	1978	24.8	13.1	19.0 (-0.4)	Total 148.6 (-12.0)	44

[a]From U. S. Weather Bureau (1977a), U. S. Weather Bureau (1978a).

hickory, Americam elm, sugarberry and sweetgum. The midstory is dominated by bluebeech and boxelder (Tables 56-61, Appendix).

The understory vegetation consisted mostly of Murphy's grass, switchcane, greenbriers, water-willow, dewberries and poison ivy (Tables 62-67, Appendix).

Durango A riverfront hardwood stand and an adjacent cottonwood plantation, owned by International Paper Co., Inc. were selected to represent a second habitat type (Figure 1). This area is located about 19 km north of Natchez, Mississippi, and about 4 km northwest of Church Hill, Mississippi, Section 5, T9N, R11E, latitude 31°46'0", longitude 91°18'0".

Much of the area has been converted from bottomland hardwoods to soybeans and monoculture stands of cottonwood and sycamore. The agricultural land is leased to Mr. L. E. Guedon and Sons, while the timber land is managed by foresters of International Paper Co., Inc.

Weems et al. (1968:18) reported the soil of the Durango area as a clayey alluvial land of a Sharkey association with 0 to 5 percent slope and subject to overflow. On several occasions (1927, 1937, 1973, 1979) the area was completely innundated for several weeks to several months. The average elevation of the Durango area is 15.3 m above mean sea level. The monthly mean temperature for the period from 1941 to 1970 recorded at the Natchez weather station, Adams County, Mississippi was 19.5°C; the mean annual precipitation was 139.6 cm (U. S. Weather Bureau 1977b) (Table 3).

The dominant overstory vegetation of Durango consisted of cottonwood, sweet pecan, water hickory, sugarberry and waterlocust,

Table 3. Monthly climatic data, Natchez weather station, Adams County, Mississippi, January 1977 to December 1978 (deviations from normal indicated parenthetically).[a]

Month	Year	Average temperature (°C) Daily maximum	Daily minimum	Monthly		Total precipitation (cm)	Number of days with a frost
January	1977	9.6	-0.7	4.5 (-5.2)		17.2 (4.0)	20
February		18.5	4.5	11.5 (0.1)		7.7 (-4.8)	9
March		24.0	11.0	17.5 (2.7)		21.1 (4.9)	0
April		26.3	13.4	19.9 (0.2)		37.9 (25.4)	0
May		30.6	18.1	24.4 (1.1)		6.4 (-7.9)	0
June		34.6	21.8	28.3 (1.4)		3.8 (-6.1)	0
July		34.0	23.0	28.5 (0.6)		12.2 (1.5)	0
August		32.7	22.9	27.8 (1.5)		21.5 (-1.1)	0
September		31.6	21.4	26.5 (0.0)		7.1 (12.8)	0
October		25.8	12.6	19.2 (-0.6)		5.5 (-1.3)	0
November		20.7	9.9	15.3 (1.1)		22.2 (11.1)	1
December		16.7	5.2	11.0 (0.1)		10.2 (-4.0)	7
Average	1977	25.4	13.6	19.5 (0.3)	Total	172.8 (34.7)	37
January	1978	9.1	0.3	4.7 (-5.0)		15.3 (2.2)	19
February		12.9	0.6	6.8(-4.7)		7.4 (-5.2)	18
March		20.3	6.8	13.6 (0.2)		5.2 (-10.9)	2
April		26.5	13.4	19.9 (0.7)		4.9 (-7.5)	0
May		30.0	17.9	24.0 (0.2)		23.1 (8.8)	0
June		32.8	21.1	27.0 (0.9)		16.4 (6.5)	0
July		34.8	23.0	28.9 (0.9)		12.7 (2.1)	0
August		33.6	22.6	28.1 (0.3)		14.2 (5.6)	0
September		31.6	20.7	26.2 (1.1)		1.6 (-6.6)	0
October		28.2	11.5	19.9 (0.1)		1.7 (-5.1)	0
November		23.3	11.4	17.4 (3.3)		11.8 (0.7)	0
December		18.3	4.8	11.6 (0.8)		16.0 (1.7)	10
Average	1978	25.1	12.9	19.0 (-0.2)	Total	130.3 (-7.7)	49

[a]From U. S. Weather Bureau (1977b), U. S. Weather Bureau (1978b).

with boxelder, swamp-privet and swamp dogwood the common midstory species (Tables 68 and 69, Appendix). The understory in the cottonwood plantation was considerably more dense than the understory in the riverfront hardwoods (Figures 2 and 3). Common understory plants included trumpet creeper, red-berried moonseed and asters in the riverfront hardwoods, and trumpet creeper, dewberries and poison ivy in the cottonwood plantation (Tables 70 and 71, Appendix).

Donohoe The third study area is located on Donohoe plantation in the loessial uplands of Jefferson County, Mississippi (Figure 1). This area is 11 km west of Fayette, Mississippi; latitude 31°42' and longitude 91°14', Section 54, T9N, R13E. The land is owned by the Allen Mardis Estate, and the forested portion is managed for timber and wildlife.

The soil of the Donohoe area is highly erosive deep loess of the Memphis series, with 0 to 60 percent slope (Morris et al. 1970:19). The erosive nature of these soils results in high local relief. The average elevation of Donohoe is 76 m above mean sea level. Local relief may be as much as 40 m.

The climate of the Donohoe area is similar to that at Durango, except for local differences due to topography. Monthly climatic data for the course of the study are presented in Table 3.

The overstory of Donohoe is mostly loblolly pine, shortleaf pine, water oak, and sweetgum. The midstory is characterized by eastern hophornbeam and flowering dogwood (Tables 72 and 73, Appendix). The understory of Donohoe is dominated by grasses,

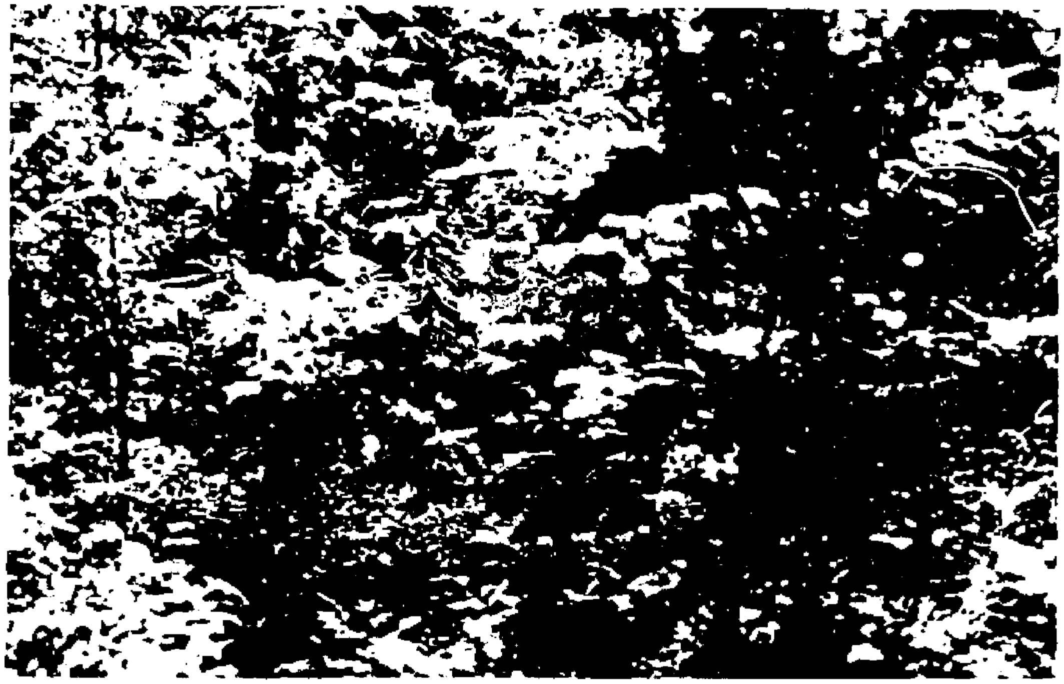


Figure 2. Understory density, Durango large-box-plot, Jefferson County, Mississippi, June 1977.

Figure 3. Understory density, Durango control-plot, Jefferson County, Mississippi, June 1977.

winged elm, blackgum, yellow jessamine and sweetgum (Tables 74 and 75, Appendix).

Procedures

Cavity Selection Cavities were located in the three habitats from 20 January to 16 February 1977. A 0.4-ha plot was delineated and binoculars were used to examine each tree on the plot. When a potential cavity was located, it was inspected, if possible, and if the entrance was at least 5 x 5 cm and the cavity was at least 10 cm deep, then the cavity location was recorded and the tree marked with plastic flagging. Since at least 30 cavities were needed for an adequate sample size, and some loss due to attrition could be expected, at least 35 cavities were located in each habitat type. After all of the cavities had been located on one 0.4-ha plot, another 0.4-ha plot was established adjacent to the first and the procedure was repeated until the desired number of cavities (35 or more) was attained. All of the cavity-trees were numbered with paint and the boundary of the entire plot was marked with paint and/or flagging. An average of 0.5 man-hours was spent locating and inspecting each cavity. Inspection of some cavities required as much as two hours while others required only about ten minutes. Climbing spikes and Swedish climbing ladders were used to gain access to cavities.

Ben Hur control plot was 0.8 ha with 70 cavities, Durango control plot was 1.2 ha with 46 cavities and Donohoe control plot was 2.8 ha with 47 cavities.

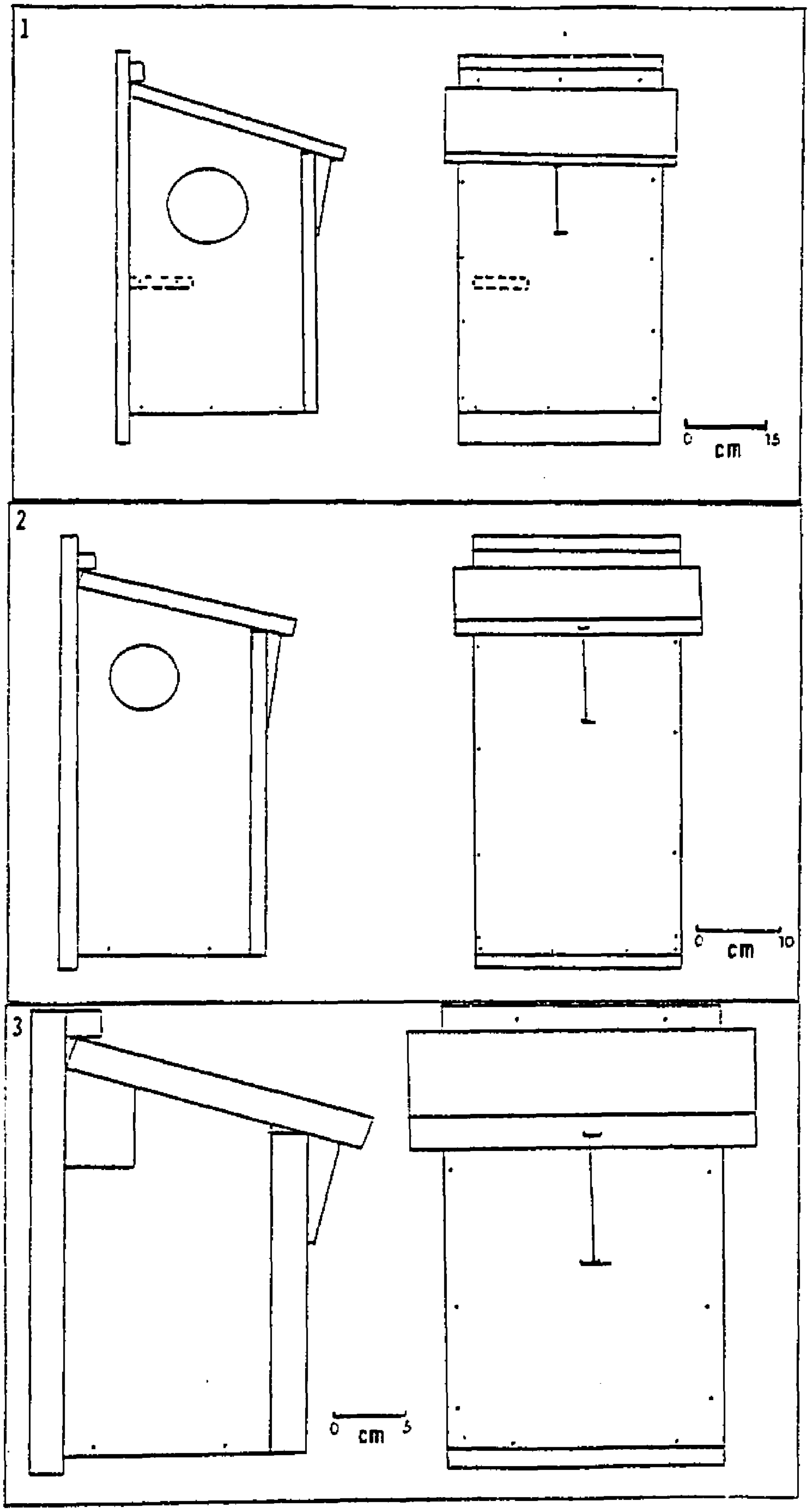
Box Erection Nest boxes were constructed from 2.5-cm thick rough-sawn baldcypress (Figure 4). Sides and tops of some boxes were composed of two or more narrow boards spliced together with 3 x 3 cm electrical staples. Number 8 common nails were used to fasten the sides and bottoms of boxes. A shelf 15 x 13 x 2.5 cm was placed inside large boxes approximately 8 cm below the entrance to encourage use by small cavity-nesters that might require a shorter distance from the cavity floor to the entrance. No shelves were placed in medium or small boxes. Boxes were provided with 5 to 10 cm of pine shavings and were numbered with paint on the side opposite the entrance.

Boxes were wired to previously selected trees at a height of approximately 5.8 m, the average height of all natural cavities at Ben Hur control-plot. Entrances of boxes faced roughly north or east, away from the prevailing winds in the spring and summer.

Five 0.8-ha plots were established near Ben Hur control-plot between 22 February and 6 March 1977. At least 70 m separated all plots. Cavity-bearing trees on all plots were marked with paint. All marked trees were cut down on three plots resulting in basal area reductions of 57 percent (Ben Hur large-box-plot), 66 percent (Ben Hur medium-box-plot) and 58 percent (Ben Hur small-box-plot) (Tables 58-60, Appendix).

Thirty large boxes were erected on Ben Hur large-box-plot, 30 medium boxes were erected on Ben Hur medium-box-plot and 30 small boxes were erected on Ben Hur small-box-plot from 27 February to 5 April 1977. Boxes were spaced 12 m apart within the rows and 20 m apart between the rows. These three plots were used to test the

Figure 4. Right side and front views of a 1) large nest box, 2) medium nest box, and 3) small nest box. Boxes were constructed of rough-sawn baldcypress.


1
0 cm 15
2
0 cm 10
3
0 cm 5

effect of box size on use by wildlife.

Thirty large boxes were erected on Ben Hur large-box-uncut-plot, with spacing as above, from 14 April to 20 April 1977. The entrances of most of the natural cavities on this plot were covered with galvanized screening to prevent admittance by most vertebrates. Comparison of box use at Ben Hur large-box-plot with box use at Ben Hur large-box-uncut-plot was used to test the effect of cutting on use of nest boxes by wildlife.

Fifteen boxes were erected on Ben Hur box-cavity-plot from 17 March to 25 March 1977. Boxes were spaced 24 m apart within the rows and 20 m apart between the rows. Galvanized screening was stapled over the entrances of all but 15 similarly spaced natural cavities on this plot. This treatment tested preference for boxes or natural cavities where both were equally available.

A 1.2-ha plot was established in a cottonwood plantation near the Durango riverfront hardwood control plot, 29 January 1978. Thirty large boxes were erected on Durango large-box-plot, 29-30 January 1977, spaced 20 m apart within the rows and 21 m apart between the rows. Two 0.4-ha plots were established in the cottonwood plantation near Durango large-box-plot, 20 February 1977. Ten medium boxes were erected on Durango medium-box-plot and ten small boxes were erected on Durango small-box-plot, with spacing as above.

A 2.8-ha plot was established in the upland mixed pine-hardwood stand at Donohoe Plantation, 12 February 1977. Thirty large boxes were erected on Donohoe large-box-plot, 12-13 February 1977, and spaced 32 m apart within the rows and 30 m apart between the rows.

Two 0.9-ha plots were established, 19 February 1977, near Donohoe large-box-plot. Ten medium boxes were erected on Donohoe medium-box-plot and ten small boxes were erected on Donohoe small-box-plot, with spacing as above. Most of the natural cavity-trees on these three plots were cut down between 22 February and 6 March 1977. Additional cavity and non-cavity trees were cut down during a commercial timber harvest in December 1977. The basal area on Donohoe large-box-plot was reduced 38 percent following cutting (Table 73, Appendix). Boxes were the exclusive form of cavity on all treated plots except Ben Hur box-cavity-plot. Natural cavities were the exclusive form of cavity on all control plots.

<u>Hourly Microclimate</u> Solar radiation is radiation (0.2 - 4.5 m wavelength) emanating from the sun and measured as direct, scattered or diffuse radiation (Ford-Robertson 1971:248). Light is the sensation produced on the human (and presumably other organisms') eye and brain by electromagnetic radiation (Anderson 1964:427).

Temperature, relative humidity, solar radiation and light were measured inside and outside of two randomly selected boxes on Ben Hur large-box-plot and inside and outside of two randomly selected natural cavities on Ben Hur control-plot every hour for 24 consecutive hours twice a month for 18 months. Similarly, the same measurements were taken at one box on Ben Hur large-box-uncut-plot every three hours. Readings were begun 15 minutes before the hour and the last reading was finished by 15 minutes after the hour. Readings were always made in the same order to ensure consistency.

Monthly Microclimate Present temperature, maximum temperature, minimum temperature, relative humidity, solar radiation and light data were collected at five randomly selected boxes on Ben Hur large-box-plot and at five randomly selected natural cavities on Ben Hur control-plot five days per month for 18 months. Five sets of measurements were taken at a box and a natural cavity at the same time after official sunrise ($\pm$30 minutes) each day. At least 60 minutes separated each set of measurements. For instance, readings were taken at 0900, 1000, 1400, 1500 and 1600 hours if official sunrise were at 0630 hours (CST).

Temperature data were collected to the nearest 0.1°C with Taylor maximum-minimum thermometers. Thermometers were checked for consistency before use. One thermometer was placed inside each box and natural cavity and another thermometer was placed outside, within 1 m of the box or natural cavity. Thermometers were reset to present temperature whenever maximum or minimum temperatures were recorded.

Relative humidity data were collected to the nearest 1 percent with a Beckman hygrometer from 11 June to 18 September 1977 at which time serious malfunctions precluded further use of this instrument. Relative humidity data were collected from 13 August 1977 to 12 December 1978 using Humichek hygrometer-thermometer. Advertised accuracy of this instrument is $\pm$3 percent in the middle of the relative humidity scale. The sensor of the hygrometer was placed 15 cm inside the nest box or natural cavity perpendicular to the plane of entrance and allowed to stabilize for two to three minutes before a reading was taken. The sensor was then removed from the cavity and again

allowed to stabilize to obtain ambient relative humidity. Stabilization time was greater when the difference between internal and ambient relative humidity was greater than 25 percent or when the ambient relative humidity was greater than 95 percent.

Temperature and relative humidity were checked with a Casella hygrothermograph mounted on a platform 1.2 m above the ground in the forest between Ben Hur control-plot and Ben Hur large-box-plot.

Solar radiation and light data were collected with a LICOR-185 photometer-pyranometer-quantum meter with interchangeable, cosine-corrected sensors. Data were collected to the nearest 0.1 watts/m^2 and to the nearest 1.0 lux, respectively. Advertised accuracy is ± 1 percent over the total range (0.0-3000 watts/m^2; 0-3×10^5 lux). Accuracy was checked periodically with another identical unit. Accuracy of solar radiation readings decrease with increasing diffuse solar radiation, but provides an adequate index for total isolation. Four solar radiation and four light readings were taken at each box and at each natural cavity at each occasion. The first measurement was taken 15 cm inside the natural cavity or nest box perpendicular to the plane of entrance with the sensor facing the entrance to measure the internal incoming solar radiation or light. Since Anderson (1964:443) suggested that albedo be accounted for in all irradiance measurements, the second reading was taken 15 cm inside the natural cavity or box with the sensor facing 180^o from the first reading. This measurement provided an index to the amount of light or solar radiation reflected from the inside of the box or natural cavity. The third reading was taken outside the box or natural

cavity, parallel to the box or tree surface, with the sensor facing away from the surface, thereby measuring the amount of solar radiation or light striking the surface of the box or natural cavity-tree. The final reading was taken outside of the box or natural cavity, 2.5 cm from the surface of the box or natural cavity-tree, with the sensor facing the surface, providing an index to the amount of solar radiation or light reflected from the surface.

Microclimate data collection began 8 June 1977 and was terminated 12 December 1978. Data were not collected during rainstorms since damage to equipment may have resulted. If no data were collected for one box or natural cavity, then no data were collected for any other box or natural cavity at that time. This ensured equal sample sizes between plots.

The null hypothesis that all hourly measurements were equal between plots, months, days, cavities and times was tested with a completely randomized design analysis of variance (Snedecor and Cochran 1967:279):

$$Y = u + M + D/M + A + N/A + T + M \times A + M \times N/A + M/D \times N/A + A \times T + M \times T + N/A \times T + M \times T \times N/A + \epsilon$$

where: Y = each observation of a dependent variable

u = the overall mean

M = the effect due to months

D/M = the effect due to days within months

A = the effect due to plot

N/A = the effect due to cavities within each plot

T = the effect due to time of day

ϵ = the residual

The effect due to months was tested with D/M as an error term. The effect due to plot was tested with M x N/A as an error term. The effect due to time was tested with M x T x N/A as an error term.

The null hypothesis that all monthly microclimate measurements were equal between plots, months, hours, and location inside or outside the cavity was tested with a completely randomized design analysis of variance (Snedecor and Cochran 1967:279):

$$Y = \mu + M + D/M + H + A + L + M \times T + D/M \times H + M \times A + H \times A + M \times H \times A + \epsilon$$

where: Y = each observation of a dependent variable

μ = the overall mean

M = the effect due to months

D/M = the effect due to days within months

H = the effect due to hour

A = the effect due to plot

L = the effect due to location

ϵ = residual

The effect due to months was tested with D/M as an error term. The effect due to hour was tested with D/M x H as an error term. The effects due to plot and location were tested with the residual as an error term.

Monthly maximum and minimum temperature data were analyzed with a randomized block design analysis of variance (Snedecor and Cochran 1967:303).

Since hourly microclimate readings were collected at the box on the uncut plot less frequently than those on the cut plot or the

control plot the results were graphed for comparative purposes but the data were not subjected to any statistical analyses.

Hourly and monthly data were stratified by synoptic weather types with a synoptic weather calendar provided by R. Muller, Department of Geography and Anthropology, LSU. Means for each variable were then obtained by synoptic weather type (Muller 1978).

Cavity Characteristics Data were collected on 30 characteristics of all boxes and natural cavities to allow comparison of these characteristics among habitat types and to determine which characteristics were correlated with use by certain species. Those characteristics of the boxes and natural cavities were:

Entrance shape (round, triangular, square, rectangular, oval or irregular)
Entrance height (cm)
Entrance width (cm)
Cavity depth (cm)
Cavity width (cm)
Cavity height (cm)
Compass direction (degrees azimuth)
Angle from horizontal of cavity entrance (0° = down; 180° = up)
Location of cavity in tree (bole vs. limb)
Frequency under limb (percent)
Cavity origin (animal-made, man-made, natural)

Tree characteristics in which the box or natural cavity occurred were:

Species
Age (years)
dbh (cm)
Height (m)
Site
Snag (+ or -)[1]
Height of the lowest live branch (m)
Angle of lean from vertical

[1]A snag is any dead tree over 10 cm dbh and over 2.0 m tall.

Presence of a fork
Height of fork if present (m)
Percent bark on tree
Presence or absence of liana
Species of lianas if present
Height of cavity in tree (m)
Diameter of tree at the cavity (cm)
Number of cavities in the same tree
Distance to nearest cavity-tree (m)
Distance to water (m)
Number of trees over 10 cm dbh in a 0.02-ha plot surrounding the cavity-tree

Data for inaccessible cavities were estimated. Cavity dimensions were measured to the nearest 1 cm with a steel tape. A 30 m metallic tape was used to measure ground distances. A Suunto clinometer was used to measure height characteristics to the nearest 0.1 m, to measure the angle of the cavity entrance from horizontal and to measure the angle of cavity-tree lean. Entrance direction was measured to the nearest degree azimuth with a Leopold compass.

An increment borer was used to extract a core from each tree containing a box or natural cavity. Age at breast height (1.37 m) was determined by counting annual rings. Ages of hollow trees were not estimated.

Tree diameters were measured to the nearest 1 cm with a diameter tape.

Percent bark on trees and qualitative characteristics were estimated ocularly. Site is ridge, slough or flat in the bottomland habitats, or ridgetop, upper 1/3 slope, middle 1/3 slope, lower 1/3 slope or drainage bottom in the upland habitat.

Data were coded, keypunched and verified. The data were subjected to a completely randomized design analysis of variance (Snedecor and Cochran (1967:279).

The correlation procedure was used to determine which characteristics were correlated with use by certain species (Snedecor and Cochran 1967:172).

Bird Observations Bird counts were conducted twice a month from 12 February 1977 to 10 February 1979 at Durango control-plot, Durango large-box-plot, Donohoe control-plot and Donohoe large-box-plot. Counts were made five times a month from 15 February 1977 to 15 February 1979 at Ben Hur control-plot and Ben Hur large-box-plot.

The observer walked slowly around the perimeter of each plot for one hour, recording all birds seen or heard. Binoculars (7x50) were used to aid identification. Birds flying over the plot were not recorded except for raptors, goatsuckers or swifts which could use the area for feeding. Most observations were made at dawn or dusk.

Small Mammal Trapping Thirty Museum Specials were set on each plot at the base of each box or natural cavity-tree, one night each month, 5 May 1977 to 24 February 1979. "Crunchy" style peanut butter was used as bait. The date, species, location of capture and sex was recorded for each capture.

Vegetation Inventory A 20 percent cruise of all plots except Durango small-box, Durango medium-box, Donohoe small-box and Donohoe medium-box-plots was made from 20-25 May 1977 and 19 September 1978 to quantify the overstory vegetation. Species, dbh and height were recorded for each tree within each 0.04-ha circular plot. Basal area per ha, average diameter, average height, relative density and relative dominance were calculated for each species by area (Cox 1976:35).

Understory vegetation was quantified from 3-4 September 1977 and from 27 July to 22 September 1978 with a modified Aldous browse survey described by Noble and Murphy (1975). Thirty 0.0004-ha circular plots were established on each study plot, 3 m west of each box-bearing tree or in a similar grid pattern on control areas. Cover of each plant taxon was estimated ocularly for any portion of the plant below 1.8 m (Noble and Murphy 1975). The median of each 10 percent bracket of cover was used as the cover estimate. The percent frequency, percent ground cover and average percent ground cover (relative abundance) was calculated for each taxon. All surveys were made in late summer since Murphy and Noble (1972) reported the largest number of plant species encountered could be expected in August in a bottomland hardwood area in Tensas Parish, Louisiana.

Activity Counters Activity counters were attached to the entrances of ten randomly selected nest boxes on Ben Hur large-box-plot and ten randomly selected natural cavities on Ben Hur control-plot, 7 October 1977.

Each counter consisted of a mercury switch fastened to the underside of a wooden treadle (2.5 x 10 cm). The mercury switch was wired to a counter, powered by a 12-volt battery. Counter design resulted from ideas presented by Lawrence and Sherman (1963), Balgooyen (1972), Carlson and Sloan (1976), W. Dodge (1976, University of Massachusetts, Amherst, personal communication), and Lieberman and McCarthy (1976). The battery and counter were housed in a 20 x 20 x 20-cm wooden box which was covered with plastic and nailed to the tree near the nest box or natural cavity.

Connections were sealed with electrical tape or epoxy. A wire stop was placed beneath the treadle to prevent the treadle from being depressed too far and thereby causing damage to the mercury switch. The sensitivity of the treadle was adjusted to allow activation when about 10 g or more were placed on the end of the treadle. This allowed activation by organisms as small as a Carolina chickadee (Baldwin and Kendeigh 1938).

Readings were taken from each counter every seven days. All units were tested at least once every two weeks. Data collection began 14 October 1977 and was terminated 6 February 1979. Data were coded, keypunched and verified. The null hypothesis that the number of entrances and exits were equal at both cavity types was tested with a randomized block design analysis of variance (Snedecor and Cochran 1967:303).

Natural Cavity and Nest Box Inspection All nest boxes and natural cavities were checked every four weeks (± one week) for any signs of animal use (hair, feathers, nest[2], or scats). Use by all invertebrates and vertebrates, and presence or absence of nesting material was recorded for each nest box and natural cavity. Use was recorded to the lowest possible taxonomic group which could accurately be determined on the basis of the available sign. The presence or absence of water was also recorded for all natural cavities. One cavity check is one natural cavity or one nest box inspected for animal use during one sampling period. All animal sign was removed (except nests) at each

[2]A nest is any structure made in a cavity by a spider, social insect or vertebrate.

inspection.

The bow-fishing method described by Gysel (1961) was attempted several times, but was found to be more time consuming than ladders or climbing spikes. Natural cavities were inspected with a mirror and flashlight (Seidensticker and Kilham 1969) or with a lighted periscope (Dewees et al. 1975). Natural cavities in some snags, in dead or small limbs, or above 18 m high were not inspected. Use in these natural cavities was determined by at least two hours of observation with binoculars at dusk or dawn each sampling period.

Data were coded, keypunched and placed on computer disk for analysis. Frequency of occurrence was calculated for each cavity-using taxon by area and by sampling period where:

$$\text{Percent frequency} = \frac{\text{Number of cavities used}}{\text{Number of cavities checked}}\,(100)$$

The null hypothesis that use by a species or a group of species was equal on all plots was tested with a randomized block design analysis of variance (Snedecor and Cochran 1967:303).

The General Linear Models procedure of the Statistical Analysis System was used whenever the sample sizes among treatments were not equal (Barr et al. 1976:127). The Duncan's Multiple Range option was used to allow all possible comparisons of treatments (Steel and Torie 1960:107).

The results of this study may have been affected by several forms of bias. Cavity use by small mammals may have been adversely affected due to small mammal trapping, but since trapping was equal on all plots, the use recorded should be an accurate index to total small mammal use.

Hunting of gray and fox squirrels was allowed at Donohoe and Durango. Three gray squirrels were known harvested from Donohoe control plot and two from Donohoe large-box plot. Illegal hunting was noted at Ben Hur both years.

My presence may have adversely affected cavity use by species such as pileated woodpeckers and brown-headed nuthatches. My presence may have also affected solar radiation and light readings, but this affect should have been constant throughout the study.

RESULTS AND DISCUSSION

Macroclimate

The percentage of occurrence of each synoptic weather type for days on which data were collected over the course of this study agree closely with three-year averages provided by R. Muller, Department of Geography and Anthropology, LSU.

In most instances the mesoclimate within the forest stand was directly affected by synoptic weather types. Stand structure and composition also affect the mesoclimate within the forest stand. Geiger (1965:298-368) described in some detail the affect of a forest stand on the climate within it.

The microclimate within a nest box or natural cavity within the forest stand is a function of synoptic weather type, time, the composition and structure of the forest stand, the location (both horizontally and vertically) of the box or natural cavity in the stand, and the characteristics of each box or natural cavity.

Mesoclimate

Ambient[1] Temperature Mean hourly ambient temperature on Ben Hur control-plot was not different ($p > 0.05$) from that on Ben Hur large-box-plot (Table 4).

[1]ambient refers to the mesoclimate of the forest stand.

Table 4. Average temperature (°C), relative humidity (%), solar radiation (watts/m^2), and light (lux), Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (standard error indicated parenthetically).

Climatic factor	Hourly		Monthly	
	Nest boxes	Natural cavities	Nest boxes	Natural cavities
Internal temperature (N_h = 3450; N_m = 900)	18.9	18.2 (0.05)	22.1	18.9 (0.17)
Ambient temperature (N_h = 3450; N_m = 900)	18.3	18.3 (0.04)	22.3	21.6 (0.10)
Internal relative humidity (N_h = 2202; N_m = 590)	72.7	73.6 (0.36)	61.9	66.3 (0.29)
Ambient relative humidity (N_h = 2202; N_m = 590)	70.4	69.2 (0.15)	57.2	56.8 (0.21)
Internal incoming solar radiation (N_h = 1850; N_m = 900)	9.16	4.44 (0.15)	9.28	6.64 (0.19)
Internal reflected solar radiation (N_h = 1850; N_m = 900)	0.90	0.30 (0.015)	1.02	0.26 (0.015)
Ambient incoming solar radiation (N_h = 1850; N_m = 900)	46.3	26.5 (1.08)	49.8	87.2 (3.36)
Ambient reflected solar radiation (N_h = 1850; N_m = 900)	14.8	8.2 (0.40)	17.3	22.1 (0.92)
Internal incoming light (N_h = 1850; N_m = 900)	385	176 (8.2)	309	284 (7.9)
Internal reflected light (N_h = 1850; N_m = 900)	12.1	5.4 (0.22)	11.6	4.0 (0.21)
Ambient incoming light (N_h = 1850; N_m = 900)	2501	1108 (132.4)	2258	5875 (282.1)
Ambient reflected light (N_h = 1850; N_m = 900)	522	205 (29.2)	422	693 (30.0)

N_h = hourly data

N_m = monthly data

Ambient temperature at the box in the uncut-plot was lower than ambient temperatures on the control-plot or the large-box-plot, possibly due to closer proximity to water.

Average monthly temperature on Ben Hur control-plot (18.9^{o}C) was lower ($p < 0.01$) than that on the large-box plot (22.1^{o}C) (Table 4). Since the monthly data were collected only during daylight hours, night-time data (comprising 50 percent of hourly data) were excluded from the monthly data set. This may account for the difference between plots found with monthly data which was not found with hourly data. Indeed, mean hourly temperature (18.3^{o}C) and mean daily temperature at LSU Ben Hur Experiment Station (19.1^{o}C) were both lower than the mean monthly temperature on both Ben Hur plots.

Mean monthly maximum temperature was higher on the large-box-plot (28.1^{o}C; SE=0.11) than on the control plot (27.2^{o}C; SE=0.11) ($p < 0.01$). Mean monthly minimum temperature on Ben Hur control-plot was not different from that on Ben Hur large-box-plot (12.6^{o}C; SE=0.05) ($p > 0.05$). The range between mean monthly maximum temperature and mean monthly minimum temperature was narrower on Ben Hur control-plot than on Ben Hur large-box-plot. These results concur with the results of the hourly data and those of Geiger (1965:315).

Ambient Relative Humidity Relative humidity data were collected for 12 months. Mean hourly relative humidity was lower on Ben Hur control-plot (69.2 percent) than on Ben Hur large-box plot (70.4 percent) ($p < 0.01$).

Mean hourly relative humidity dropped faster in the morning and

rose faster in the evening on the large-box-plot than on the control-plot.

Mean monthly relative humidity on Ben Hur control-plot was not different ($p > 0.05$) from that on Ben Hur large-box-plot (57.0 percent) (Table 4). That differences in monthly relative humidity were found with hourly data but were not found with monthly data can partially be explained by a larger number of observations taken at each cavity during hourly data collection and exclusion of high night-time relative humidities from monthly measurements.

Ambient Incoming Solar Radiation Median daily insolation from 1963-1973 recorded at Lake Charles weather station, Calcasieu Parish, Louisiana indicated maximum insolation occurred in June; minimum insolation occurred in January. This insolation is largely direct solar radiation while that in the forest stand is primarily scattered and diffuse solar radiation (Anderson 1964:432). Geiger (1965:303) and Miller (1965:192) reported that only about 20 percent of the outside solar radiation penetrates the canopy reaching the forest floor.

Mean incoming solar radiation on the control-plot (26.5 watts/m^2) was lower ($p < 0.01$) than that on the large-box-plot (46.3 watts/m^2) (Table 4).

Maximum hourly incoming solar radiation occurred at 1300 hours on both plots. Solar radiation remained consistently higher on the large-box-cut-plot than on either the control-plot or the large-box-uncut-plot (Figure 5).

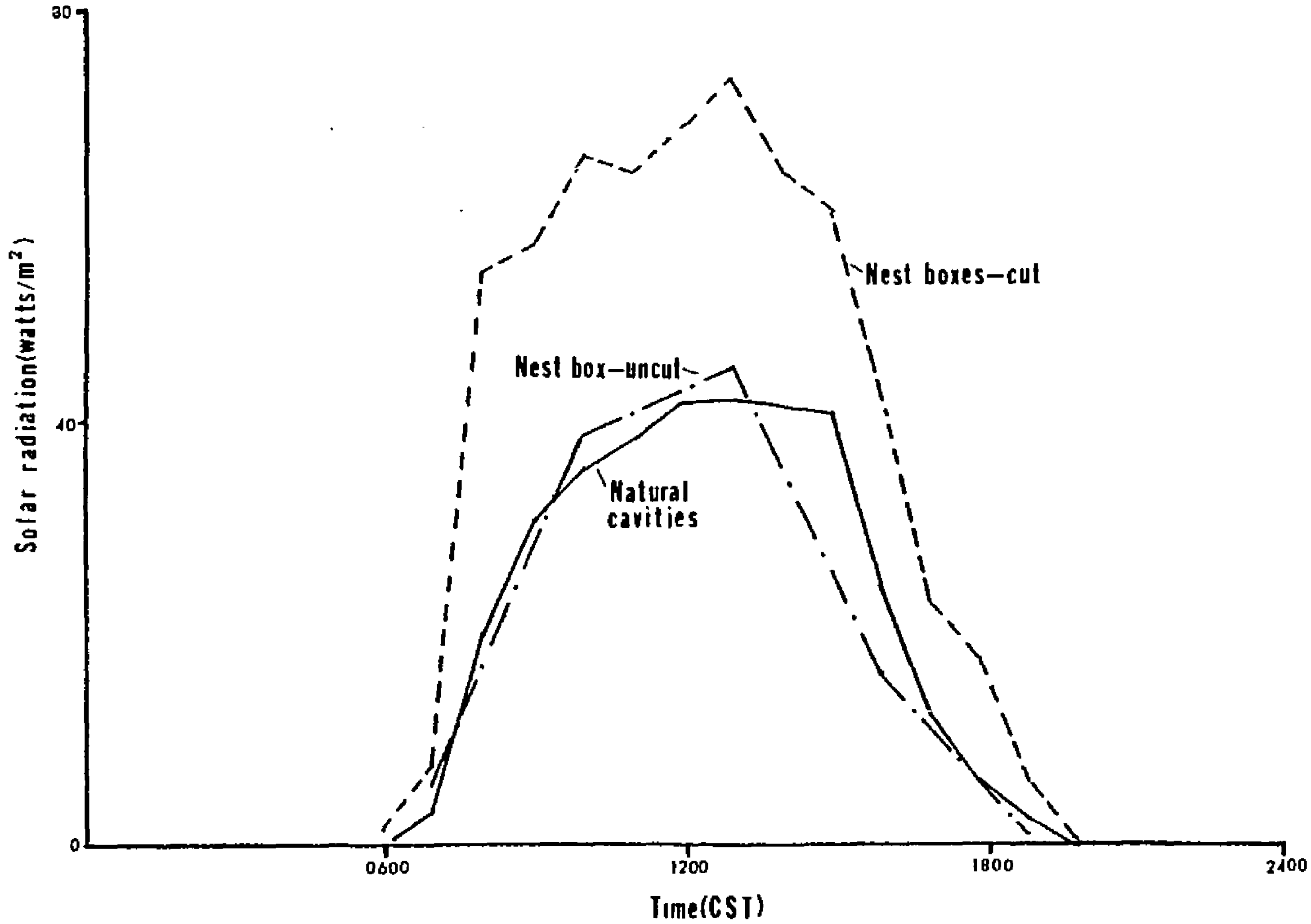


Figure 5. Temporal variation of hourly ambient incoming solar radiation, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 1850; SE = 2.37).

Monthly averages of hourly incoming solar radiation indicate that both cloud cover and leaf cover probably affected insolation. Peaks occurred when insolation outside the stand was highest and when cloud cover was lowest (May and June), and troughs occurred when outside insolation was lowest and when cloud cover and leaf cover were high (August to November) (Figure 6). Anderson (1964:450) reported similar results and suggested the angle of incidence also influences insolation values.

Analysis of monthly incoming solar radiation produced results contradictory to those of the hourly data. Monthly incoming solar radiation on the control plot (87.2 watts/m^2) averaged higher ($p < 0.01$) than that on the large-box plot (49.8 watts/m^2) (Table 4).

Anderson (1964:449), Reifsnyder et al. (1971), Muller (1971) and Gay and Knoerr (1975:40) discussed the importance of sunflecks (direct solar radiation penetrating the canopy) to the total energy budget within forest stands. Entrance orientation of three natural cavities monitored during monthly data collection accounted for unusually high frequency of sunfleck occurrence. The sunflecks encountered at these three cavities probably accounted for the higher insolation values recorded on Ben Hur control-plot than on Ben Hur large-box-plot. Standard errors for hourly solar radiation data, where few sunflecks were encountered, were lower than those for monthly data (Table 4).

<u>Ambient Reflected Solar Radiation</u> Reflected solar radiation is directly related to the amount of ambient incoming solar radiation,

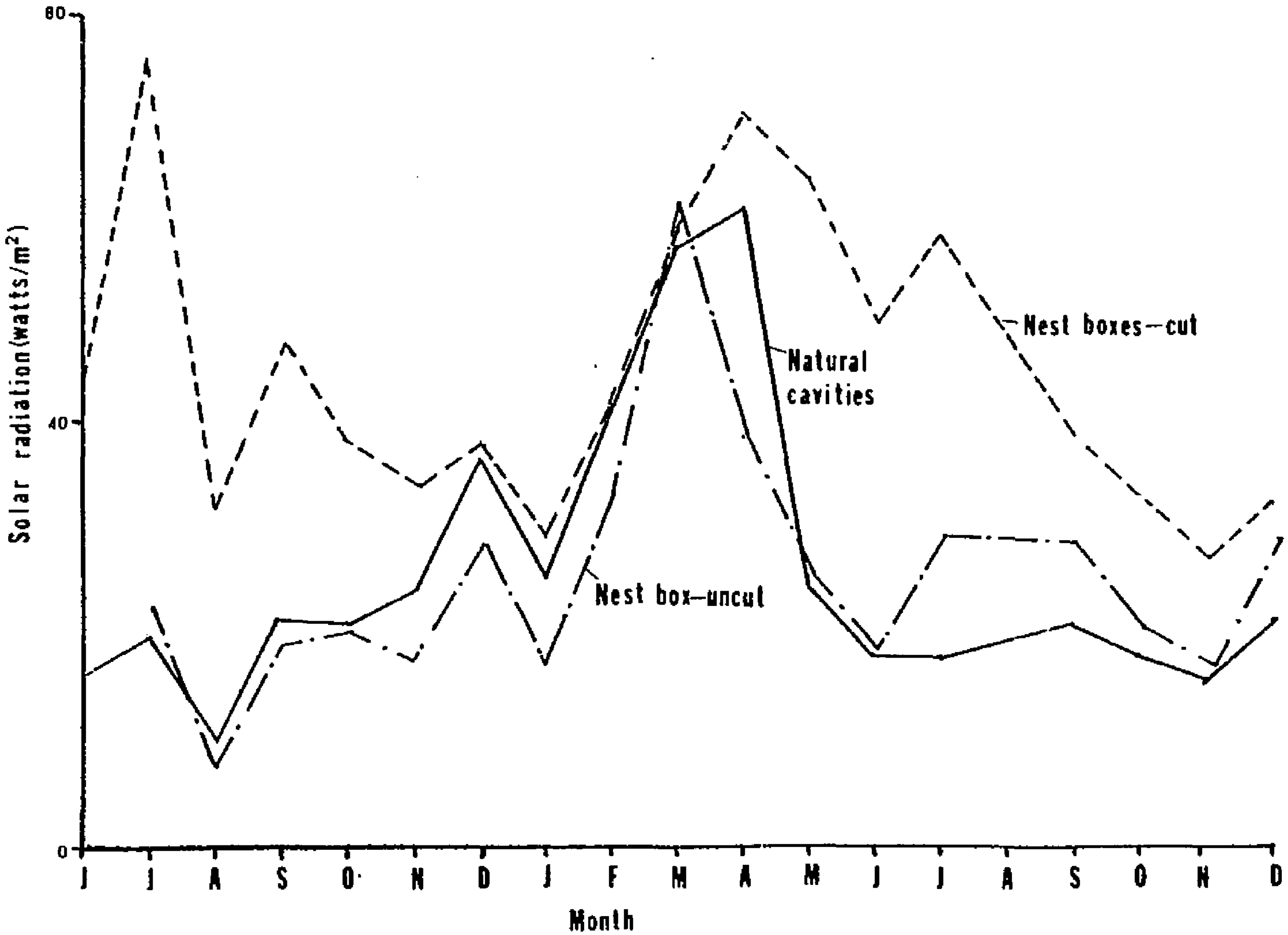


Figure 6. Monthly variation of hourly ambient incoming solar radiation, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 1850; SE = 4.31).

but it is also affected by the amount of scattering, the color of the surface it strikes and the texture of that surface (Anderson 1964: 465, Gay and Knoerr 1975:26). A deciduous forest reflects 10 to 20 percent of the incoming solar radiation (Gay and Knoerr 1975:27). Additional solar radiation is absorbed, transmitted or scattered (Muller 1971).

Hourly reflected solar radiation differed ($p < 0.01$) between plots ($p < 0.01$). Peaks and lows of hourly reflected solar radiation occurred at the same times as those for incoming insolation.

Solar radiation reflected from boxes (32.2 percent) was similar to that reflected from natural cavity-trees (31.3 percent).

Monthly reflected solar radiation differed ($p < 0.01$) between plots (Table 4). Slightly more solar radiation was reflected from boxes (34.7 percent) than from natural cavity-trees (25.3 percent).

Ambient Incoming Light No data are available defining levels of light outside the forest stand in the Baton Rouge area. Since visible light is a subset of the solar radiation spectrum, the curve for incoming light should follow closely that for insolation.

Hourly incoming light was higher ($p < 0.01$) on Ben Hur large-box-plot (2501 lux) than on Ben Hur control-plot (1108 lux) (Table 4). Incoming light appeared to be more affected by leaf cover on Ben Hur control-plot than on Ben Hur large-box-plot.

Monthly ambient incoming light differed ($p < 0.01$) between plots (Table 4). High levels of light on Ben Hur control-plot were probably the result of sunfleck frequency.

Ambient Reflected Light Gay and Knoerr (1975:27) reported that 4 to 15 percent of the light striking a forest stand is reflected from the canopy. Hourly reflected light differed ($p < 0.01$) between plots (Table 4). Relatively more light was reflected from boxes (20.9 percent) than from natural cavity-trees (18.5 percent).

Mean monthly reflected light differed ($p < 0.01$) between plots (Table 4). Relatively more light was reflected from boxes (18.7 percent) than from natural cavity-trees (11.8 percent).

Microclimate

Internal Temperature Hourly internal temperature differed ($p < 0.01$) between boxes (18.9°C) and natural cavities (18.2°C) (Table 4). Mean maximum hourly temperature occurred two hours later in natural cavities than in nest boxes (Figure 7). The range of mean hourly temperature was narrower inside natural cavities than it was inside nest boxes.

Mean monthly temperatures inside boxes and natural cavities were different ($p < 0.01$) from ambient temperatures (Table 4) (Figures 8 and 9). Kendeigh's (1961) results on energy conservation in cavities are questionable since he based his experiment on the premise that internal and ambient temperatures were equal. Since Kendeigh (1961) did not account for this difference before calculating the amount of energy saved by roosting in cavities, his figure of energy conservation was probably inflated.

Minimum hourly temperature occurred one hour later inside natural cavities than outside natural cavities (Figure 8). This is slightly less than the two hours reported by Stains (1961) in raccoon dens and

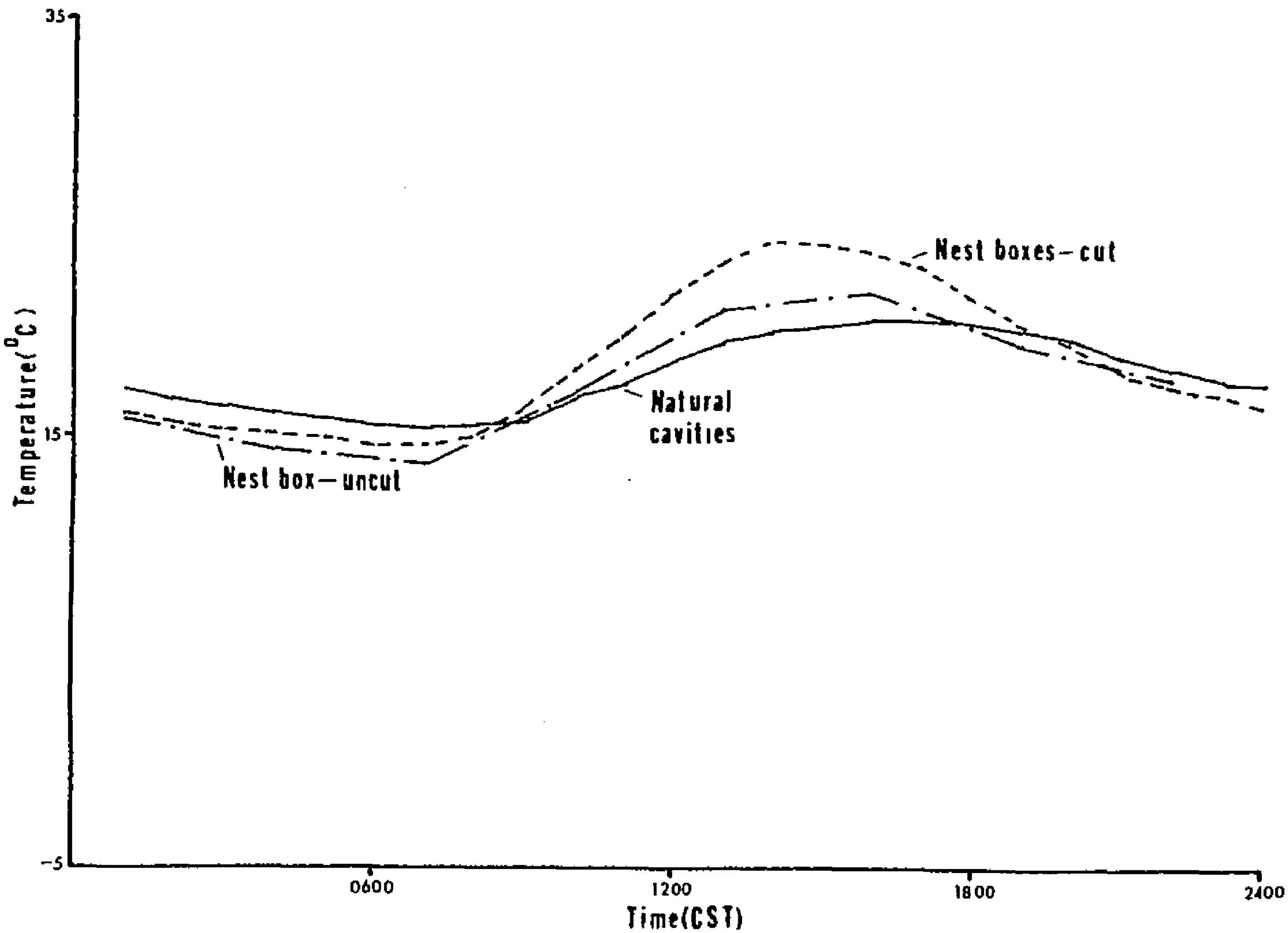


Figure 7. Temporal variation of hourly internal temperature, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 3450; SE = 0.75).

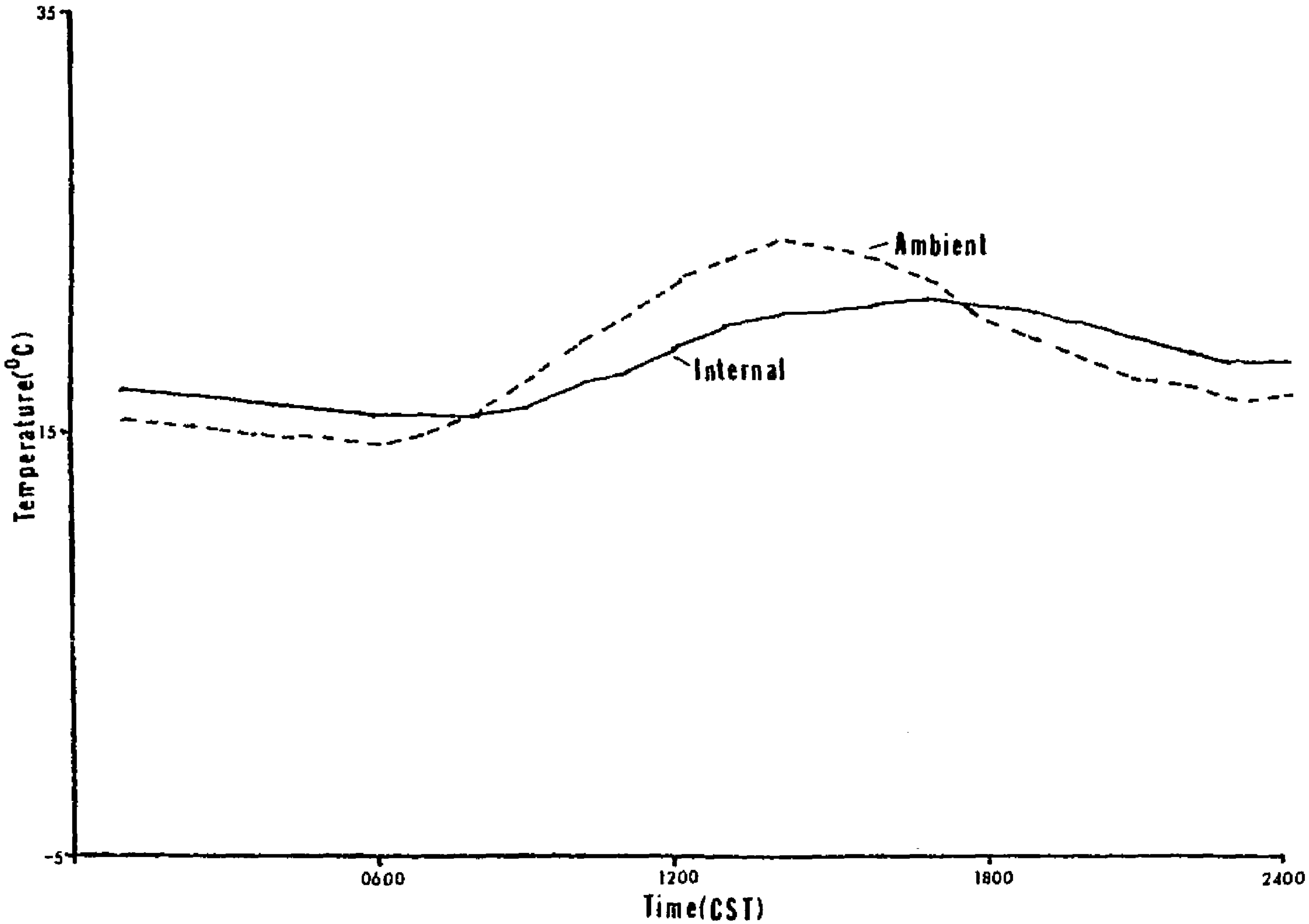


Figure 8. Temporal variation of temperature in natural cavities, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 3450).

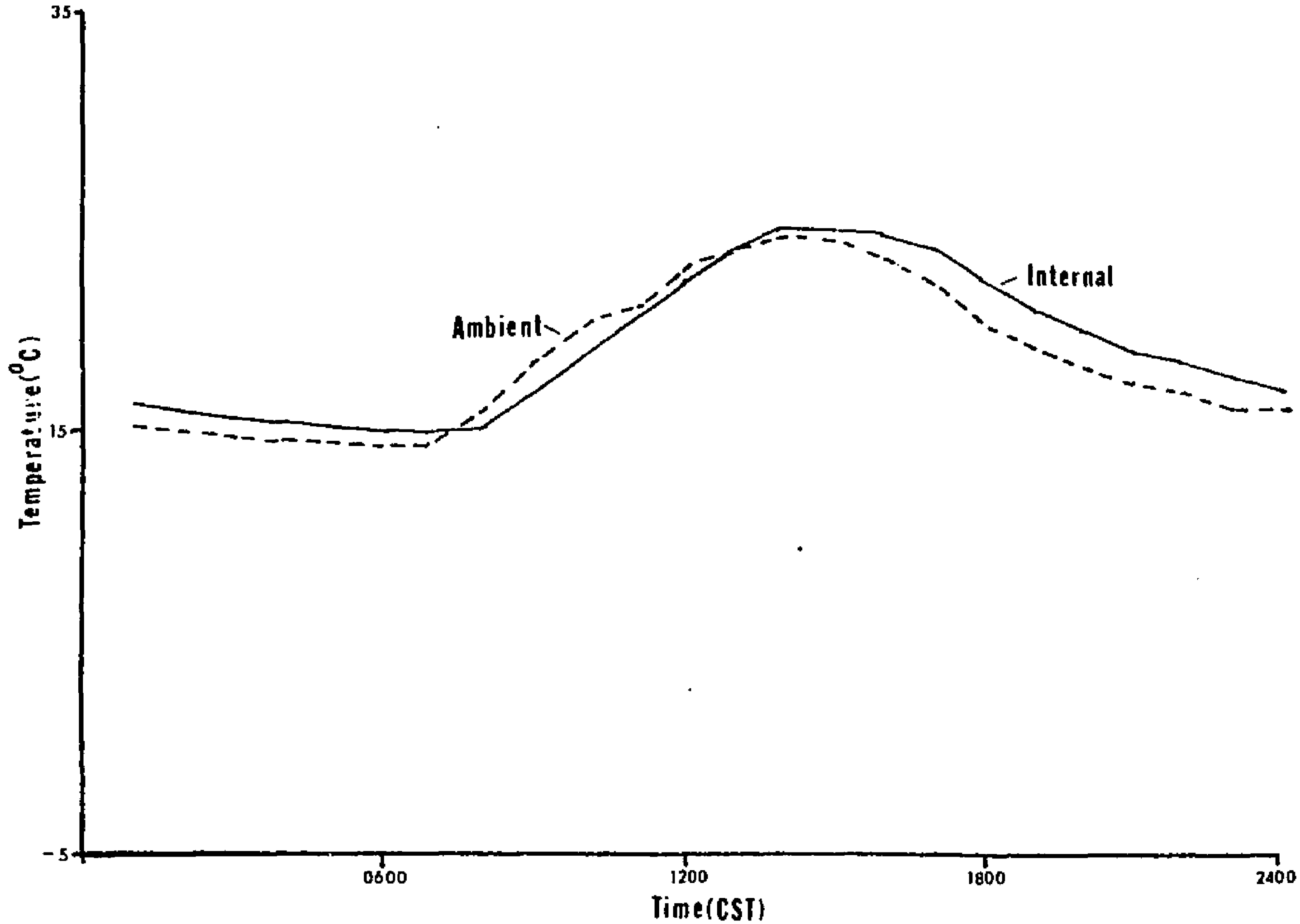


Figure 9. Temporal variation of temperature in nest boxes, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 3450).

by MacArthur and Aleksiuk (1979) in muskrat lodges in Canada. Maximum hourly temperature occurred two hours later inside natural cavities than outside natural cavities. This is less than the 3.8 hours reported by Stains (1961) but greater than the 0.5 hours reported by MacArthur and Aleksiuk (1979). The temperature lag in natural cavities was greater during rising temperatures than during falling temperatures. Stains (1961) made a similar observation.

Temperature lags in nest boxes were considerably less than those in natural cavities (Figure 9). Havera (1979) reported temperatures lower than ambient in unoccupied nest boxes when ambient temperatures were greater than $-0.8^{o}C$, but he did not report the amount of exposure to direct solar radiation.

Monthly internal temperature differed ($p < 0.01$) between boxes ($22.1^{o}C$) and natural cavities ($18.9^{o}C$) (Table 4). Mean monthly temperatures inside boxes remained 1.3 to $4.5^{o}C$ higher than natural cavity temperatures.

Monthly maximum temperature differed ($p < 0.01$) between boxes ($28.7^{o}C$; SE=0.08) and natural cavities ($23.0^{o}C$; SE=0.08) (Figure 10). The same was true for monthly minimum temperature (Figure 11). Natural cavities had a narrower range of temperatures than boxes throughout the year. Zeleny (1968) found that a simulated woodpecker cavity had lower maximum internal temperatures when exposed to full sunlight than did a nest box with 1.9 cm thick walls.

Internal Relative Humidity Hourly internal relative humidity was not different ($p > 0.05$) between boxes and natural cavities (73.2 percent) (Table 4). Relative humidity inside boxes remained from 1.0 to 6.0

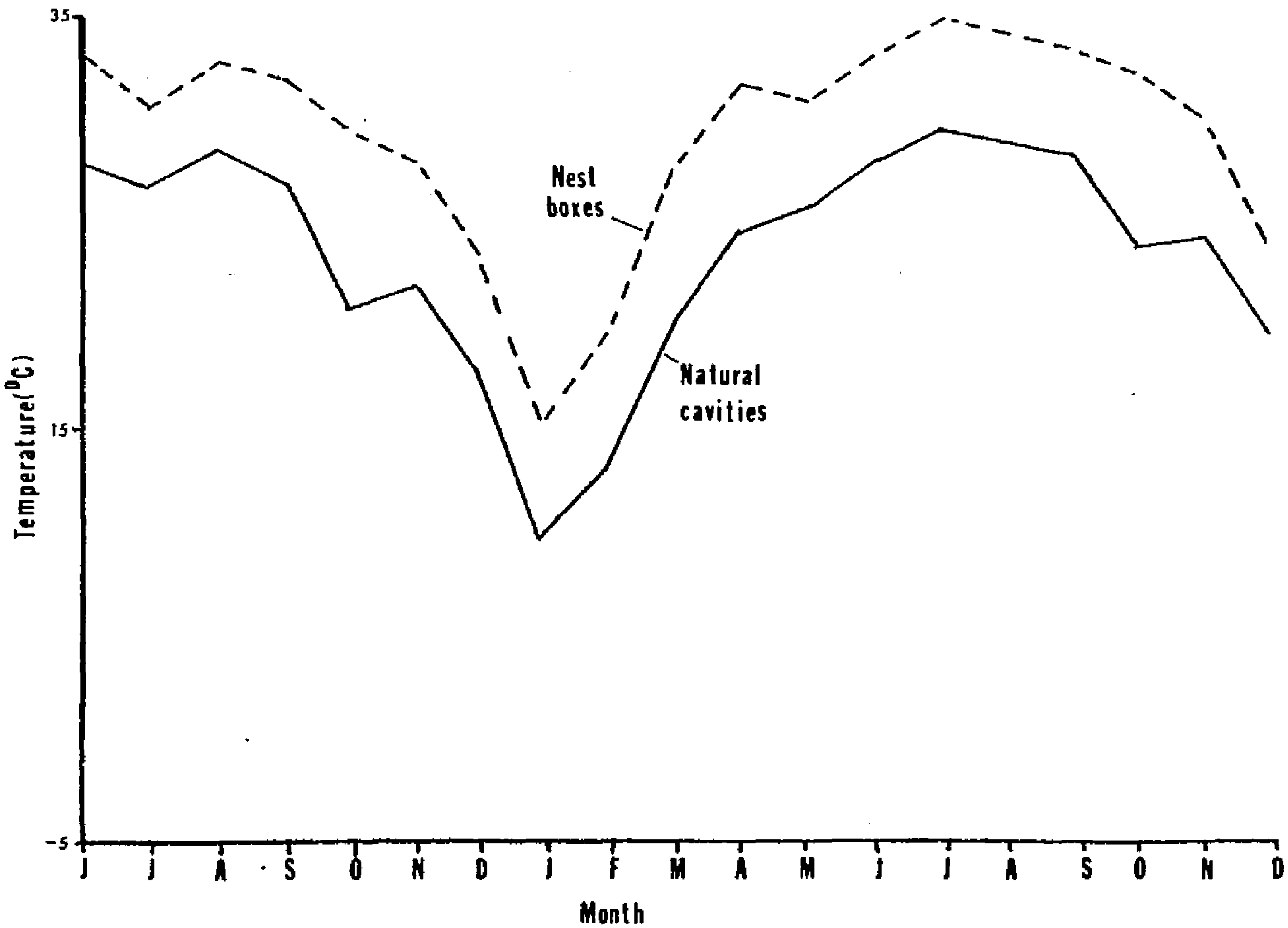


Figure 10. Temporal variation of monthly maximum internal temperature, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 900).

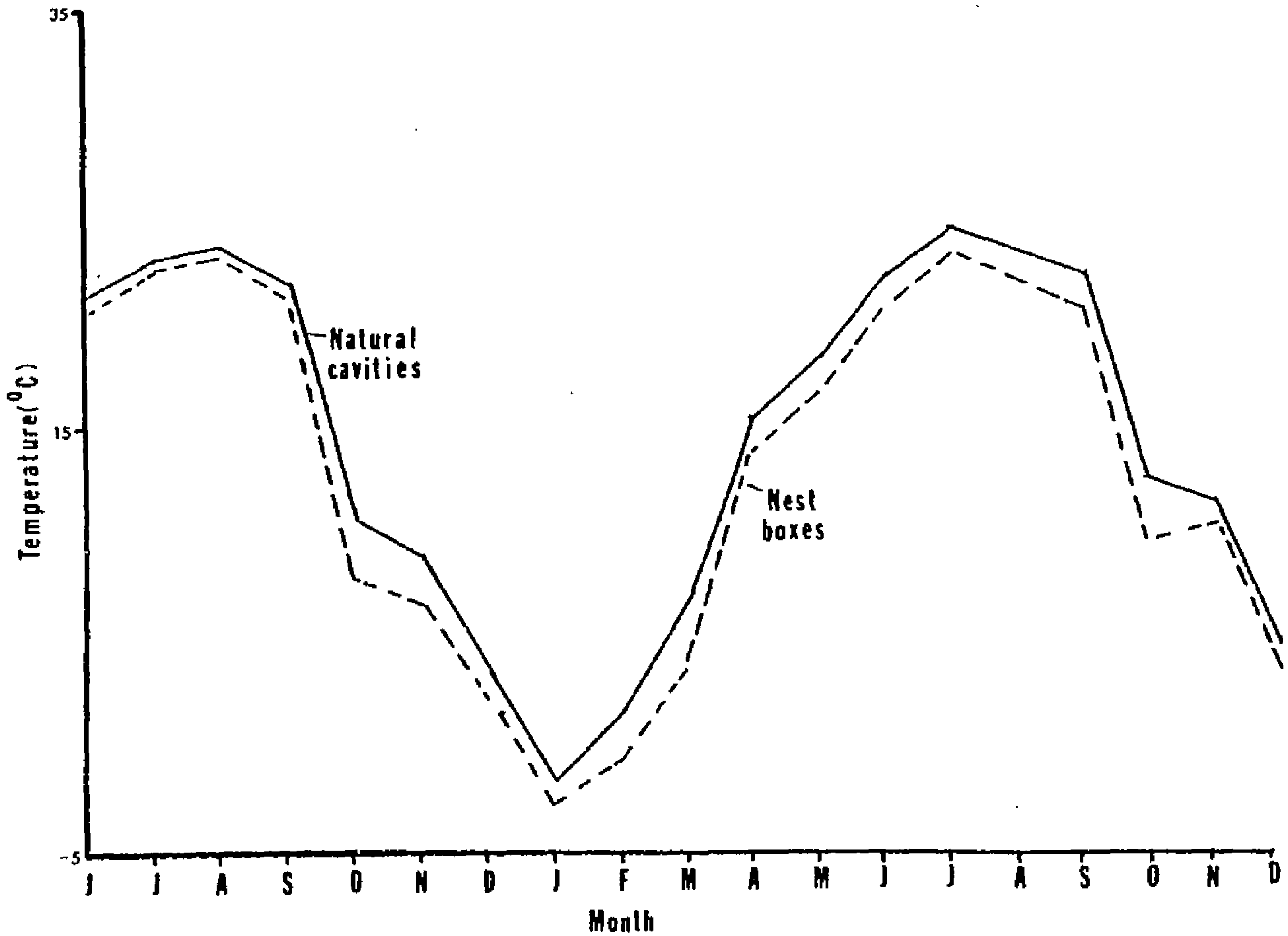


Figure 11. Temporal variation of monthly minimum internal temperature, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 900).

percent higher than ambient while relative humidity inside natural cavities remained from 2.0 to 25 percent higher than ambient ($p < 0.01$).

Monthly internal relative humidity differed ($p < 0.01$) between boxes (57.2 percent) and natural cavities (56.8 percent) (Table 4). The difference found between boxes and natural cavities with monthly data which was not found with hourly data can partially be explained by the exclusion of high night-time relative humidities from the monthly data set. Mean relative humidity in boxes remained slightly lower than that in natural cavities only during the daylight hours. Monthly relative humidity remained consistently lower in boxes than in natural cavities. No comparable studies of relative humidity inside nest boxes or natural cavities were found in the literature.

Internal Incoming Solar Radiation Solar radiation entering boxes and natural cavities was almost totally diffuse. A mediating effect by cavities could thus be expected since sunfleck occurrence should have been eliminated. Sunfleck occurrence is a source of high variation in solar radiation measurements (Anderson 1964:449, Muller 1971, Gay and Knoerr 1975:40).

Hourly incoming solar radiation was higher ($p < 0.01$) in boxes (9.16 watts/m^2) than in natural cavities (4.44 watts/m^2) (Table 4). Mean hourly incoming solar radiation in boxes peaked at 1300 hours; the same time that ambient incoming solar radiation peaked (Figure 12). Mean hourly incoming solar radiation in natural cavities peaked at 1400 hours; one hour later than peak ambient incoming solar radiation (Figure 12). Maximum hourly internal incoming solar

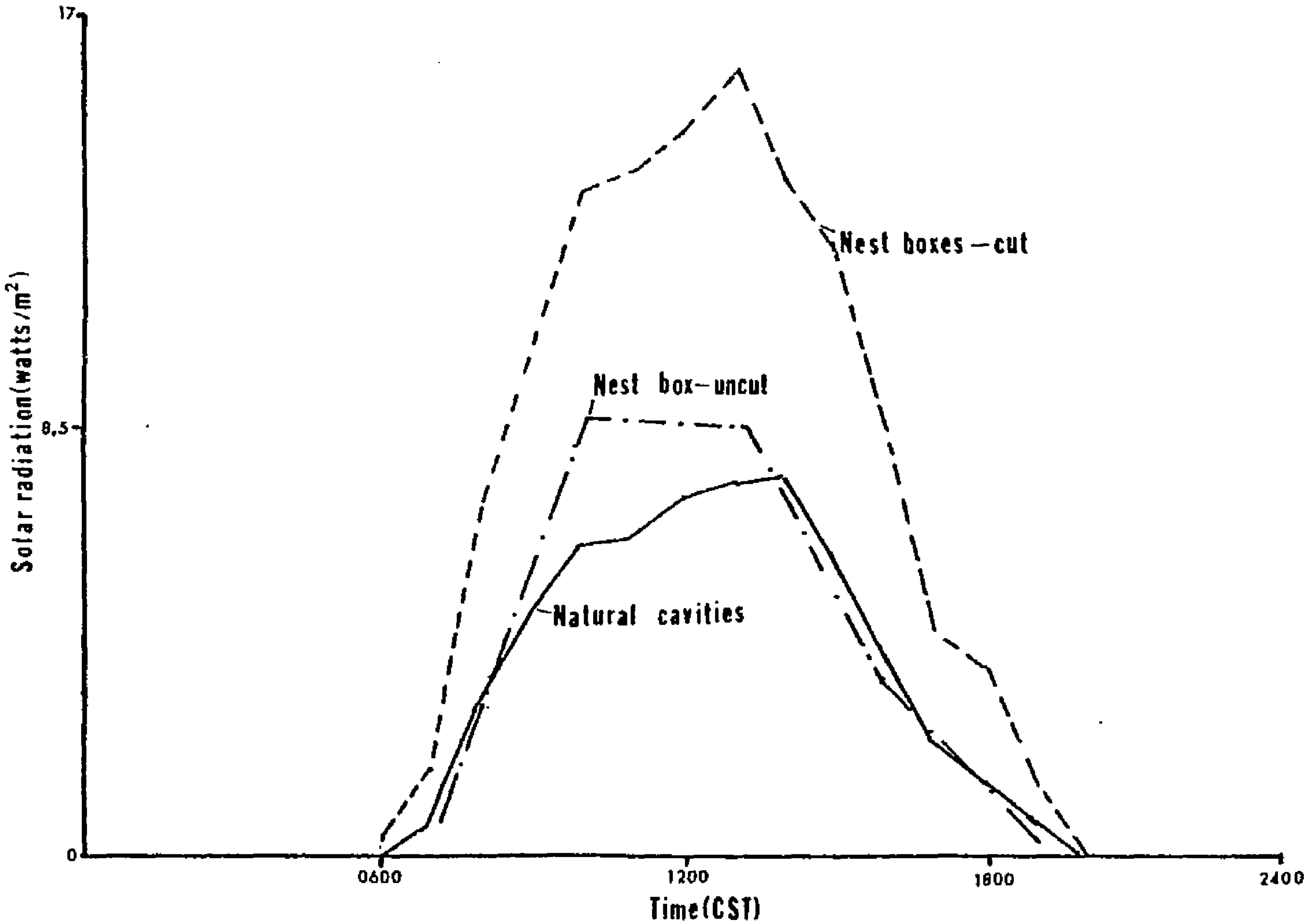


Figure 12. Temporal variation of hourly internal incoming solar radiation, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 1850; SE = 0.40).

radiation occurred in July 1977 and April 1978 in boxes and in April 1978 in natural cavities (similar to ambient trends). An average of 19.7 percent of the ambient incoming solar radiation striking boxes and natural cavities entered boxes to a depth of 15 cm, while an average of 16.7 percent entered natural cavities to that depth.

Monthly incoming solar radiation was higher ($p < 0.01$) in boxes (9.28 watts/m^2) than in natural cavities (6.64 watts/m^2) (Table 4). The mediating effect of cavities upon solar radiation is apparent. Monthly ambient incoming solar radiation at natural cavities was higher than at boxes, probably due to frequency of sunflecks. Monthly internal incoming solar radiation in natural cavities was lower than in boxes, partially because sunflecks were eliminated. An average of 13.7 percent of the solar radiation striking boxes and natural cavities entered boxes to a depth of 15 cm, while 4.8 percent entered natural cavities to that depth.

Internal Reflected Solar Radiation Solar radiation reflected from the inside of boxes and natural cavities is a function of the level of incoming solar radiation and the color and texture of the internal surfaces. Incoming solar radiation entering cavities was higher ($p < 0.01$) in boxes than in natural cavities, the internal surface of most natural cavities appeared darker in color than the internal surface of most boxes, and small cracks resulting from construction of boxes were lacking in natural cavities, so internal reflected solar radiation should have been lower in natural cavities than in nest boxes.

Hourly reflected solar radiation was higher ($p < 0.01$) in boxes (0.90 watts/m^2) than in natural cavities (0.30 watts/m^2) (Table 4). Temporal variation of hourly internal reflected solar radiation was similar to that of hourly internal incoming solar radiation (Figure 12). An average of 9.8 percent of the solar radiation striking the inside of boxes was reflected while 6.8 percent was reflected from inside natural cavities. A similar relationship was apparent at the box in the uncut-plot. Mean hourly reflected solar radiation remained consistently lower in natural cavities than in nest boxes.

Mean monthly reflected solar radiation was higher ($p < 0.01$) in boxes (1.02 watts/m^2) than in natural cavities (0.26 watts/m^2) (Table 4).

Internal Incoming Light Internal incoming light should be a function of the amount of ambient incoming light, time, the size and orientation of the cavity entrance and the angle of incidence of the incoming light (Anderson 1964:450). Internal light levels should be less variable than ambient since sunfleck occurrence should be reduced.

Hourly incoming light was higher ($p < 0.01$) in boxes (385 lux) than in natural cavities (176 lux) ($p < 0.01$) (Table 4). An average of 15.4 percent of the ambient incoming light entered boxes to a depth of 15 cm, and an average of 15.9 percent entered natural cavities to that depth. Mean hourly incoming light in boxes remained consistently higher than that in natural cavities (Figure 13). Monthly means of hourly incoming light remained consistently higher in boxes than in natural cavities (Figure 14).

Monthly incoming light was higher ($p < 0.01$) in boxes (309 lux)

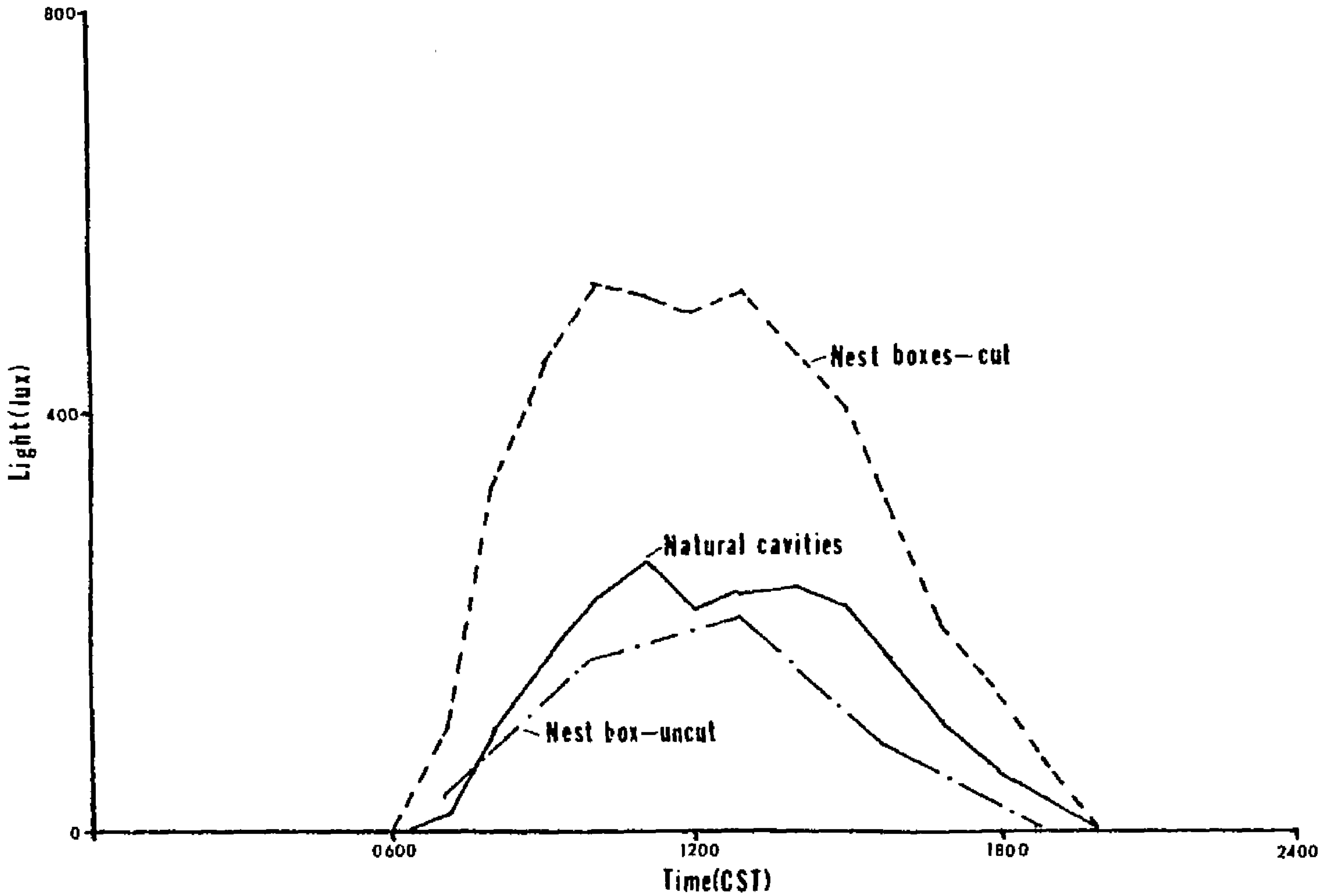


Figure 13. Temporal variation of hourly internal incoming light, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 1850; SE = 6.70).

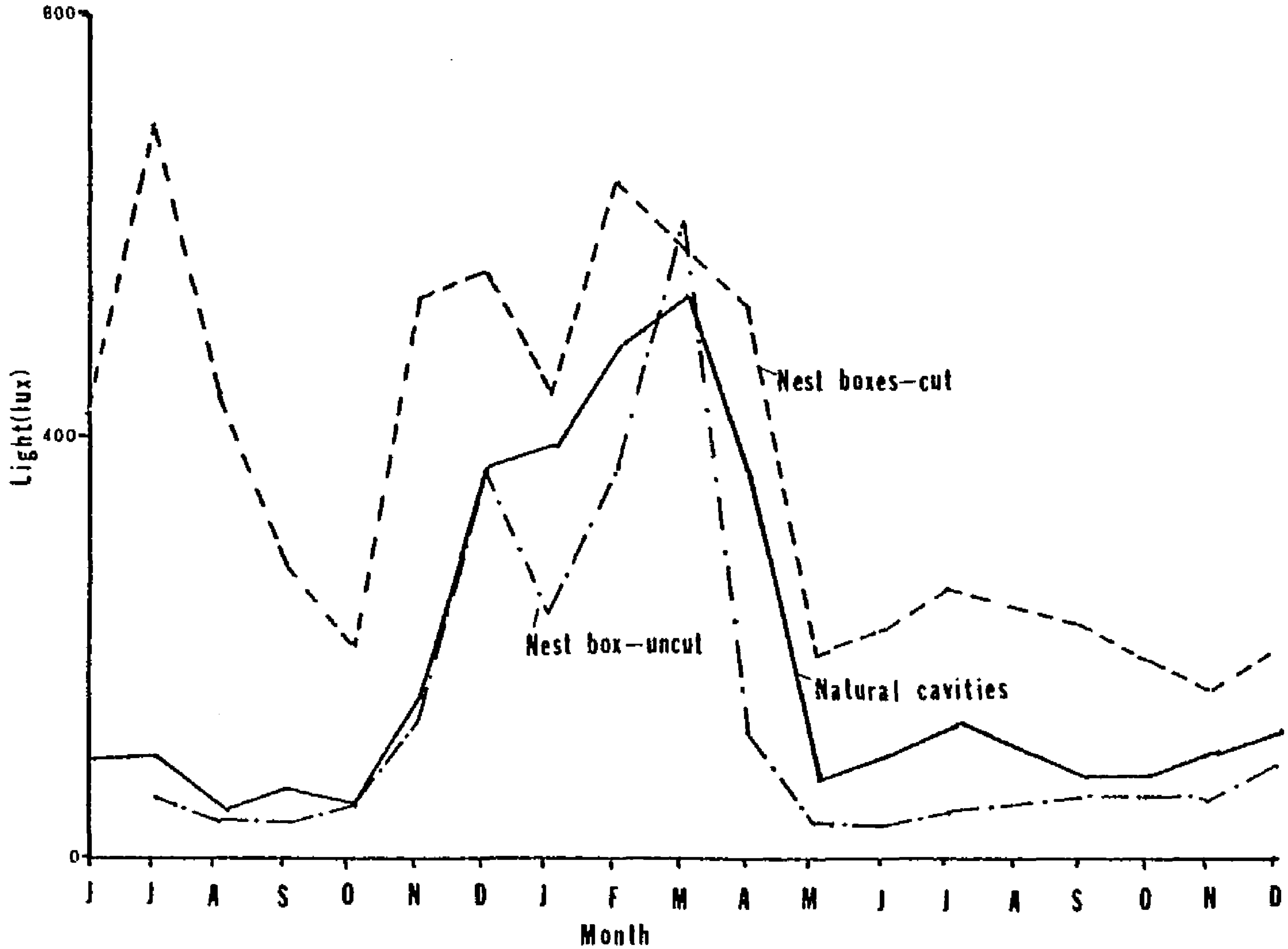


Figure 14. Monthly variation of hourly internal incoming light, Ben Hur, East Baton Rouge Parish, Louisiana, June 1977 to December 1978 (N = 1850; SE = 11.0).

than in natural cavities (284 lux) (Table 4). An average of 13.7 percent of the ambient incoming light entered boxes to a depth of 15 cm, but only 4.8 percent entered natural cavities to that depth. Average monthly incoming light was higher in natural cavities than in nest boxes from November 1977 to March 1978, and from September to December 1978, i.e. after leaf-fall. Monthly internal incoming light was less variable than monthly ambient incoming light.

Internal Reflected Light Reflected internal light is a function of time, the amount of internal incoming light, and the incidence of the incoming light (Anderson 1964:450). Construction of the cavity may have also affected reflection readings.

Hourly reflected light was higher ($p < 0.01$) in boxes (12.1 lux) than in natural cavities (5.4 lux) (Table 4). Internal surfaces of boxes reflected 3.2 percent of the incoming light; 3.1 percent was reflected from natural cavities. Temporal variation of hourly internal reflected light was similar to that for internal incoming light. Mean hourly reflected light remained consistently higher in boxes than in natural cavities.

Monthly reflected light was higher ($p < 0.01$) in boxes (11.6 lux) than in natural cavities (4.0 lux) (Table 4). Internal surfaces of boxes reflected 3.8 percent of the incoming light, while 1.4 percent of the incoming light was reflected from inside natural cavities.

Daily Microclimate Trends Daily trends of ambient microclimate in forest stands have been discussed by Geiger (1965:298-367) and

Francis (1976). Anderson (1964), Lull and Reigner (1967), Muller (1971), Reifsnyder et al. (1971), Gay and Knoerr (1975:40), Krantz and Gauthreaux (1975) discussed daily trends in solar radiation or light in forest stands, but these studies relied on measurements taken on horizontal surfaces. Fowells (1948) discussed vertical variation of temperature in a forest stand.

All prior investigations of internal microclimates of nest boxes or natural cavities were limited solely to temperature (Kendeigh 1961, Stains 1961, Gysel and Berner 1967, Zeleny 1968, Caccamise and Weathers 1977, Norman and Riggert 1977, Havera 1979).

Daily microclimate inside boxes and natural cavities is a function of characteristics of the cavity and of the mesoclimate surrounding the cavity. Just as the canopy of the forest stand had a mediating effect on the climate within the stand, a natural cavity or nest box has a mediating effect on the microclimate within it.

Light within the cavities appeared to be dependent upon the ambient light striking the entrance. Boxes allowed some light to enter around the top as well as through the entrance.

The temperature inside boxes and natural cavities was controlled by the amount of solar radiation absorbed by the outside surface, heating that surface and conducting that heat to the inside of the cavity. Robinson (1966:27) stated that the three factors affecting the amount of solar radiation striking a surface are the amount of scattering, the amount of absorption and the amount of incoming solar radiation. Another source of heat available for natural cavities and nest boxes was the transfer of warm air with cool air across the

temperature gradient at the entrance. Diffuse and scattered insolation entering the cavity and absorbed by the inside of the cavity also caused some release of longwave radiation, heating the cavity (Muller 1971). Internal temperature lagged ambient temperature because internal incoming solar radiation was only 7 to 19 percent of ambient incoming solar radiation. Heat must be conducted across the thickness of the cavity wall before internal temperatures are affected and ambient temperature must be raised above (or lowered below) internal temperature before there is any heat exchange across the face of the entrance. Differences between cavities within areas indicate that the size of this lag may vary with each cavity. The average lag was up to 2.0 hours in natural cavities and 1.0 hour or less in boxes with rising temperatures, and was up to 1.0 hour or less in both natural cavities and nest boxes with falling temperatures.

As temperatures rose inside cavities, relative humidity declined. Relative humidity was lower in nest boxes than in natural cavities. This may have been due to the higher temperatures attained in nest boxes than in natural cavities ($p < 0.01$), or because natural cavities in living trees continually had water in the cavity walls due to translocation of water from tree roots to the leaves.

Several factors may have accounted for higher midday temperatures in boxes than in natural cavities. First, more solar radiation struck boxes than natural cavities, due to the thinner canopy on the cut-plot. Also, the walls of most natural cavities were thicker than the walls of most boxes, thereby slowing the conduction of heat to the inside of the cavity. Third, the walls of natural cavities contained more moisture than the walls of nest boxes. Since the

latent heat of water is higher than most other substances, more heat would have been needed to raise the temperature of a given volume of natural cavity wall than would have been needed to raise the temperature of an equal volume of nest box wall.

Fourth, the shape of the box or natural cavity may have affected internal temperatures. Solar radiation striking the flat surface of a nest box would have resulted in uniform rapid heating of the surface, increasing the rate of heat conduction to the inside. The natural cavity-tree, being round or oval, was progressively heated through the day about 180° or less of its outside surface (Geiger 1965:481). The surface area to volume ratio was also smaller for that portion of the cavity tree containing the cavity than for nest boxes. Insolation would not have been concentrated at any given point for any long period of time on the relatively small surface area of the natural cavity-tree.

Fifth, the average height of natural cavities was lower than that of boxes. Fowells (1948) and Geiger (1965:306) reported an increase in temperature with increasing height in a forest stand.

Finally, the orientation of the entrances of boxes or natural cavities into the prevailing winds could have caused rapid mixing with ambient air, leading to rapid changes in internal temperatures.

As darkness approached, heat loss from the stand increased. Heat was also lost to the forest stand from natural cavities and nest boxes at night. Boxes lost more heat to the ambient environment than did natural cavities. Radiative heat loss was enhanced from nest boxes due to the larger surface area to volume ratio of boxes than of

natural cavities. Heat was also lost from boxes and natural cavities by way of air exchange across the entrance. Wind would have increased the rate of heat loss from cavities by mixing warmer internal air with cooler ambient air.

It is apparent that time of day influenced greatly the ambient mesoclimate of the forest stand and the internal microclimates of the cavities. Indeed, differences among times were found for all dependent variables measured under both data collection methods ($p < 0.01$).

<u>Annual Microclimate Trends</u> Annual trends in ambient and internal solar radiation appeared to be influenced by wind, cloud cover, canopy cover, solar altitude and the mosaic of leaves and branches in the canopy which allowed sunflecks to strike boxes and natural cavities (Geiger 1965:300-308, Muller 1971) (Figure 15). Incoming solar radiation appeared to be affected primarily by leaf cover from April to November and primarily by cloud cover from November to April.

Annual microclimate trends inside boxes and natural cavities were a function of the ambient mesoclimate and cavity characteristics. The mediating affect of cavities upon the microclimate within them is perhaps best exemplified by levels of monthly incoming solar radiation. Monthly ambient solar radiation on the control-plot was greatly influenced by sunflecks leading to higher levels than were recorded on the large-box-plot, but monthly internal incoming solar radiation in natural cavities was usually lower than in boxes. Internal incoming solar radiation trends were similar to those for ambient incoming solar radiation. A larger proportion of scattered solar radiation (15.9 percent) entered natural cavities than did direct solar

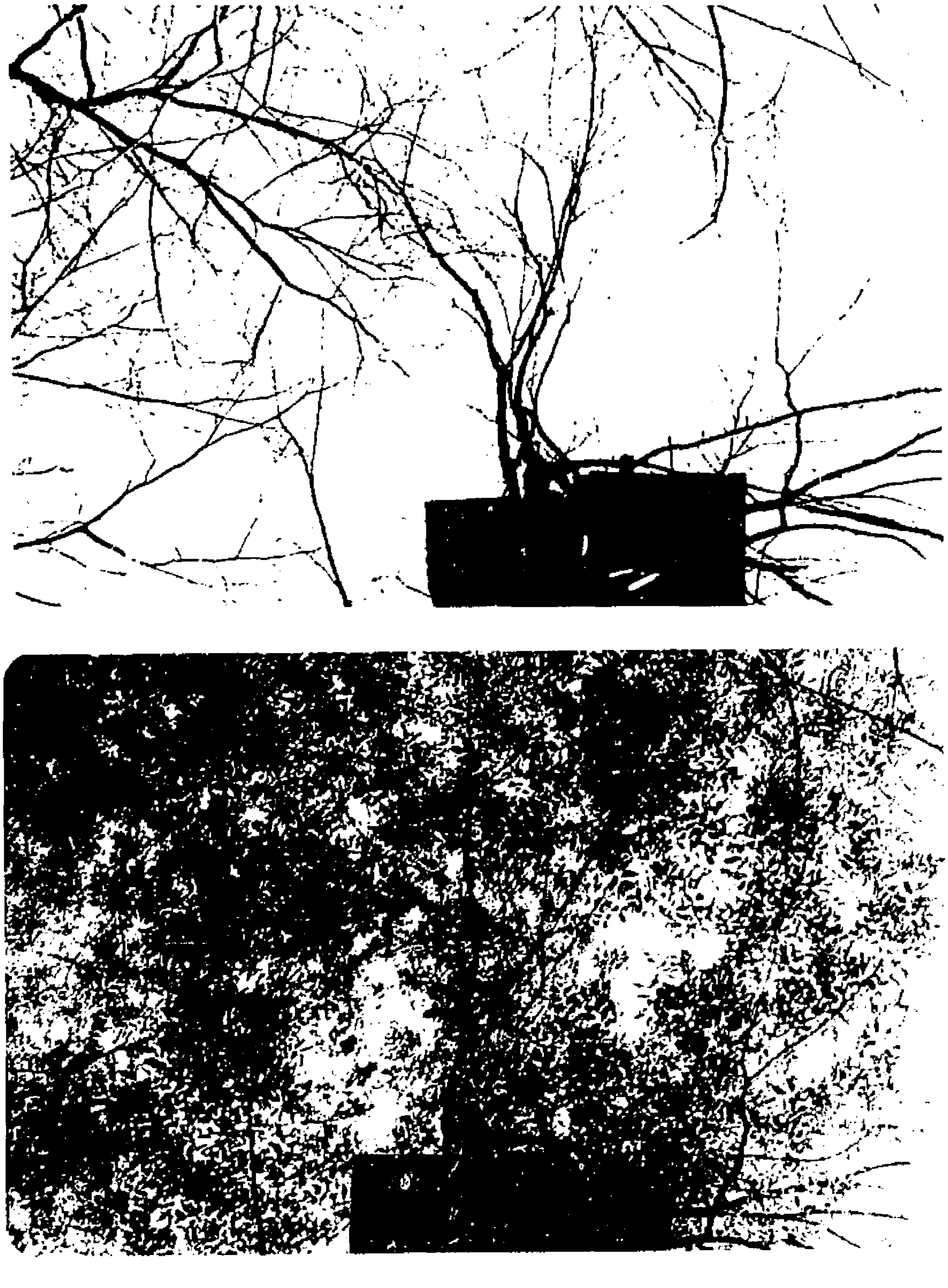


Figure 15. Box 89, right, and activity recorder, left, Ben Hur, East Baton Rouge Parish, Louisiana, 17 March 1979 (above) and 15 April 1979 (below). Mean incoming solar radiation decreased sharply from March to April because of canopy foliage development.

radiation (4.8 percent). The angle of incidence may have been an important factor (Anderson 1964:450). Light was similarly affected. Primarily scattered solar radiation measurements were taken at Ben Hur large-box-plot, consequently the amount of solar radiation or light entering boxes was similar regardless of data source (hourly or monthly).

Monthly temperature trends inside boxes and natural cavities seemed to be a function of ambient temperature and the characteristics of the cavity. Mean monthly temperatures inside boxes remained consistently above natural cavity temperatures. Mean monthly box temperatures followed closely mean monthly ambient temperatures; mean monthly natural cavity temperatures remained below mean monthly ambient temperatures. Apparently the superior insulating properities of natural cavities prevented the cool air received at night from escaping during the day. The range between maximum monthly temperature and minimum monthly temperature was narrower in natural cavities than in next boxes.

Mean monthly relative humidity in boxes and natural cavities remained above ambient for the 12 months during which data were collected. Although ambient relative humidity on Ben Hur control-plot was lower than that on Ben Hur large-box-plot, relative humidity in natural cavities was higher than in boxes. The moisture content of the walls of natural cavities was higher than that in the walls of nest boxes, thereby acting as a reservoir supplying moisture to the internal air as ambient relative humidity decreased. Ambient relative humidity probably controlled internal relative humidity ultimately,

since the curves of monthly internal and monthly ambient relative humidity were very similar.

Implications for Nest Box and Natural Cavity Use by Wildlife

Temperature is probably the most important climatic factor for most life forms (National Academy of Sciences 1971:215). All organisms have a preferred temperature (Precht et al. 1973:614). Within the zone of thermal neutrality, other factors become more important than temperature (National Academy of Sciences 1971:215). Hall and Root (1930) demonstrated the effect of humidity on the body temperatures of certain ectotherms. Precht et al. (1971:614) suggested that there is a thermohydro-preferendum, especially in soft-skinned ectotherms. Body temperatures become more stable in ectotherms as relative humidity increases (Hall and Root 1930); however, heat is more easily lost from an organism at low temperatures and high relative humidities (National Academy of Sciences 1971:216).

Klein (1975) stated that the amount of light entering a nest box affects use by wood ducks, though he provided no data to support this claim. The effect of light and temperature as "zeitgebers" (external timing mechanisms) has been suggested by several authors (Smith 1966: 103, Krantz and Gauthreaux 1975).

Brattstrom (1963, 1965) indicated that the preferred temperature for certain temperate terrestrial reptiles and amphibians usually fell within the range of 25° to 30°C. The National Academy of Sciences (1971:216) suggested a zone of thermal neutrality for most life forms between 10 and 20°C. The egg temperatures of certain cavity-nesting birds range between 34.1 and 34.3°C (Huggins 1941). Kendeigh (1969)

found that 22°C and 17 percent relative humidity were the conditions most favorable for house sparrow activity. Any microenvironment which would approach these conditions would be the one most likely to be used by most of the individuals of a given species. Natural cavities should be preferred by those individuals seeking a temperature about 5.5°C cooler than ambient during the day and/or about 2.3°C warmer than ambient during the night. Individuals seeking temperatures about 1.0°C warmer than ambient during the day and/or about 1.3°C warmer than ambient during the night should prefer nest boxes. Measurements taken at the box in the uncut-plot indicated that there was little difference between internal and ambient temperatures and relative humidities. However, these factors must be kept in mind:

(1) Kendeigh (1961), Havera (1979) and MacArthur and Aleksiuk (1979) demonstrated that an endothermic organism (bird or mammal) within a cavity or enclosed nest will raise the temperature within that cavity through the release of metabolic heat. The same insulating factors which resulted in lags of temperature in boxes and natural cavities will also help conserve metabolic heat. In this respect, it appears that most natural cavities are superior to most nest boxes.

(2) Many birds and mammals build nests inside the cavity. Dead air trapped between the fibers and leaves of a nest add to the insulating properties of the box or natural cavity. Indeed, Weigle and Osgood (1974) reported temperatures inside leaf nests alone, when occupied by a northern flying squirrel, up to 21°C higher than ambient temperatures of 4 to 15°C. Havera (1979) found that the presence of an adult fox squirrel in a leaf-lined nest box raised the temperature within the nest 28°C above the ambient temperature of -20°C.

(3) Some species of mammals may huddle thereby raising the temperature within the box or natural cavity (Rose 1967:443).

(4) Any structure which decreases wind speed will be more thermally stable (Shilov 1973:218, Francis 1976). Boxes or natural cavities placed in openings and/or with entrances facing the prevailing winds would be less desirable from this standpoint.

(5) The lower limit to temperature tolerance may change from season to season, as Kendeigh (1969) reported for house sparrows.

Cavity dependent wildlife, especially those species which build nests or huddle, should prefer natural cavities because natural cavities appear to have better insulating properties than nest boxes.

High relative humidities in natural cavities may cause occupants to lose more heat than they would lose in nest boxes at temperatures below about 15^{o}C (Hall and Root 1930). To my knowledge, the effect of the presence of an organism upon the relative humidity within a nest box or natural cavity has not been investigated. Relative humidity inside two adjacent nest boxes at Donohoe large-box-plot was measured 10 May 1977. One box was empty, the other contained an adult gray-phase screech owl with three eggs. Relative humidity in the vacant box was 45 percent, while that in the occupied box was 60 percent. Ambient relative humidity was 42 to 45 percent. The internal relative humidity of the box was likely elevated by the respiratory release of water vapor from the screech owl. The water vapor released through respiration would be at, or near body temperature. This warm moisture, plus the metabolic heat lost through the integument would further stabilize the surrounding microclimate. The release of warm water vapor by respiration may be more important to such soft-skinned ectotherms as

nestling birds, than to endotherms. Increased relative humidity would help stabilize the microclimate and create less stress on an organism (Hall and Root 1930).

Many organisms use absorption of direct solar radiation to raise their body temperature (Precht et al. 1973:458). Those cavities which are prone to high sunfleck occurrence may be preferred by such organisms.

The effect of extreme temperature upon several species of cavity-nesting birds has been discussed by Kendeigh and Baldwin (1928), Musselman (1934), Zeleny (1968) and Kendeigh (1969). The ability to withstand extreme temperatures may vary with age within a single individual (Vernberg 1963). Since the range of extreme daily temperature was narrower in natural cavities than in nest boxes, natural cavities should be preferred.

In light of the above discussion, it appears that most species using cavities at night should prefer natural cavities since the minimum internal temperature was usually higher than in nest boxes. The high relative humidities inside natural cavities may discourage use during cold weather. Most species using cavities during the day and during cold weather should prefer nest boxes, since maximum temperature in boxes is higher than in natural cavities. Additional warmth in a box may contribute to incubation in some bird species (Kendeigh 1963). Natural cavities should be preferred during hot weather because the mean maximum temperature in natural cavities is lower than in boxes. The increased insulating properties of a nest may decrease the advantages of one cavity form over another. Indeed the past or present use of a cavity by a nest-building species may

encourage or discourage use of that cavity by other species.

Certain predatory species may select a cavity form depending upon the suitability of the cavity for its prey. For instance, Rundquist and Collins (1974) reported that southeastern five-lined skinks[2] included wood roaches (Parcoblatta spp.) in their diet. Southeastern five-lined skinks and/or five-lined skinks were frequently found in boxes in this study possibly because the microenvironment of boxes was preferred by their prey.

Cavity Characteristics

Tree Species Differences in tree species were found among areas ($p < 0.01$). Since boxes were arranged in a grid pattern, the probability that a tree would be selected for a box would be similar to the probability that it would be included in an overstory cruise (also a grid pattern). Indeed, in most instances, box-bearing tree species had relative density values similar to the relative density values for all overstory trees. Mid-story species such as bluebeech and boxelder were not chosen for boxes in proportion to their availability because of their usual small dbh.

More natural cavities were found in sweetgums than in any other tree species. Sweetgums were prone to natural cavity formation. The density of sweetgum at Ben Hur control-plot relative to all species was 2.5 times smaller than the relative density of cavity-bearing sweetgums. Similarly, Nuttall oak and American elm were also prone to cavity formation. Bellrose (1976:187) reported American elm,

[2]Reptilian and amphibian nomenclature from Conant (1975); scientific and common names are presented in Table 74 of the Appendix.

sweetgum and red maple the best cavity producing species in both uplands and bottomlands. Baumgartner (1939) and Gilmer et al. (1978) also reported American elm as a good cavity-producing tree species. Baumgartner (1939) and Bellrose et al. (1964) reported the red oak group to be good cavity producers.

The most cavity prone tree species at Durango was waterlocust. The density of cavity-bearing waterlocust relative to all species was almost ten times the relative density of waterlocust in the stand. No other investigator has reported waterlocust an important cavity-tree species, but Sanderson et al. (1975) reported black locust, another legume, a cavity producer in West Virginia.

Tree age Cavity-bearing trees on Ben Hur control, Ben Hur box-natural cavity, and Donohoe control-plots were older than cavity-bearing trees on the other plots ($p < 0.05$) (Table 5). Cutting removed older trees. Since only cavity-bearing trees were cut, cavity presence appeared to be associated with old trees. This result supports the idea of Goodrum (1938), Sanderson et al. (1975) and others, that management for a sustained yield of natural cavities would require long rotations. These old trees are also species desirable for hardwood timber production (sweetgum). Long rotations of sweetgum in mixed hardwood stands could provide both natural cavities and timber, but the timber yield would be less due to decreasing growth rates and internal decay. A 78-year rotation in bottomland hardwood stands such as Ben Hur control-plot would maintain present natural cavity density (Table 5).

Nest boxes could be placed in 8-year old cottonwoods and be

Table 5. Evaluation of average cavity-tree age at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean age (years)	Grouping
Ben Hur natural cavities	45	78.3	A
Ben Hur large boxes	28	26.6	C
Ben Hur medium boxes	29	43.4	B
Ben Hur small boxes	30	45.6	B
Ben Hur large boxes - uncut	29	37.9	B C
Ben Hur boxes - cavities	24	78.5	A
Durango natural cavities	44	44.2	B
Durango large boxes	30	14.0	D
Durango medium boxes	10	14.0	D
Durango small boxes	10	14.0	D
Donohoe natural cavities	15	85.0	A
Donohoe large boxes	30	34.1	B C
Donohoe medium boxes	10	31.4	B C
Donohoe small boxes	10	33.3	B C

[a] F = 12862/503.4 with 13 and 333 df.

present through the rest of the 15-20 year rotation (Dutrow 1970). In such situations, box dependent species would have to move to a new box-bearing stand every 7-12 years.

Diameter at Breast Height The largest diameter natural cavity-bearing trees were found at Ben Hur control-plot ($p < 0.05$) (Table 6). Diameters of eastern cottonwoods at Durango were as large as diameters of natural cavity-bearing trees on the three control plots ($p < 0.05$). Harlow and Harrar (1969:233) reported 2.5 cm of diameter growth per year by some eastern cottonwoods. The cottonwoods at Durango appear to be approaching that growth rate.

Natural cavities were restricted to larger than average diameter trees; generally 40 cm and above. The results of Dalke (1948), Gysel (1961), Grice and Rogers (1965), Prince (1965) and Gilmer et al. (1978) concurred with mine. The average rate of upward spread of established heart rot in bottomland hardwoods is 2.7 to 6.1 cm per year (Putnam et al. 1960). At least five to ten years would probably be required for natural cavity formation. Since diameter growth would probably continue, an average of 4 to 8 cm of diameter growth would have accrued during this time. As trees become older and growth rate slows, additional physiological stresses would probably encourage heart rot formation.

Tree Height Natural cavities occurred in trees taller than average at Ben Hur control-plot and Donohoe control-plot, and they occurred more frequently in shorter than average trees at Durango control-plot (Table 7). The height of natural cavity-trees is probably a function of site. On a good site, cavity formation occurs mostly in mature or

Table 6. Evaluation of average cavity-tree dbh at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean dbh (cm)	Grouping
Ben Hur natural cavities	70	58.2 (22.9)[b]	A
Ben Hur large boxes	30	26.3 (24.0)	C
Ben Hur medium boxes	30	27.5 (25.9)	C
Ben Hur small boxes	30	20.9 (20.2)	C
Ben Hur large boxes - uncut	30	25.3 (36.5)	C
Ben Hur boxes - cavities	30	39.5 (21.2)	B
Durango natural cavities	46	40.8 (19.4)	B
Durango large boxes	30	27.9 (21.8)	C
Durango medium boxes	10	32.2	B C
Durango small boxes	10	32.1	B C
Donohoe natural cavities	45	41.9 (16.9)	B
Donohoe large boxes	30	25.9 (16.2)	C
Donohoe medium boxes	10	18.1	C
Donohoe small boxes	10	14.7	C

[a] $F = 5088.12/312.57$ with 13 and 402 df.

[b] Mean dbh of all trees per plot indicated parenthetically.

Table 7. Evaluation of average height of cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean height (m)	Grouping
Ben Hur natural cavities	70	23.4 (17.8)[b]	A
Ben Hur large boxes	30	15.8 (15.6)	C D
Ben Hur medium boxes	30	18.8 (17.1)	B C
Ben Hur small boxes	30	14.2 (15.7)	D
Ben Hur large boxes - uncut	30	16.0 (21.7)	C D
Ben Hur boxes - cavities	30	17.8 (16.5)	B C D
Durango natural cavities	46	19.2 (14.4)	B C
Durango large boxes	30	19.7 (24.3)	B C
Durango medium boxes	10	20.7	A B C
Durango small boxes	10	20.6	A B C
Donohoe natural cavities	45	19.0 (15.4)	B C
Donohoe large boxes	30	20.8 (16.2)	A B
Donohoe medium boxes	10	17.3	B C D
Donohoe small boxes	10	13.5	D

[a] $F = 244.75/40.92$ with 13 and 402 df.

[b] Mean tree height per plot indicated parenthetically.

overly mature trees; on a poor site cavity formation may occur early in life due to additional environmental stress.

Height of box-bearing trees was similar to the height of all trees on the plot in most instances.

Site The distribution of cavity-bearing trees on ridges, flats and sloughs at Ben Hur varied among plots (Tables 8 and 9). Cavity-trees at Durango control-plot occurred primarily on ridges and in sloughs, but boxes on Durango treated plots occurred exclusively on a flat. Box-bearing trees on Donohoe large-box-plot were located on higher sites than cavity-trees on the other plots. Natural cavities on Donohoe control-plot were distributed over all sites (Table 10). In all of the above instances, cavity-trees occurred on sites in proportion to site availability. No previous investigator has examined natural cavity frequency on physiographic sites on the mid-South. More extensive data are needed to determine which sites produce the most cavity-bearing trees.

Percent Bark on Cavity-trees and Number of Snags per Plot The percent bark cover of cavity-trees was lower at Donohoe control-plot than at any other plot ($p < 0.05$). More snags were present at Donohoe control-plot than at any other plot ($p < 0.05$). The percent bark cover of box-bearing trees approached 100 percent since only living trees were selected for box placement. Trees become more attractive to some woodpeckers as the tree loses bark (Noble 1978). Cavities may be more visible on barkless trees than on trees with a full covering of bark.

Forty-eight percent of the cavity-trees at Donohoe control-plot were snags, resulting in an average of 8.2 snags per ha. An average

Table 8. Evaluation of occurrence of cavity-trees on sites at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean site[b]	Grouping
Ben Hur natural cavities	70	1.9	D
Ben Hur large boxes	30	1.7	D
Ben Hur medium boxes	30	1.9	D
Ben Hur small boxes	30	1.6	D
Ben Hur large boxes - uncut	30	1.8	D
Ben Hur boxes - cavities	30	2.1	C D
Durango natural cavities	46	2.5	C
Durango large boxes	30	2.0	D
Durango medium boxes	10	2.0	D
Durango small boxes	10	2.0	D
Donohoe natural cavities	45	5.9	A
Donohoe large boxes	30	5.4	B
Donohoe medium boxes	10	6.5	A
Donohoe small boxes	10	6.6	A

[a] $F = 92.09/0.84$ with 13 and 402 df.

[b] Within each habitat type, higher numbers indicate lower sites.

Table 9. Percent frequency of sites at Ben Hur and Durango, July 1977 to February 1979.

Plot	Site		
	Ridge	Flat	Slough
Ben Hur natural cavities	6	93	1
Ben Hur large boxes	47	37	17
Ben Hur medium boxes	50	13	37
Ben Hur small boxes	41	55	4
Ben Hur large boxes - uncut	23	70	7
Ben Hur boxes - cavities	3	80	17
Durango natural cavities	20	9	71
Durango large boxes	0	100	0
Durango medium boxes	0	100	0
Durango small boxes	0	100	0

Table 10. Percent frequency of sites at Donohoe July 1977 to February 1979.

Plot	Site				
	Ridge-top	Upper 1/3	Mid 1/3	Lower 1/3	Drainage
Donohoe natural cavities	20	27	16	18	20
Donohoe large boxes	11	17	23	34	3
Donohoe medium boxes	0	10	30	60	0
Donohoe small boxes	0	10	30	50	10

of 8.8 snags per ha were found on Ben Hur control-plot, though snags made up only 10 percent of the cavity-tree composition on that plot. Durango control-plot had an average of only 3.3 snags per ha. Snags made up 8.7 percent of the cavity-bearing trees on Durango control-plot. All box-bearing trees appeared sound through the course of the study.

Lianas on Cavity-trees Lianas were present on 100 percent of the eastern cottonwoods at Durango; more than was found on natural cavity-trees at Durango control-plot ($p < 0.05$) (Table 11). Poison ivy, Japanese honeysuckle and grapes were the most frequently occurring lianoid species on cottonwoods. Trumper creeper, grapes, and poison ivy were found most frequently on natural cavity-trees at Durango.

Frequency of lianoid cover on natural cavity-trees was the same on all control plots ($p > 0.05$) (Table 11). Generally, a larger percentage of cavity-trees in the bottomland plots had lianoid cover than did cavity-trees at Donohoe. Poison ivy, grapes and crossvine occurred most frequently on cavity-trees at Ben Hur. Poison ivy, rattan-vine and crossvine occurred most frequently on cavity-trees at Donohoe.

The presence of lianas may assist some species such as rat snakes and Virginia opossums, in reaching nest boxes and natural cavities. Lianoid cover may affect the visibility of the cavity entrance. Lianoid cover may make a cavity more desirable by individuals or species.

Height of the Lowest Live Limb The height of the lowest live limb may

Table 11. Evaluation of occurrence of lianas on cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean occurrence of epiphytes[b]	Grouping
Ben Hur natural cavities	70	1.38	A B C
Ben Hur large boxes	30	1.50	A B C
Ben Hur medium boxes	30	1.17	C D
Ben Hur small boxes	30	1.17	C D
Ben Hur large boxes - uncut	30	1.07	D
Ben Hur boxes - cavities	30	1.23	C D
Durango natural cavities	46	1.30	B C
Durango large boxes	30	1.00	D
Durango medium boxes	10	1.00	D
Durango small boxes	10	1.00	D
Donohoe natural cavities	45	1.42	A B C
Donohoe large boxes	30	1.54	A
Donohoe medium boxes	10	1.70	A
Donohoe small boxes	10	1.50	A B C

[a]F = 1.060/0.200 with 13 and 402 df.

[b]Lower number indicates higher frequency of occurrence (1 = 100%; 2 = 0%).

influence visibility of the cavity entrance and accessibility of the cavity by reptiles and mammals. Gysel (1961) reported the height of cavities related to crown height. Silviculturally the height of the lowest live limb reflects the self-pruning ability of certain tree species. Height of the lowest live branch was highest at Donohoe large-box-plot and Donohoe medium-box-plot, and lowest at the three Durango treated plots ($p < 0.05$) (Table 12).

Cavity-tree Lean Cavity-trees at Durango control-plot leaned more than cavity-trees on any other plot except Ben Hur box-natural cavity-plot ($p < 0.05$) (Table 13). Apparently waterlocust, which comprised 58 percent of the natural cavity-bearing trees at Durango, is phototropic, resulting in excessive lean to attain needed sunlight.

Average lean on all sites was 3.2^{0}(SD = 4.0). This value is similar to that reported for snags in southeastern Alaska by Noble (1978). A leaning tree may allow freer access to the cavity for quadrupeds, or may be a preferred nesting site by some primary cavity-nesters (Conner 1975).

Cavity-tree Fork and Fork Height Fewer eastern cottonwoods at Durango had forks than cavity-trees on all other plots except Donohoe large-box, Donohoe medium-box and Donohoe small-box-plots ($p < 0.05$) (Table 14). Forked cavity-trees occurred most frequently at Ben Hur box-natural cavity plot (53 percent).

There was no difference in the height of forks in cavity-trees among areas (p 0.05) ($\bar{x}$ = 7.2 m; SD = 3.45).

Forking is usually the result of damage to the terminal bud

Table 12. Evaluation of average height of the lowest live branch on cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean height (m)	Grouping
Ben Hur natural cavities	63	6.9	B C D E
Ben Hur large boxes	30	7.2	B C D
Ben Hur medium boxes	29	8.3	A B
Ben Hur small boxes	27	5.9	B C D E
Ben Hur large boxes - uncut	30	7.0	B C D E
Ben Hur boxes - cavities	26	7.0	B C D E
Durango natural cavities	42	7.5	B
Durango large boxes	30	5.4	C D E
Durango medium boxes	10	4.1	E
Durango small boxes	10	4.3	D E
Donohoe natural cavities	24	7.4	B
Donohoe large boxes	30	9.9	A
Donohoe medium boxes	10	8.6	A B
Donohoe small boxes	10	5.9	B C D E

[a] $F = 50.32/11.83$ with 13 and 362 df.

Table 13. Evaluation of average angle of cavity-tree lean at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Average lean (°)	Grouping
Ben Hur natural cavities	66	2.7	C D
Ben Hur large boxes	30	2.2	C D
Ben Hur medium boxes	30	3.9	B C
Ben Hur small boxes	30	3.1	B C D
Ben Hur large boxes - uncut	30	3.4	B C D
Ben Hur boxes - cavities	30	4.9	A B
Durango natural cavities	46	6.2	A
Durango large boxes	30	3.1	B C D
Durango medium boxes	10	1.7	C D
Durango small boxes	10	0.5	D
Donohoe natural cavities	45	2.6	C D
Donohoe large boxes	30	1.5	D
Donohoe medium boxes	10	2.1	C D
Donohoe small boxes	10	3.7	B C D

[a]$F = 60.98/15.87$ with 13 and 397 df.

Table 14. Evaluation of frequency of forks in cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plots	N	Frequency of forks	Grouping
Ben Hur natural cavities	70	0.31	C D
Ben Hur large boxes	30	0.27	B C
Ben Hur medium boxes	29	0.38	C D
Ben Hur small boxes	30	0.37	C D
Ben Hur large boxes - uncut	30	0.37	C D
Ben Hur boxes - cavities	30	0.53	D
Durango natural cavities	46	0.35	C D
Durango large boxes	30	0.00	A
Durango medium boxes	10	0.11	A B C
Durango small boxes	10	0.10	A B C
Donohoe natural cavities	39	0.31	C D
Donohoe large boxes	30	0.09	A B
Donohoe medium boxes	10	0.10	A B C
Donohoe small boxes	10	0.10	A B C

[a] $F = 0.588/0.191$ with 13 and 395 df.

followed by increased upward growth of two or more of the lateral shoots. Since forked or multi-branched trees have a greater surface area to volume ratio than do unforked or few branched trees, then the probability of damage and subsequent disease occurrence is greater in the former than in the latter. The frequency of forked cavity-trees on the three control plots was almost identical (31-35 percent) (Table 14). I did not count the number of forked trees on each plot, so I cannot say forked trees were more likely to have natural cavities.

Distance to the Nearest Cavity Tree The distance between cavity-trees was greater at the upland treated plots than distances between cavity-trees at all bottomland plots and Donohoe control-plot ($p < 0.05$) (Table 15). Distances between cavity-trees were greater at Durango treated plots than at Durango control-plots ($p < 0.05$) (Table 15). Distances between cavity-trees were greater at Ben Hur treated plots than at Ben Hur control-plots ($p < 0.05$) (Table 15). These results are due to differences in cavity density among habitats and to the even distribution of boxes versus the random or clumped distribution of natural cavities. Closely grouped cavities increase the likelihood that an animal will become aware of more cavities than if the cavities were spaced widely. Evenly spaced cavities increase the likelihood that an animal will encounter at least one cavity, regardless of where the animal is on the plot. Clumped cavities may decrease the likelihood that an animal will encounter a cavity, but if a cavity is found, others are also likely to be found. This latter likelihood is increased if more than one cavity is present in the same tree.

Table 15. Evaluation of average distance to the nearest cavity-tree at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean distance (m)	Grouping
Ben Hur natural cavities	69	5.6	F
Ben Hur large boxes	30	11.2	D
Ben Hur medium boxes	30	12.5	D
Ben Hur small boxes	30	11.3	D
Ben Hur large boxes - uncut	30	11.6	D
Ben Hur boxes - cavities	30	8.2	E
Durango natural cavities	46	8.3	E
Durango large boxes	30	17.0	C
Durango medium boxes	10	10.7	D E
Durango small boxes	10	10.7	D E
Donohoe natural cavities	45	13.2	D
Donohoe large boxes	30	24.2	A B
Donohoe medium boxes	10	25.8	A
Donohoe small boxes	10	21.4	B

[a] F = 967.65/23.50 with 13 and 400 df.

Number of Cavities per Tree Natural cavities at Ben Hur control-plot were spaced closer together and occurred more frequently in the same tree than cavities on any other plot ($p < 0.05$) (Table 16). The number of cavities per tree at Ben Hur control-plot was greater than the number of cavities per tree reported by Gilmer et al. (1978).

If an animal encountered one cavity at Ben Hur control-plot, it is likely that it would have encountered more cavities there than it would have at any other plot. The likelihood that an animal would have encountered at least one cavity was greatest at Ben Hur box-natural cavity-plot, Durango medium-box-plot and Durango small-box-plot.

Distance to Water Gilmer et al. (1978) indicated that use of cavities by wood ducks was influenced by the distance of the cavity from water. Cavities at Durango control-plot were closer to water than cavities on any other plot except Ben Hur medium-box-plot ($p < 0.05$) (Table 17). This finding should be expected on the basis of the predominant physiographic features of these plots (primarily sloughs). No wood duck use was found at Durango despite its proximity to water.

Number of Trees per 0.02 ha Surrounding the Cavity-tree An average of eight trees (over 10 cm dbh) surrounded cavity-trees at Durango large-box-plot; more than on any other plot ($p < 0.05$) (Table 18). Boxes were placed in a grid pattern in the cottonwood plantation. Trees in the plantation were spaced 6 x 6 m. Since the radius of an 0.02-ha plot is about 8 m, we would expect an average of eight trees surrounding each box.

Since most natural cavities were found in old, large diameter

Table 16. Evaluation of the average number of additional cavities per cavity-tree at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean number of cavities[b]	Grouping
Ben Hur natural cavities	70	1.9	A
Ben Hur large boxes	30	0.0	D
Ben Hur medium boxes	30	0.0	D
Ben Hur small boxes	30	0.0	D
Ben Hur large boxes - uncut	30	0.0	D
Ben Hur boxes - cavities	30	0.1	D
Durango natural cavities	46	0.8	C
Durango large boxes	30	0.0	D
Durango medium boxes	10	0.0	D
Durango small boxes	10	0.0	D
Donohoe natural cavities	45	1.3	B
Donohoe large boxes	30	0.0	D
Donohoe medium boxes	10	0.0	D
Donohoe small boxes	10	0.0	D

[a]$F = 21.22/0.91$ with 13 and 402 df.

[b]The average number of cavities per tree is this value plus one.

Table 17. Evaluation of average distance to water from cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean distance (m)	Grouping
Ben Hur natural cavities	69	18.3	A B
Ben Hur large boxes	30	24.1	A
Ben Hur medium boxes	30	9.6	C D
Ben Hur small boxes	30	21.4	A
Ben Hur large boxes - uncut	30	18.2	A B
Ben Hur boxes - cavities	30	11.7	B C
Durango natural cavities	46	2.5	D
Durango large boxes	30	30.5	A
Durango medium boxes	10	30.5	A
Durango small boxes	10	30.5	A
Donohoe natural cavities	45	25.5	A
Donohoe large boxes	30	28.1	A
Donohoe medium boxes	10	29.9	A
Donohoe small boxes	10	26.9	A

[a] $F = 2373.5/287.7$ with 13 and 401 df.

Table 18. Evaluation of the average number of trees per 0.02 ha around cavity-tree at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean number of trees	Grouping
Ben Hur natural cavities	69	3.3	E
Ben Hur large boxes	30	6.3	B
Ben Hur medium boxes	30	3.7	D E
Ben Hur small boxes	30	3.5	E
Ben Hur large boxes - uncut	30	3.8	D E
Ben Hur boxes - cavities	30	5.4	B C
Durango natural cavities	46	3.3	E
Durango large boxes	30	8.0	A
Durango medium boxes	10	4.4	C D
Durango small boxes	10	3.4	E
Donohoe natural cavities	45	3.2	E
Donohoe large boxes	30	3.7	E
Donohoe medium boxes	10	4.2	C D E
Donohoe small boxes	10	5.2	B C D

[a]$F = 62.44/3.45$ with 13 and 400 df.

trees, few cavity-trees would be found in close proximity to one another. Also the larger canopies of such trees would prevent all but the most shade tolerant species from existing below them. Similar results were reported by Gilmer et al. (1978).

Height of Cavity in the Tree Boxes and natural cavities were located lower in trees at Durango than at the other plots ($p < 0.05$) (Table 19). Since the height of boxes was determined by the average height of natural cavities, few differences were found among plots within habitats (Table 19).

Hardin and Evans (1977) reported preferred nesting heights of 12 m or less for 14 cavity-nesting bird species. The average height of all nest boxes and natural cavities falls within this range.

Diameter of the Tree at the Cavity The diameter of cavity-trees at the cavity was larger at Ben Hur control-plot than at any other plot ($p < 0.05$) (Table 20). Diameter-at-breast-height of cavity-trees was also larger at Ben Hur control-plot than at any other plot ($p < 0.05$) (Table 14). Mean diameter of trees at the cavity was directly related to the dbh of cavity-trees. The diameter of the tree at the cavity is important because it limits the size of a nest box or natural cavity which can be located there. Of course, restrictions on natural cavity size are more stringent than restrictions on box size.

Entrance Shape and Dimensions Entrance characteristics may be important to species with a search-image for a particular entrance size

Table 19. Evaluation of average height of cavity in cavity-trees at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean height (m)	Grouping
Ben Hur natural cavities	70	7.5	A B
Ben Hur large boxes	30	6.1	B C
Ben Hur medium boxes	30	6.1	B C
Ben Hur small boxes	30	6.1	B C
Ben Hur large boxes - uncut	30	6.1	B C
Ben Hur boxes - cavities	30	5.8	C
Durango natural cavities	46	5.6	C
Durango large boxes	30	5.5	C
Durango medium boxes	10	5.5	C
Durango small boxes	10	5.5	C
Donohoe natural cavities	45	8.1	A
Donohoe large boxes	30	6.1	B C
Donohoe medium boxes	10	6.1	A B C
Donohoe small boxes	10	6.1	A B C

[a] $F = 24.84/11.08$ with 13 and 403 df.

Table 20. Evaluation of average diameter of cavity-tree at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean diameter (cm)	Grouping
Ben Hur natural cavities	70	42.7	A
Ben Hur large boxes	30	16.6	C
Ben Hur medium boxes	30	21.4	B C
Ben Hur small boxes	30	16.5	C
Ben Hur large boxes - uncut	30	21.2	B C
Ben Hur boxes - cavities	29	30.9	B
Durango natural cavities	46	31.5	B
Durango large boxes	30	25.1	B C
Durango medium boxes	10	29.5	B C
Durango small boxes	10	28.4	B C
Donohoe natural cavities	45	29.0	B C
Donohoe large boxes	30	27.4	B C
Donohoe medium boxes	10	14.9	C
Donohoe small boxes	10	10.9	C

[a]F = 2423.4/419.01 with 13 and 399 df.

and/or shape.

A wider range of entrance shapes was found at cavities on Durango control-plot than on other plots. Circular entrances predominated on all plots except those with small boxes (Table 21).

Natural cavity entrance heights at Ben Hur control-plot and Ben Hur box-natural cavity-plot were larger than those at Durango control-plot and all plots with medium and small boxes ($p < 0.05$) (Table 22).

The width of entrances of cavities at Durango control-plot were greater than those at Ben Hur control-plot ($p < 0.05$) (Table 23). The width of entrances of natural cavities at Donohoe control-plot were not different from entrance widths on the other two control plots ($p > 0.05$). The average size of cavity entrances at Ben Hur control plot was 129.0 cm^2; at Durango, 114.4 cm^2; and at Donohoe, 140.3 cm^2. Entrance sizes of large boxes were 126.7 cm^2; medium boxes, 45.5 cm^2; and small boxes, 38.8 cm^2. All of these figures are within the range of sizes reported desirable for a variety of species (Baumgartner 1939, Bellrose et al. 1964, Flyger and Cooper 1967, and others).

Differences in cavity entrance size and shape among plots may be due to differences in species composition. The effect of damage to tree tissue and subsequent heart-rot may be species specific. More research is needed to determine the affects of fungal heart-rots upon cavity formation in a variety of tree species.

<u>Internal Cavity Dimensions</u> Differences among box sizes stratified as expected. Mean cavity dimensions and volume were larger at Donohoe control-plot than at Durango control-plot ($p < 0.05$) (Tables 24-27). Dimensions and volumes of natural cavities at Ben Hur control-plot

Table 21. Percent frequency of entrance shapes at the three study areas, June 1977 to February 1979.

Plot	Shape				
	Round	Square	Triangular	Rectangular	Oval
Ben Hur natural cavities	76	4	1	6	13
Ben Hur large boxes	100	0	0	0	0
Ben Hur medium boxes	100	0	0	0	0
Ben Hur small boxes	0	0	0	100	0
Ben Hur large boxes - uncut	100	0	0	0	0
Ben Hur boxes - cavities	77	0	7	0	17
Durango natural cavities	60	2	13	13	11
Durango large boxes	100	0	0	0	0
Durango medium boxes	100	0	0	0	0
Durango small boxes	0	0	0	100	0

Table 21. Continued.

Table 21. Continued.

Plot	Shape				
	Round	Square	Triangular	Rectangular	Oval
Donohoe natural cavities	85	2	2	10	0
Donohoe large boxes	100	0	0	0	0
Donohoe medium boxes	100	0	0	0	0
Donohoe small boxes	0	0	0	100	0

Table 22. Evaluation of average height of cavity entrance at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean entrance height (cm)	Grouping
Ben Hur natural cavities	70	13.3	A
Ben Hur large boxes	30	12.7	A B
Ben Hur medium boxes	30	7.6	B C
Ben Hur small boxes	30	5.1	C
Ben Hur large boxes - uncut	30	12.7	A B
Ben Hur boxes - cavities	30	14.3	A
Durango natural cavities	46	8.6	B C
Durango large boxes	30	12.7	A B
Durango medium boxes	10	7.6	B C
Durango small boxes	10	5.1	C
Donohoe natural cavities	45	12.2	A B
Donohoe large boxes	30	12.7	A B
Donohoe medium boxes	10	7.6	B C
Donohoe small boxes	10	5.1	C

[a]F = 248.58/69.17 with 13 and 402 df.

Table 23. Evaluation of average width of cavity entrance at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean entrance width (cm)	Grouping
Ben Hur natural cavities	70	9.7	B C D
Ben Hur large boxes	30	12.7	A
Ben Hur medium boxes	30	7.6	D E
Ben Hur small boxes	30	5.1	E
Ben Hur large boxes - uncut	30	12.7	A
Ben Hur boxes - cavities	30	12.2	A B
Durango natural cavities	46	13.3	A
Durango large boxes	30	12.7	A
Durango medium boxes	10	7.6	C D E
Durango small boxes	10	5.1	E
Donohoe natural cavities	45	11.5	A B C
Donohoe large boxes	30	12.7	A
Donohoe medium boxes	10	7.6	C D E
Donohoe small boxes	10	5.1	E

[a]F = 231.02/30.94 with 13 and 403 df.

Table 24. Evaluation of average internal cavity height at the three study areas, July 1977 to February 1979 (means with different letters vary significantly $p < 0.05$).[a]

Plot	N	Mean cavity height (cm)	Grouping
Ben Hur natural cavities	57	35.6	C D
Ben Hur large boxes	30	61.0	A
Ben Hur medium boxes	30	45.7	B C
Ben Hur small boxes	30	30.5	C D
Ben Hur large boxes - uncut	30	61.0	A
Ben Hur boxes - cavities	29	52.5	A B
Durango natural cavities	41	25.3	D
Durango large boxes	30	61.0	A
Durango medium boxes	10	45.7	A B C
Durango small boxes	10	30.5	C D
Donohoe natural cavities	34	45.0	B C
Donohoe large boxes	30	61.0	A
Donohoe medium boxes	10	45.7	A B C
Donohoe small boxes	10	30.5	C D

[a]F = 4969.0/521.7 with 13 and 372 df.

Table 25. Evaluation of average internal cavity width at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean cavity width (cm)	Grouping
Ben Hur natural cavities	57	13.6	D
Ben Hur large boxes	30	30.5	A
Ben Hur medium boxes	30	20.3	B C
Ben Hur small boxes	30	15.2	C D
Ben Hur large boxes - uncut	30	30.5	A
Ben Hur boxes - cavities	29	22.4	B
Durango natural cavities	41	11.5	D
Durango large boxes	30	30.5	A
Durango medium boxes	10	20.3	B C
Durango small boxes	10	15.2	C D
Donohoe natural cavities	34	17.3	C
Donohoe large boxes	30	30.5	A
Donohoe medium boxes	10	20.3	B C
Donohoe small boxes	10	15.2	C D

[a]F = 1557.9/47.2 with 13 and 372 df.

Table 26. Evaluation of average internal cavity depth at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean cavity depth (cm)	Grouping
Ben Hur natural cavities	57	14.3	D E
Ben Hur large boxes	30	30.5	A
Ben Hur medium boxes	30	20.3	B C D
Ben Hur small boxes	30	15.2	D E
Ben Hur large boxes - uncut	30	30.5	A
Ben Hur boxes - cavities	29	23.4	B
Durango natural cavities	41	12.3	E
Durango large boxes	30	30.5	A
Durango medium boxes	10	20.3	B C D
Durango small boxes	10	15.2	C D E
Donohoe natural cavities	37	20.7	B C
Donohoe large boxes	30	30.5	A
Donohoe medium boxes	10	20.3	B C D
Donohoe small boxes	10	15.2	C D E

[a] $F = 1422.9/59.4$ with 13 and 375 df.

Table 27. Evaluation of average cavity volume at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean cavity volume (cm^3)	Grouping
Ben Hur natural cavities	57	22000	C D
Ben Hur large boxes	30	57000	A
Ben Hur medium boxes	30	19000	C D E
Ben Hur small boxes	30	7000	D E
Ben Hur large boxes - uncut	30	57000	A
Ben Hur boxes - cavities	29	41000	A B
Durango natural cavities	41	6000	E
Durango large boxes	30	57000	A
Durango medium boxes	10	19000	C D E
Durangc small boxes	10	7000	D E
Donohoe natural cavities	34	34000	B C
Donohoe large boxes	30	57000	A
Donohoe medium boxes	10	19000	C D E
Donohoe small boxes	10	7000	D E

[a]F = 11605859789/1135586048 with 13 and 372 df.

remained intermediate between those at Durango and Donohoe control-plots. Mean cavity depth, mean cavity width and mean cavity volume were larger at Ben Hur control-plot that at Durango control-plot ($p < 0.05$) (Tables 25-27), but mean cavity height was not different between these two plots ($p > 0.05$) (Table 24). The older cavity-trees at Donohoe ($\overline{x}$ = 85 years) and Ben Hur ($\overline{x}$ = 78 years) control-plots had a longer period of time to decay than cavity-trees at Durango control-plot ($\overline{x}$ = 44 years) possibly resulting in slightly larger cavities having been formed in trees on the former plots. Differences in cavity size may also have been due to species specific effects of fungal heart-rots. Mean cavity volume of all boxes and natural cavities except small boxes and natural cavities at Durango control-plot was within the range desirable to wood ducks (Bellrose et al. 1964).

Cavity Location and Angle from Horizontal The percentage of cavities located in limbs was not different among the control-plots ($p > 0.05$) (Table 28) (13-19 percent). Some species of woodpeckers prefer nesting and roosting sites with entrances greater than 90^{o} from horizontal, and since the underside of limbs invariably meet this requirement, cavities located in limbs may be important to some woodpeckers as well as secondary cavity-users (Conner 1975).

More cavity entrances faced upward at Donohoe control-plot than on any other plot ($p < 0.05$) ($\overline{x} = 73.1^{o}$). Many of the cavities on this plot may have been undesirable for use by woodpeckers and other cavity-users because the entrances of most cavities faced up allowing rain to enter the cavity.

Table 28. Evaluation of occurrence of cavity in limb or trunk at the three study areas, July 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Mean location	Grouping
Ben Hur natural cavities	70	1.19[b]	A
Ben Hur large boxes	30	1.00	C
Ben Hur medium boxes	30	1.00	C
Ben Hur small boxes	30	1.03	B C
Ben Hur large boxes - uncut	30	1.00	C
Ben Hur boxes - cavities	30	1.00	C
Durango natural cavities	46	1.13	B C
Durango large boxes	30	1.00	C
Durango medium boxes	10	1.00	C
Durango small boxes	10	1.00	C
Donohoe natural cavities	45	1.13	B C
Donohoe large boxes	30	1.00	C
Donohoe medium boxes	10	1.00	C
Donohoe small boxes	10	1.00	C

[a] $F = 0.149/0.086$ with 13 and 397 df.

[b] Larger number indicates greater frequency of cavity occurrence on limbs (1 = 0%; 2 = 100%).

Conner (1975) indicated that woodpeckers prefer to excavate cavities on the bole of a tree under a limb. I found no differences in the frequency of cavities under limbs among plots ($p > 0.05$) ($\overline{x}$ = 10 percent; range = 0-24 percent).

Cavity Origin Limb breakage was the most frequent form of cavity formation on all control plots, though 38 percent of the cavities at Donohoe control-plot were made by animals; more than on any other plot (Table 29). Baumgartner (1939) described in detail cavity formation following limb breakage.

Entrance Orientation Conner (1975) and Gilmer et al. (1978) indicated that entrances to cavities used by woodpeckers and wood ducks were non-random. Entrances to natural cavities on the control plots were distributed in all directions (Table 30). Animal-made cavities faced mostly north and west at Donohoe (n = 17), south and southweast at Ben Hur (n = 9), and south at Durango (n = 2). Conner (1975) reported entrances opening primarily northeast in Virginia. The sun-warmth theory of Lawrence (1967) and Dennis (1969) may be applicable to the Ben Hur and Durango animal-made cavities. Prevailing winds probably determine cavity orientation at Donohoe. The prevailing winds at Donohoe are southeasterly so north or west facing cavities should be preferred. Light relations within the forest stand may also contribute to cavity orientation.

Management Implications The heights of forks in cavity-trees and the frequency of cavities under limbs were the only cavity characteristics not different among plots ($p > 0.05$). If only natural cavities are

Table 29. Percent frequency of cavity origins at the three study areas, January 1977 to February 1979.

Plot	Origin			
	Man-made	Limb-break	Butt-rot	Animal-made
Ben Hur natural cavities	0	88.4	0	12.6
Ben Hur large boxes	100	0	0	0
Ben Hur medium boxes	100	0	0	0
Ben Hur small boxes	100	0	0	0
Ben Hur large boxes - uncut	100	0	0	0
Ben Hur boxes - cavities	50	37	7	7
Durango natural cavities	0	80	13	6
Durango large boxes	100	0	0	0
Durango medium boxes	100	0	0	0
Durango small boxes	100	0	0	0
Donohoe natural cavities	0	51	11	38
Donohoe large boxes	100	0	0	0
Donohoe medium boxes	100	0	0	0
Donohoe small boxes	100	0	0	0

Table 30. Percent frequency of cavity entrance orientation at the three study areas, January 1977 to February 1979.

Plot	Aspect							
	N	NE	E	SE	S	SW	W	NW
Ben Hur natural cavities	6	7	17	7	20	16	17	10
Ben Hur large boxes	17	57	0	0	0	0	0	27
Ben Hur medium boxes	33	53	10	0	0	0	0	3
Ben Hur small boxes	52	24	0	0	0	3	0	23
Ben Hur large boxes - uncut	40	23	3	0	3	0	10	20
Ben Hur boxes - cavities	17	7	10	3	17	10	10	27
Durango natural cavities	30	5	23	9	19	5	5	5
Durango large boxes	0	84	13	3	0	0	0	0
Durango medium boxes	0	56	33	11	0	0	0	0
Durango small boxes	0	70	30	0	0	0	0	0

Table 30. Continued.

Table 30. Continued.

Plot	Aspect							
	N	NE	E	SE	S	SW	W	NW
Donohoe natural cavities	11	11	11	11	14	7	27	7
Donohoe large boxes	0	40	60	0	0	0	0	0
Donohoe medium boxes	10	40	0	40	10	0	0	0
Donohoe small boxes	0	0	70	20	10	0	0	0

considered in comparisons, then frequency of lianas on cavity-trees, height of the lowest live branch, frequency of forks, and number of trees surrounding the cavity-tree were not different among plots ($p > 0.05$). Differences in all other characteristics among plots within habitats and among habitats could partially explain differences in use of nest boxes and natural cavities by wildlife. The importance of cavity characteristics to cavity-dependent wildlife species can only be evaluated in light of characteristics preferred by each species. Retention of the most suitable cavities (both nest boxes and natural cavities) for a target species or for a variety of species, depending upon the manager's objectives, would maximize the probability of use of each cavity while minimizing the number of cavity-bearing trees in the stand.

Bird Observation

Eighty species of birds, representing 27 families and 7013 individuals were recorded at the three habitat types, March 1977 to February 1979. The following were the most abundant species at each plot:

<u>Ben Hur control-plot</u>

common grackle
Carolina chickadee
northern cardinal

<u>Ben Hur large-box-plot</u>

white-throated sparrow
Carolina chickadee
northern cardinal

<u>Durango control-plot</u>

northern cardinal
Carolina chickadee
Carolina wren

<u>Durango large-box-plot</u>

white-throated sparrow
northern cardinal
yellow-rumped warbler

Donohoe control-plot	Donohoe large-box-plot
Carolina chickadee	Carolina chickadee
American robin	northern parula warbler
northern parula warbler	northern cardinal

Cavity-nesting species comprised 22.4 to 27.2 percent of the bird species and 25.0 to 44.0 percent of the individuals on all plots (Table 31). Hardin and Evans (1977) reported similar species composition in oak-hickory forests. Carolina chickadees, Carolina wrens, tufted titmice and red-bellied woodpeckers were the most abundant cavity-nesters on all areas. These species were more abundant in the spring and summer of 1977 than 1978 on Ben Hur large-box-plot, Durango large-box-plot and Donohoe large-box-plot (Table 32) while they were more abundant in the spring and summer of 1978 than 1977 on Ben Hur control-plot and Donohoe control-plot. They were equally abundant both years on Durango control-plot. In most instances the densities of cavity-nesters fluctuated seasonally with the densities of all bird species. Since the populations of the four most abundant cavity-nesters on all plots were higher in 1977 than in 1978, I would expect higher cavity use in 1977 than in 1978 by these species and indeed that is what I found. Habituation could decrease the effect that high populations could have on nest box use during the first year. The super-releaser theory of Hinde (1959) could explain an increase in nest box use. Seemingly neither condition would apply to natural cavity use.

Small Mammal Trapping

Nine species of small mammals which represented three families and 173 individuals were captured at the three habitat types, May 1977 to

Table 31. Percent composition of avian cavity-nesters at the three study areas, March 1977 to February 1979.

Plot	Species	Individuals
Ben Hur control	26.8	25.0
Ben Hur large-box	23.0	31.4
Durango control	22.4	38.4
Durango large-box	26.2	27.4
Donohoe control	25.3	44.4
Donohoe large-box	27.2	40.4

Table 32. Individuals observed per hour of the four most frequently observed cavity-nesting bird species, spring and summer, 1977 and 1978, Ben Hur (BH), Durango (DR) and Donohoe (CN).

Plot	Year	Species				Total	Total all birds
		Red-bellied woodpeckers	Carolina chickadees	Tufted titmice	Carolina wrens		
BHC[a]	77	0.52	0.78	0.38	0.25	1.9	5.9
	78	0.27	0.62	0.28	0.57	1.7	7.5
BHLB[b]	77	0.47	1.39	0.46	0.98	3.3	12.9
	78	0.23	0.86	0.75	0.75	2.6	9.0
DRC	77	0.94	1.59	0.41	0.88	2.8	11.8
	78	0.76	1.00	0.76	1.00	3.6	11.9
DRLB	77	0.12	0.88	0.94	0.76	2.7	11.0
	78	0.06	0.18	0.41	1.06	1.5	6.6
DNC	77	0.68	1.11	0.36	0.47	3.5	7.6
	78	0.16	1.26	0.37	0.47	2.3	8.7

Table 32. Continued.

Table 32. Continued.

Plot	Year	Species				Total	Total all birds
		Red-bellied woodpeckers	Carolina chickadees	Tufted titmice	Carolina wrens		
DNLB	77	0.58	0.79	0.58	0.47	2.4	8.5
	78	0.37	0.47	0.37	0.53	1.7	5.6
Average	77	0.55	1.09	0.51	0.64	2.6	9.6
	78	0.31	0.73	0.49	0.74	2.2	8.2

[a]C = control

[b]LB = large box

February 1979. Cotton mice comprised 75 percent of all captures. White-footed mice, golden mice and eastern woodrats were the only other arboreal species captured. Captures of these species were highest at Donohoe and highest in the winter and early spring. Higher cavity use could be expected at Donohoe than at Ben Hur or Durango unless high water forced individuals to find refuge in cavities. Since captures were lowest in the summer, lowest cavity use by small mammals should occur in the summer.

Activity Counters

Although more boxes than natural cavities were used during each four week sampling period by vertebrates, the average amount of activity at cavities on Ben Hur control-plot was not different from that on Ben Hur large-box-plot ($p > 0.05$) ($\bar{\bar{x}} = 2.9$ visits per cavity per week; SE = 0.26). Activity at boxes and natural cavities was seasonal. Boxes were used more frequently in June 1977, October 1977, May 1978 and February 1979 (see discussion of cavity use by vertebrates). Activity at boxes in October was low; resident vertebrates were probably still habituating to counter mechanisms (Figure 16). Activity at boxes in May 1978 and February 1979 was also low, indicating that although many boxes were being used, no box was being used consistently. Periods of high activity at boxes were associated with a small number of boxes used, i.e. a few boxes were used heavily.

Natural cavities were used most frequently from October 1977 to April 1978 and from August 1978 to January 1979 (see discussion of natural cavity use by vertebrates). Activity at natural cavities was

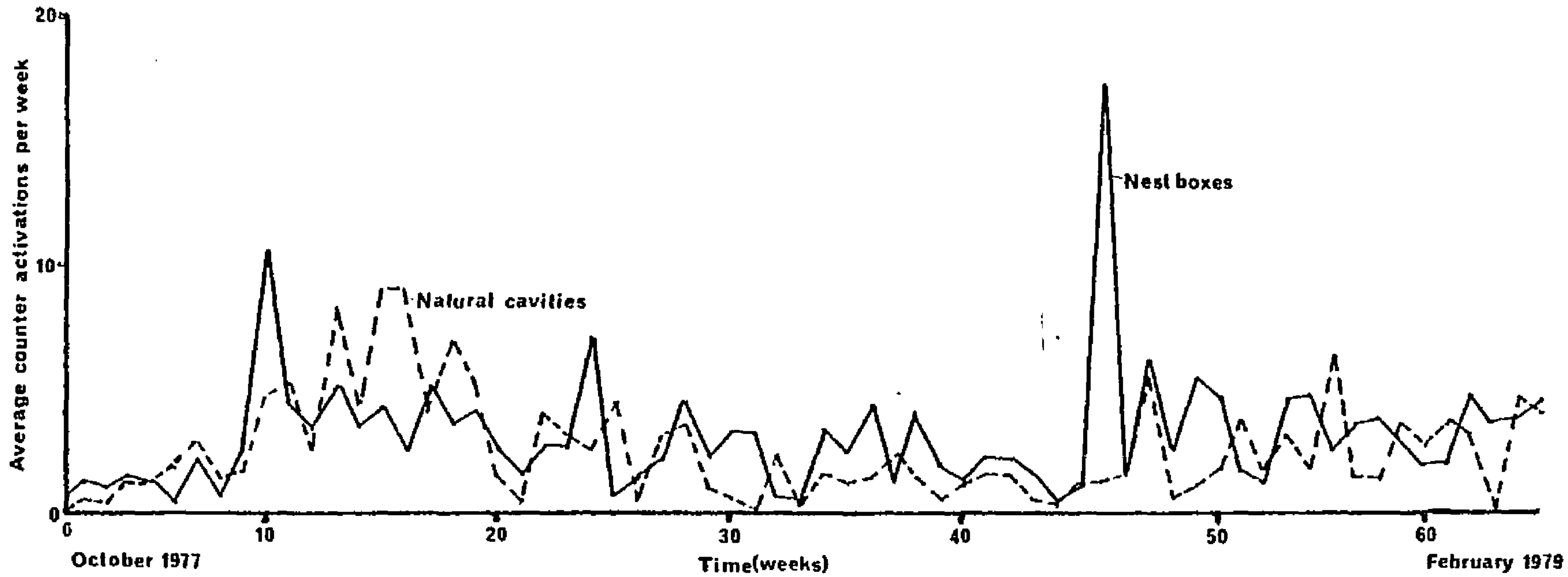


Figure 16. Mean weekly entrances and exits by vertebrates from natural cavities and from nest boxes, Ben Hur, October 1977 to February 1979.

highest from mid-December 1977 to early March 1978 and in September and November 1978 (Figure 16). Natural cavities were used consistently when they were used.

Nest Box and Natural Cavity Use

There were 4,136 natural cavities checked and 6,712 nest boxes checked from January 1977 to February 1979. Use by some animal, whether vertebrate or invertebrate, was recorded in 21.8 percent of the natural cavities checked and in 70.8 percent of the nest boxes checked. Nest boxes were used more frequently on all plots than were natural cavities ($p < 0.05$) (Table 33). Peak cavity use occurred in the summer of 1978 (Table 34). Minimum use was recorded in the spring both years. Low initial use was probably due to lack of habituation to boxes by most species. Nest boxes may act as super-releasers which elicit more use than natural cavities (Hinde 1959).

Invertebrates Invertebrates occurred in 13.0 percent of the natural cavities checked and in 56.5 percent of the nest boxes checked. Invertebrates occurred more frequently in nest boxes and natural cavities than did vertebrates. Invertebrates were found more frequently in nest boxes than in natural cavities in all three habitat types ($p < 0.05$) (Table 35). The highest frequency of occurrence of invertebrates was at Durango large-box-plot ($p < 0.05$) (Table 35). Peak cavity use occurred in the late spring of 1978. Lowest cavity use occurred in late spring 1977 ($p < 0.05$) (Table 36). Low use during the spring or 1977 was probably due to lack of habituation to nest boxes and/or lack of encounter of nest boxes. Other periods

Table 33. Evaluation of cavity use by invertebrates and vertebrates at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	23.0	E
Ben Hur large boxes	715	69.7	B
Ben Hur medium boxes	671	71.7	B
Ben Hur small boxes	677	69.7	B
Ben Hur large boxes - uncut	646	77.7	A
Ben Hur boxes - cavities	721	51.3	D
Durango natural cavities	1032	22.5	E
Durango large boxes	675	76.9	A
Durango medium boxes	223	79.4	A
Durango small boxes	222	73.9	A B
Donohoe natural cavities	821	20.1	E
Donohoe large boxes	710	63.5	C
Donohoe medium boxes	241	72.2	A B
Donohoe small boxes	233	72.5	A B

[a] $F = 35.047/0.171$ with 13 and 9060 df.

Table 34. Evaluation of seasonal cavity use by invertebrates and vertebrates, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
1	Apr/May	412	25.5	E
2		412	20.1	E
3		411	28.5	E
4		411	54.0	C
5		412	54.1	C
6		409	54.0	C
7		400	63.0	A B
8		403	56.9	B C
9		409	53.0	C
10	Dec/Jan	403	55.4	B C
11		401	53.7	C
12		410	53.9	C
13		410	59.4	B C
14		408	66.6	A
15		412	59.8	B C
16		410	62.4	A B
17		403	54.8	B C
18		411	63.0	A B

Table 34. Continued.

Table 34. Continued.

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
19		403	53.1	C
20		402	54.1	C
21		405	55.6	B C
22		401	53.1	C
23	Jan/Feb	409	41.5	D

[a]F = 4.798/0.171 with 22 and 9060 df.

Table 35. Evaluation of cavity use by invertebrates at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	15.4	F
Ben Hur large boxes	715	53.4	D
Ben Hur medium boxes	671	55.7	C D
Ben Hur small boxes	677	54.9	D
Ben Hur large boxes - uncut	646	63.9	B
Ben Hur boxes - cavities	721	40.7	E
Durango natural cavities	1032	15.4	F
Durango large boxes	675	69.2	A
Durango medium boxes	223	62.3	B C
Durango small boxes	222	58.6	B C D
Donohoe natural cavities	821	8.3	G
Donohoe large boxes	710	52.4	D
Donohoe medium boxes	241	58.5	B C D
Donohoe small boxes	233	59.2	B C D

[a]F = 28.158/0.165 with 13 and 9060 df.

Table 36. Evaluation of seasonal cavity use by invertebrates, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
1	Apr/May	412	9.7	H
2		412	7.9	H
3		411	23.0	G
4		411	42.8	D E F
5		412	47.3	C D
6		409	48.9	C D
7		400	43.5	D E F
8		403	43.3	D E F
9		409	43.7	D E
10	Dec/Jan	403	39.4	E F
11		401	37.3	E F
12		410	40.3	E F
13		410	38.7	E F
14		408	55.4	A B
15		412	59.7	A
16		410	55.1	A B
17		403	55.5	A B
18		411	53.2	B C
19		403	48.1	C D
20		402	42.2	D E F

Table 36. Continued.

Table 36. Continued.

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
21		405	43.2	D E F
22		401	36.5	F
23	Jan/Feb	409	28.0	G

[a]F = 6.021/0.165 with 22 and 9060 df.

of low cavity use by invertebrates were in the winter months both years.

The most frequently occurring invertebrates in nest boxes were spiders (Araneida), wood roaches, stinkbugs (Nezara spp.), red wasps (Polistes spp.) and ants (Formicidae). Snails (Vallonia spp.), slugs (Limax spp.), spiders and carpenter ants (Camponotus spp.) occurred most frequently in natural cavities. Wasps, bees and spiders have been found in nest boxes and natural cavities in previous studies (Klein 1955, Flyger and Cooper 1967, Allen 1952, Hawkins and Bellrose 1940, McAtee 1929, 1931).

Insects are often highly selective of nesting sites (Smith 1966: 498). Some arthropods, such as pselaphid beetles (Pselaphidae: Coleoptera), are only found in tree-hole habitats (Hickman et al. 1974:880). Removal of natural cavities in a stand would remove the habitat necessary for the existence of those invertebrates which prefer natural cavities reducing their populations and perhaps reducing the populations of their predators. Maintainence of some natural cavities in a stand may be necessary to provide habitat for invertebrates which could be important food sources for other cavity- and non-cavity using wildlife such as carpenter ants for pileated woodpeckers (Conner et al. 1975).

A greater variety of invertebrates was found in nest boxes (39 taxa) than in natural cavities (28 taxa). Insectivores may benefit from such an increased food base.

Vertebrates Vertebrates occurred in 22.5 percent of the 6,712 nest boxes checked and 9.5 percent of the 4,136 natural cavities checked

(Table 37). Use of nest boxes by vertebrates was higher than use of natural cavities, except those natural cavities at Donohoe control-plot ($p < 0.05$) (Table 38). Peak vertebrate use occurred in the fall, minimum vertebrate use occurred in the summer (Table 39).

Amphibians Three species of Hylidae occurred in nest boxes and/or natural cavities; squirrel treefrogs, green treefrogs, and gray treefrogs. Nest boxes were used more frequently than natural cavities except at all Donohoe plots and at Ben Hur box-natural cavity-plot ($p < 0.05$). Gray treefrogs were found more frequently than squirrel treefrogs or green treefrogs in both boxes and natural cavities. Conant (1975:323) indicated that gray treefrogs are frequently found foraging in the crowns of low trees but he did not report this behavior for squirrel treefrogs or green treefrogs. Gray treefrogs apparently climb to about 6 m more frequently than do squirrel treefrogs or green treefrogs, or gray treefrogs may be more abundant than squirrel treefrogs or green treefrogs.

Peak occurrence of amphibians in cavities was in the late summer and early fall. Minimum use occurred during the spring. Most treefrogs breed from March to August (Conant 1975:320-323). Treefrogs return to water to breed and lay eggs, so arboreal existence during this time would be reduced. Goin (1958) reported similar findings in Florida. Several authors discussed the breeding behavior of green, gray and squirrel treefrogs, but little is known about their winter habits (Einem and Ober 1956, Smith 1961b, Brattstrom 1963). Einem and Ober (1956) described "hibernating niches" in the axils of bromeliad leaves in Florida. These niches retain water which is

Table 37. Percent frequency of cavity use by vertebrates at the three study areas, January 1977 to February 1979.

Taxa	BHC[a]	BHLB[b]	BHMB[c]	BHSB[d]	BHLBUC[e]	BHBC[f]	DRC[g]	DRLB[h]	DRMB[i]	DRSB[j]	DNC[k]	DNLB[l]	DNMB[m]	DNSB[n]
Amphibians	0.3	7.0	4.2	3.6	6.2	1.4	0.9	2.7	4.1	2.6	0.6	0.0	0.4	1.3
Squirrel treefrog	0.0	1.4	0.7	0.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Green treefrog	0.0	1.4	1.1	0.5	0.4	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Gray treefrog	0.3	1.9	2.0	2.5	4.0	1.4	0.7	2.6	4.1	2.6	0.6	0.0	0.4	1.3
Unidentified Hylidae	0.0	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reptiles	1.0	4.6	2.5	2.3	3.3	1.6	1.0	0.9	1.8	1.9	0.5	0.2	0.0	0.7
Green anole	0.3	0.5	0.4	0.5	1.7	0.9	0.0	0.2	0.7	0.4	0.0	0.0	0.0	0.0
Five-lined skink	0.4	2.9	1.6	1.8	1.3	0.7	0.2	0.1	0.0	0.0	0.3	0.2	0.0	0.0
Broad-headed skink	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0
Texas rat snake	0.1	0.9	0.4	0.0	0.3	0.0	0.8	0.5	1.1	1.5	0.0	0.0	0.0	0.7
Birds	0.9	6.6	10.4	11.0	3.8	2.3	2.3	6.4	12.3	14.1	1.0	2.7	2.6	1.5
Wood duck	0.0	0.9	0.0	0.0	0.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 37. Continued.

Table 37. Continued.

Taxa	BHC[a]	BHLB[b]	BHMB[c]	BHSB[d]	BHLBUC[e]	BHBC[f]	DRC[g]	DRLB[h]	DRMB[i]	DRSB[j]	DNC[k]	DNLB[l]	DNMB[m]	DNSB[n]
Screech owl	0.0	0.0	0.0	0.0	0.9	0.2	0.1	1.2	1.9	0.0	0.0	1.7	0.0	0.4
Barred owl	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common flicker	0.0	0.0	2.7	0.0	0.8	0.5	0.1	0.2	4.1	2.6	0.0	0.0	0.7	0.0
Red-bellied woodpecker	0.4	0.3	0.4	2.1	0.0	0.0	0.3	0.0	0.0	0.4	0.3	0.0	0.7	0.4
Red-headed woodpecker	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hairy woodpecker	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great crested flycatcher	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.0
Carolina chickadee	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tufted titmouse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.7
White-breasted nuthatch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Carolina wren	0.0	0.4	0.5	0.1	0.9	0.0	0.3	1.1	0.0	1.1	0.0	0.0	0.4	0.0
Prothonotary warbler	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0

Table 37. Continued.

Table 37. Continued.

Taxa	BHC[a]	BHLB[b]	BHMB[c]	BHSB[d]	BHLBUC[e]	BHBC[f]	DRC[g]	DRLB[h]	DRMB[i]	DRSB[j]	DNC[k]	DNLB[l]	DNMB[m]	DNSB[n]
Unidentified birds	0.4	5.2	6.5	8.5	0.9	2.0	1.5	3.9	6.3	8.5	0.6	0.8	0.0	0.0
Mammals	3.4	8.8	9.1	7.1	11.1	5.8	3.9	7.9	8.6	1.4	11.0	9.1	12.6	12.6
Virginia opossum	0.1	0.7	1.5	0.3	4.5	1.4	0.0	0.5	5.3	0.0	0.0	0.0	0.0	0.0
Gray squirrel	0.4	3.1	1.3	2.6	0.8	0.1	0.3	0.0	0.0	0.0	4.2	2.4	2.2	0.4
Fox squirrel	0.0	0.1	1.9	0.3	0.6	0.1	1.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Southern flying squirrel	0.3	0.3	1.5	2.2	1.2	0.2	0.2	0.6	0.0	0.7	0.3	2.7	6.3	8.5
Golden mouse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Eastern woodrat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Unidentified rodent	2.4	2.7	0.6	0.0	1.6	0.6	0.5	4.1	0.0	0.0	1.3	2.0	1.5	0.0
Unidentified mammal	2.2	1.9	2.3	1.7	2.7	2.9	2.8	1.7	0.7	0.7	5.2	3.2	2.6	3.7

[a]BHC = Ben Hur natural cavities

[b]BHLB = Ben Hur large boxes

[c]BHMB = Ben Hur medium boxes

Table 37. Continued.

[d]BHSB = Ben Hur small boxes

[e]BHLBUC = Ben Hur large boxes - uncut

[f]BHBC = Ben Hur boxes - natural cavities

[g]DRC = Durango natural cavities

[h]DRLB = Durango large boxes

[i]DRMB = Durango medium boxes

[j]DRSB = Durango small boxes

[k]DNC - Donohoe natural cavities

[l]DNLB = Donohoe large boxes

[m]DNMB - Donohoe medium boxes

[n]DNSB = Donohoe small boxes

Table 38. Evaluation of cavity use by vertebrates at the three study areas, April 1977 to February 1979 (means with different letters vary significant, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	8.2	F
Ben Hur large boxes	715	27.6	A
Ben Hur medium boxes	671	26.2	A
Ben Hur small boxes	677	25.7	A B
Ben Hur large boxes - uncut	646	25.4	A B
Ben Hur boxes - cavities	721	15.1	D E
Durango natural cavities	1032	7.6	F
Durango large boxes	675	21.0	B C
Durango medium boxes	223	26.0	A B
Durango small boxes	222	24.3	A B C
Donohoe natural cavities	821	12.5	E
Donohoe large boxes	710	15.6	D E
Donohoe medium boxes	241	17.4	C D E
Donohoe small boxes	233	18.9	B C D

[a]F = 3.231/0.130 with 13 and 9060 df.

Table 39. Evaluation of seasonal cavity use by vertebrates, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
1	Apr/May	412	11.9	E F
2		412	12.7	D E F
3		411	13.0	D E F
4		411	14.1	C D E F
5		412	10.7	E F
6		409	15.3	C D E F
7		400	16.7	B C D E
8		403	22.9	A B
9		409	21.9	A B
10	Dec/Jan	403	23.7	A
11		401	23.8	A
12		410	22.6	A B
13		410	22.8	A B
14		408	18.3	A B C D
15		412	10.7	E F
16		410	9.0	F
17		403	12.5	D E F
18		411	14.8	C D E F
19		403	17.9	A B C D
20		402	21.9	A B

Table 39. Continued

Table 39. Continued.

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
21		405	18.3	A B C D
22		401	23.9	A
23	Jan/Feb	409	19.9	A B C

[a]F = 1.066/1.30 with 22 and 9060 df.

apparently needed for "hibernating" treefrogs. I found one gray treefrog and one green treefrog sharing the same natural cavity at Durango control-plot, October 1978. The cavity contained some water, and the two treefrogs were huddled together in the farthest reaches of the cavity. No one has previously described interspecific sharing of cavities by treefrogs. Treefrogs in boxes were frequently found between the top and the side of the box or in a corner of the box. Goin (1958) described similar behavior by squirrel treefrogs.

Treefrogs may prefer nest boxes to natural cavities because nest boxes make a better thermo-hydro preferendum or to exploit an arthropod food source. Goin (1958) reported that squirrel treefrogs prefer artificial resting places. This behavior apparently also applies to gray treefrogs and to a lesser extent, green treefrogs.

Reptiles Six species of reptiles, representing three families and four genera were found in boxes and natural cavities on 13 of the 14 plots, January 1977 to February 1979 (Table 37). Reptiles were found more frequently in cavities in bottomland habitats than in upland habitats. Boxes at Ben Hur large-box-plot, Ben Hur large-box-uncut-plot and Ben Hur medium-box-plot were used more frequently than natural cavities ($p < 0.05$) (Table 40). Peak cavity use by reptiles occurred in late summer and fall. Lowest use occurred in the winter. Reptiles become less active as temperatures decline (Brattstrom 1965).

Texas rat snake Rat snakes are the single most important cause of wood duck nest loss in Louisiana (Smith 1961a). I found a Texas rat snake destroying a wood duck nest at Ben Hur large-box-plot,

Table 40. Evaluation of cavity use by reptiles at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	1.1	E
Ben Hur large boxes	715	5.0	A
Ben Hur medium boxes	671	2.7	B C
Ben Hur small boxes	677	2.5	B C D
Ben Hur large boxes - uncut	646	3.7	A B
Ben Hur boxes - cavities	721	1.8	C D E
Durango natural cavities	1032	1.2	D E
Durango large boxes	675	1.2	C D E
Durango medium boxes	223	1.8	C D E
Durango small boxes	222	2.3	C D E
Donohoe natural cavities	821	0.6	E
Donohoe large boxes	710	0.3	E
Donohoe medium boxes	241	0.0	E
Donohoe small boxes	233	0.9	E

[a] $F = 0.0808/0.165$ with 13 and 9060 df.

5 April 1978. This species may also be an important predator on other cavity-nesting wildlife. They were found in nest boxes and natural cavities on nine of the 14 plots. Texas rat snakes were found more frequently in cavities in bottomland plots than in upland plots. Maximum cavity use occurred in the summer. Little winter use of cavities was noted. Davis (1978) reported frequent spring and summer occurrence of black rat snakes in wood duck boxes in north Louisiana. Use of nest boxes by rat snakes was also reported by Barkalow and Soots (1965) and Bolen (1967).

Rat snakes were frequently observed at the entrances of natural cavities or on top of nest boxes in the early morning - presumably sunning. Only once were two rat snakes found sharing the same cavity, and these appeared to be breeding (Durango large-box-plot, 28 April 1978).

Rough green snake One rough green snake was observed in a natural cavity 10.6 m high in a waterlocust, Durango control-plot, 22 July 1978. Although Conant (1975:184) reported rough green snakes excellent climbers, the literature provides no record of this species occurring in natural cavities.

Green anole Green anoles occurred in boxes and natural cavities on nine of the 14 plots. Green anoles were found exclusively in cavities in bottomland plots, and most frequently at Ben Hur large-box-plot. Frequency of lizard occurrence may have been underestimated, since all four species were observed sharing boxes with wasps. Nest boxes and natural cavities were also shared by lizards with a variety of invertebrates, gray treefrogs, Carolina wrens, gray squirrels and

fox squirrels.

Scincidae Three species of skinks were found in boxes and natural cavities on ten of the 14 plots. Although Smith (1961b) considered broad-headed skinks more arboreal than five-lined or southeastern five-lined skinks, the latter two species were more frequently found in nest boxes and natural cavities than were broad-headed skinks. Both five-lined and southeastern five-lined skinks were captured on occasion and identified by mid-ventral scale arrangement and size of the post-labials (Conant 1975). Both species were considered together in analysis, since capture and positive identification of most individuals was nearly impossible. Nest boxes may prove useful in further studies of these species. Five-lined skinks occurred most frequently at Ben Hur large-box-plot ($p < 0.05$) and least frequently at the Durango and Donohoe plots. Peak occurrence of five-lined skinks was recorded in August 1978 ($p < 0.05$). Infrequent use of cavities by skinks was noted in the winter.

Skinks were frequently observed sunning on top of a box or at the entrance of a cavity during warm weather, but when ambient temperature fell below about 10^{o}C they were found most frequently in corners or cracks in boxes or natural cavities. They may use cavities to seek a thermo-hydro preferendum or to exploit an arthropod food storage.

Birds Bird use was found in 8.1 percent of the 6,712 nest boxes checked and 1.4 percent of the 4,136 natural cavities checked. Birds occurred most frequently in small boxes and medium boxes at Durango and Ben Hur ($p < 0.05$) (Table 41). Cavity dimensions described by

Table 41. Evaluation of cavity use by birds at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	1.1	F
Ben Hur large boxes	715	7.4	D
Ben Hur medium boxes	671	11.2	C
Ben Hur small boxes	677	12.6	B C
Ben Hur large boxes - uncut	646	4.5	E
Ben Hur boxes - cavities	721	4.7	E
Durango natural cavities	1032	1.9	F
Durango large boxes	675	7.7	D
Durango medium boxes	223	15.2	A B
Durango small boxes	222	17.1	A
Donohoe natural cavities	821	1.1	F
Donohoe large boxes	710	2.8	E F
Donohoe medium boxes	241	2.9	E F
Donohoe small boxes	233	3.0	E F

[a]F = 1.252/0.044 with 13 and 9060 df.

Kalmbach and McAtee (1942), Davison (1965) and Hardin and Evans (1977) indicate that all cavity-nesting birds except wood ducks and barred owls should prefer small- and medium-sized boxes. Lowest use was recorded at all Donohoe plots, all control plots and at both Ben Hur uncut plots ($p < 0.05$) (Table 41). Peak avian cavity use was in the winter (roosting) and spring (nesting) (Table 42). Lowest use was in the late summer and fall (Table 42). Fewer cavity-nesting bird species and fewer individuals per ha were observed at Donohoe than at Durango or Ben Hur. Low bird density may have resulted in low cavity use. Nests of nine bird species were found in 27 of the 4,136 natural cavities checked and in 212 of the 6,712 boxes checked. Nesting was most frequent during March, April and May, both years. Mowbray and Goertz (1972) reported similar results for north Louisiana.

Wood duck The literature is replete with studies describing the use of natural cavities and nest boxes by wood ducks (Bellrose et al. 1964, Heusmann 1975, Bellrose 1976:174-194, Gilmer et al. 1978, and others). I found only one wood duck using a natural cavity at Ben Hur box-natural cavity-plot. Wood ducks were found in 20 of the 6,712 nest boxes checked at Ben Hur large-box-plot (1.0 percent), Ben Hur large-box-uncut-plot (0.3 percent) and Ben Hur box-natural cavity-plot (1.3 percent). More wood ducks were found in boxes at Ben Hur large-box-plot and Ben Hur box-natural cavity-plot than on any other plot ($p < 0.05$). Peak cavity use was in April and May 1977 and March and April 1978. Leopold (1951) reported peak wood duck nesting in the South from late March through April.

Use of cavities by wood ducks was correlated with site ($p < 0.01$)

Table 42. Evaluation of seasonal cavity use by birds, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
1	Apr/May	412	3.9	D E F G H I J
2		412	5.3	C D E F G H
3		411	5.3	C D E F G H
4		411	6.1	A B C D E F
5		412	1.9	H I J
6		409	2.8	F G H I J
7		400	2.4	G H I J
8		403	7.4	A B C D
9		409	6.4	A B C D E
10	Dec/Jan	403	9.2	A
11		401	9.0	A B
12		410	6.7	A B C D E
13		410	7.4	A B C
14		408	9.3	A
15		412	5.6	B C D E F G
16		410	1.3	J
17		403	1.5	I J
18		411	2.3	G H I J
19		403	5.0	C D E F G H I
20		402	7.4	A B C
21		405	4.9	C D E F G H I

Table 42. Continued.

Table 42. Continued.

Sample Period	Month	N	Frequency of occurrence (%)	Grouping
22		401	5.6	C D E F G H I
23	Jan/Feb	409	3.4	E F G H I J

[a] $F = 0.281/0.044$ with 22 and 9060 df.

(85 percent flats and sloughs), living trees ($p < 0.05$), cavity-tree species ($p < 0.05$), entrance shape and size ($p < 0.01$) (round; $\overline{x}$ = 12.0 x 11.6 cm; SD = 1.82 x 2.73), and distance to the nearest cavity-tree ($p < 0.05$) ($\overline{x}$ = 10.8 m; SD = 4.7) (Tables 43 and 44).

Gilmer et al. (1978) found distance to water frequently important to cavity use by wood ducks. Cavities at Ben Hur were an average of 18 m from water. I found cavities in which wood ducks occurred averaged 10.8 m from water. Wood ducks were selecting cavities near water.

Bellrose et al. (1964) reported natural cavities with entrances 65 to 195 cm^2 most frequently used by wood ducks, and that use increased with decreasing entrance size. My results support these findings (Table 44). I found a mean entrance size of 140 cm^2 and increasing use with decreasing entrance size.

Wood ducks used cavities which were an average of 10.8 m from the nearest cavity-tree and increasing use with increasing distance.

Bellrose et al. (1964) found cavities with volumes between 16,400 and 49,200 cm^3 used most frequently by wood ducks. I found wood ducks using cavities with a mean volume of 44,200 cm^3 (SD = 22,000), which agrees closely with Bellrose's et al. (1964).

Screech owl Screech owls were found in 35 of 6,712 nest boxes checked and in one of 4,136 natural cavities checked. Many authors have reported use of wood duck boxes by screech owls (Brown and Bellrose 1943, Bryan 1946, Strange et al. 1971, Stewart 1972, Muncy and Burbank 1975, Davis 1978).

Large and medium sized boxes were used at Durango, large and small

Table 43. Matrix of correlation coefficients among nine cavity-using vertebrates and twenty-six cavity characteristics, nest boxes and natural cavities, Ben Hur, Durango and Donohoe, April 1977 to February 1979.

Characteristic	Species								
	Wood duck	Screech owl	Red-bellied woodpecker	Great crested flycatcher	Carolina wren	Virginia opossum	Gray squirrel	Fox squirrel	Flying squirrel
Nest presence	.02	.00	-.49**	.32	.00	-.39**	-.13	.11	-.21*
Tree age	-.02	.04	.03	.66	-.27	-.24**	-.27**	.38**	.07
Tree dbh	-.11	.11	.07	-.81*	.12	-.08	-.30**	-.07	-.02
Tree height	.07	.22	.00	-.23	.13	-.03	-.26**	-.19	-.05
Height lowest live branch	.41	.13	.03	-.06	.36	-.31**	-.14	.19	.10
Tree lean from vertical	-.41	.24	-.13	.33	-.23	.10	-.07	.08	.23*
Tree species	.54*	-.37*	-.01	.07	.12	-.29**	.08	.27	-.04
Tree forked	-.07	.00	.11	.00	.11	.14	.22	-.13	-.15
Tree dead or alive	-.44*	.00	.02	.00	.00	.02	-.07	.00	-.04
Percent bark on tree	.00	.00	.00	.00	.00	.01	.05	-.08	.00

Table 43. Continued.

Table 43. Continued.

Characteristic	Species								
	Wood duck	Screech owl	Red-bellied woodpecker	Great crested flycatcher	Carolina wren	Virginia opossum	Gray squirrel	Fox squirrel	Flying squirrel
Tree with lianas	-.13	.32*	.04	.45	.31	.01	.14	.18	.05
Number cavities per tree	.00	-.18	.11	-.63	.15	.04	-.17*	-.49**	-.09
Distance to cavity-tree	.64**	-.10	-.20	.63	.09	.02	.20*	-.43**	.01
Distance to water	.40	-.33	-.13	-.33	.06	.26*	.04	-.45**	.07
Number of trees per 0.02 ha	.01	-.03	.00	-.28	.40*	.01	.19*	-.25	.09
Physiographic site	.62**	-.33*	-.14	.34	.09	-.04	-.04	-.05	.08
Cavity origin	-.24	.00	.09	.00	.13	-.49**	-.32**	.00	-.09
Height of cavity	.00	-.17	.00	1.0**	-.02	.07	-.16	.34*	-.03
Diameter at cavity	-.07	-.06	-.02	-.90**	-.10	-.03	-.28**	-.28	-.04
Entrance shape	.60**	.00	-.02	.32	.03	-.43**	-.03	.11	-.02
Angle from horizontal	-.05	.26	.06	-.63	-.09	.22	-.19**	-.06	.01

Table 43. Continued.

Table 43. Continued.

Characteristic	Species								
	Wood duck	Screech owl	Red-bellied woodpecker	Great crested flycatcher	Carolina wren	Virginia opossum	Gray squirrel	Fox squirrel	Flying squirrel
Compass direction	.07	-.42**	.16	.26	.31	-.16	-.03	.16	.01
Entrance width	-.60**	.00	-.10	.12	.17	-.05	-.04	-.37*	-.06
Entrance height	-.60**	.00	-.11	.12	.16	-.14	.02	-.37*	-.06
Cavity volume	.22	.00	-.10	.18	.11	.28*	-.07	-.38*	-.06

*$p < 0.05$

**$p < 0.01$

Table 44. Mean cavity characteristics for selected bird species, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (standard deviations indicated parenthetically).

Characteristic	Wood duck (N=21)	Screech owl (N=36)	Barred owl (N=1)	Common Flicker (N=44)	Red-bellied woodpecker (N=37)	Red-headed wood-pecker (N=1)	Hairy wood-pecker (N=1)	Overall mean (N=9376)
Nest presence (%)	95 (2.2)	44 (5.0)	100	20 (4.1)	13 (3.4)	0	0	25.6 (38.4)
Tree age (years)	45.2 (29.7)	28.6 (17.2)	108	33.7 (18.9)	43.5 (22.2)	---	---	44.9 (22.4)
Tree dbh (cm)	29.0 (13.7)	24.4 (8.9)	61.5	24.4 (9.7)	34.8 (21.7)	76.7	51.3	35.4 (17.7)
Tree height (m)	16.7 (5.6)	17.6 (3.6)	22.9	16.8 (4.9)	18.8 (6.4)	18.3	21.9	19.0 (6.4)
Living trees (%)	95 (2.3)	100 (0)	100	100 (0)	88 (4.2)	100	0	90 (2.8)
Lowest branch (m)	6.4 (2.1)	6.5 (2.9)	6.7	6.7 (3.1)	8.4 (3.3)	10.0	---	7.1 (3.4)
Lean (^{o})	5.9 (5.9)	1.4 (3.5)	8.0	4.6 (5.1)	2.0 (3.5)	3.0	4.0	3.2 (4.0)
Tree forked (%)	33 (4.8)	19 (4.0)	0	16 (3.7)	23 (4.2)	0	100	28 (4.4)
Bark cover (%)	100 (0)	99 (1.2)	100	91 (29.0)	94 (19.1)	100	100	96 (13.7)
Lianas (%)	62 (5.0)	94 (5.3)	0	86 (3.5)	65 (4.8)	100	0	70 (4.4)
Additional cavities	0 (0)	1.4 (0.9)	0	0.6 (0.9)	1.1 (1.6)	4	0	0.9 (1.0)

Table 44. Continued.

Table 44. Continued.

Characteristic	Wood duck (N=21)	Screech owl (N=36)	Barred owl (N=1)	Common Flicker (N=44)	Red-bellied woodpecker (N=37)	Red-headed wood-pecker (N=1)	Hairy wood-pecker (N=1)	Overall mean (N=9376)
Distance to cavity-tree (m)	10.8 (4.7)	15.3 (7.4)	13.7	13.0 (5.9)	12.2 (5.4)	12.8	7.6	12.2 (4.8)
Distance to water (m)	10.8 (13.4)	27.5 (7.1)	0	20.3 (14.8)	18.2 (22.2)	0	16.8	19.7 (16.9)
Trees per 0.02 ha	5.4 (3.1)	5.0 (2.5)	8	4.4 (2.5)	4.5 (2.0)	4	3	4.2 (1.9)
Diameter at cavity (cm)	18.6 (7.4)	27.0 (31.7)	47.0	19.3 (18.9)	19.3 (9.3)	15.2	43.9	27.6 (20.5)
Height of cavity (m)	6.1 (0)	5.9 (0.3)	5.5	5.9 (0.3)	9.0 (4.4)	14.6	3.7	6.4 (3.3)
Height of entrance (cm)	12.0 (1.8)	11.9 (1.9)	31.8	8.5 (2.1)	7.0 (2.3)	7.6	122.9	11.0 (8.3)
Width of entrance (cm)	11.6 (2.7)	11.8 (2.1)	39.4	3.5 (0.8)	7.2 (2.9)	7.6	7.6	10.6 (5.6)
Angle of entrance from horizontal (°)	89.2 (1.6)	89.7 (1.3)	75.0	89.8 (2.1)	92.1 (17.3)	120	80	86.3 (16.7)
Location in trunk (%)	100 (0)	100 (0)	100	100 (0)	86 (3.5)	0	100	94 (2.3)
Under limb (%)	14 (3.6)	33 (4.2)	0	14 (3.4)	20 (4.1)	100	0	10 (2.9)
Cavity volume (cm^3)	44000 (22036)	49000 (15871)	127000	19000 (12284)	18000 (19277)	---	29000	32000 (33698)

boxes at Donohoe and only large boxes at Ben Hur. Durango large- and medium-boxes and Donohoe large-boxes at Ben Hur. Durango large- and medium-boxes and Donohoe large-boxes were used most frequently. Maximum box use by screech owls was in the winter and spring. Cavity use by screech owls was correlated with site ($p < 0.05$) (64 percent flats), tree species ($p < 0.05$), the presence of lianas ($p < 0.05$), and aspect ($p < 0.01$).

Screech owls occurred in cavities at Ben Hur and Durango on plots consisting primarily of flats topography. A correlation of screech owl use with physiographic features should have been expected.

Screech owls used cavity-tree species roughly in accordance with their availability. An exception was relatively high frequency of use of a box in a flowering dogwood at Donohoe large-box-plot. This could have been due to chance, since there seems to be little advantage for screech owls choosing flowering dogwood as a cavity-tree.

Lianoid cover occurred on 94 percent of the cavity-trees used by screech owls. The average percent of cavity-trees with lianoid cover on all plots on which screech owls occurred was 76.6 percent. Screech owls probably selected cavities located in trees with lianas present. No one has previously reported this correlation. Advantages of lianoid cover are presented in the discussion of cavity characteristics.

Screech owls used cavities with entrances facing predominantly north (north to east). The range of aspects of cavity entrances used by screech owls was narrower than the range of aspects of all cavity entrances. This aspect preference was consistent over habitat types. Such a preference may be in response to prevailing winds or to light relations within the forest.

Screech owls preferred cavities under limbs. Thirty-three percent of the cavities used by screech owls were located under limbs, but only 10 percent of all cavities were under limbs.

I found two adult screech owls sharing a box on several occasions. Brown and Bellrose (1943) reported similar behavior. Non-nesting screech owls used nest boxes as feeding sites. Brown and Bellrose (1943) and Hardin and Evans (1977) also observed this behavior.

Barred owl A barred owl nest was found in the same natural cavity in three consecutive years at Ben Hur box-natural cavity-plot. The cavity-tree was an American elm located at the edge of a slough. The entrance faced southwest (220^{o}) and up at an angle of 75^{o}. Further quantitative characteristics for this nest site are presented in Table 44.

Harrison (1975:100) reported barred owls returning to the same cavity for up to four consecutive years. Weirer (1966), Nicholls and Warner (1972) and Hardin and Evans (1977) also reported barred owls nesting in natural cavities; only Bryan (1946) found barred owls using nest boxes.

Common flicker Common flicker use was found in 49 of the 6,712 nest boxes checked and five of the 4,136 natural cavities checked on eight of the 14 plots. Common flickers occurred most frequently in medium boxes at Durango ($p < 0.05$). Common flicker use of Durango small-boxes and Ben Hur medium-boxes was greater than use of any other cavity type except medium boxes at Durango ($p < 0.05$). Common flickers preferred medium sized boxes. The dimensions of cavities used by

common flickers on other areas support my conclusions (Kalmbach and McAtee 1942, Davison 1965). Common flickers also used plots near open fields (except Ben Hur control-plot). Common flickers prefer open woodlands and fields (Conner and Adkisson 1976, Hardin and Evans 1977).

Cavity use by common flickers was restricted to the fall, winter and early spring, and all use was for roosting. McAtee (1940), Dennis (1969) and Harrison (1975:109) reported common flickers nesting in boxes, but they did not mention roosting habits.

Scats, probably from a picid, were found in some boxes, but if no identifiable feathers were found, the use was attributed to unidentified birds. Consequently, the percent of boxes used by common flickers may have been underestimated.

No cavity characteristics were correlated with use by common flickers ($p > 0.05$) (Table 43). Lawrence (1967) reported non-random entrance orientation for common flickers. Perhaps common flickers have less stringent requirements for roost sites than for nest sites.

Red-bellied woodpeckers I found red-bellied woodpecker use in 25 of 6,712 nest boxes checked and 13 of 4,136 natural cavities checked on nine of the 14 plots. Red-bellied woodpeckers were more frequently found in small boxes at Ben Hur than on any other plot ($p < 0.05$). Use of this size cavity would be expected on the basis of Davison's (1965) results.

One nest was found in a small box at Ben Hur and one in a natural cavity at Ben Hur control-plot. All other use appeared to be for roosting purposes, although some observed large-box use may have been foraging activity. Maximum use occurred during late fall and spring.

Cavity use by red-bellied woodpeckers was negatively correlated with the presence of a nest ($p < 0.01$) (Table 43). Red-bellied woodpeckers nest and roost on wood chips that accumulate during excavation of the cavity, or on sawdust or shavings supplied in boxes (Jackson 1976, Harrison 1975:111). No other nest material is used.

No other correlations were found between cavity use by red-bellied woodpeckers and cavity characteristics ($p > 0.05$). Cavity characteristics reported for red-bellied woodpeckers by Reller (1972), Williams (1975) and Jackson (1976) were similar to those I observed (Table 44).

Nesting occurred in May and June. These dates agree with those reported by Stickel (1965), Harrison (1975:111) and Jackson (1976).

The entrance of many of the small boxes used by red-bellied woodpeckers were modified by the occupants resulting in nearly circular entrances. Apparently rectangular entrances were not preferred by red-bellied woodpeckers.

<u>Red-headed woodpecker</u> One red-headed woodpecker was observed entering a natural cavity on a limb, Ben Hur control-plot, 17 February 1978. Characteristics for that cavity are presented in Table 47. Jackson (1976) reported that red-headed woodpeckers prefer cavities in limbs. They also prefer cavities in trees near or in open fields (Hardin and Evans 1977). The cavity used at Ben Hur was within 70 m of an open field.

<u>Hairy woodpecker</u> One hairy woodpecker was observed leaving a cavity in a sweetgum snag, Ben Hur control-plot, 13 March 1977. Lawrence (1967) found that 91 percent of the cavities used by hairy

woodpeckers were in living trees. The height of the cavity and the dbh of the snag I observed were similar to average measurements reported by Kilham (1968).

Great crested flycatcher Great crested flycatcher use was found in six nest box checks on three plots. Nest box use by great crested flycatchers was not different among areas, but the sample size may have been too small to detect a difference ($p > 0.05$). Great crested flycatchers used boxes in April, May and June.

Great crested flycatcher use was negatively correlated with cavity-tree dbh ($p < 0.05$) and with diameter of the cavity-tree at the cavity ($p < 0.05$). Crested flycatcher use was positively correlated with cavity height ($p < 0.05$) (Table 43). Correlation with cavity height would be expected since all use was in boxes and all boxes were erected at a uniform height (5.5 - 6.1 m).

Graber et al. (1974) reported great crested flycatchers in Illinois using cavities in trees where the tree diameter at the cavity was 15 cm. No other author suggested preference for trees of certain diameters. I found no preference for tree species. Graber et al. (1974) reported a preference for cavities in apple.

Four great crested flycatcher nests were found in boxes. Large, medium and small boxes were used for nesting.

Carolina chickadee One Carolina chickadee nested in a natural cavity in a limb, Ben Hur control-plot, 7 April 1977. Characteristics of the cavity are presented in Table 45.

Carolina chickadees usually excavate their own cavities (Hardin and Evans 1977). Brewer (1961) and Pitts (1978) partially filled nest

Table 45. Mean cavity characteristics for selected birds, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (standard deviations are indicated parenthetically).

Characteristic	Great crested flycatcher (N=6)	Carolina chickadee (N=1)	Tufted titmouse (N=5)	White-breasted nuthatch (N=1)	Carolina wren (N=27)	Prothonotary warbler (N=2)	Overall mean (N=9376)
Nest presence (%)	67 (5.2)	100	100 (0)	0	100 (0)	100	25.6 (38.4)
Tree age (years)	34.0 (14.8)	19.0	28 (4.4)	-	26.7 (13.4)	29.0	44.9 (22.4)
Tree dbh (cm)	22.8 (6.9)	18.0	14.7 (2.7)	32.0	26.1 (10.9)	16.5	35.4 (17.7)
Tree height (m)	19.1 (4.5)	9.8	13.2 (4.5)	21.7	16.3 (5.0)	11.6	19.0 (6.4)
Tree living (%)	100 (0)	100	100 (0)	0	100 (0)	100	90 (2.8)
Lowest branch (m)	8.9 (2.2)	1.8	6.8 (2.8)	-	6.5 (3.5)	6.7	7.1 (3.4)
Tree lean (^{o})	2.3 (3.4)	14.0	1.7 (2.9)	0	4.3 (8.0)	2.0	3.2 (4.0)
Tree forked (%)	0 (0)	0	0 (0)	0	40 (5.0)	0	28 (4.4)
Bark cover (%)	100 (0)	99	100 (0)	20	100 (0)	100	96 (13.7)
Lianas (%)	50 (5.6)	100	67 (5.8)	0	88 (4.2)	100	70 (4.4)
Additional cavities	0.7 (1.0)	0	0 (0)	2	0.6 (0.9)	0	0.9 (1.0)

Table 45. Continued.

Table 45. Continued.

Characteristic	Great crested flycatcher (N=6)	Carolina chickadee (N=1)	Tufted titmouse (N=5)	White-breasted nuthatch (N=1)	Carolina wren (N=27)	Prothonotary warbler (N=2)	Overall mean (N=9376)
Distance to cavity-tree	18.3 (5.9)	6.1	21.9 (3.5)	12.2	12.1 (4.7)	11.6	12.2 (4.8)
Distance to water	25.2 (7.7)	33.6	25.4 (8.8)	91.5	21.5 (18.5)	39.7	19.7 (16.9)
Trees per 0.02 ha	3.2 (1.5)	7.0	2.7 (1.5)	4.0	4.7 (3.5)	2.0	4.2 (1.9)
Diameter at cavity (cm)	18.9 (7.4)	10.2	11.6 (2.7)	15.2	20.4 (8.1)	12.4	27.6 (20.5)
Height of cavity (m)	6.0 (0.3)	5.2	6.1 (0)	18.3	6.0 (0.7)	6.1	6.4 (3.3)
Entrance height (cm)	8.5 (3.5)	5.1	7.6 (0)	10.2	11.0 (2.6)	5.1	11.0 (8.3)
Entrance width (cm)	8.5 (3.5)	5.1	5.9 (1.5)	10.2	11.8 (3.6)	5.1	10.6 (5.6)
Angle from horizontal (^{o})	88.7 (1.0)	110	90 (0)	90	85.1 (13.4)	90	86.3 (16.7)

Table 45. Continued.

Table 45. Continued.

Characteristic	Great crested flycatcher (N=6)	Carolina chickadee (N=1)	Tufted titmouse (N=5)	White-breasted nuthatch (N=1)	Carolina wren (N=27)	Prothonotary warbler (N=2)	Overall mean (N=9376)
Location in trunk (%)	100 (0)	0	100 (0)	100	100 (0)	100	94 (2.3)
Under limb (%)	0 (0)	100	0 (0)	0	26 (4.5)	0	10 (2.9)
Cavity volume (cm^3)	27500 (23153)	390	11000 (6812)	---	42000 (21817)	7000	32000 (33698)

boxes with sawdust and reported use by Carolina chickadees. Odum (1942) reported Carolina chickadees infrequently roosting in cavities. Pitts (1978) reported no nest boxes used for roosting. Since I filled no boxes with sawdust, no or little use of boxes by Carolina chickadees was expected. Provisions should be made in future forest management plans for sawdust filled boxes or for a sustained yield of soft snags desired by Carolina chickadees.

Tufted titmouse Five nest boxes on three plots were found used by tufted titmice. All five boxes had active nests. Small boxes at Donohoe were used more frequently than boxes on any other plot ($p < 0.05$). A medium box at Donohoe and a small box at Durango were also used by tufted titmice. Davison (1965) reported cavity dimensions for tufted titmouse nests which were similar in size to small nest boxes. Boxes were used only during April and May. These dates coincide with the nesting period described by Mowbray and Goertz (1972).

Tufted titmice populations were lower in 1978 than in 1977, but cavity use by tufted titmice was higher in 1978 than in 1977.

The average height of boxes used by tufted titmice (6.1 m) was higher than the average height of boxes and natural cavities (1.8 m) reported by Laskey (1957). This is probably due to availability and not preference.

Tufted titmice selected boxes in open areas. An average of 2.7 trees surrounded tufted titmouse nest trees, while an average of 4.3 trees surrounded all trees on the plots in which tufted titmice used boxes.

I found no evidence of nest failure. Females were very protective of clutches and broods, being reluctant to leave the nest, and remaining in the vicinity after being dislodged from the nest. I observed wing-quivering behavior of females when the boxes were opened. Similar behavior was reported by Brackbill (1970).

White-breasted nuthatch One white-breasted nuthatch was observed leaving a woodpecker cavity in a pine snag, Donohoe control-plot, 7 April 1977. I do not know if this was a roost site, a nest site or just an inspection, since the cavity was located 18.3 m above ground and the snag was unstable. The entrance of the cavity was rectangular indicating previous pileated woodpecker activity at the cavity (Harrison 1975:110). Kilham (1971) found that such a cavity was a common nest or roost site, but Kilham (1968) found that many nests occur in natural cavities of living trees. The characteristics of the above cavity are presented in Table 45. Kilham (1968) and Harrison (1975:144) stated that white-breasted nuthatches will nest in nest boxes but none used boxes in my study.

Carolina wren Carolina wren use was found in 27 of 6,712 nest boxes checked and three of 4,136 natural cavities checked on eight of the 14 plots. Carolina wrens occurred in small, medium and large boxes and in two natural cavities. Several authors have reported unusual nesting sites of Carolina wrens (Harrison 1975:150, Hardin and Evans 1977). Peak cavity use was in May, with use recorded from April to September. Mowbray and Goertz (1972) reported peak nesting of Carolina wrens in Louisiana in April and May. I found more frequent use of nest boxes by Carolina wrens in 1977 than in 1978. Bird observation

data indicated similar populations both years in all habitat types. Hardin and Evans (1977) reported Carolina wrens not totally dependent upon cavities for nest sites, so increased use of boxes by other species in 1978 may have discouraged use by Carolina wrens. Nest frequency at Durango control-plot was similar both years.

Cavity use by Carolina wrens was positively correlated with the number of trees per 0.02 ha surrounding the cavity-tree ($p < 0.05$) (Table 43). Laskey (1948) and Harrison (1975:150) stated that Carolina wrens prefer dense, brushy forests. My results support these findings. Twenty-six percent of all cavities were located under limbs while only 10 percent of all cavities were located under limbs. Carolina wrens selected nest sites under limbs.

Cavity use by Carolina wrens was for nesting only. Two "dummy" nests were constructed (nests built but never used). Dead young were found in two nests; Apaulina larvae were also found in these nests. Hicks (1959:235) reported occurrence of Apaulina larvae in Carolina wren nests. Mason (1944) suggested the removal of nesting material will increase the chance of Apaulina parasitism during the nest nesting season. Nests should be left in some boxes at all times for this reason.

Prothonotary warbler Prothonotary warbler use was found in five nest boxes checked on two of the 14 plots. Prothonotary warblers occurred only in small boxes at Ben Hur and Durango ($p < 0.05$). Cavity dimensions presented by Davison (1965) for prothonotary warbler use are similar to the dimensions of a small nest box. All cavity use was for nesting. Use occurred from May to July. Mowbray and Goertz (1972)

indicated May as the height of prothonotary warbler nesting activity. Three active nests were found in nest boxes. Characteristics of cavities used by prothonotary warblers are presented in Table 45. Reed (1939), Walkinshaw (1953) and Simpson (1969) reported prothonotary warblers nesting in cavities below 4 m in height. All the nests I found were 5.5 - 6.1 m above ground. Only Griscom and Sprout (1957:48) and Harrison (1975:176) reported prothonotary warblers nesting above 5.5 m. Walkinshaw (1953) found that prothonotary warblers prefer to nest over water. The nests I found were over land, with a mean distance to water of 39.7 m.

Unidentified birds Anytime unidentifiable bird scats or feathers were found in nest boxes or natural cavities use was attributed to unidentified birds. Most of this use appeared to be from Picidae, since scats were large and contained seeds and insect parts. Several boxes contained small passerine scats.

Except for boxes on Ben Hur large-box-plot, use by unidentified birds was highest in small and medium boxes at Ben Hur and Durango ($p < 0.05$). These plots also had the highest overall bird use ($p < 0.05$). All cavity use by unidentified birds was for roosting, feeding or inspection prior to nesting. Peak cavity use by unidentified birds was in late fall, winter and early spring. Night cavity checks may have reduced the high percentage of unidentified bird use.

Mammals Mammal use was found in 9.5 percent of the 4,136 natural cavities checked and in 23.3 percent of the 6,712 nest boxes checked. Generally, mammal use was higher at Donohoe than at the other habitat types (Table 46). More cotton mice and white-footed mice were captured

Table 46. Evaluation of cavity use by mammals at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	5.9	E F
Ben Hur large boxes	715	9.9	B C D
Ben Hur medium boxes	671	9.2	C D
Ben Hur small boxes	677	7.8	C D E
Ben Hur large boxes - uncut	646	12.7	A B
Ben Hur boxes - cavities	721	6.9	D E
Durango natural cavities	1032	3.8	F
Durango large boxes	675	9.3	C D
Durango medium boxes	223	4.9	E F
Durango small boxes	222	1.8	F
Donohoe natural cavities	821	10.3	A B C
Donohoe large boxes	710	12.7	A B
Donohoe medium boxes	241	14.1	A B
Donohoe small boxes	233	14.6	A

[a] $F = 0.6499/0.1312$ with 13 and 9060 df.

at Donohoe than at Durango or Ben Hur. Mammals occurred more frequently in nest boxes than in natural cavities. Peak mammal use of cavities occurred during the winter. Brown and Bellrose (1943), Baker (1944) and Allen (1952) found box use by Virginia opossums, gray squirrels, fox squirrels, and northern raccoons higher in the winter than in the spring. I found frequency of occurrence of mammals in cavities lowest in the summer. Moore (1947), Barkalow and Soots (1965), Dawson (1967) and Lowery (1974:172-187) reported use of leaf nests by sciurids during the summer.

Virginia opossum Virginia opossums were found in 0.2 percent of the 4,136 natural cavities checked and 1.2 percent of the 6,712 nest boxes checked. I found Virginia opossum nests in eight natural cavities and 175 nest boxes. Two litters of opossums were found in boxes at Ben Hur large-box-uncut-plot. Virginia opossums were found more frequently at Ben Hur large-box-uncut-plot than at any other plot ($p < 0.05$) (Table 47). Opossums occurred most frequently in large and medium sized boxes. No opossums were found in either nest boxes or natural cavities at Donohoe, although opossum tracks were noted in the area on several occasions. Opossums have different denning habits in different habitats. Reynolds (1945), Wiseman and Hendrickson (1950), and Fitch and Shirer (1970) reported underground dens common in Missouri, Iowa and Kansas, respectively. Lay (1942) found no opossum use of nest boxes placed in forests in east Texas. Opossums at Ben Hur preferred boxes in uncut plots.

Peak cavity use was in late fall, winter and early spring. Lowest use by opossums occurred in late spring, summer and early fall. Brown

Table 47. Evaluation of cavity use by Virginia opossums at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	0.1	D
Ben Hur large boxes	715	0.8	B C D
Ben Hur medium boxes	671	1.3	B C
Ben Hur small boxes	677	0.3	D
Ben Hur large boxes - uncut	646	5.1	A
Ben Hur boxes - cavities	721	1.8	B
Durango natural cavities	1032	0.0	D
Durango large boxes	675	0.6	C D
Durango medium boxes	223	1.8	B C
Durango small boxes	222	0.0	D
Donohoe natural cavities	821	0.0	D
Donohoe large boxes	710	0.0	D
Donohoe medium boxes	241	0.0	D
Donohoe small boxes	233	0.0	D

[a]$F = 0.052/0.007$ with 13 and 9060 df.

and Bellrose (1943) reported more frequent opossum use of nest boxes in the spring than in the winter. No other author reported seasonal shifts in den sites by opossums.

Cavity use by opossums was correlated with the presence of nests ($p < 0.01$) (Table 43). Leaf nests were found in 91.6 percent of the cavities used by opossums. Nest building behavior was described by McManus (1970). Several authors reported leaf nests in opossum dens (Smith 1941, Reynolds 1945, Lowery 1974:64). Cavity use by opossums increased with decreasing tree age ($p < 0.05$) (Table 43).

Opossum use of cavities increased as height of the lowest live limb decreased ($p < 0.05$) (Table 43 and 48). Lower branches would facilitate access to the cavity. Ninety-nine percent of the cavity-trees used by opossums had lianoid cover; 84 percent of all cavity-trees had lianoid cover. The presence of lianas could aid in access to the cavity. Intensive forest management would preclude high live crown ratios and liana presence.

Cavity use by opossums was correlated with cavity-tree species ($p < 0.05$) (Table 43). Cavities in sugarberries and American elms accounted for 42.3 and 15.5 percent of opossum use respectively. Sugarberries and American elms made up 47 percent and 7 percent of the cavity-bearing trees on Ben Hur large-box-uncut-plot.

Cavity use by opossums was correlated with entrance shape and cavity origin ($p < 0.05$) (Table 43). This correlation is probably a function of higher nest box use than natural cavity use by opossums.

Opossum use of cavities increased with increasing distance to water ($p < 0.05$) (Table 43).

Table 48. Mean cavity characteristics for selected mammals, Ben Hur, Durango and Donohoe, April 1977 to February 1979 (standard deviations indicated parenthetically).

Characteristic	Virginia opossum (N=72)	Gray squirrel (N=132)	Fox squirrel (N=36)	Flying squirrel (N=117)	Golden mouse (N=1)	Eastern woodrat (N=1)	Overall mean (N=9376)
Nest presence (%)	92 (2.7)	83 (3.8)	95 (2.3)	89 (5.7)	100	100	25.6 (38.4)
Tree age (years)	44.8 (20.9)	47.9 (27.1)	39.7 (30.9)	36.4 (17.9)	36	21	44.9 (22.4)
Tree dbh (cm)	31.5 (12.8)	37.8 (23.4)	27.2 (11.3)	23.0 (10.5)	25.4	15.5	35.4 (17.7)
Tree height (m)	18.1 (4.6)	20.4 (6.4)	18.1 (4.1)	17.3 (6.1)	24.4	13.7	19.0 (6.4)
Tree living (%)	97.0 (1.7)	98 (1.5)	100 (0)	97 (1.8)	100	100	90 (2.8)
Lowest branch (m)	7.4 (2.7)	8.0 (3.2)	6.9 (3.1)	7.8 (3.6)	12.2	4.6	7.1 (3.4)
Tree lean (^{o})	3.0 (3.5)	2.7 (3.2)	2.1 (2.2)	2.7 (3.7)	10.0	0.0	3.2 (4.0)
Tree forked (%)	43 (5.0)	37 (4.8)	31 (4.7)	24 (4.3)	0	0	28 (4.4)
Bark cover (%)	99.9 (1.2)	99.2 (7.9)	99.7 (1.7)	100 (0)	100	100	96 (13.7)
Lianas (%)	99 (1.2)	77 (4.3)	86 (3.5)	64 (4.8)	100	100	70 (4.4)
Additional cavities	0.3 (0.9)	1.0 (1.1)	0.7 (1.0)	0.5 (0.8)	0	0	0.9 (1.0)

Table 48. Continued.

Table 48. Continued.

Characteristic	Virginia opossum (N=72)	Gray squirrel (N=132)	Fox squirrel (N=36)	Flying squirrel (N=117)	Golden mouse (N=1)	Eastern woodrat (N=1)	Overall mean (N=9376)
Distance to cavity-tree (m)	10.5 (3.6)	13.3 (6.6)	12.4 (4.3)	18.3 (7.3)	30.5	29.0	12.2 (4.8)
Distance to water (m)	18.4 (12.1)	19.4 (16.8)	17.5 (13.1)	19.0 (13.3)	30.5	30.5	19.7 (16.9)
Trees per 0.02 ha	4.7 (2.2)	4.0 (2.0)	5.3 (2.4)	4.3 (2.2)	2	4	4.2 (1.9)
Diameter at cavity (cm)	27.7 (22.2)	30.2 (21.9)	20.9 (8.5)	21.3 (24.8)	23.6	12.7	27.6 (20.5)
Height of cavity (m)	6.0 (1.4)	6.6 (1.5)	6.0 (0.7)	6.3 (1.2)	6.1	6.1	6.4 (3.3)
Entrance height (cm)	13.3 (9.2)	10.1 (3.1)	9.7 (2.7)	9.4 (3.4)	12.7	12.7	11.0 (8.3)
Entrance width (cm)	11.7 (2.6)	10.3 (3.1)	9.7 (2.7)	8.7 (3.4)	12.7	12.7	10.6 (5.6)
Angle from horizontal (^{o})	89.1 (2.0)	89.1 (11.1)	88.2 (13.5)	88.6 (8.8)	86	86	96.3 (16.7)

Table 48. Continued.

Table 48. Continued.

Characteristic	Virginia opossum (N=72)	Gray squirrel (N=132)	Fox squirrel (N=36)	Flying squirrel (N=117)	Golden mouse (N=1)	Eastern woodrat (N=1)	Overall mean (N=9376)
Location in trunk (%)	100 (0)	92 (2.8)	100 (0)	100 (0)	100	100	94 (2.3)
Under limb (%)	6 (2.3)	8 (2.7)	31 (4.7)	9 (2.8)	0	100	10 (2.9)
Cavity volume (cm^3)	46000 (19345)	43000 (28448)	34000 (19556)	26000 (22042)	57000	57000	32000 (33698)

A positive correlation found between cavity use by opossums and cavity volume ($p < 0.05$) (Table 43) explains why opossums occurred more frequently in large boxes than in medium or small boxes.

Gray squirrel Gray squirrels were found in 43 natural cavities checked and 89 nest boxes checked. Gray squirrels used boxes of all sizes. Cavity use at Donohoe was higher than at any other habitat type. No boxes were used by gray squirrels at Durango. Natural cavity use by gray squirrels was higher at Donohoe than at any other control plot ($p < 0.05$) (Table 49). Peak cavity use by gray squirrels occurred in the winter. Lowest use was in the spring and summer. Gray squirrels use natural cavities during the winter and leaf nests during the summer (Baker 1944, Allen 1952, Lowery 1974:176, Sanderson et al. 1975).

Use of cavities by gray squirrels was negatively correlated with cavity-tree age, cavity-tree dbh, diameter of the tree at the cavity, and cavity-tree height ($p < 0.01$) (Table 43). Boxes were used more than natural cavities and boxes were placed in trees smaller and younger than natural cavity-trees (Table 48). Sanderson et al. (1975) found gray squirrels most frequently using natural cavities in trees over 100 cm dbh. The average age of cavity-trees on the plots used by gray squirrels was 44.5 years.

Cavity use by gray squirrels was negatively correlated with angle of cavity entrance from horizontal ($p < 0.05$) (Table 43). The average angle from horizontal of cavity entrances on the plots used by gray squirrels was 85.9^{o}. This is disadvantageous to the occupants because it affords less protection from water entering the cavity (Conner

Table 49. Evaluation of cavity use by gray squirrels at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	0.5	C D
Ben Hur large boxes	715	3.5	A
Ben Hur medium boxes	671	1.5	B C
Ben Hur small boxes	677	3.0	A
Ben Hur large boxes - uncut	646	0.9	B C D
Ben Hur boxes - cavities	721	0.1	D
Durango natural cavities	1032	0.2	D
Durango large boxes	675	0.0	D
Durango medium boxes	223	0.0	D
Durango small boxes	222	0.0	D
Donohoe natural cavities	821	3.9	A
Donohoe large boxes	710	2.8	A
Donohoe medium boxes	241	2.5	A B
Donohoe small boxes	233	0.4	C D

[a]$F = 0.120/0.013$ with 13 and 9060 df.

1975).

Gray squirrel use was correlated with cavity origin ($p < 0.01$) (Table 43). This correlation was expected since 61.6 percent of gray squirrel use occurred in boxes and 38.4 percent in natural cavities originating from limb break and subsequent heart rot. Since boxes were used more frequently than natural cavities a negative correlation with the number of cavities per tree was expected ($p < 0.05$) (Table 43). Indeed, trees with more than one cavity available were used by gray squirrels. An average of 0.26 additional cavities per tree were found on the plots used by gray squirrels, while 0.96 additional cavities per tree were present in the cavity-trees used by gray squirrels.

There was a positive correlation between gray squirrel use and distance to the nearest cavity-tree ($p < 0.05$) (Table 43).

There was a positive correlation between gray squirrel use and the number of trees surrounding the cavity-tree ($p < 0.05$) (Table 42). An average of 5.2 trees surrounded cavity-trees on the plots used by gray squirrels, but an average of 4.0 trees surrounded trees used by gray squirrels. Goodrum (1961) suggested that dense stands are more suitable to gray squirrels than open stands.

Fox squirrel Fox squirrels were found in one of 4,136 natural cavities checked and 36 of 6,712 nest boxes checked. Fox squirrels were found most frequently in medium boxes at Ben Hur and Durango ($p < 0.05$) (Table 50). I found no fox squirrels using cavities at Donohoe. Fox squirrels are not found in the Donohoe area. Goodrum (1938) reported fox squirrels using old trees and snags for dens more

Table 50. Evaluation of cavity use by fox squirrels at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	0.0	D
Ben Hur large boxes	715	0.1	C D
Ben Hur medium boxes	671	2.1	A
Ben Hur small boxes	677	0.3	C D
Ben Hur large boxes - uncut	646	0.3	C D
Ben Hur boxes - cavities	721	0.7	B C
Durango natural cavities	1032	0.1	C D
Durango large boxes	675	1.0	B
Durango medium boxes	223	2.2	A
Durango small boxes	222	0.0	D
Donohoe natural cavities	821	0.0	D
Donohoe large boxes	710	0.0	D
Donohoe medium boxes	241	0.0	D
Donohoe small boxes	233	0.0	D

[a] F = 0.017/0.004 with 13 and 9060 df.

frequently than did gray squirrels. Brown and Bellrose (1943) found that fox squirrels preferred natural cavities over nest boxes. My findings from the bottomland plots do not concur with those of Goodrum (1938) or Brown and Bellrose (1943). Use of cavities was only slightly higher during the late fall, winter and early spring than during the rest of the year. Brown and Bellrose (1943) suggested decreased use of cavities by males in spring and that female cavity use remained constant year round.

Cavity use by fox squirrels was positively correlated with cavity-tree age ($p < 0.05$) (Table 43). Baumgartner (1938) reported maximum fox squirrel use of natural cavities in large diameter, old growth timber.

There was a positive correlation between cavity height above ground and cavity use by fox squirrels ($p < 0.05$) (Table 43), and a negative correlation between number of cavities per tree and cavity use by fox squirrels ($p < 0.05$) (Table 43). These correlations were expected since all boxes were erected between 5.5 and 6.1 m in trees which contained no other cavities.

Cavity use by fox squirrels was negatively correlated with cavity entrance height ($p < 0.01$), cavity entrance width ($p < 0.01$), and cavity volume ($p < 0.01$) (Table 43). These correlations were expected since fox squirrel use of medium and small boxes was higher than that of large boxes ($p < 0.05$).

Cavity use by fox squirrels was negatively correlated with distance to nearest cavity-tree ($p < 0.01$) (Table 43) and distance to water ($p < 0.01$) (Table 43). The average distance to water from

cavities on the plots used by fox squirrels was 20.6 m; the average distance to water from all cavity-trees used by fox squirrels was 13.1 m. Fox squirrels seemed to select cavities near water. Goodrum (1961) reported proximity to water an important factor in use of cavities by gray squirrels, but to my knowledge no one has suggested this relationship for fox squirrels.

Thirty-one percent of the cavities used by fox squirrels were under limbs, but only 10 percent of all cavities were under limbs. Fox squirrels appeared to prefer cavities under limbs.

Southern flying squirrel Flying squirrel use was found in eight of 4,136 natural cavities checked and in 111 of 6,712 nest boxes checked. Flying squirrels were found most frequently in small boxes at Donohoe ($p < 0.05$) and next most frequently in medium boxes at Donohoe ($p < 0.05$) (Table 51). Use of small and medium sized boxes was higher than use of large boxes except at Donohoe large-box-plot and Ben Hur large-box-uncut-plot. One to six flying squirrels were found per cavity. Lowery (1974:201) and Heidt (1977) reported communal living by flying squirrels. Nests in large boxes were frequently located under the shelf and a noticeable waste storage area was usually located in the opposite corner. Peak cavity use occurred in the winter and spring and the lowest use occurred in the summer and fall. Dawson (1967) reported similar results.

Use by flying squirrels was correlated with the presence of any vertebrate nest ($p < 0.05$) (Table 43). Eighty-nine percent of the cavities used by flying squirrels contained vertebrate-made nests.

There was a positive correlation between cavity use by flying

Table 51. Evaluation of cavity use by Southern flying squirrels, April 1977 to February 1979 (means with different letters vary significantly, $p < 0.05$).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	0.3	F G
Ben Hur large boxes	715	0.3	F G
Ben Hur medium boxes	671	1.6	D E
Ben Hur small boxes	677	2.5	C D
Ben Hur large boxes - uncut	646	1.4	D E F
Ben Hur boxes - cavities	721	0.3	F G
Durango natural cavities	1032	0.1	G
Durango large boxes	675	0.7	E F G
Durango medium boxes	223	0.0	G
Durango small boxes	222	0.9	D E F G
Donohoe natural cavities	821	0.1	F G
Donohoe large boxes	710	3.2	C
Donohoe medium boxes	241	7.0	B
Donohoe small boxes	233	10.0	A

[a] $F = 0.207/0.011$ with 13 and 9060 df.

squirrels and cavity-tree lean ($p < 0.05$) (Table 43).

Golden mouse One golden mouse was found in a nest box, 21 July 1978, Donohoe large-box-plot. A small globular nest of shredded bark was also found in the box. Golden mouse nests of shredded bark were described by Barbour (1942). Goodpaster and Hoffmeister (1954) found no nests in cavities in Kentucky. Packard and Garner (1964) reported that golden mice are more arboreal than cotton mice. Two golden mice and 32 cotton mice were captured at Donohoe large-box-plot during small mammal trapping. I found no positive evidence of cotton mouse use of nest boxes.

Eastern woodrat An eastern woodrat was found on four occasions (September, November, December 1977, and June 1978) in a large box at Donohoe. Eastern woodrats used cavities at Donohoe large-box-plot more frequently than cavities on any other plot ($p < 0.05$). Lowery (1974:256) stated that eastern woodrats are more common in bottomland habitats than in upland pine-hardwood habitats of Louisiana. My cavity use and small mammal trapping data do not support that finding.

A large nest of shredded bark was found in the box used by eastern woodrats. Neal (1967) reported no eastern woodrat nests in cavities and no arboreal nests above 3.1 m. Dawson (1967) reported eastern woodrat use of nest boxes on upland sites in north Louisiana. A large stick nest similar to that described by Neal (1967) was found in a felled hollow log, about 1 m above ground and about 18 m from the large box occupied by eastern woodrats. Apparently the nesting habits of eastern woodrats in the loessial bluffs are different from the

nesting habits of woodrats in bottomlands.

Only one adult woodrat was found on each occasion. Lowery (1974: 257) also reported solitary nesting behavior of eastern woodrats.

Unidentified mammals Unidentified mammal use was found in 116 of 4,136 natural cavities checked and 150 of 6,712 nest boxes checked. Most appeared to be small mammal use based upon the size of scats frequently found in the cavity, and upon partially eaten mast and fruits. Since cotton mice were the most abundant small mammal on all plots, it seems likely that this species comprised some of this cavity use. The highest frequency of unidentified mammal use was found in cavities at Donohoe. Small mammal captures were also higher at Donohoe than at Durango or Ben Hur. Peak use occurred in winter. Small mammal captures, Sciurid use, and Virginia opossum use were highest during the winter. Hesselscherdt (1942), Brown and Bellrose (1943), Frank (1948), Klein (1955), and Flyger and Cooper (1967) reported winter use of boxes by *Peromyscus* spp.

Many boxes and natural cavities were used for escape cover and feeding sites by mammals, but not used for nesting or denning.

Nests It is important to know the number of nests and type of nests which occur in nest boxes and natural cavities because some species of cavity users are more or less likely to use a cavity with a nest present. Red-bellied woodpeckers do not use cavities with old vertebrate nests present, but Virginia opossums and flying squirrels seemed to prefer cavities with vertebrate nests present. Carpenter bees only used boxes with flying squirrel nests. Nests were found in 6.4 percent of the 4,136 natural cavities checked and 37.6 percent of

the 6,712 nest boxes checked. The most frequently found invertebrate nests were made by spiders, wasps, and honeybees. Vertebrate nests comprised 80.5 percent of all nests found in cavities. The most frequently found nests were made by unidentified mammals and Sciurids.

Nests were found more frequently in small boxes at Donohoe than at any other plot ($p < 0.05$) (Table 52). Nest occurrence in boxes was higher than nest occurrence in natural cavities in all three habitat types ($p < 0.05$). The highest occurrence of nests was in the winter of 1978-79. Nests accumulated in cavities over time.

Brown and Bellrose (1943) found up to 43 percent of their boxes contained nests within one year, though they indicated that leaves had been carried into many more boxes by fox squirrels. I know of no other author who quantified annual nest presence in cavities.

Management Implications At least 18 of the 26 vertebrate species known to use cavities at Ben Hur, Durango and Donohoe preferred boxes to natural cavities for escape cover, roosting, nesting or denning. Only barred owls preferred natural cavities over nest boxes for nesting. The microclimatic advantages and disadvantages of nest boxes and natural cavities have been discussed earlier. Boxes may act as super-releasers, stimulating greater use than natural cavities (Hinde 1959). Cavity use by red-headed woodpeckers, hairy woodpeckers, Carolina chickadees, white-breasted nuthatches and golden mice were too few to allow any statement of preference. Nor can I make any statement about cavity preference by those cavity-dependent species which occurred neither in natural cavities nor nest boxes, but which were known to have been present on some of the plots (pileated

Table 52. Evaluation of frequency of occurrence of nests in cavities at the three study areas, April 1977 to February 1979 (means with different letters vary significantly, p <0.05).[a]

Plot	N	Frequency of occurrence (%)	Grouping
Ben Hur natural cavities	1780	5.0	G
Ben Hur large boxes	715	35.7	E
Ben Hur medium boxes	671	31.6	E
Ben Hur small boxes	677	33.8	E
Ben Hur large boxes - uncut	646	51.2	B
Ben Hur boxes - cavities	721	18.3	F
Durango natural cavities	1032	5.9	G
Durango large boxes	675	33.3	E
Durango medium boxes	223	50.2	B C
Durango small boxes	222	45.5	B C D
Donohoe natural cavities	821	5.9	G
Donohoe large boxes	710	44.6	C D
Donohoe medium boxes	241	41.5	D
Donohoe small boxes	233	80.3	A

[a] F = 22.002/0.148 with 13 and 9060 df.

woodpecker, brown-headed nuthatch, brown creeper, northern raccoon, etc.).

Cavity size was important for such species as wood ducks, common flickers, red-bellied woodpeckers, tufted titmice, and prothonotary warblers. The presence of a shelf in large nest boxes did not increase use by small cavity-nesting birds. Cutting adversely affected box use by Virginia opossums, but positively affected box use by gray squirrels in bottomland hardwoods. High nest box use in the cottonwood plantation at Durango might be attributed to the diversity of the surrounding habitat (riverfront hardwoods, soybean fields, sloughs, sump areas, etc.). Box use in uninterrupted stands of monoculture cottonwoods may be somewhat different. Plantations composed of several tree species may create the habitat diversity necessary to overcome this problem should it arise.

The density of cavities on all plots was high enough to preclude 100 percent use at any point in time. Reduction of cavity density may be possible without increasing intra- or interspecific competition for cavities; however, I do not know if a minimum cavity density is needed before a given percentage of cavities will be used. For instance, ten out of 30 boxes may be used in a given unit of space and time, but if cavity density were reduced to ten boxes, none may be used, three may be used, or all ten may be used. Mean box use by vertebrates at all habitat types ranged from 15.8 to 29.3 percent and mean natural cavity use ranged from 7.6 to 12.5 percent. This difference could be due to cavity arrangement (systematic versus random or clumped) or to preference for a cavity type by species or individuals. Possibly a

certain percentage of a given cavity type is used regardless of cavity density. Box use by vertebrates, regardless of box size, was similar on all plots within and among three habitats (Table 38). A similar relationship existed for invertebrates (Table 35). Once mean use by cavity-nesters of a given cavity type is determined for habitats, breeding and wintering populations of cavity-dependent species could be accurately controlled by adjusting cavity density given adequate food, water, cover and tolerable climatic conditions. Increased cavity use may result if boxes were placed in situations meeting the criteria of the species present. For instance, the constant percentage of cavities used may be higher if the cavities were in desirable locations than if the cavities were arranged randomly or systematically through the stand. An even mixture of large, medium, and small boxes are indicated unless population increases of species preferring a particular box are desired.

Provisions should be made for natural cavity density sufficient to accommodate those species which do not prefer nest boxes. Natural cavities selected in residual trees during thinning or harvesting operations should be those with characteristics preferred by as many of the natural cavity preferring species present in the stand as possible to increase the probability of natural cavity use. Nest boxes interspersed with natural cavities would reduce competition for natural cavities by natural cavity-dependent species; fewer natural cavities per unit area would be needed to support given populations of cavity-dependent species if natural cavities were interspersed with nest boxes.

Use of each cavity could be increased if seasonal cavity use is

considered. Amphibian and reptilian cavity use was highest in the summer, followed by high mammalian use in the late fall and winter, followed by high avian use in the spring and early summer. Although some overlap competition is inevitable, one cavity could benefit several species each year. For instance, a large box placed in a dense stand might be used by gray squirrels and Carolina wrens, but the same box placed in an open stand might be used by fox squirrels and great crested flycatchers.

There appear to be three alternatives to management of cavity-dependent species in intensively managed forests. First, each cavity site could be selected to meet the requirements of as many species as possible, or second, each cavity in a series of cavity sites should attempt to meet the requirements for single species, or third, systematic distribution of nest boxes and natural cavities would result in use by a number of species at a lower cost and without technical knowledge of the requirements of each cavity-dependent species present.

SUMMARY AND CONCLUSIONS

Microclimates and physical characteristics of nest boxes were compared to natural cavities to help determine why one cavity type should be preferred over the other by cavity-dependent vertebrates in mid-South hardwoods. Microclimate comparisons were made on seven nest boxes and six natural cavities for 18 months in a bottomland hardwood stand. Physical characteristic comparisons were made on 235 nest boxes of three sizes and 163 natural cavities in bottomland hardwoods, a cottonwood plantation, and upland pine-hardwoods. Small mammal and bird populations were indexed in each habitat type for two years. Activity counters were attached to ten nest boxes and ten natural cavities in the bottomland hardwoods to determine consistency of cavity use. All nest boxes and natural cavities were inspected for vertebrate use every four weeks for two years.

Internal temperatures, ambient relative humidity, and internal and ambient solar radiation and light differed between boxes and natural cavities ($p < 0.05$). All differences were consistent over time. All cavity characteristics were different among plots and habitats ($p < 0.05$) except the height of forks in cavity-trees, and the frequency of cavities under limbs ($p > 0.05$). I found no differences in frequency of lianas, height of the lowest live branch, frequency of forks and number of trees per 0.02 ha surrounding cavity-trees when only natural cavity-trees were considered in analysis.

Small mammals were captured more frequently in the upland pine-hardwoods than in the bottomland plots. Four cavity-dependent species of small mammals were captured. Cavity dependent birds constituted a larger percentage of the bird populations in the upland pine-hardwood plots than in the bottomland plots.

Activity counters were activated as frequently at nest boxes as at natural cavities ($p > 0.05$) ($\bar{\bar{x}} = 2.9$ visits per week). Cavity inspection revealed that nest boxes were used more frequently than natural cavities by most cavity-using vertebrates. Most cavity using vertebrates selected cavities on the basis of one or more cavity characteristics.

In conclusion:

1. Temperature and relative humidity inside natural cavities is more stable than that inside nest boxes, but nest presence and endotherm presence may alter internal microclimates significantly.
2. Box temperatures are probably influenced more by solar radiation incidence than are natural cavity temperatures. Light entering natural cavities and nest boxes is primarily diffuse, but sunfleck occurrence can raise internal incoming light levels significantly.
3. Natural cavities should be preferred during the night, especially during warm weather, and boxes should be preferred during the day, especially during cold weather.
4. Natural cavity density is highest in bottomland hardwoods

and lowest in upland hardwoods.

5. Most cavity characteristics vary among the three habitats studied but heights of forks in cavity-trees and frequency of cavities under limbs are the same in all three habitats.
6. Animal-made cavities in uplands face predominantly north and west, while those in the bottomlands face predominantly south and southwest. Orientation may be in response to prevailing winds or light.
7. Cavity-nesters comprise a larger percentage of bird density in uplands than in bottomlands
8. Density of cavity-dependent small mammals is higher in the uplands than in the bottomlands.
9. Periods of high activity at boxes are associated with a low percentage of boxes used, but high activity at natural cavities is associated with a large percentage of natural cavities used.
10. Vertebrate and invertebrates use of systematically arranged nest boxes or of randomly or clumped arranged natural cavities is relatively constant after two years regardless of cavity size or cavity density.
11. Cavity use may be increased if cavities are placed in desirable situations.
12. Placement of boxes to satisfy the criteria of several species may increase the probability of seasonal nest box use by cavity-dependent wildlife.

13. Interspersion of nest boxes with natural cavities may reduce interspecific competition for natural cavities thereby aiding species which prefer natural cavities over nest boxes.

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APPENDIX

Table 53. Overstory and midstory vegetation, Ben Hur control-plot East Baton Rouge Parish, Louisiana, 20 May 1977.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Water oak	34.0	34.0	11.13	24.1	17.0
Sweetgum	21.9	9.7	7.18	42.7	16.5
Coast pignut hickory	18.7	12.9	6.12	34.5	21.5
Sugarberry	9.4	14.5	3.08	24.9	15.9
American sycamore	4.5	1.6	1.49	55.4	33.6
Boxelder	4.3	11.3	1.39	18.8	10.5
Nuttall oak	3.8	1.6	1.23	50.3	33.6
American elm	0.9	4.8	0.28	13.7	9.2
Sweet pecan	0.8	1.6	0.26	23.1	18.9
Bluebeech	0.7	3.2	0.24	15.2	9.9
Winged sumac	0.6	3.2	0.21	14.7	14.8
Carolina basswood	0.2	1.6	0.08	13.0	12.2
Total	99.8	100.0	32.69	22.9	17.8

*382 trees per ha.

Table 54. Overstory and midstory vegetation, Ben Hur large-box-plot, East Baton Rouge Parish, Louisiana, 20 May 1977 (values before cutting indicated parenthetically).

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Cow oak	31.5 (13.6)	11.6 (8.8)	3.56 (3.56)	34.5 (34.5)	20.1 (20.1)
Sugarberry	22.3 (10.0)	34.9 (28.1)	2.52 (2.62)	17.5 (17.3)	13.8 (13.6)
Carolina basswood	14.0 (7.9)	11.6 (13.8)	1.58 (2.07)	23.9 (21.8)	14.0 (15.6)
Water oak	8.5 (7.0)	7.0 (7.0)	0.96 (1.83)	25.1 (28.4)	18.3 (18.3)
Sweet pecan	5.4 (2.3)	2.3 (1.8)	0.61 (0.61)	35.6 (35.6)	25.9 (25.9)
Bluebeech	4.8 (2.0)	14.0 (10.5)	0.54 (0.54)	13.7 (13.7)	10.3 (10.3)
Sweetgum	4.2 (49.8)	2.3 (15.8)	0.47 (12.92)	79.5 (52.6)	30.5 (23.9)
Boxelder	3.3 (1.4)	4.6 (3.6)	0.37 (0.37)	19.3 (19.3)	13.3 (13.3)
Sweetleaf	2.3 (1.0)	2.3 (1.8)	0.26 (0.26)	18.0 (18.0)	12.2 (12.2)
Coast pignut hickory	1.5 (0.7)	4.7 (3.5)	0.17 (0.17)	12.9 (12.9)	14.0 (14.0)
American elm	1.5 (0.7)	2.3 (1.8)	0.17 (0.17)	19.6 (19.6)	13.7 (13.7)
Drummond red maple	0.7 (0.2)	2.3 (1.8)	0.08 (0.08)	12.7 (12.7)	16.8 (16.8)

Table 54. Continued.

Table 54. Continued.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Green ash	0.0 (3.9)	0.0 (1.8)	0.00 (1.04)	0.0 (46.2)	0.0 (18.3)
Total	100.0 (100.0)	99.9 (100.1)	11.29 (26.24)	24.0 (25.6)	15.6 (16.6)

*265 (352) trees per ha.

Table 55. Overstory and midstory vegetation, Ben Hur large-box-uncut-plot, East Baton Rouge Parish, Louisiana, 20 May 1977.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Sweetgum	34.7	9.1	8.90	59.9	29.3
Sugarberry	29.2	58.4	7.49	20.1	15.2
Water oak	21.4	3.5	5.47	74.9	33.6
Boxelder	7.4	23.6	1.90	15.7	14.1
American sycamore	6.6	1.8	1.70	59.2	33.6
Green ash	0.4	1.8	0.06	11.4	12.2
Total	99.9	100.0	25.62	36.5	21.7

*339 trees per ha.

Table 56. Overstory and midstory vegetation, Ben Hur medium-box-plot, East Baton Rouge Parish, Louisiana, 21 May 1977 (values before cutting indicated parenthetically).

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Sugarberry	35.0 (21.6)	47.4 (40.7)	3.67 (6.66)	17.8 (22.9)	14.6 (16.0)
American elm	21.8 (31.1)	10.2 (13.0)	2.27 (9.47)	33.3 (47.0)	20.1 (22.9)
Boxelder	12.1 (4.1)	18.4 (13.0)	1.25 (1.25)	18.8 (18.8)	15.7 (15.7)
Green ash	11.1 (3.8)	5.3 (3.7)	1.17 (1.17)	38.9 (38.9)	24.4 (24.4)
Sweetgum	10.4 (30.1)	2.6 (11.1)	1.09 (9.16)	47.5 (54.1)	22.9 (25.2)
Drummond red maple	6.2 (7.8)	5.3 (11.1)	0.65 (2.40)	24.4 (26.9)	16.0 (16.8)
Bluebeech	2.5 (0.8)	7.9 (5.6)	0.27 (0.27)	13.2 (13.2)	9.2 (9.2)
Water oak	0.8 (0.3)	2.6 (1.9)	0.09 (0.09)	13.7 (13.7)	13.7 (13.7)
Total	100.0 (99.9)	99.7 (100.0)	10.46 (30.47)	25.9 (29.4)	17.1 (18.0)

*234 (335) trees per ha.

Table 57. Overstory and midstory vegetation, Ben Hur small-box-plot, East Baton Rouge Parish, Louisiana, 21 May 1977 (values before cutting indicated parenthetically).

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Cow oak	35.0 (15.9)	10.0 (8.5)	4.00 (4.00)	32.5 (32.5)	18.9 (18.9)
Sugarberry	24.2 (26.6)	32.0 (33.8)	2.40 (6.71)	17.0 (22.4)	12.5 (14.5)
Boxelder	20.5 (9.2)	34.0 (28.8)	2.32 (2.32)	16.5 (16.5)	12.7 (12.7)
Coast pignut hickory	9.5 (1.1)	4.0 (3.4)	1.09 (1.09)	33.4 (33.5)	24.4 (24.4)
American elm	3.3 (1.5)	8.0 (6.8)	0.38 (0.38)	14.0 (14.0)	9.9 (9.9)
Sweetgum	3.1 (43.8)	6.0 (13.6)	0.36 (11.26)	15.5 (47.0)	14.2 (22.7)
Black cherry	1.6 (0.7)	2.0 (1.7)	0.19 (0.19)	19.6 (19.6)	13.7 (13.7)
Water oak	1.2 (0.5)	2.0 (1.7)	0.13 (0.13)	16.5 (16.5)	16.8 (16.8)
Green ash	1.2 (0.5)	2.0 (1.7)	0.13 (0.13)	16.5 (16.5)	18.3 (18.3)
Total	99.6 (99.8)	100.0 (100.0)	11.00 (26.08)	20.2 (24.3)	15.7 (16.9)

*234 (335) trees per ha.

Table 58. Overstory and midstory vegetation, Ben Hur box-natural cavity-plot, East Baton Rouge Parish, Louisiana, 19 May 1977.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Sugarberry	38.2	30.0	10.18	29.9	19.4
Sweetgum	34.8	12.9	9.28	40.6	25.8
American elm	13.3	12.9	3.55	26.2	19.0
Boxelder	5.6	14.3	1.49	16.3	13.1
Nuttall oak	2.6	10.0	0.70	14.0	11.1
Drummond red maple	1.8	8.6	0.49	12.7	14.5
Water oak	1.7	4.3	0.48	17.8	15.9
Persimmon	1.0	1.4	0.25	22.9	19.8
Winged elm	0.9	5.7	0.23	10.7	9.8
Total	99.9	100.1	26.65	21.2	16.5

*434 trees per ha.

Table 59. Understory vegetation, Ben Hur control-plot, East Baton Rouge Parish, Louisiana, 22 September 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Murphy's grass	21.1	20.8	63
Grasses	8.0	8.0	67
Thoroughworts	5.7	5.8	47
Sugarberry	4.9	4.8	77
Crossvine	4.2	4.2	83
Poison ivy	3.5	3.5	70
Oaks	3.4	3.3	67
Common greenbrier	3.2	3.2	63
Coast pignut hickory	3.2	3.2	50
Jumpseed	2.8	2.8	50
Trumpet creeper	2.8	2.8	50
Asters	2.2	2.2	43
Red-berried moonseed	2.0	2.0	40
Elephant's-foot	2.0	2.0	40
Virginia creeper	1.8	1.8	37
Boxelder	1.7	1.7	33
Wax-leaved ligustrum	1.7	1.7	13
Japanese honeysuckle	1.7	1.7	33
Indian strawberry	1.5	1.5	30
35 other taxa	22.6	22.3	87
Total		99.3	

Table 60. Understory vegetation, Ben Hur large-box-plot, East Baton Rouge Parish, Louisiana, 27 July 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Murphy's grass	7.0	9.3	47
Water-willow	5.4	7.2	57
Sedges	4.9	6.5	50
Spicebush	4.4	5.8	50
Southern shield fern	3.9	5.2	30
Sugarberry	3.6	4.8	70
Boxelder	3.2	4.3	73
Grasses	3.0	4.0	60
Clearweed	2.9	3.8	57
False-nettle	2.9	3.8	30
Dewberries	2.8	3.7	30
Poison ivy	2.8	3.7	53
Climbing hempweed	2.8	3.7	67
Grapes	2.6	3.5	43
Crossvine	2.6	3.5	70
Bluebeech	2.5	3.3	40
Oaks	2.4	3.2	63
Elderberry	2.3	3.0	40
Elephant's-foot	2.0	2.7	47
Japanese honeysuckle	1.9	2.5	30
Avens	1.7	2.2	43

Table 60. Continued.

Table 60. Continued.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Fall asters	1.5	2.0	27
59 other taxa	30.9	41.0	90
Total		132.7	

Table 61. Understory vegetation, Ben Hur medium-box-plot, East Baton Rouge Parish, Louisiana, 1 August 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Grasses	11.1	15.8	40
Murphy's grass	7.9	11.3	40
Sedges	5.5	7.8	57
Spicebush	4.9	7.0	53
Lizard's-tail	4.4	6.3	27
Dewberries	4.4	6.3	33
Elderberry	4.2	6.0	33
Water-willow	3.7	5.3	33
Poison ivy	3.3	4.7	60
Climbing hempweed	2.9	4.2	50
Sugarberry	2.5	3.5	63
Boxelder	2.3	3.3	53
Crossvine	2.2	3.2	63
Thoroughworts	2.2	3.2	57
Asters	2.1	3.0	33
Bluebeech	2.0	2.8	23
Grapes	1.9	2.7	27
Common greenbrier	1.8	2.5	43
Oaks	1.8	2.5	50
Jumpseed	1.6	2.3	47
60 other taxa	27.3	36.5	83
Total		140.2	

Table 62. Understory vegetation, Ben Hur small-box-plot, East Baton Rouge Parish, Louisiana, 2 August 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Switchcane	10.4	16.5	47
Murphy's grass	6.5	10.3	40
Southern shield fern	6.2	9.8	50
Grasses	5.2	8.3	67
Dewberries	4.8	7.7	60
Sugarberry	4.2	6.7	80
Grapes	4.0	6.5	57
Spicebush	3.3	5.2	43
Poison ivy	3.3	5.2	70
Asters	2.8	4.5	43
Thoroughwort	2.7	4.3	60
Boxelder	2.5	4.0	60
Crossvine	2.5	4.0	80
Elephant's-foot	2.5	4.0	67
Jumpseed	2.4	3.8	77
Common greenbrier	1.8	2.8	57
Avens	1.8	2.8	50
Virginia creeper	1.8	2.8	50
Sedges	1.4	2.2	30
Beggar-ticks	1.4	2.2	43
Peppervine	1.4	2.2	30

Table 62. Continued.

Table 62. Continued.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Elderberry	1.4	2.2	30
Climbing hempweed	1.4	2.2	47
53 other taxa	24.3	38.6	87
Total		158.8	

Table 63. Understory vegetation, Ben Hur large-box-uncut-plot, East Baton Rouge Parish, Louisiana, 28 July 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Switchcane	12.0	15.2	63
Southern shield fern	6.6	8.3	40
Dewberries	4.3	5.5	63
Poison ivy	4.2	5.3	93
Boxelder	3.9	5.0	60
Sedges	3.7	4.7	40
Spicebush	3.7	4.7	67
Crossvine	3.7	4.7	87
Water-willow	3.6	4.5	37
Grasses	3.0	3.8	30
Common greenbrier	3.0	3.8	70
Oaks	2.6	3.3	67
Sugarberry	2.6	3.3	53
Jumpseed	2.6	3.3	67
Avens	2.6	3.3	60
Murphy's grass	2.2	2.8	43
Elderberry	2.2	2.8	50
Elephant's-foot	2.1	2.7	53
Climbing hempweed	2.0	2.5	37
Red-berried moonseed	1.8	2.3	47
Virginia creeper	1.8	2.3	47

Table 63. Continued.

Table 63. Continued.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Asters	1.8	2.3	47
Trumpet creeper	1.7	2.2	37
Grapes	1.6	2.0	33
Indian-turnip	1.4	1.8	37
Leather-flower	1.4	1.8	37
35 other taxa	17.9	22.7	53
Total		126.9	

Table 64. Understory vegetation, Ben Hur box-natural cavity-plot, East Baton Rouge Parish, Louisiana, 26 September 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Grasses	15.0	12.7	67
Water-willow	11.5	9.7	67
Dewberries	5.0	4.2	50
Poison ivy	4.1	3.5	63
Lizard's-tail	3.5	3.0	40
Japanese honeysuckle	3.5	3.0	53
Spicebush	3.0	2.5	37
Asters	3.0	2.5	50
Peppervine	2.7	2.3	47
Crossvine	2.7	2.3	47
Elderberry	2.7	2.3	40
Common greenbrier	2.6	2.2	43
Clearweed	2.4	2.0	40
Jumpseed	2.4	2.0	40
Southern shield fern	2.1	1.8	55
Red-berried moonseed	2.1	1.8	37
Leather-flower	1.8	1.5	30
Boxelder	1.8	1.5	30
Drummond red maple	1.8	1.5	30
Oaks	1.4	1.2	23
Sugarberry	1.4	1.2	23

Table 64. Continued.

Table 64. Continued.

Species	Percent vegetation cover	Average percent ground cover	Percent frequency
Virginia creeper	1.4	1.2	23
Climbing hempweed	1.4	1.2	23
40 other taxa	20.7	17.5	40
Total		84.6	

Table 65. Overstory and midstory vegetation, Durango control-plot, Jefferson County, Mississippi, 18 September 1978.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Water hickory	57.3	28.8	5.40	29.6	21.7
Sugarberry	17.0	24.2	1.60	17.2	12.0
Waterlocust	11.0	6.1	1.04	16.3	12.2
Swamp-privet	7.7	27.3	0.73	11.1	5.9
Boxelder	5.2	10.6	0.49	14.5	12.0
Planertree	1.7	3.0	0.16	27.6	22.5
Total	99.9	100.0	9.32	19.4	14.4

*271 trees per ha.

Table 66. Overstory and midstory vegetation, Durango large-box-plot, Jefferson County, Mississippi, 15 September 1978.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Cottonwood	100.0	100.0	12.1	21.8	24.3

*325 trees per ha.

Table 67. Understory vegetation, Durango control-plot, Jefferson County Mississippi, 3 September 1977.

Species	Percent vegetation cover	Average percent ground cover	Percent frequency
Red-berried moonseed	9.4	4.0	80
Trumpet creeper	8.7	3.7	67
Asters	8.7	3.7	53
Grasses	6.3	2.7	17
Ladies'-eardrops	6.3	2.7	53
Peppervine	6.3	2.7	33
Climbing dogbane	5.9	2.5	50
Sawtooth greenbrier	4.7	2.0	40
False-nettle	4.7	2.0	33
Dewberries	4.7	2.0	27
White-leaved greenbrier	3.5	1.5	30
Virginia creeper	3.5	1.5	30
Unknown	3.1	1.3	27
Rattan-vine	2.8	1.2	23
Wild chervil	2.4	1.0	20
Grapes	1.9	0.8	17
Pecan hickory	1.6	0.7	13
Sugarberry	1.6	0.7	13
20 other taxa	13.9	5.9	53
Total		42.6	

Table 68. Understory vegetation, Durango large-box-plot, Jefferson County, Mississippi, 3 September 1977.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Poison ivy	21.6	19.0	100
Trumper creeper	19.1	16.8	100
Dewberries	15.0	13.2	90
Goldenrods	6.0	5.3	60
Boxelder	5.9	5.2	57
Grasses	2.6	2.3	33
Sugarberry	2.6	2.3	47
False-nettle	2.6	2.3	47
Grapes	2.5	2.2	43
Pecan hickory	2.2	2.0	40
Virginia creeper	2.2	2.0	40
Johnson grass	2.0	1.8	23
Asters	1.7	1.5	30
Partridge-pea	1.4	1.3	27
Morning glory	1.3	1.2	23
Tuberous hedge-nettle	1.3	1.2	23
22 other taxa	10.0	8.8	60
Total		88.4	

Table 69. Overstory and midstory vegetation, Donohoe control-plot Jefferson County, Mississippi, 25 May 1977.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Loblolly pine	48.8	25.6	11.33	31.0	25.8
Water oak	11.3	17.1	2.61	17.0	16.6
Shortleaf pine	11.0	6.6	2.56	28.7	24.4
Sweetgum	10.0	14.7	2.51	18.3	16.6
Cherrybark oak	5.9	8.1	1.37	19.1	20.1
Winged elm	4.7	3.8	0.99	22.1	17.1
Flowering dogwood	3.5	10.0	0.81	13.5	10.2
Southern red oak	2.7	6.6	0.64	15.0	16.9
Shumard oak	0.4	2.4	0.10	14.2	14.0
Carolina basswood	0.4	1.0	0.08	13.7	18.3
Eastern redcedar	0.3	0.9	0.06	16.5	9.8
Yellow-poplar	0.3	0.5	0.05	14.7	15.3
Southern magnolia	0.2	0.5	0.04	16.0	15.3

Table 69. Continued.

Table 69. Continued.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Bitternut hickory	0.1	0.5	0.02	18.0	9.5
Bluebeech	0.1	0.5	0.02	10.7	9.2
Hill red maple	0.1	0.5	0.02	10.9	10.7
Blackgum	0.1	0.5	0.02	10.7	10.7
White ash	0.1	0.5	0.02	10.9	10.7
Total	99.7	100.3	23.25	16.9	15.4

*519 trees per ha.

Table 70. Overstory and midstory vegetation, Donohoe large-box-plot, Jefferson County, Mississippi, 25 May 1977 (values before cutting indicated parenthetically).

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ha)	Mean dbh (cm)	Mean height (m)
Loblolly pine	53.5 (44.2)	33.0 (28.7)	11.07 (11.74)	30.7 (31.5)	24.5 (24.6)
Shortleaf pine	21.3 (15.4)	14.4 (13.4)	4.08 (4.08)	27.9 (27.9)	24.8 (24.8)
Blackgum	5.5 (7.5)	4.4 (5.3)	1.15 (1.97)	26.2 (30.2)	20.0 (21.0)
Sweetgum	4.5 (8.4)	5.7 (7.4)	0.92 (2.20)	20.1 (25.4)	16.1 (18.3)
Flowering dogwood	3.2 (2.6)	10.6 (9.9)	0.66 (0.66)	13.2 (13.2)	11.0 (11.0)
Yellow-poplar	2.6 (2.0)	6.9 (6.1)	0.54 (0.54)	15.7 (15.7)	18.6 (18.6)
American beech	2.3 (3.4)	3.1 (3.3)	0.49 (0.88)	13.7 (20.8)	13.5 (15.6)
Eastern hophornbeam	2.1 (1.7)	8.1 (7.4)	0.43 (0.43)	12.7 (12.7)	12.5 (12.5)
Water oak	1.6 (6.2)	5.7 (6.1)	0.35 (1.63)	16.3 (22.1)	14.4 (16.8)
Winged elm	1.4 (2.6)	0.6 (1.6)	0.30 (0.67)	32.8 (34.5)	22.9 (20.2)
Bitternut hickory	0.6 (0.6)	0.6 (0.4)	0.15 (0.15)	32.5 (32.5)	25.9 (25.9)
Southern red oak	0.6 (0.6)	3.1 (2.8)	0.14 (0.14)	11.9 (11.9)	13.7 (13.7)

Table 70. Continued.

Table 70. Continued.

Species	Relative dominance (percent)	Relative density (percent)*	Basal area (m^2/ ha)	Mean dbh (cm)	Mean height (m)
Bluebeech	0.4 (0.4)	1.3 (1.2)	0.10 (0.10)	15.2 (15.2)	13.1 (13.1)
White oak	0.2 (3.9)	1.3 (2.0)	0.06 (1.06)	11.9 (25.1)	16.2 (22.0)
Cherrybark oak	0.2 (0.2)	0.6 (0.8)	0.05 (0.05)	13.7 (13.7)	13.7 (13.7)
Southern magnolia	0.1 (0.1)	0.6 (0.8)	0.03 (0.03)	13.5 (13.5)	12.2 (12.2)
Shumard oak	0.0 (0.1)	0.6 (0.4)	0.02 (0.02)	10.4 (10.4)	12.2 (12.2)
American holly	0.0 (0.1)	0.6 (0.4)	0.02 (0.02)	11.2 (11.2)	7.6 (7.6)
Total	100.1 (100)	101.2 (98)	19.70 (26.39)	18.2 (20.3)	16.2 (16.8)

*391 (426) trees per ha.

Table 71. Understory vegetation, Donohoe control-plot, Jefferson County, Mississippi, 10 September 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Poison ivy	13.5	6.7	93
Grasses	7.0	3.5	70
Winged elm	5.4	2.7	53
White ash	5.4	2.7	53
Flowering dogwood	5.0	2.5	37
Muscadine grape	4.6	2.3	40
Yellow jessamine	4.6	2.3	47
Sweetgum	4.0	2.0	33
Rattan-vine	3.6	1.8	37
Christmas fern	3.4	1.7	27
Beggar-ticks	3.4	1.7	33
Virginia creeper	3.0	1.5	30
Crossvine	3.0	1.5	30
Oaks	2.6	1.3	40
Common greenbrier	2.4	1.2	23
Hickories	2.0	1.0	20
Switchcane	1.6	0.8	10
Black cherry	1.6	0.8	17
Violets	1.6	0.8	17
Asters	1.6	0.8	17
Climbing hydrangea	1.4	0.7	7

Table 71. Continued.

Table 71. Continued.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Climbing dogbane	1.4	0.7	13
Ruellia	1.4	0.7	13
Elephant's-foot	1.4	0.7	13
26 other taxa	15.1	7.5	53
Total		50.9	

Table 72. Understory vegetation, Donohoe large-box-plot, Jefferson County, Mississippi, 9 September 1978.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Flowering dogwood	7.7	4.7	40
Poison ivy	6.2	3.8	70
Grasses	6.0	3.7	67
Black cherry	5.4	3.3	13
Sweetgum	4.6	2.8	37
Eastern hophornbeam	3.8	2.3	27
Unknown	3.8	2.3	47
Winged elm	3.6	2.2	37
Rattan-vine	3.6	2.2	37
Violets	2.9	1.8	37
Hill blackgum	2.9	1.8	37
Beggar-ticks	2.8	1.7	33
Muscadine grape	2.5	1.5	30
Yellow jessamine	2.5	1.5	30
Oaks	2.1	1.3	20
White ash	2.1	1.3	20
Crossvine	2.1	1.3	27
American beech	2.0	1.2	17
Southern yellow pine	1.6	1.0	20
White-leaved greenbrier	1.6	1.0	20
Coral-bean	1.6	1.0	20

Table 72. Continued.

Table 72. Continued.

Species	Percent vegetative cover	Average percent ground cover	Percent frequency
Three-seeded mercury	1.6	1.0	20
Virginia creeper	1.6	1.0	20
Asters	1.6	1.0	20
39 other taxa	23.8	14.5	83
Total		61.2	

Table 73. Common and scientific names of plants mentioned in the text.[a]

Common name	Scientific name
American beech	*Fagus grandifolia*
American elm	*Ulmus americana*
American holly	*Ilex opaca*
American sycamore	*Platanus occidentalis*
Apple	*Malus pumila*
Asters	*Aster* spp.
Avens	*Geum* spp.
Baldcypress	*Taxodium distichum*
Beggar-ticks	*Desmodium* spp.
Bitternut hickory	*Carya cordiformis*
Black cherry	*Prunus serotina*
Bluebeech	*Carpinus caroliniana*
Boxelder	*Acer negundo*
Carolina basswood	*Tilia caroliniana*
Cherrybark oak	*Quercus falcata* var. *pagodaefolia*
Christmas fern	*Polystichum acrostichoides*
Clearweed	*Pilea pumila*
Climbing dogbane	*Trachelospermum difforme*
Climbing hempweed	*Mikania scandens*
Climbing hydrangea	*Decumaria barbara*
Coast pignut hickory	*Carya glabra* var. *megacarpa*
Common greenbrier	*Smilax rotundifolia*
Coral bean	*Erythrina herbacea*

Table 73. Continued.

Table 73. Continued.

Common name	Scientific name
Cottonwood	*Populus deltoides*
Cow oak	*Quercus michauxii*
Crossvine	*Anistostichus capreolata*
Dewberries	*Rubus* spp.
Drummond red maple	*Acer rubrum* var. *drummondii*
Eastern hophornbeam	*Ostrya virginiana*
Eastern redcedar	*Juniperus virginiana*
Elderberry	*Sambucus canadensis*
Elephant's-foot	*Elaphantopus tomentosa*
Fall asters	*Aster* spp.
False nettle	*Boehmeria cylindrica*
Flowering dogwood	*Cornus florida*
Goldenrods	*Solidago* spp.
Grapes	*Vitis* spp.
Grasses	Poaceae
Green ash	*Fraxinus pennsylvanica*
Hickories	*Carya* spp.
Hill blackgum	*Nyssa sylvatica*
Hill red maple	*Acer rubrum*
Indian-strawberry	*Duchesnea indica*
Indian-turnip	*Arisaema triphyllum*
Japanese honeysuckle	*Lonicera japonica*
Johnson grass	*Sorghum halpense*

Table 73. Continued.

Table 73. Continued.

Common name	Scientific name
Jumpseed	Tovara virginiana
Ladies'-eardrops	Brunnichia cirrhosa
Leather-flower	Clematis spp.
Lizard's-tail	Saururus cernuus
Loblolly pine	Pinus taeda
Morning glory	Ipomea spp.
Murphy's grass	Oplismenus setarius
Muscadine grape	Vitis rotundifolia
Nuttall oak	Quercus nuttallii[b]
Partridge pea	Cassia fasiculata
Pecan hickory	Carya aquatica or C. illinoensis
Peppervine	Ampleopsis arborea
Persimmon	Diospyros virginiana
Planertree	Planera aquatica
Poison ivy	Rhus radicans
Rattan-vine	Berchemia scandens
Red-berried moonseed	Cocculus carolinus
Ruellia	Ruellia carolinensis
Sawtooth greenbrier	Smilax bona-nox
Sedges	Cyperaceae
Shortleaf pine	Pinus echinata
Shumard oak	Quercus shumardii
Southern magnolia	Magnolia grandiflora

Table 73. Continued.

Table 73. Continued.

Common name	Scientific name
Southern red oak	_Quercus falcata_
Southern shield fern	_Dryopteris ludoviciana_
Southern yellow pine	_Pinus taeda_ or _P. echinata_
Soybean	_Glycine max_
Spicebush	_Lindera benzoin_
Sugarberry	_Celtis laevigata_
Swamp-privet	_Foresteria acuminata_
Sweetgum	_Liquidambar styraciflua_
Sweetleaf	_Symplocos tinctoria_
Sweet pecan	_Carya illinoensis_
Switchcane	_Arundinaria gigantea_
Thoroughworts	_Eupatorium_ spp.
Three-seeded mercury	_Acalypha_ spp.
Trumpet-creeper	_Campsis radicans_
Tuberous hedge-nettle	_Stachys floridana_
Violets	_Viola_ spp.
Virginia creeper	_Parthenocissus quinquefolia_
Water hickory	_Carya aquatica_
Waterlocust	_Gleditsia aquatica_
Water oak	_Quercus nigra_
Water-willow	_Justicia ovata_
Wax-leaved ligustrum	_Ligustrum sinense_
White ash	_Fraxinus americana_

Table 73. Continued.

Table 73. Continued.

Common name	Scientific name
White-leaved greenbrier	*Smilax glauca*
Wild chervil	*Chaerophyllum procumbens*
Winged elm	*Ulmus alata*
Winged sumac	*Rhus copallina*
Yellow jessamine	*Gelsemium sempervirens*
Yellow-poplar	*Liriodendron tulipifera*

[a]From Radford et al. (1968) unless otherwise noted.

[b]From Fernald (1950)

Table 74. Common and scientific names of reptiles and amphibians mentioned in the text.[a]

Common name	Scientific name
Green anole	*Anolis carolinensis*
Five-lined skink	*Eumeces fasciatus*
Southeastern five-lined skink	*Eumeces inexpectatutus*
Broad-headed skink	*Eumeces laticeps*
Rough green snake	*Opheodrys aestivus*
Black rat snake	*Elaphe obsoleta obsoleta*
Texas rat snake	*Elaphe obsoleta lindheimeri*
Squirrel treefrog	*Hyla squirrella*
Green treefrog	*Hyla cinerea*
Gray treefrog	*Hyla versicolor* or *Hyla chrysoscelis*

[a]From Conant (1975).

Table 75. Common and scientific names of birds mentioned in the text.[a]

Common name	Scientific name
Wood duck	*Aix sponsa*
American kestrel	*Falco sparverius*
Screech owl	*Otus asio*
Barred owl	*Strix varia*
Common flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Red-bellied woodpecker	*Centurus carolinus*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Hairy woodpecker	*Dendrocopus villosus*
Downy woodpecker	*Dendrocopus pubescens*
Great crested flycatcher	*Myiarchus crinitus*
Carolina chickadee	*Parus carolinensis*
Tufted titmouse	*Parus bicolor*
White-breasted nuthatch	*Sitta carolinensis*
Brown-headed nuthatch	*Sitta pusilla*
Northern house wren	*Troglodytes aedon*
Carolina wren	*Thryothorus ludovicianus*
American robin	*Turdus migratorius*
Eastern bluebird	*Sialia sialis*
Prothonotary warbler	*Prothonotaria citrea*
Northern parula warbler	*Parula americana*
Yellow-rumped warbler	*Dendroica coronata*
House sparrow	*Passer domesticus*

Table 75. Continued.

Table 75. Continued.

Common name	Scientific name
Common grackle	*Quiscalus quiscala*
Brown-headed cowbird	*Molothrus ater*
Northern cardinal	*Cardinalis cardinalis*
White-throated sparrow	*Zonotrichia albocollis*

[a]From American Ornithologists Union (1957).

Table 76. Common and scientific names of mammals mentioned in the text.[a]

Common name	Scientific name
Virginia opossum	Didelphis virginiana pigra
Gray squirrel	Sciurus carolinensis
Fox squirrel	Sciurus niger
Southern flying squirrel	Glaucomys volans
White-footed mouse	Peromyscus leucopus
Cotton mouse	Peromyscus gossypinus
Golden mouse	Ochrotomys nuttalli
Eastern woodrat	Neotoma floridana
Muskrat	Ondatra zibethicus
House mouse	Mus musculus
Northern raccoon	Procyon lotor
Bobcat	Lynx rufus

[a]From Lowery (1974).

VITA

William Curtis McComb was born in Hartford, Connecticut, 8 November 1952. He graduated from Suffield High School, Suffield, Connecticut in 1970. In September 1970 he began his undergraduate education at the University of Connecticut and he received a Bachelor of Science degree in Natural Resources Conservation in May 1974. He remained at the University of Connecticut as a graduate student receiving a Master of Science degree in Wildlife Management in May 1976. In September 1976 he entered the Louisiana State University Graduate School and is now a candidate for the degree of Doctor of Philosophy in Forestry.

EXAMINATION AND THESIS REPORT

Candidate: William Curtis McComb

Major Field: Forestry

Title of Thesis: Nest Box and Natural Cavity Use by Wildlife in Mid-South Hardwoods as Related to Physical and Microclimate Characteristics

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

August 30, 1979