Wood Duck Nest Cavities in Bald Cypress-Tupelo Gum Stands

Darin M. Lee,[1] *Mississippi Cooperative Fish and Wildlife Research Unit, P.O. Drawer BX, Mississippi State, MS 39762*

Edward P. Hill,[2] *Mississippi Cooperative Fish and Wildlife Research Unit, P.O. Drawer BX, Mississippi State, MS 39762*

Abstract: We studied availability of natural cavities for wood ducks (*Aix sponsa*) on 5 areas in 3 southeastern states in 1988–1990 because of U.S. Fish and Wildlife Service (USFWS) guidelines that called for the reduction of nest boxes on National Wildlife Refuges. Selected forested wetlands dominated by bald cypress (*Taxodium distichum*) or tupelo gum (*Nyssa aquatica*) were randomly sampled using 0.5-ha plots to estimate the density of cavities suitable for wood duck nesting. Density of suitable natural cavities in live, mature (≥28 cm dbh, $\bar{x}$ age = 117.6 years) bald cypress-tupelo gum stands averaged 0.08/ha (SE = 0.03) and ranged from 0.00 to 0.29/ha. Bucket cavities were deemed unsuitable because of their tendency to retain moisture in dry periods. The mean cavity density for all areas in this study was among the lowest densities reported for timber stands in North America. The low cavity densities in these bald cypress-tupelo gum areas, and other bottomland hardwood stands in the Southeast suggest that nesting boxes may be needed if wood duck production is a management goal.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 50:466-474

The wood duck faced extinction in the early 1900s because of liberal bag limits, long hunting seasons, illegal harvest, and habitat destruction (Bellrose 1976). Populations began to recover when states and federal agencies imposed strict harvest regulations. The large-scale erection of nesting boxes in several states during the late 1930s (Soulliere 1986) also promoted wood duck population recovery.

In the late 1970s, U.S. Fish and Wildlife Service (USFWS) guidelines (USFWS 1979) called for the gradual reduction of wood duck nest boxes on National Wildlife Refuges. These guidelines were intended to enhance the aesthetics of refuge landscapes and to wean wood duck populations from artificial nest sites. The strategy was based on data from northern areas within the range of the wood duck (Prince 1968,

[1] Present address: Coastal Restoration Division, La Department of Natural Resources, Baton Rouge, LA 70804-9396.

[2] Present address: 5668 S. Iris Way, Littleton, CO 80123.

Haramis 1975, Gilmer et al. 1978) and indications that densities of natural cavities (≥ 3.95 cavities/ha) in the wood duck's range seemed adequate for nesting. The USFWS guidelines for the southeastern United States were modified (USFWS 1987) after a study of Mississippi bottomland hardwood (BLH) forests (Lowney and Hill 1989) revealed that the density of suitable cavities (0.19 to 0.23 cavities/ha) was substantially below levels reported for northern latitudes and inadequate to support recruitment objectives on most southern refuges (USFWS 1987).

Managers need information on how species, size, age class, and density of tree stands affect availability of suitable nest cavities as a basis for wood duck management decisions (Aultfather 1966). Because of the paucity of data on natural cavity density in stands of bald cypress and tupelo gum, management policies and strategies for wood ducks in the southeastern United States are incomplete. We examined selected stands of these wetland trees to estimate the occurrence of natural cavities suitable for wood duck nests.

We thank A. R. Aderman, S. C. Barry, and D. W. Burnett for their assistance with field work. L. A. Brennan, R. M. Kaminski, and B. D. Leopold provided helpful editorial suggestions. The study was funded jointly through Federal Aid in Wildlife Restoration Funds through the Mississippi Department of Wildlife, Fisheries, and Parks (Project W-48) and the USFWS (Coop. Agreement 14-16-0009-1543) through the Mississippi Cooperative Fish and Wildlife Research Unit.

Methods

Study Area

Ten forest stands on 5 study sites in Alabama, Mississippi, and Louisiana were selected for sampling (Fig. 1). The study areas were palustrine forested wetlands (Cowardin et al. 1979), dominated by BLH forests and bald cypress-tupelo gum. Sites and stands to be sampled were selected based upon location in Mississippi's dominant river floodplains, accessibility, easily delineated stand boundaries on aerial photography, and geomorphological features that could be located in the field and on aerial photos. Only plots within bald cypress-tupelo gum wetlands were sampled, but descriptions of whole areas are given along with details on each individual stand sampled.

Silver Spur Hunting Club. Silver Spur Hunting Club (SSHC) was a private tract located approximately 4 km southeast of Columbus, Lowndes county, Mississippi.

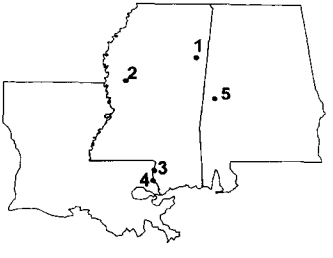

Figure 1. Location of 1) Silver Spur Hunting Club, 2) Panther Swamp NWR, 3) Old River WMA, 4) Bogue Chitto NWR, and 5) Wilkes Creek study areas sampled to determine densities of suitable wood duck cavities in bald cypress-tupelo gum stands in 3 southeastern states from 1988 through 1990.

The area was in the Tennessee-Tombigbee Waterway (Tenn-Tom Waterway) floodplain, and included an old river oxbow slough of 46 ha containing tupelo gum-bald cypress. Water levels were relatively stable because of several large beaver (*Castor canadensis*) dams. The majority of tupelo gum was stressed or dead as a result of increased water level and girdling by beaver.

Old River Wildlife Management Area. Old River Wildlife Management Area (ORWMA) was a 5,977-ha state-owned wildlife management area within the floodplain of the Pearl River in Pearl River County, Mississippi. Water levels in the numerous rivers, bayous, and sloughs were influenced by rainfall amounts and water discharge from Ross Barnett Reservoir located 180 km to the north. Major forest types on the area were approximately 95% palustrine forested wetlands of both BLH (oak-gum mix) and bald cypress-tupelo gum wetlands, with the other 5% consisting of pine-hardwood stands (C. Hunt, Miss. Dep. Wildl., Fish., and Parks, pers. commun.).

Three large tupelo gum-bald cypress stands within this area were selected for sampling: 1) a 35.5-ha stand of tupelo gum-bald cypress and blackgum (*Nyssa sylvatica*) north of Ten Landing; 2) a 3.5-ha bald cypress stand in Socias Lake Pond; and 3) a 15.5-ha tupelo gum-bald cypress stand northeast of Wise Lake.

Bogue Chitto National Wildlife Refuge. Bogue Chitto National Wildlife Refuge (BCNWR) in the Pearl River floodplain contained timber stands similar to ORWMA. A 27-ha bald cypress-tupelo gum stand, located east of the Pearl River Ship Canal and approximately 2 km south of Lock No. 2 in St. Tammany Parish, Louisiana, was sampled.

Panther Swamp National Wildlife Refuge. Panther Swamp National Wildlife Refuge (PSNWR) was a 10,985-ha area located in the Delta region of Yazoo County, Mississippi. About 360 ha of the refuge were bald cypress-tupelo gum wetlands. Brushy Lake, Mink Slough, Little Tupelo Brake, and Middle Slough, containing a total of 79.5 ha, were selected for sampling.

Wilkes Creek. Wilkes Creek (WC) was a 65-ha, tupelo gum-bald cypress stand located within the Tenn-Tom Waterway floodplain in Greene County, Alabama. The Waterway lock and dam system stabilized water levels and killed timber near the mouth of Wilkes Creek. This area was considered unsafe to sample, but a 32.5-ha area of live tupelo gum-bald cypress just upstream was chosen for sampling.

Sampling Scheme

Stands chosen for sampling were delineated on U.S. Geological Survey 7.5′ topographic maps. A grid of 0.5-ha plots was overlaid on maps and oriented along cardinal compass headings. Any plot with ≥75% of the area falling within a stand was considered available for sampling. Available plots were assigned numbers and a 10% sample was randomly taken from each stand. Plots chosen were delineated on the ground by fluorescent vinyl tape. All trees ≥10.16 cm dbh within 17.84 m of the center point of each plot were measured (dbh was measured 45.7 cm above the butt swell) to estimate mean dbh and basal area. These parameters were used to determine stand characteristics and allow comparisons among plots and stands.

Ages of the stands were determined using the tree closest to the centerpoint

within each quarter. This method was believed adequate because regeneration characteristics of bald cypress and tupelo gum usually provide even-aged stands (J. Hodges, Miss. State Univ., pers. commun.). An increment bore was used to extract cores for aging. Core samples of tupelo gum were stained to show annual rings.

All trees ≥28 cm dbh within each plot were searched for cavities using binoculars. Canopies were searched again during the tree-climbing phase to insure that no cavities had been overlooked.

Reported characteristics of suitable cavities ranged from 1.2 to 17.1 m above the ground with a tree dbh ≥28 cm, a horizontal entrance 7.6 cm in diameter, a cavity depth of 10.2 to 198 cm, and a base platform ≥12.7 × 17.7 cm (Dreis and Hendrickson 1952, Bellrose et al. 1964, Grice and Rogers 1965, McGilvery 1968, Prince 1968, Gilmer 1971, Bellrose 1976, Lowney 1987).

Trees with cavity entrances appearing to be ≥5 cm in diameter were tagged in our study with fluorescent vinyl tape and marked with numbered aluminum tags. Observed frequencies of cavity entrance formation were analyzed using a Chi-square contingency table (Steel and Torrie 1980) to determine if cavity entrance formation was directly related to tree species. We measured cavity dimensions, tree species, age, stand density within 0.01 ha (5.64-m radius), cardinal direction of cavity entrance, cavity orientation to the nearest 0.01-ha opening in the forest canopy, distance to nearest canopy opening, and cause of cavity formation. Evidence of cavity use by wildlife was noted.

Results

A total of 18 tree species were represented in the plots sampled. Tupelo gum had the highest importance value (Oostings 1956) in all study sites except BCNWR (Table 1), where bald cypress was most important. Bald cypress ($\bar{x}$ dbh = 35.8 cm) were larger ($P < 0.05$) than tupelo gum ($\bar{x}$ dbh = 31.8 cm). Bald cypress and tupelo

Table 1. Characteristics for bald cypress (*Taxodium distichum*) (*T.d.*) and tupelo gum (*Nyssa aquatica*) (*N.a.*) stands on Silver Spur Hunting Club (SSHC), Old River Wildlife Management Area (ORWMA), Bogue Chitto National Wildlife Refuge (BCNWR), Panther Swamp National Wildlife Refuge (PSNWR), and Wilkes Creek (WC) study areas, 1988–1990.

Study area	Area (ha)	Plots (*N*)	$\bar{x}$ age	$\bar{x}$ dbh	Importance value (%)[a]	
					T.d.	*N.a.*
SSHC	47.0	9	78.5	31.2	60.7	200.8
ORWMA	55.0	11	112.2	29.2	81.0	89.1
BCNWR	27.0	6	147.3	37.1	99.7	82.3
PSNWR	79.5	15	153.7	27.4	70.0	155.1
WC	32.5	7	96.4	26.9	76.6	175.2
Average			117.6	30.4	77.6	140.5

[a] Importance value defined as the additive total of relative frequency, density, and dominance (Oosting 1956).

gum were similarly distributed within the stands, with $\bar{x}$ relative frequencies of 26.3% and 24.9%, respectively. Bald cypress appeared in 47 of 48 total plots, whereas tupelo gum was absent from only 2 plots. Other species were less well-distributed and occurred less frequently. Tupelo gum averaged 798 stems/ha and bald cypress averaged 269 stems/ha among stands. Mean age of the stands was 117.6 ± 16.7 (N = 192) years, with a range of 78.5 to 153.7 years among study areas (Table 1).

Only 2 of 165 side-entrance cavities (1.2%) examined on 48 0.5-ha plots were suitable for wood duck nesting (Table 2). The mean density of suitable cavities was 0.08/ha (SE = 0.03) of bald cypress-tupelo gum habitat (Table 2). These data suggest a total of 20 suitable cavities distributed within the 241 ha studied. Cavity densities within study areas ranged from 0.0/ha to 0.29/ha. Eight dead trees and 3 live bald cypress trees containing potential cavities were not climbed because of honey bees (*Apis* sp.) and safety hazards.

Side-entrance cavities (96.7%) predominated in bald cypress. Tupelo gum and black gum (*Nyssa sylvatica*) tended to form bucket cavities (χ^2 = 86.13, d.f. = 2, P < 0.05).

Only 42.6% of the 61 side-entrance cavities in bald cypress located from the ground had adequate entrance dimensions. Tupelo gum and black gum contained 87 and 12 side entrance cavities, respectively, and 75% of the entrances met *suitability* requirements (Table 3). However, these cavities were unsuitable because of unacceptable internal dimensions or the presence of water within the cavity.

Of the 165 potential cavities, 152 (92.1%) of them were formed by damage to the tree. Of these, 97% (N = 147), including the 2 suitable cavities, formed where limbs had broken. Entrance dimensions in most cases were deemed too small for a wood duck to enter.

The 215 bucket cavities examined during this study were excluded from the analysis after examinations revealed they were filled with water and debris and were

Table 2. Densities of cavities suitable for wood duck nests on Silver Spur Hunting Club (SSHC), Old River Wildlife Management Area (ORWMA), Bogue Chitto National Wildlife Refuge (BCNWR), Panther Swamp National Wildlife Refuge (PSNWR), and Wilkes Creek (WC) study areas, 1988–1990.

Study area	Area sampled (ha)	Trees climbed (N)	Suitable cavities (N)	Suitable cavities/ha
SSHC	4.5	13	0[a]	0.000
ORWMA	5.5	32	1[b]	0.182
BCNWR	3.0	15	0[b]	0.000
PSNWR	7.5	57	0[b,c]	0.000
WC	3.5	31	1	0.286
Total	24.0	148	2	0.083

[a]Two cavity trees contained honey bees (*Apis* sp.) and were not climbed for internal measurements.

[b]One cavity met dimensional criteria, but moisture within the cavity rendered it unsuitable.

[c]One cavity tree contained honey bees (*Apis* sp.) and was not climbed for internal measurements.

Table 3. Number of side-entrance cavities with suitable entrance dimensions (7.6 cm diameter) by tree species on 5 study sites in 3 southeastern states from 1988 through 1990.

Species	Side entrance cavities (*N*)	Cavities with suitable entrance dimensions (*N*)
Bald cypress (*Taxodium distichum*)	61	26
Tupelo gum (*Nyssa aquatica*)	87	65
Sugarberry (*Celtis laevigata*)	3	0
Black gum (*Nyssa sylvatica*)	12	9
Cottonwood (*Populus deltoides*)	2	0
Totals	165	100

therefore not suitable for wood duck nesting. Two side-entrance cavities with suitable dimensions also were deemed unsuitable because of standing water within. Two of the study areas were sampled during summer periods, and water was found inside bucket cavities when measurable rainfall had not been recorded for approximately 4 weeks. Clearly, bucket cavities examined during the present study were not suitable nest sites because of excessive rainfall and its retention (Hester 1955, Lowney 1987).

Discussion

Compared to cavity densities suitable for wood duck nesting reported at more northern latitudes (Bellrose et al. 1964, Grice and Rogers 1965, Prince 1968, Gilmer 1971, Gilmer et al. 1978, Soulliere 1988), our study areas contained only a small percentage of suitable cavities. The mean density of suitable natural cavities found in the bald cypress-tupelo gum stands on the 5 areas sampled was among the lowest densities reported for timber stands in North America. Three of 5 study sites contained no suitable cavities. Woods (1964) reported a similar density of suitable cavities (0.075/ha) for a site in Mississippi, but the stand types were mostly oak (*Quercus* spp.)-sweetgum (*Liquidambar styraciflua*). Strange et al. (1971) and Teels (1975) reported higher cavity densities (0.52–0.62/ha) than we found in similar stand types. The stands studied by Strange et al. (1971) were in sloughs containing primarily bald cypress and black willow (*Salix nigra*), whereas Teels (1975) studied a 53-ha tupelo gum swamp located about 2 km from the SSHC study site.

Most suitable cavities (81.1%–100%) reported in other studies were in live trees (Prince 1968, Weier 1966, Boyer 1974, Teels 1975, Soulliere 1985, Robb 1986). Soulliere (1990) noted that cavities in live trees were more important to wood ducks as long as entrances remained open and stable platforms existed.

Broken limbs and heartrot accounted for ≥60% of tree cavity formation in forest stands in Wisconsin (Souilliere 1990). Limbs that had become shaded and that occurred below the main canopy appeared to be most vulnerable to limb breakage. Baumgartner (1939) noted that shaded limbs unable to carry on photosynthesis weakened and broke easily.

Prince (1968) and Gilmer (1971) reported the use of both vertical or bucket nests

by wood ducks; however, Hester (1955) noted that wood ducks abandoned bucket cavities in the southeast after heavy rains. Moreover, Lowney (1987) reported that bucket cavities retained water even during dry periods and were not used.

None of the cavities found within stands sampled were attributed to pileated woodpecker (*Hylatomus pileatus*) activity. However, we noticed several (unmeasured) cavities outside the study plots made by woodpeckers. Cavity size indicated that other species besides the pileated woodpecker were responsible for their development. Pileated woodpecker cavities were not considered to significantly contribute to cavity densities in several studies (Weier 1966, Prince 1968, Nagel 1969, Robb 1986, Lowney 1987); however, their high use rates by wood ducks may increase their importance (Soulliere 1990).

Lowney (1987) reported that beech (*Fagus grandifolia*) and sycamore (*Platanus occidentalis*) had the greatest potential in southern forests to produce wood duck nesting sites, exclusive of bald cypress and tupelo gum. Prince (1968) listed silver maple (*Acer saccharinum*) and American elm (*Ulmus americana*) as having the greatest cavity-forming potential, but like beech and sycamore, these species were not located within the 5 areas studied. Red maple (*Acer rubrum*), the only species listed among northern studies as a significant cavity producer (Haramis 1975, Robb 1986), also occurred in bald cypress-tupelo gum plots we sampled. However, most red maple trees were too small ($\bar{x}$ dbh = 15.0 cm) to be considered for cavity production.

Management Implications

A shortage of suitable wood duck nesting cavities in southern bottomland hardwood forest stands was quantified earlier (Lowney and Hill 1989). Information from the present study on natural cavities in bald cypress-tupelo gum stands fills an important data gap regarding the suitability of riparian and wetland forests in the southern United States as nesting habitat for wood ducks. We did not determine whether cavity densities were a limiting factor on population levels, as noted for other locations (Hawkins and Bellrose 1940, McLaughlin and Grice 1952, McGilvery 1968). Because of comparatively low cavity density rates in bald cypress-tupelo gum and other southern (Lowney and Hill 1989) and midwestern (Bellrose et al. 1964, Nagle 1969) riparian and bottomland forest types, managers should consider the limited density of natural nesting sites in local wood duck management. Opportunities to enhance recruitment with nest box programs should be considered in areas where numbers of natural nesting cavities are inadequate.

Soulliere (1986) questioned the value of nest box programs in Wisconsin, where only 0.3% of an estimated 162,500 nesting females used boxes erected by the Wisconsin Department of Natural Resources. Soulliere (1990) also questioned the value of nest boxes in population management on the regional level. However, nest boxes with predator guards have proven successful in establishing and maintaining nesting populations where previously none or only isolated pairs existed (Hawkins and Bellrose 1940, Dreis 1951, Bellrose et al. 1964, Grice and Rogers 1965, Cunningham 1969, Gore 1978). Lowney (1987) reported that a Mississippi population decreased

when local nest boxes were phased out. Because bald cypress and tupelo gum stands contained low densities of cavities similar to other southern riparian stands (Lowney and Hill 1989), maintaining densities of nesting sites comparable to densities of suitable natural cavities at more northern latitudes would be required through supplemental means.

Although decreasing trends in timber harvests within the bottomland hardwood forests of the lower Mississippi alluvial valley are expected to close the gap between hardwood growth and removal (U.S. For. Serv. 1988), current regulations on timber harvest practices within wetlands should discourage harvest in bald cypress-tupelo gum stands. Decreasing harvest rates should increase stand ages and individual tree size, which should increase the potential for suitable cavity formation (Hansen 1966).

Literature Cited

Aultfather, W. A. 1966. Impact of forest management and other human activities on northern wood duck habitat. Pages 23–29 *in* J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, D.C. 212pp.

Baumgartner, L. L. 1939. Fox squirrel dens. J. Mammal. 20:456–465.

Bellrose, F. C. 1976. The comeback of the wood duck. Wildl. Soc. Bull. 4:107–110.

———, K. L. Johnson, and T. U. Meyers. 1964. Relative value of natural cavities and nesting houses for wood ducks. J. Wildl. Manage. 28:661–676.

Boyer, R. L. 1974. A survey of wood duck nest sites and brood habitat on the Shiawassee National Wildlife Refuge. M.S. Thesis, Central Mich. Univ., Mount Pleasant. 65pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. FWS/OBS - 79/31. 131pp.

Cunningham, E. R. 1969. A three-year study of the wood duck on the Yazoo National Wildlife Refuge. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 22:145–155.

Dreis, R. E. 1951. Productivity of the wood duck in eastern Louisa Co., Iowa, 1951. Iowa Bird Life 22:18–22.

——— and G. O. Hendrickson. 1952. Wood duck production from nest boxes and natural cavities on Lake Odessa area, Iowa, in 1951. Iowa Bird Life 22:18–22.

Gilmer, D. S. 1971. Home range and habitat use of breeding mallards and wood ducks in north central Minnesota as determined by radio tracking. Ph.D. Diss., Univ. Minn., St. Paul. 142pp.

———, I. J. Ball, L. M. Cowardin, J. E. Matisen, and J. H. Reechman. 1978. Natural cavities used by wood ducks in north-central Minnesota. J. Wildl. Manage. 42:288–298.

Gore, J. F. 1978. Wood duck response to nesting boxes placed in low quality habitat. Trans. Ill. State Acad. Sci., 71:295–299.

Grice, D. and J. P. Rogers. 1965. The wood duck in Massachusetts. Mass. Div. Fish and Game, Final Rep., Fed. Aid Proj. No. W-19-R. 96pp.

Hansen, H. L. 1966. Silvical characteristics of tree species and decay process as related to cavity production. Pages 65–69 *in* J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, D.C. 212pp.

Haramis, G. M. 1975. Wood duck (*Aix sponsa*) ecology and management within the green-timber impoundments at Montezuma National Wildlife Refuge. M.S. Thesis, Cornell Univ., Ithaca, N.Y. 153pp.

Hawkins, A. S. and F. C. Bellrose. 1940. Wood duck habitat management in Illinois. Trans. North Am. Wildl. Conf. 5:392–395.

Hester, F. E. 1955. The wood duck in east-central North Carolina. M.S. Thesis, North Carolina State College, Raleigh. 59pp.

Lowney, M. S. 1987. Availability and use of natural cavities for wood duck production in bottomland hardwood forests in the lower Mississippi flyway. M.S. Thesis, Miss. State Univ., Starkville. 52pp.

——— and E. P. Hill. 1989. Wood duck nest sites in bottomland hardwood forests of Mississippi. J. Wildl. Manage. 53:378–382.

McGilvery, F. B. 1968. Wood duck production habitat requirements. U.S. Fish and Wildl. Resour. Publ. 60. 32pp.

McLaughlin, C. L. and D. Grice. 1952. The effectiveness of large scale erection of wood duck boxes as a management procedure. Trans. North Am. Wildl. Conf. 17:242–259.

Nagel, R. E. 1969. Predation on eggs in simulated nests and tree cavity abundance in wood duck nesting habitat. M.S. Thesis, Iowa State Univ., Ames. 90pp.

Oosting, H. J. The study of plant communities. W. H. Freeman and Company, San Francisco. 440pp.

Prince, H. H. 1968. Nest sites of wood ducks and common goldeneye in central New Brunswick. J. Wildl. Manage. 32:489–500.

Robb, J. R. 1986. The importance of nesting cavities and brood habitat to wood duck production. M.S. Thesis, Ohio State Univ., Columbus. 135pp.

Soulliere, G. J. 1985. Wood duck production and management in central Wisconsin. M.S. Thesis, Univ. Wisc., Stevens Point. 60pp.

———. 1986. Cost and significance of a wood duck nest house program in Wisconsin: an evaluation. Wildl. Soc. Bull. 14:391–395.

———. 1988. Density of suitable wood duck nest cavities in a northern hardwood forest. J. Wildl. Manage. 52:86–89.

———. 1990. Review of wood duck nest-cavity characteristics. Pages 153–162 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North Am. Wood Duck Symp., St. Louis.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach, second ed. McGraw-Hill Book Company, New York. 633pp.

Strange, T. H., E. R. Cunningham, and J. W. Goertz. 1971. Use of nest boxes by wood ducks in Mississippi. J. Wildl. Manage. 35:786–793.

Teels, B. M. 1975. Waterfowl production and utilization along the proposed route of the Tennessee-Tombigbee Waterway. Ph.D. Diss., Miss. State Univ., Starkville. 84pp.

U.S. Fish and Wildlife Service. 1979. Objectives, policies, and strategies for wood duck box programs in region IV. U.S. Dep. Int., Fish and Wildl. Serv., Atlanta, Ga. 2pp.

———. 1987. Increasing wood duck production on refuge lands. U.S. Dep. Int., Fish and Wildl. Serv., Atlanta, Ga. 5pp.

U.S. Forest Service. 1988. The South's fourth forest: alternatives for the future. U.S. Dep. Agric., For. Serv. For. Resour. Rep. 24, 512pp.

Weier, W. R. 1966. A survey of wood duck nest sites on Mingo National Wildlife Refuge in southeast Missouri. Pages 91–108 *in* J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, D.C. 212pp.

Woods, E. 1964. A preliminary study of wood duck habitat and production on Noxubee National Wildlife Refuge. M.S. Thesis, Miss. State Univ., Starkville. 31pp.