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Artificial cavities enhance breeding bird densities in managed cottonwood forests

Daniel J. Twedt and Jackie L. Henne-Kerr

Abstract The paucity of natural cavities within short-rotation hardwood agroforests restricts occupancy by cavity-nesting birds. However, providing 1.6 artificial nesting cavities (nest boxes)/ha within 3- to 10-year-old managed cottonwood forests in the Mississippi Alluvial Valley increased territory density of cavity-nesting birds. Differences in territory densities between forests with and without nest boxes increased as stands aged. Seven bird species initiated 38 nests in 173 boxes during 1997 and 39 nests in 172 boxes during 1998. Prothonotary warblers (*Protonotaria citrea*) and eastern bluebirds (*Sialia sialis*) accounted for 67% of nests; nearly all warbler nests were in 1.8-L, plastic-coated cardboard (paper) boxes, whereas bluebird nests were divided between paper boxes and 3.5-L wooden boxes. Larger-volume (16.5-L) wooden nest boxes were used by eastern screech owls (*Otus asio*) and great crested flycatchers (*Myiarchus crinitus*), but this box type often was usurped by honey bees (*Apis mellifera*). To enhance territory densities of cavity-nesting birds in cottonwood agroforests, we recommend placement of plastic-coated paper nest boxes, at a density of 0.5/ha, after trees are >4 years old but at least 2 years before anticipated timber harvest.

Key words agroforestry, artificial cavity, cottonwood, eastern bluebird, Mississippi, nest box, plantation, *Populus deltoides,* prothonotary warbler, *Protonotaria citrea, Sialia sialis*

Less than 25% of the historical bottomland forest remains within the now largely agricultural landscape of the Mississippi Alluvial Valley (Twedt and Loesch 1999). An avian conservation plan for this physiographic region recommends restoration of a substantial area of bottomland hardwood forest (Mueller et al. 2000). In recent years, reforestation on public land accessions and on privately owned lands through the Wetland Reserve Program (United States Department of Agriculture) has made remarkable progress toward meeting the conservation objective of increased area of bottomland forest. Even so, these additions to the forested landscape are insufficient to achieve all habitat objectives proposed for avian conservation by Mueller et al. (2000). Augmenting existing bottomland forests with intensively managed hardwood agroforests would further increase this region's total forested landscape and could act as a buffer that would increase the area of forest interior habitat (Twedt and Uihlein 2000).

In the Mississippi Alluvial Valley, intensively managed hardwood agroforests are often planted with eastern cottonwood (*Populus deltoides*) and harvested on a comparatively short rotation of 10 to 15 years. Other species used in agroforestry (e.g.,

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American sycamore [*Platanus occidentalis*] and sweetgum [*Liquidambar styraciflua*]) lengthen this rotation period to about 20 years, but this is still considerably shorter than that of hardwood stands managed for sawtimber. Previous investigations (Tomlinson 1977, Twedt et al. 1999) found that number of bird species and their territory densities were significantly less in young cottonwood agroforests than in mature bottomland hardwood forests. In particular, 7 of 12 species with significantly reduced territory densities in agroforests nest in cavities (Twedt et al. 1996).

Despite the paucity of cavity-nesting species in cottonwood agroforests, the few natural cavities present are used by cavity nesters such as red-bellied woodpeckers (*Melanerpes carolinus*), eastern bluebirds (*Sialia sialis*), and Carolina chickadees (*Poecile carolinensis*; D. J. Twedt, personal observation). Use of natural cavities within cottonwood agroforests and 54% annual use by breeding birds of nest boxes along roadways adjacent to cottonwood agroforests (J. L. Henne-Kerr, unpublished data) suggested that providing artificial cavities within intensively managed cottonwood agroforests could increase territory density and productivity of cavity-nesting species.

Previous researchers have achieved mixed results by providing nest boxes in forested habitats. Conner et al. (1995) found minimal avian use of nest boxes (13 occupants in 240 boxes visited 3 times/year for 6 years) within 4 forest types in east Texas. In mixed pine-hardwood forests of the Ouachita Mountains, Arkansas, Caster et al. (1994) reported 15% avian use of nest boxes. However, Blem and Blem (1991) found prothonotary warbler (*Protonotaria citrea*) eggs in 31% of 355 nest boxes in tidal swamps of Virginia. Even greater use of nest boxes was reported by Fleming and Petit (1986):81 of 145 boxes within bottomland hardwoods in west Tennessee were used by prothonotary warblers.

We erected nest boxes within cottonwood agroforests and monitored use to evaluate their acceptance, to ascertain nest survival, and to assess their influence on avian territory density. Based on previous studies, we hypothesized that bird occupancy of nest boxes would be between 10% and 30%. Additionally, we hypothesized that providing nest boxes would increase density of breeding birds within cottonwood agroforests. Thus, we compared breeding bird density and richness between stands with and without nest boxes and as a function of stand age.

If nest boxes were accepted by breeding birds and they increased avian densities, then expansion of nest-box placement to large commercial agroforests requires an additional assessment of their cost and durability. Therefore, we compared durability and cost of wooden and plastic-coated paper nest boxes.

Study area

Cottonwood agroforest stands were on or adjacent to Fitler Managed Forest, Issaquena County, Mississippi (32° 40′ N, 91° 02′ W). Fitler is a private industrial forest managed primarily for production of pulpwood. The mainstem Mississippi River levee transected Fitler Managed Forest and protected 11 of 15 study stands from Mississippi River floodwater. However, during spring, some protected stands experienced flooding from backwater associated with the Steele Bayou drainage and local cypress brakes. Study stands ranged from 23 to 81 ha ($\bar{x}$= 48), and each represented a separate management unit. Study stands were interspersed among a matrix of 8,000 ha of young (<12 years old) cottonwood agroforests and 4,000 ha of bottomland hardwood forests and managed wetlands. Trees were planted on a 3.7 m × 3.7-m (12 × 12 ft) spacing and ranged from 2 to 10 years old (Table 1).

Table 1. Cottonwood agroforest stands on Fitler Managed Forest, Fitler, Mississippi, surveyed for breeding birds from 1994 to 1998 using Breeding Bird Census methodology. Age is in years when first surveyed, × = stand surveyed, ⊗ = nest boxes on stand when surveyed.

Stand	Age	1994	1995	1996	1997	1998
Brak	6	×	×	×	⊗	⊗
Leve	6	×	×	×	×	—
Pipe	6	×	×	×	⊗	—
Gumt	6	×	×	×	—	—
Grov	2	—	—	×	⊗	⊗
Offl	2	—	—	×	⊗	⊗
Reed	4	—	—	×	×	×
Hous	2	—	—	×	—	—
Bayo	7	—	—	—	×	×
East	4	—	—	—	⊗	⊗
Rive	7	—	—	—	⊗	⊗
Sec1	3	—	—	—	⊗	⊗
Stee	7	—	—	—	⊗	⊗
Tric	5	—	—	—	×	—
Tabo	7	—	—	—	—	⊗
Total		4	4	8	12	10

Methods

We determined species richness and territory density of breeding birds on study stands using 13.5-ha (300 × 450 m) study plots that were spot-mapped during ≥8 visits/year following standard Breeding Bird Census techniques (Anonymous 1970). We standardized densities for each bird species to number of territories/40 ha. Distances between study plots ranged from 0.8 km to 9.1 km. We obtained pretreatment data on avian species richness and territory density from 4 stands during 1994 and 1995 and from 8 stands during 1996 (Table 1).

During February 1997, we randomly selected 4 of these previously surveyed stands for treatment with nest boxes with the restriction that nest boxes be equally divided between young (3 to 6 years old) and old (7 to 10 years old) cottonwood stands. We also selected 8 additional, previously unsurveyed, cottonwood agroforest stands. We randomly (with age restriction) chose 4 of these newly selected stands for treatment with nest boxes (Table 1). Within each treated stand, we placed 20 small nest boxes. Ten cypress (wood) nest boxes had inside dimensions of 10 × 14 × 25 cm (width, depth, height) with a 3.5-cm-diameter entrance hole. Ten plastic-coated cardboard (paper) nest boxes (Fleming and Petit 1986) were 9.5 × 9.5 × 20 cm with a 3.8-cm-diameter entrance hole. We randomly assigned box types to placement locations at 80 × 100-m grid intersections on study plots. Additionally, we placed 1 or 2 large (20 × 23 × 36 cm, 7.6-cm-diameter entrance hole) wooden nest boxes in each treated stand. All wood boxes were mounted to trees with aluminum nails. Paper boxes were taped to trees with plastic strapping tape. After one breeding season, we replaced paper boxes, this time attaching boxes to trees using an aluminum nail through a 5-cm-wide wooden block (Twedt and Henne-Kerr 2000). All nest boxes were mottled brown, gray, and black with spray paint.

During 1997 we installed 80 wood, 80 paper, and 13 large boxes among 8 cottonwood stands. Because of timber harvest, boxes from one 10-year-old stand were moved to a 7-year-old stand after the 1997 breeding season. One large box was destroyed during this move, and only 12 large boxes were available during 1998. Boxes were placed at an average height of 2.4 m (range = 1.5–3.1 m). Orientation of boxes was haphazard, but we avoided subjecting boxes to southern exposures, as suggested by Blem and Blem (1991).

During 1997 we surveyed birds on 8 stands treated with nest boxes and 4 stands without boxes (Table 1). During 1998 we surveyed 8 treated stands and 2 untreated stands. Because of ongoing timber harvests and limitations on stand access, only one stand was surveyed over all 5 years of this study (Table 1).

We assessed box occupancy on treated stands by monitoring nest boxes every 7 to 10 days from 31 March to 25 July 1997 and from 1 April to 3 July 1998. During each visit to a box we recorded species occupying the box (including non-avian species that were potential box competitors), number of eggs or young (host and parasite), and the physical condition of the box. When boxes contained nests, we assessed nest survival by monitoring at 3- to 5-day intervals as young approached fledging (Martin and Guepel 1990). We determined rate of parasitism, mean egg production, and mean number of fledglings produced/successful nest for each breeding species.

We compared box occupancy rates between years, among box types, and among stand ages using likelihood-ratio chi-square tests (Fienberg 1989), with number of occupied boxes of each type being the observed values. We calculated modified Mayfield (1961, 1975) nest survival rates (Johnson 1979, Bart and Robson 1982) and their associated variances (Hensler and Nichols 1981). We tested the null hypothesis of equal nest survival among box types using the program CONTRAST (Hines and Sauer 1989).

We compared species richness and territory density of breeding birds between forest stands provisioned with artificial cavities and those without artificial cavities using a repeated measures analysis of variance (ANOVA). Because we did not survey all stands in all years, we accounted for the gaps in the experimental design by using an ANOVA with unequal number of subplots (Milliken and Johnson 1984). We also accounted for repeated censuses (i.e., breeding bird censuses conducted within the same stand in different years) by constructing approximate F-ratios within this ANOVA wherein number of stands within each nest box treatment was the error term to test differences between nest-box treatments (Milliken and Johnson 1984). Because avian densities appeared to increase with stand age, we also used analysis of covariance, with age of forest stands as the covariate, to examine the interaction of stand age and provision of artificial cavities.

Table 2. Use of 80 paper nest boxes, 80 small wooden nest boxes, and 13 large wooden nest boxes by breeding birds in intensively managed cottonwood agroforests at Filter Managed Forest, Filter, Mississippi, USA.

Box type	1997	1998	Both
Paper	11[a]	19[a]	6
Wood	11[b]	8[b]	1
Large [c]	5	1	1

[a] Two boxes had 2 nests in same box.
[b] One box had 2 nests in same box.
[c] Only 12 large boxes available in 1998.

Results

We detected 62 bird species on our study stands (Appendix 1). Seven avian species built 77 nests in 63 boxes during the 2 years they were available (Table 2). An additional 13 boxes contained nesting material, but these nests were not completed, eggs were never laid, or nests were depredated before an observer visit; we did not use these nests to calculate nest survival. Box occupancy by birds within study stands ranged from 1 to 11 boxes ($\bar{x}$=4.8)/ year.

Rate of box occupancy by birds did not differ between study years (G^2_1=0.001, P=0.98), and box use was not related to age of forest stand (G^2_6= 10.35, P=0.11). However, we detected significant differences in occupancy among box types (G^2_2= 10.2, P<0.01). Large boxes had the greatest occupancy rate (32%), followed closely by paper boxes (28%), whereas only 14% of wood boxes were occupied.

Overall daily survival rates for nests in large boxes (0.984±0.009, $\bar{x}$±SE), paper boxes (0.973± 0.006), and wood boxes (0.964±0.010) did not differ significantly (χ^2_2=2.41, P= 0.30). Nest success of individual species with ≥6 nests ranged from 23.3% for eastern bluebird to 62.2% for Carolina chickadee (Table 3). Selection of box types and subsequent nest success varied among species (Table 3). Only eastern bluebird had ≥10 nests in paper and wood boxes; their nest success was greater (χ^2_1= 5.60, P = 0.02) in paper boxes (0.982 ± 0.009) than in wood boxes (0.927±0.021).

Two species were parasitized by brown-headed cowbirds (*Molothrus ater*); 1 of 7 Carolina wren (*Thryothorus ludovicianus*) nests and 13 of 29 prothonotary warbler nests were parasitized. However, all nests that fledged cowbirds also fledged prothonotary warblers (Table 3).

Analysis of covariance on breeding bird census data revealed that species richness increased with age of forest stands ($F_{1,34}$=17.42, P<0.01), with an average of 1.3 species added annually within the 13.5-ha study plots (Figure 1). The number of species detected on cottonwood agroforests with artificial cavities (20.2±1.0) was similar ($F_{1,19.5}$= 2.43, P= 0.14) to species richness on untreated cottonwood stands (18.0±0.9).

Total territory density of all birds ($F_{1,34}$=13.78, P < 0.01) and the territory density of cavity-nesting birds ($F_{1,34}$=29.16, P< 0.01) increased with stand age. For cavity-nesting birds, an average of 1.9 territories/40 ha were added for each year of forest age. However, the annual increase in cavity-nesting bird territories was greater ($F_{1,34}$=6.43, P =0.02) on stands provisioned with next boxes than on stands without artificial cavities (Figure 1). On stands with nest boxes, territory density of all birds (218.2± 15.3 territories/40 ha) was

Table 3. Number of nests, by species, within large wooden (16.5-L), small wooden (3.5-L), and paper (1.8-L) nest boxes within cottonwood agroforests at Fitler Managed Forest, Fitler, Mississippi, and the total number of exposure days, daily nest survival rate (DSR), percentage nest success, mean number of eggs laid, and mean number of young fledged from successful nests during 1997 and 1998.

	Nests: total (successful)							
Species	Large	Wood	Paper	Exposure days	DSR ± SE	Nest success	Eggs	Young fledged
Carolina chickadee	0	2 (1)	5 (3)[a]	140	0.986 ± 0.010	62.2	5.2	5.0
Carolina wren	3 (1)	2 (2)	2 (0)	104	0.962 ± 0.019	29.6	4.3 (0.4)[b]	4.3
Eastern bluebird	0	13 (2)	10 (6)	368	0.959 ± 0.010	23.3	4.3	3.2
Eastern screech owl	2 (2)	0	0	90	1.000 ± 0.000	100.0	3.5	2.0
Tufted titmouse	0	5 (3)	1 (0)	126	0.976 ± 0.014	42.0	5.2	3.7
Great-crested flycatcher	3 (2)	0	0	57	0.982 ± 0.017	52.0	3.7	3.0
Prothonotary warbler	0	1 (1)	28 (14)	515	0.972 ± 0.007	44.3	4.1 (0.8)[b]	3.1 (0.5)[b]

[a] One nest destroyed by observer not used in calculating nest success.
[b] Eggs or young of brown-headed cowbirds (*Molothrus ater*).

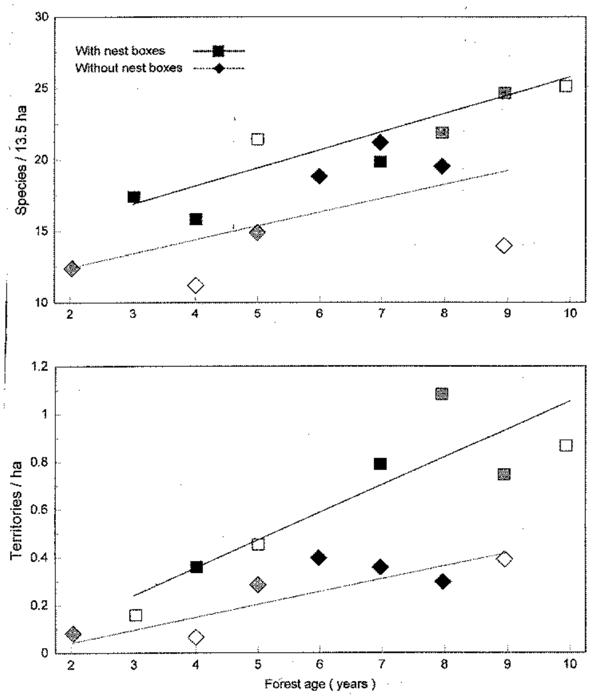

Figure 1. Mean species richness and density of cavity-nesting birds within 13.5-ha study plots on cottonwood agroforests on Fitler Managed Forest, Fitler, Mississippi, from 1994 to 1998. Open polygons (n = 1), shaded polygons (n = 2), solid polygons ($n \geq 3$).

greater ($F_{1,18}$= 6.45, P< 0.01) than the 161.0±10.8 territories/40 ha on stands without nest boxes (Appendix 1). Notably, density of cavity-nesting birds was greater ($F_{1,19.5}$= 19.55, P<0.01) on stands provisioned with nest boxes (24.7±4.1 territories/40 ha) than on stands without nest boxes (11.8±1.8 territories/40 ha). The territory densities of 3 species of cavity-nesting birds (Carolina chickadee, Carolina wren, and prothonotary warbler) were markedly increased after addition of nest boxes.

Although nest boxes were intended for use by birds, invertebrates were by far the most frequent occupants of the 345 nest boxes that were available over the 2 years of our study. Wasps (Vespidae) were nearly ubiquitous, present in 311 boxes. Paper wasps (*Polistes* spp.) were encountered most commonly, but yellowjackets (*Vespula* spp.) and mud-daubers (*Trypoxylon* spp.) also were present. We also detected spiders (Araneae) at 68 boxes and ants (primarily fire ants [*Solenopsis invicta*]) at 27 boxes, despite recording their presence only when we subjectively estimated that their presence might deter bird use (e.g., webs covered box entrance or large masses of fire ants). Honey bees (*Apis mellifera*) filled 7 large boxes with honeycombs, rendering these boxes unusable by birds. We also encountered bats (2), frogs (10), lizards (4), mice (8), and snakes (6) within nest boxes.

Discussion

Overall nest-box occupancy (22%), although less than that for nest boxes in tidal swamps (Blem and Blem 1991) and bottomland hardwood forests (Fleming and Petit 1986), was within our hypothesized range of acceptable occupancy rates. Thus, nest boxes within cottonwood agroforests are accepted by breeding birds. Even so, we found relatively few nests for most species; therefore, species-specific estimates of nesting success are tenuous.

Species preference for box type and their relative nest success within box types were discernable from our data. Prothonotary warblers selected paper boxes, with 28 of 29 nests in this box type. Similarly, Carolina chickadees appeared to exploit paper boxes, with 5 of 7 nests and greater nest success in paper boxes. Eastern bluebirds nested in both paper and wood boxes, but nest success was greater for nests in paper boxes. Conversely, tufted titmice (*Baeolophus bicolor*) used wood boxes more than paper; only 1 of 6 nests was in a paper box and that nest was unsuccessful.

As expected, larger birds—eastern screech owls (*Otus asio*) and great crested flycatchers (*Myiarchus crinitus*)—nested only in large boxes. Unfortunately, occupation by honey bees rendered >50% of large boxes unsuitable for use by birds. This high rate of occupancy by honey bees was surprising. Coelho and Sullivan (1994) encountered honey bees in nest boxes only after the entry hole had been sealed. Similarly, Morse et al. (1993) found that honey bees rejected boxes with 6.4-cm-diameter entrance holes, instead preferring large boxes (10-13 L) with smaller (3.2-cm-diameter) entrance holes.

Our initial method of using tape to attach paper boxes to tree trunks was suitable for only a single breeding season. As trees grew, the inflexible tape constricted the paper boxes so that by the beginning of the second breeding season many boxes were unsuitable for use by breeding birds. Using aluminum nails inserted though predrilled wooden blocks to attach boxes to trees prevented crushed boxes (Twedt and Henne-Kerr 2000).

Excluding box failure due to constriction, we deemed 8 paper boxes, 11 wood boxes, and 7 large boxes unusable by birds during this study. We recorded an additional 31 paper boxes, 24 wood boxes, and 3 large boxes as damaged but still usable. Based on observed weathering of paper boxes and observations reported by Fleming and Petit (1986), we believe most paper boxes will be usable by breeding birds for only 2 breeding seasons, even with our improved attachment method.

Management implications

Overall, paper boxes outperformed wooden boxes in the areas of use and nest survival. However, providing only paper boxes will restrict occupancy by larger birds. Even so, we recommend paper boxes for extensive installation in agroforests managed with short duration between harvests. In addition to their greater use by birds and generally greater nesting success therein, a paper box costs much less (circa $0.50 US) than a wood box (circa $5.00 US).

Because placement of nest boxes enhanced territory density among stands of all ages, installation of nest boxes in relatively young stands will provide the greatest long-term benefit. However, increased territory density of cavity-nesting birds due to the provision of nest boxes was further enhanced as forest stands aged. Moreover, nailing boxes to trees <4 years old was difficult and necessitated low placement heights. Therefore, when longevity of nest boxes is less than the harvest-rotation interval (e.g., a 2-year life expectancy for paper boxes within 10-year-harvest-rotation forests), provision of artificial cavities during the latter stages of the rotation interval confers greater benefit to breeding birds. Because use of nest boxes placed at a density of 1.6 boxes/ha was <25%, placement at a density of 0.5 boxes/ha (circa 25% of original density) may be sufficient to increase densities of cavity-nesting birds within managed cottonwood forests. Thus, we recommend provision of plastic-coated paper nest boxes within cottonwood agroforests at a density of 1 box/2 ha in stands that are >4 years old, but that are at least 2 years away from timber harvest.

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Literature cited

ANONYMOUS. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723–726.

BART, J., AND D. S. ROBSON. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63:1078–1090.

BLEM, C. R., AND L. B. BLEM. 1991. Nest-box selection by prothonotary warblers. Journal of Field Ornithology 62: 299–307.

CASTER, P. T., G. A. HEIDT, K. D. STONE. 1994. Faunal use of nest boxes in the Ouachita Mountains of Central Arkansas. Southwestern Naturalist 39:380–382.

COELHO, J. R., AND J. B. SULLIVAN. 1994. Colonization of wildlife nest boxes by honey bee swarms. 1994. Apicultural Research 134:697–699.

CONNER, R. N., D. SAENZ, AND D. C. RUDOLPH. 1995. Fauna using nest boxes in four timber types in eastern Texas. Bulletin of the Texas Ornithological Society 28:2–6.

FIENBERG, S. E. 1989. The analysis of cross-classified data. Second edition. Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

FLEMING, W. J., AND D. R. PETIT. 1986. Modified milk carton nest box for studies of prothonotary warblers. Journal of Field Ornithology 57:313–315.

HENSLER, G. L., AND J. D. NICHOLS. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bulletin 93:42–53.

HINES, J. E., AND J. R. SAUER. 1989. Program CONTRAST: a general program for the analysis of several survival or recovery rate estimates. United States Fish and Wildlife Service, Technical Report 24, Washington, D.C., USA.

JOHNSON, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651–661.

MARTIN, T. E., AND G. R. GUEPEL. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:509–519.

MAYFIELD, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

MAYFIELD, H. F. 1975. Suggestions for calculating nesting success. Wilson Bulletin 87:456–466.

MILLIKEN, G. A., AND D. E. JOHNSON. 1984. Analysis of messy data. Van Nostrand Reinhold, New York, New York, USA.

MORSE, R. A., J. N. LAYNE, P. K. VISSCHER, F. RATNIEKS. 1993. Selection of nest cavity volume and entrance size by honey bees in Florida. Florida Scientist 56:163–167.

MUELLER, A. J., D. J. TWEDT, AND C. R. LOESCH. 2000. Development of management objectives for breeding birds in the Mississippi Alluvial Valley. Pages 12–17 *in* Bonney, Rick, David N. Pashley, Robert Cooper, and Larry Niles, editors. Strategies for bird conservation: the partners in flight planning process, Proceedings of the third partners in flight workshop. Proceedings RMRS-P-16, 1–5 October 1995, Cape May, New Jersey, United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah, USA.

TOMLINSON, W. H., JR. 1977. The effects of even-aged cottonwood monocultures on nongame birds and bobwhite quail. Thesis, Mississippi State University, Mississippi State, USA.

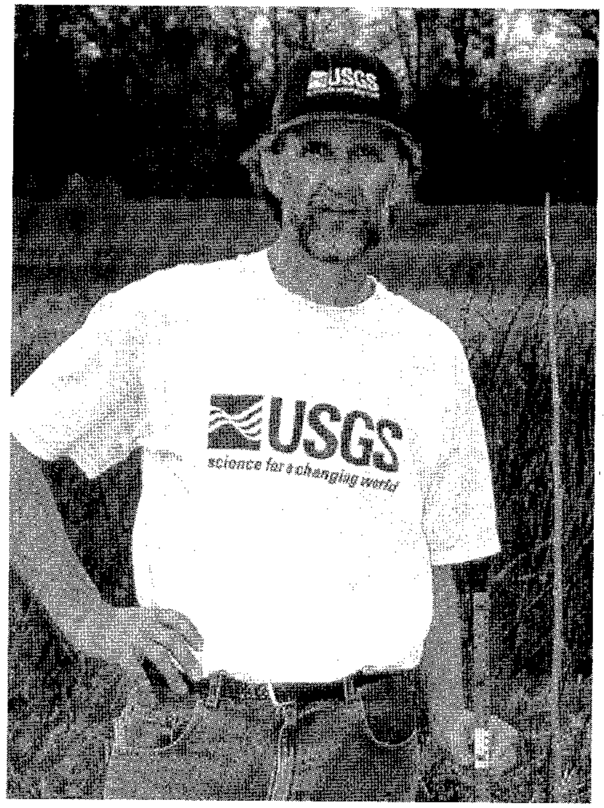
TWEDT, D. J., AND J. HENNE-KERR. 2000. Attaching paper nest boxes to fast-growing trees. North American Bird Bander 25(4): 123–133.

TWEDT, D. J., J. HENNE-KERR, W. H. TOMLINSON, AND R. B. HAMILTON. 1996. Preliminary estimates of avian density in intensively managed forests of the Mississippi Alluvial Valley. Pages 111–119 *in* Proceedings of The DELTA: Connecting points of view for sustainable natural resources. 13–16 August 1996, Memphis, Tennessee, USA.

TWEDT, D. J., AND C. R. LOESCH. 1999. Forest area and distribution in the Mississippi Alluvial Valley: implications for breeding bird conservation. Journal of Biogeography 26: 1215–1224.

TWEDT, D. J., AND W. B. UIHLEIN, III. 2000. Landscape level reforestation priorities for forest breeding landbirds in the Mississippi Alluvial Valley. In press, L. Fredrickson, editor. Ecology and management of bottomland hardwood systems symposium. 11–13 March 1999, Memphis, Tennessee, USA.

TWEDT, D. J., R. R. WILSON, J. HENNE-KERR, AND R. B. HAMILTON. 1999. Impact of bottomland hardwood forest management on avian densities. Forest Ecology and Management 123: 261–274.



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Associate editor: Frank Thompson

(See Appendix 1, next page.)

Appendix 1. Mean (± SE) territory density/40 ha and frequency of occurrence (*f*) of breeding birds[a] in cottonwood agroforest stands on Fitler Managed Forest with and without artificial cavities as determined from Breeding Bird Censuses from 1994 to 1998.

		Without nest boxes $n = 22$		With nest boxes $n = 16$	
Common Name	Scientific Name	mean ± SE	*f*	mean ± SE	*f*
northern bobwhite	*Colinus virginianus*	1.63 ± 0.38	14	1.87 ± 0.47	12
mourning dove	*Zenaida macroura*	3.86 ± 1.29	16	2.09 ± 0.65	9
yellow-billed cuckoo	*Coccyzus americanus*	2.74 ± 0.56	21	5.96 ± 0.59	16
ruby-throated hummingbird	*Archilochus colubris*	3.32 ± 0.81	17	2.89 ± 0.64	13
red-bellied woodpecker	*Melanerpes carolinus*	1.37 ± 0.39	16	1.09 ± 0.34	11
downy woodpecker	*Picoides pubescens*	2.21 ± 0.53	16	2.78 ± 0.59	14
eastern wood-pewee	*Contopus virens*	1.99 ± 0.53	13	1.63 ± 0.45	9
Acadian flycatcher	*Empidonax virescens*	2.25 ± 0.69	12	2.43 ± 0.67	9
great-crested flycatcher	*Myiarchus crinitus*	0.38 ± 0.18	7	1.20 ± 0.44	9
white-eyed vireo	*Vireo griseus*	2.36 ± 0.73	11	2.50 ± 1.17	7
Bell's vireo	*Vireo bellii*	0.00 ± 0.00	0	0.20 ± 0.16	2
yellow-throated vireo	*Vireo flavifrons*	0.39 ± 0.19	6	0.09 ± 0.04	4
warbling vireo	*Vireo gilvus*	4.55 ± 1.10	18	13.63 ± 2.38	15
red-eyed vireo	*Vireo olivaceus*	0.16 ± 0.07	6	0.67 ± 0.34	5
blue jay	*Cyanocitta cristata*	0.04 ± 0.02	3	0.32 ± 0.16	6
Carolina chickadee	*Poecile carolinensis*	2.19 ± 0.55	15	4.33 ± 0.80	14
tufted titmouse	*Baeolophus bicolor*	0.77 ± 0.31	10	1.06 ± 0.31	10
Carolina wren	*Thrythorus ludovicianus*	4.46 ± 0.82	17	8.17 ± 1.38	14
blue-gray gnatcatcher	*Polioptila caerulea*	4.23 ± 0.96	17	3.87 ± 1.07	14
eastern bluebird	*Sialia sialis*	0.28 ± 0.27	2	1.09 ± 0.36	9
wood thrush	*Hylocichla mustelina*	0.27 ± 0.15	6	0.26 ± 0.16	5
northern mockingbird	*Mimus polyglottos*	0.50 ± 0.47	3	0.00 ± 0.00	0
prothonotary warbler	*Protonotaria citrea*	0.24 ± 0.13	8	5.11 ± 1.47	10
Swainson's warbler	*Limnothlypis swainsonii*	0.00 ± 0.00	0	0.37 ± 0.22	2
Kentucky warbler	*Oporornis formosus*	0.24 ± 0.11	6	0.69 ± 0.30	4
common yellowthroat	*Geothlypis trichas*	4.70 ± 1.01	17	8.26 ± 1.40	14
hooded warbler	*Wilsonia citrina*	0.03 ± 0.02	2	0.20 ± 0.16	2
yellow-breasted chat	*Icteria virens*	20.77 ± 4.74	17	18.93 ± 4.16	13
summer tanager	*Piranga rubra*	0.46 ± 0.26	12	0.24 ± 0.08	8
eastern towhee	*Pipilo erythrophthalmus*	10.51 ± 2.01	17	12.13 ± 2.03	13
northern cardinal	*Cardinalis cardinalis*	17.43 ± 1.59	22	24.35 ± 1.76	16
indigo bunting	*Passerina cyanea*	23.91 ± 2.51	21	31.57 ± 1.93	16
dickcissel	*Spiza americana*	2.34 ± 1.72	4	0.06 ± 0.03	2
red-winged blackbird	*Agelaius phoeniceus*	14.34 ± 5.42	17	18.96 ± 4.45	15
common grackle	*Quiscalus quiscula*	1.34 ± 0.48	12	1.57 ± 0.33	13
brown-headed cowbird	*Molothrus ater*	11.98 ± 1.33	22	9.09 ± 0.77	16
orchard oriole	*Icterus spurius*	5.55 ± 1.01	21	7.57 ± 1.04	15
Baltimore oriole	*Icterus galbula*	7.17 ± 1.56	21	21.23 ± 3.52	16

[a] Species with mean territory densities of <0.20 territories / 40 ha: great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), little blue heron (*Egretta caerulea*), green heron (*Butorides virescens*), wood duck (*Aix sponsa*), red-shouldered hawk (*Buteo lineatus*), red-tailed hawk (*Buteo jamaicensis*), wild turkey (*Meleagris gallopavo*), killdeer (*Charadrius vociferus*), eastern screech-owl (*Otus asio*), barred owl (*Strix varia*), red-headed woodpecker (*Melanerpes erythrocephalus*), hairy woodpecker (*Picoides villosus*), northern flicker (*Colaptes auratus*), pileated woodpecker (*Dryocupus pileatus*), eastern kingbird (*Tyrannus tyrannus*), loggerhead shrike (*Lanius ludovicianus*), American crow (*Corvus brachyrhynchos*), fish crow (*Corvus ossifragus*), brown thrasher (*Toxostoma rufum*), northern parula (*Parula americana*), painted bunting (*Passerina ciris*), house finch (*Carpodacus mexicanus*).