Wood Duck Reproduction in Small and Large Nest Boxes in Mississippi: A Continued Experiment

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Abstract: Multi-year studies in wildlife science and management can provide novel insights not detected in short-term investigations. Therefore, we continued a 2-year study by Stephens et al. (1998) to evaluate wood duck *(Aix sponsa)* reproduction in conventional and small nest boxes (i.e., approximately one-half conventional size) at Noxubee and Yazoo National Wildlife Refuges (NWRs) in Mississippi. Small nest boxes were designed to deter excessive dump nesting by wood ducks at these refuges. During 1994–1997, use of large boxes by wood ducks remained high (≥70%) at both study areas, but use of small boxes declined from 61% in 1994 to 34% in 1997 at Noxubee NWR. Concomitantly, use of small boxes by passerine birds increased from 14% to 65% at Noxubee NWR, but use of large boxes by passerines never exceeded 15%. Large boxes never were used by passerines at Yazoo NWR. Large boxes contained more duck eggs and dump nests than small boxes, but wood duck nest success did not differ between the 2 box types. More ducklings departed large boxes, but cost per duckling was less from small than large boxes because of the lesser cost of constructing small boxes. Large and small boxes provide managers with choices for producing wood ducks and other birds relative to their objectives and financial resources.

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Dump nesting can be a common problem in wood duck nest box programs (Clawson et al. 1979, Haramis and Thompson 1985, Semel et al. 1990), especially in

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southeastern United States where availability of suitable natural cavities may be lacking (e.g., Lowney and Hill 1989). Consequently, in Mississippi, Stephens et al. (1998) conducted a 2-year study of wood duck reproduction in conventional (i.e., large boxes) wooden nest boxes and ones approximately half the size (i.e., small boxes) to determine if small boxes were a viable management tool to reduce large dump nests. Stephens et al. (1998) concluded: 1) significantly fewer wood duck eggs accumulated and nest parasitism rates were less in small compared to large boxes, 2) combined production of wood ducks and hooded mergansers *(Lophodytes cucullatus)* from small boxes was more cost-effective due to the lesser cost of these boxes, and 3) small boxes were more easily transported and installed than large boxes.

Results from 2-year studies are common in wildlife science and management. However, longer-term research may provide new insights not detected in short-term investigations and cause researchers to modify previous inferences and management recommendations (Leopold et al. 1996). Therefore, we continued the 1994–1995 study by Stephens et al. (1998) and present results here for 4 consecutive years (i.e., 1994–1997) which revealed important new findings. We tested the general null hypothesis that wood duck use, numbers of eggs, nest success, and duckling production during 1994–1997 did not vary between large and small nest boxes at Noxubee and Yazoo NWRs, Mississippi. We also present new data on use of small and large nest boxes by passerine birds.

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Methods

Study Area

We studied at Noxubee and Yazoo NWRs in east- and west-central Mississippi. Noxubee and Yazoo NWRs are located in the Interior Flatwoods and the Mississippi Alluvial Valley regions of Mississippi (Pettry 1977).

We erected nest boxes in Loakfoma Lake, Doyle Arm, and Bluff Lake at Noxubee

NWR during summer 1993 (Stephens et al. 1998). Dominant shoreline vegetation in Loakfoma Lake (243 ha) was willow (*Salix* spp.), scrub-shrub (e.g., buttonbush; *Cephalanthus occidentalis*), and emergent vegetation (e.g., *Polygonum hydropiperoides*). Doyle Arm was a 16-ha wetland with scattered smartweed (*Polygonum* spp.) and other herbaceous vegetation along its shoreline. Wood duck boxes in Bluff Lake (405 ha) were situated within a needle-leaved, deciduous forest dominated by bald cypress *(Taxodium distichum)* and emergent vegetation as in Loakfoma Lake.

At Yazoo NWR, boxes were erected in Deer Lake and Alligator Pond. Deer Lake (48 ha) was dominated by southern wild rice *(Zizania miliacea)* and giant water lily *(Nelumbo lutea)*. Alligator Pond (28 ha) contained buttonbush, lotus, and dead trees. Stephens et al. (1998) and Davis (1998) provided further descriptions of the study areas.

Nest Boxes

Nest boxes were wooden structures similar to those described by Bellrose (1980:191). Stephens (1995:11–12) and Stephens et al. (1998) detailed the biological rationale and construction of large and small boxes. Briefly, inside dimensions of large (control) and small (experimental) boxes were 25×25×55 cm and 13.75×25×37.5 cm (Stephens et al. 1998). Large and small boxes were both equipped with a predator guard (Webster 1954).

We randomly assigned small or large boxes to 10×10-cm treated wooden posts, mounted boxes singly on posts in the aforementioned wetlands 20 m away from the shoreline, spaced them 50 m apart over open water, and faced the entrance of boxes away from the shoreline (Stephens et al. 1998). We placed about 10 cm of wood shavings in each box for nesting material.

In 1993, we placed 37 large and 37 small boxes at Yazoo NWR and 60 boxes of each type at Noxubee NWR. If a box became unusable by ducks during a breeding season (e.g., fell from a post), it was eliminated from analyses, and the box was replaced the next winter to ensure its availability during the entire breeding season. We inspected boxes monthly between late January and late July 1994–1997. During each inspection, we recorded (1) avian use of boxes (i.e., presence of ≥1 egg [species was identified based on eggs, feathers, or a bird's presence]), (2) species-specific number of eggs, (3) number of hatched eggs indexed by number of egg-shell membranes (Davis et al. 1998), (4) number of unhatched eggs for terminated nests, (5) number of live or dead ducklings, and (6) nest fate (hatched, abandoned, or depredated) (Henne and Hill 1990, Stephens et al. 1998). When we determined nest fate, we removed egg-shell membranes, unhatched eggs, and down feathers but retained shavings.

Statistical Analyses

We quantified use rates of boxes by dividing number of boxes in which wood ducks laid ≥1 eggs divided by total number of boxes of each type that were available for an entire season each year at a study site. We used a generalized linear model (Agresti 1990:490, PROC CATMOD, SAS Inst. 1994:409) to analyze use of boxes, nest success (i.e., ≥1 eggs hatched within a nest as evidenced by ≥1 egg shell membranes), and occurrence of unhatched eggs. We tested the following null hypotheses: (1) use did not differ between study areas and box types within years, (2) use did not differ among years and between study areas and box types, (3) nest success did not differ among years and between study areas and box types, and (4) occurrence of unhatched eggs did not differ among years and between study areas and box types. We did not analyze rates of egg or female depredation, because we observed only 1 known nest destruction in 4 years (i.e., a rat snake [*Elaphe obsoleta*] consumed eggs).

We defined maximum number of eggs as the largest number of eggs of wood ducks and/or hooded mergansers in a box during each monthly inspection and until nest fate was determined. We tested the null hypothesis that year, study area, and box type did not influence maximum number of eggs with analysis of variance (ANOVA) or ranked data (Conover and Iman 1981). We ranked data and used a nonparametric approach, because this variable failed to meet assumptions of ANOVA.

We indexed dump nests using data from Semel and Sherman (1992) and M. P. Vrtiska and R. M. Kaminski (unpubl. data, Dep. Wildl. and Fish., Miss. State Univ.). Based on known rates of wood duck dump nesting determined by daily nest box inspections, Semel and Sherman (1992) reported that an aggregation of >13 eggs likely represented a dump nest. M. P. Vrtiska and R. M. Kaminski found that 92% of 76 captive, wild-strain wood duck females at Mississippi State University laid ≤13 eggs/clutch. Therefore, following Stephens et al. (1998), we deemed clutches with >13 eggs as dump nests; ≤13 eggs constituted a normal nest. We recognize that dump nesting could have occurred in any clutch regardless of its size, but an empirical criterion was needed to test if the frequency of occurrence of relatively large clutches (i.e., >13 eggs) was independent of box size. We used a generalized linear model (Agresti 1990:490, PROC CATMOD, SAS Inst. 1994:409) to test if frequencies of dump nesting were similar among years and between study areas and box types.

We indexed number of ducklings that hatched and left a box by counting remaining egg-shell membranes (Davis et al. 1998), or the number of live ducklings in a box minus any dead ducklings found in the box during the next inspection date. Membrane and duckling counts may have underestimated total duckling production, because membranes and ducklings may have decomposed or been removed from boxes (Semel and Sherman 1986, Davis et al. 1998). Because our goal was to compare relative numbers of ducklings produced in large and small boxes, use of these counts to index duckling production was justified. We tested the null hypothesis that number of exiting ducklings did not differ among years and between study areas and box types, using ANOVA of ranked data.

We calculated cost per duckling to provide managers with a simple relative benefit:cost ratio between the 2 box types. We calculated cost per duckling for wood ducks alone and wood ducks and hooded mergansers combined. We used rates of box use and nest success and median number of ducklings that exited boxes to calculate production of wood ducks and both duck species combined. These variables were averaged across years and study areas. When the boxes were constructed in 1993, cost of cypress lumber used to construct large and small boxes averaged

$10.86 and $5.86. We divided these initial costs of boxes by averaged duckling production as described above and as calculated by Stephens et al. (1998). Costs of hardware, post, and predator shield were not included in benefit:cost analyses because these were equivalent between box types.

Results

Annual Use of Nest Boxes

Year (χ^2=23.32, 3 df, P=0.001), study area (χ^2=91.34, 1 df, P=0.001), and type of nest box (χ^2=59.60, 1 df, P=0.001) were related to annual use of boxes by wood ducks. Generally, use of small boxes declined between 1994 and 1997 at Noxubee and Yazoo NWRs, whereas use of large boxes remained relatively high (≥70%) at both NWRs (Table 1). Large boxes were used more each year than small boxes ($10.78 \leq \chi^2 \leq 21.06$, 1 df, $P \leq 0.002$), and both box types were used more at Yazoo NWR than at Noxubee NWR ($9.10 \leq \chi^2 \leq 52.21$, 1 df, $P \leq 0.003$). We continued research at Noxubee NWR in 1998; there, wood ducks used 73% of the large boxes and 43% of the small boxes.

Maximum Number of Eggs

Neither year (F=1.89; 3,974 df; P=0.129) nor study area (F=1.00; 1,974; P=0.317) influenced maximum number of eggs deposited in boxes. Therefore, data were pooled across these factors. Maximum number of eggs deposited per large box (median=17,95% CI=15–19, N=596) was greater (F=101.53; 1,979 df; P=0.001) than in small boxes (median=12,95% CI=10–14, N=384).

Dump Nesting Rates

An effect of study area (χ^2=12.51, 1 df, P=0.001) and a study-area-by-year interaction (χ^2=31.71, 10 df, P=0.001) were detected; therefore, data on dump nesting rates were analyzed by study area and year. At Noxubee NWR, dump nests occurred less in small than large boxes in 1994 (χ^2=8.31, 1 df, P=0.004), 1996 (χ^2=14.62, 1 df, P=0.001), and 1997 (χ^2=4.74, 1 df, P=0.030) but not in 1995

Table 1. Wood duck use rates (%) of small and large nest boxes at Noxubee and Yazoo National Wildlife Refuges (NWR), Mississippi, 1994–1997.

	Noxubee NWR					Yazoo NWR				
	Small box		Large box			Small box		Large box		
Year	*N*	%	*N*	%	*P*	*N*	%	*N*	%	*P*
1994	59	61	60	70	0.002	37	87	37	100	[a]
1995	60	53	57	82	0.002	35	84	35	95	[a]
1996	56	41	58	79	0.001	34	46	36	56	0.412
1997	54	34	58	71	0.001	33	73	36	95	[a]

a. Analyses were precluded by zeroes in contingency tables, or because nearly all boxes of both types were used at Yazoo NWR.

Table 2. Dump nest[a] rates (%) in small and large nest boxes at Noxubee and Yazoo National Wildlife Refuges (NWR), Mississippi, 1994–1997.

Area	Year	Small box		Large box		
		N	%	*N*	%	*P*
Noxubee NWR	1994	48	19	71	45	0.004
	1995	54	46	78	59	0.152
	1996	51	24	80	59	0.001
	1997	37	38	84	60	0.030
	Overall	190	32	313	56	0.006
Yazoo NWR	1994	52	60	77	73	0.121
	1995	51	37	76	55	0.048
	1996	44	34	63	78	0.001
	1997	48	40	67	69	0.002
	Overall	195	43	283	69	0.012

a. Aggregations of >13 eggs were declared dump nests (see Methods).

(χ^2=2.05, 1 df, P=0.152) (Table 2). At Yazoo NWR, dump nests occurred at similar rates in small and large boxes in 1994 (χ^2=2.41, 1 df, P=0.121) but less frequently in small boxes in 1995 (χ^2=3.91, 1 df, P=0.048), 1996 (χ^2=18.94, 1 df, P=0.001), and 1997 (χ^2=9.31, 1 df, P=0.002) (Table 2).

Nest Success

Nest success varied by year (χ^2=12.39, 3 df, P=0.006) and study area (χ^2=31.04, 1 df, P=0.001). However, nest success did not differ (χ^2=0.98, 1 df, P=0.323) between large (65%, N=481) and small (63%, N=297) boxes across years and study areas (Table 3).

Occurrence of Unhatched Eggs

Study area (χ^2=125.19, 1 df, P=0.001) and year (χ^2=14.52, 3 df, P=0.002) influenced percent occurrence of unhatched eggs in nest boxes. Occurrence of un-

Table 3. Wood duck nest success[a] rates (%) in small and large nest boxes at Noxubee and Yazoo National Wildlife Refuges (NWR), Mississippi, 1994–1997.

Area	Year	Small box		Large box		
		N	%	*N*	%	*P*
Noxubee NWR	1994	35	77	47	78	0.864
	1995	32	69	55	69	0.974
	1996	25	84	69	74	0.307
	1997	25	80	62	69	0.315
	Overall	117	78	233	73	0.377
Yazoo NWR	1994	42	57	56	68	0.276
	1995	52	33	63	49	0.074
	1996	41	53	50	64	0.318
	1997	45	51	79	51	0.959
	Overall	180	49	248	58	0.063

a. A successful nest contained ≥1 hatched eggs and ≥1 ducklings that departed the nest box.

Table 4. Occurrence (%) of unhatched eggs in small and large nest boxes at Noxubee and Yazoo National Wildlife Refuges (NWR), Mississippi 1994–1997.

		Small box		Large box		
Area	Year	*N*	%	*N*	%	*P*
Noxubee NWR	1994	31	12	57	23	0.001
	1995	39	12	62	17	0.012
	1996	37	13	75	26	0.001
	1997	40	14	85	29	0.001
	Overall	147	13	279	24	0.001
Yazoo NWR	1994	39	23	68	37	0.001
	1995	46	26	63	34	0.002
	1996	39	21	58	31	0.002
	1997	63	34	97	52	0.001
	Overall	187	26	286	39	0.001

hatched eggs was greater (χ^2=135.70, 1 df, P=0.001) in large than small boxes in all years and at both study areas (Table 4).

Numbers of Unhatched Eggs

Year (F=5.73; 3,898 df; P=0.001) and study area (F=76.24; 1,898 df; P=0.001) influenced numbers of unhatched eggs that remained in nest boxes after nests were terminated. More (F=64.76; 1,893 df; P=0.001) unhatched eggs remained in boxes at Yazoo NWR than at Noxubee NWR in all years except 1996. Numbers of unhatched eggs were twice greater (F=64.76; 1,893 df; P=0.001) in large (median=8,95% CI=6–9, N=564 nests) than in small nest boxes (median=4,95% CI=3–5, N=333 nests).

Numbers of Ducklings Exiting Boxes

Study area (F=3.40; 1,477 df; P=0.659) and year (F=1.39; 3,477 df; P=0.244) did not influence the number of ducklings that exited nest boxes. When data were combined across areas and years, number of exiting ducklings was greater from large than from small boxes (F=13.22; 1,482; P=0.001). Over the 4-year study, median numbers of 8.3 ducklings (N=311, CI=7.2–9.4) and 7.3 ducklings (N=172, CI=6.2–8.3) exited from large and small nest boxes.

Nest Box Use by Passerine Birds

A total of 7 species of passerine birds used nest boxes at the 2 study areas during 1994–1997, including common grackle *(Quiscalus quiscula),* great-crested flycatcher *(Myiarchus crinitus),* eastern bluebird *(Sialia sialis),* tree swallow *(Tachycineta bicolor),* eastern kingbird *(Tyrannus tyrannus),* Carolina chickadee *(Parus carolinensis),* and prothonotary warbler *(Protonotaria citrea).* Use of small boxes by passerines at Yazoo NWR between 1994 and 1997 ranged from 12%–56%. Large boxes were never used by passerines at Yazoo NWR. Between 1994–1997, use of large boxes by passerines ranged from 3%–15% at Noxubee NWR, but use of small boxes there ranged from 14%–65%. In 1998, passerines at Noxubee NWR used 11%

and 60% of large and small boxes, respectively; data were not collected at Yazoo NWR in 1998.

Cost:Benefit Evaluation

Because study area and year did not influence number of wood duck ducklings that exited nest boxes, we calculated duckling production averaged across these factors. Average costs per wood duck duckling that exited large and small boxes was \$2.34 and \$1.99, based on original (1993) lumber costs for these 2 boxes. When numbers of wood duck and hooded merganser ducklings were combined, average cost per duckling decreased to \$1.63 and \$1.47 for large and small boxes. Because the boxes remained functional throughout this study, costs per duckling over the 4 years were actually one-fourth of the above estimates (i.e., <\$0.60 per duckling per year).

Discussion

Use of Nest Boxes

Wood duck use of large nest boxes was high during the 4 years of this study. Nearly all large boxes were used at Yazoo NWR, and overall use of large boxes at Noxubee NWR was ≥70% annually. Large boxes may have been used more than small boxes because of continued high philopatry of wood duck females to conventional-sized nest boxes after the first 2 years of this study (Stephens et al. 1998). Both box types were used more at Yazoo NWR than at Noxubee NWR. This trend may have been partly related to the landscapes adjacent to Noxubee and Yazoo NWRs, which were mostly forest and agricultural land, respectively. In addition, area of wetlands at Yazoo NWR was less than that at Noxubee NWR. Other factors possibly related to differential use of boxes between Noxubee and Yazoo NWRs include local breeding densities of wood duck, hooded mergansers, and passerines, as well as the availabilities of boxes and natural cavities.

Perhaps the most intriguing pattern of nest box use was the decline in use of small boxes at both sites. Decreased use of small boxes by wood ducks was most evident at Noxubee NWR where small structures received 61% use in 1994; however, use decreased to 34% by 1997. Decreased use of small boxes also occurred at Yazoo NWR, but the decline was not dramatic (i.e., 87% to 73%). From 1994–1997, we observed increased use of small boxes by passerines at Noxubee NWR (Fig. 1). Passerines occupied small boxes later in the nesting season (May–June) when wood duck use of small boxes typically declined (Davis 1998). In contrast, use of large boxes by passerines at Noxubee NWR was generally low (i.e., ≤15%) from 1994–1997, and no large boxes were ever used by passerines at Yazoo NWR. Hooded merganser use of nest boxes likely did not affect the use of nest boxes by wood ducks, because mergansers generally completed nesting by early April (Stephens 1995:28). We could not ascertain if increased use of small boxes by passerines, philopatry of wood duck females to large boxes (Hepp and Kennamer 1992, Stephens et al. 1998), or other factors contributed to the decline in use of small boxes by wood ducks.

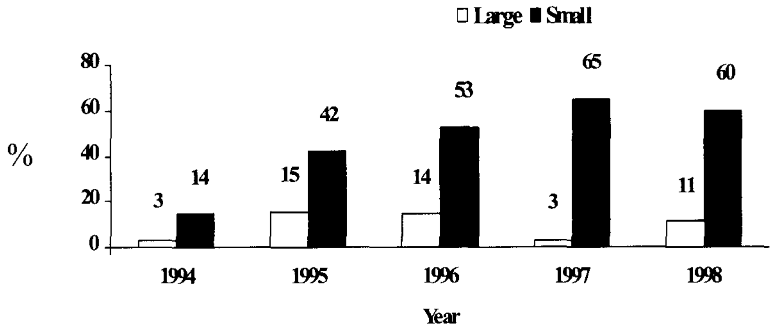

Figure 1. Use (%) of large and small wood duck nest boxes by passerines at Noxubee National Wildlife Refuge, Mississippi, 1994–1998. Numbers above bars represent actual percentages.

Seasonal trends in nest box use by wood ducks at Noxubee NWR were similar among years (Davis 1998:27). For example, large boxes appeared to be selected early in the nesting season, especially in February and March. This pattern may be related in part to female philopatry to large boxes, because females had no exposure to small nest boxes prior to 1994 (Stephens et al. 1998). In April, wood ducks occupied small and large boxes at similar rates. Peak use of small boxes in April may have resulted from little vacancy of large boxes at that time; thus, nesting hens increased their use of small boxes.

At Yazoo NWR, there also was greater use of large boxes early in the nesting season (Davis 1998:27). By April, however, large and small boxes were used at similar rates in 3 of 4 years. Similar to the pattern at Noxubee NWR, large boxes at Yazoo NWR generally were used at increasing rates later in the nesting season. Greater use of large boxes later in the nesting season may have resulted from philopatry of females to large boxes, or because more small boxes were occupied by passerines at that time.

High use of both box types at Yazoo NWR seemed consistent with results of nest box programs that used only large boxes before this study (Cunningham 1968, Barry 1992). Nest boxes have existed at Yazoo NWR since 1965. Peak use (90%) of boxes occurred there by 1968, and use remained high (66%–88%) during 1981–1986 (Wilkins et al. 1990). Wilkins et al. (1990) concluded that nest boxes were critical to sustaining wood duck populations at Yazoo NWR, probably because of a lack of suitable natural cavities (Lowney and Hill 1989). Use of small boxes by wood ducks at Yazoo NWR during 1994–1997 (73%–87%) was comparable to the use of large nest boxes there during the 1980s (Wilkins et al. 1990).

Egg Accumulations

Numbers of wood duck eggs were greater in large boxes during all months of the study. Although we could not determine the mechanisms that influenced numbers of eggs deposited in boxes, the fact that large boxes contained greater numbers of eggs was intuitive because small boxes had nearly half the internal volume of large boxes. Additionally, seasonal declines in clutch size and dump nesting (Bellrose and

Holm 1994:227,247) and increased seasonal use of small boxes by passerines at both study areas may have contributed to fewer eggs in small boxes.

Because small boxes accumulated less eggs overall, fewer eggs remained unhatched in these boxes. To better understand the relationship between seasonal reductions in egg numbers and box size, future researchers may consider conducting more frequent inspections of boxes to determine nest initiation dates. Nest initiation date could be used as a covariate in analyses to better understand effects of box size and season on egg numbers (Stephens et al. 1998). However, accurate determination of nest initiation dates is labor intensive, requiring daily nest checks and egg marking to account for parasitized eggs (Clawson et al. 1979).

Dump Nesting and Nest Success

Based on our criterion for a dump nest (>13 eggs; Stephens et al. 1998), there was a consistent trend for small boxes to contain fewer dump nests than large boxes at both areas in all years. Results from 1996–1997 corroborated those of Stephens et al. (1998); i.e., small boxes were used less by female wood ducks early in the breeding season. This differential temporal use probably resulted in fewer females depositing eggs in small boxes, thereby leading to fewer dump nests overall compared with large boxes. Also, small boxes have less internal volume to aggregate eggs and thus contain dump nests.

Previous research has suggested that nest success of wood ducks may increase in the absence of supernormal clutches; smaller clutches (e.g., ≤15 eggs) exhibited higher hatching efficiency (Semel et al. 1990). Although fewer eggs were deposited in small than large boxes during this study, nest success was similar between box types. Regardless of whether nests with ≤13 eggs were truly dump nests, the small box provided a suitable cavity for wood ducks to nest successfully, inasmuch as nest success did not differ between box types at either study area and in any year.

Number of Unhatched Eggs

Small boxes accumulated fewer eggs than large boxes. Thus, fewer unhatched eggs remained in small than large boxes. Stephens et al. (1998) hypothesized that box size and seasonal declines in eggs production and dump nesting contributed to this result. Our analyses support their contention.

Number of Wood Duck Ducklings Exiting Boxes

Because large boxes accumulated more eggs and nest success did not differ between box types, greater numbers of ducklings exited large than small boxes. In addition, because large boxes were used earlier in the nesting season, total yearly production of wood ducks from large boxes was greater.

Management Implications

This study yielded equivocal result regarding use of small nest boxes at our study areas. First, large boxes received greater use by wood ducks, accumulated more eggs, and more ducklings departed large structures. However, considering the lesser quantity of lumber needed to construct small boxes, they produced ducklings more cost efficiently. Secondly, there were fewer dump nests in small boxes. Although greater rates of dump nests did not result in lower nest success in large boxes, decreased nest and hatching successes from increased incidence of dump nesting in conventional boxes have been reported (Clawson et al. 1979, Haramis and Thompson 1985, Semel et al. 1990:166). If dump nesting becomes excessive in conventional boxes in the future, small boxes may be advantageous.

Despite greater cost efficiency of duckling production from small boxes, increased yearly use of small boxes by passerines may warrant concern regarding use of these boxes in wood duck management. This trend was detected because of our longer-term study. If passerines prevent wood ducks from using small boxes later in the nesting season, overall seasonal production of ducklings may be reduced. If the trend in increased use of small boxes by passerines continues at Noxubee and Yazoo NWRs, waterfowl managers may consider decreasing use of small boxes or implementing strategies to accommodate nesting ducks and passerines. For example, bluebird houses may be used by different species of passerines (Gowaty and Plissner 1997). Thus, both wood duck and passerine nest houses could be attached to posts, but this strategy has not been experimentally evaluated. Use of different sized boxes should be based on managers' objectives (Stephens et al. 1998). For example, if duckling production is the primary objective, large boxes should be used. However, small boxes may be more cost efficient and easier to install than large boxes (Stephens et al. 1998), and greater avian diversity may result from small than large boxes.

Managers interested in maximizing duckling production and cost efficiency should adaptively manage (Semel and Sherman 1993, Williams and Johnson 1995). For example, Semel et al. (1998, 1990) and Semel and Sherman (1995) recommended moving nest boxes in open habitats that were prone to dump nesting to forested sites to decrease dump nesting and increase duckling production. Similar strategies could be invoked for small and large boxes. Although researchers have examined the effect of box location on wood duck reproduction (Semel et al. 1990, 1995; Barry 1992), our studies were the first to examine wood duck and hooded merganser reproduction from 2 different sized boxes (Stephens 1995, Davis 1998, Stephens et al. 1998). Indeed, small boxes appeared to provide wood ducks with suitable nesting sites, but research is needed to evaluate the effect of 2 small boxes or 1 large and 1 small box per post (i.e., duplexes) on wood duck, hooded merganser, and passerine production.

Additionally, wood duck use and production from large and small boxes should be examined throughout the wood duck range. Particularly interesting would be comparative studies conducted at northern and southern latitudes (e.g., B. Hunter, La. State Univ., pers. commun.), and sites with no prior history of nest box management. Lastly, studies of survival of ducklings produced from nest boxes should be conducted to determine the overall significance of nest box programs to cavity nesting ducks and to determine brood habitats best suited for subsequent placement of boxes (Davis 1998).

Literature Cited

Agresti, A. 1990. Categorical data analysis. John Wiley & Sons, Inc. 588pp.

Barry, S. C. 1992. Evaluation of a wood duck nest box program at Yazoo National Wildlife Refuge, Mississippi, 1987–91. M.S. Thesis, Miss. State Univ., Miss. State, Miss. 84pp.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Second ed. Stackpole Books, Harrisburg, Pa. 540pp.

——— and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Mechanicsburg, Pa. 588pp.

Clawson, R. L., G. W. Hartman, and L. H. Fredrickson. 1979. Dump nesting in a Missouri wood duck population. J. Wildl. Manage. 43:347–355.

Conover, W. J. and R. L. Iman. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. Am. Stat. 35:124–129.

Cunningham, E. R. 1968. 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.

Davis, J. B. 1998. Wood duck production from nest boxes and hen and duckling survival. M.S. Thesis, Miss. State Univ., Miss. State, Miss. 125pp.

———, R. M. Kaminski, and S. E. Stephens. 1998. Wood duck egg-shell membranes predict duckling numbers. Wildl. Soc. Bull. 26:299–301.

Gowaty, P. A. and J. H. Plissner. 1997. Breeding dispersal of eastern bluebirds depends on nesting success but not on removal of old nests: an experimental study. J. Field Ornithol. 68:323–330.

Haramis, G. M. and D. Q. Thompson. 1985. Density-productivity characteristics of box-nesting wood ducks in a northern greentree impoundment. J. Wildl. Manage. 49:429–436.

Henne, J. L. and E. P. Hill. 1990. Techniques for monitoring wood duck nest boxes. Pages 303–308 *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, Mo.

Hepp, G. R. and R. A. Kennamer. 1992. Characteristics and consequences of nest-site fidelity in wood ducks. Auk 109:812–818.

Leopold, B. D., G. A. Hurst, and D. A. Miller. 1996. Long versus short-term research and effective management. Trans. N. Am. Wildl. and Natl. Resour. Conf. 61:472–482.

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

Pettry, D. E. 1977. Soil resource areas of Mississippi. Dep. Agron., Miss. Agric. and For. Exp. Sta., Info. Sheet 1278, Miss. State Univ., Miss. State, Miss. 4pp.

SAS Institute, Inc. 1994. SAS user's guide. Vers. 6, Fourth ed. SAS Inst., Cary, N.C. 1686pp.

Semel B. and P. W. Sherman. 1986. Dynamics of nest parasitism in wood ducks. Auk 103:813–816.

———, ———, and S. M. Byers. 1990. Nest boxes and brood parasitism in wood ducks: a management dilemma. Pages 163–170 *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, Mo.

Semel, B. and P. W. Sherman. 1992. Use of clutch size to infer brood parasitism in wood ducks. J. Wildl. Manage. 56:495–499.

——— and ———. 1993. Answering basic questions to address management needs: case studies of wood duck nest box programs. Trans. N. Am. Wildl. and Nat. Resour. Conf. 58:537–550.

——— and ———. 1995. Alternative placement strategies for wood duck nest boxes. Wildl. Soc. Bull. 23:463–471.

———, ———, and S. M. Byers. 1988. Effects of brood parasitism and nest-box placement on wood duck breeding ecology. Condor 90:920–930.

Stephens, S. E. 1995. Effect of reduced nest-box size on wood duck reproduction. M.S. Thesis, Miss. State Univ., Miss. State, Miss. 45pp.

———, R. M. Kaminski, B. D. Leopold, and P. D. Gerard. 1998. Reproduction of wood ducks in small and large nest boxes. Wildl. Soc. Bull. 26:159–167.

Webster, C. G. 1954. Nest boxes for wood ducks. U.S. Dep. Int., Fish and Wildl. Serv. Leafl. 351. 9pp.

Wilkins, T. M., A. L. Bowman, and J. T. Fulton. 1990. Management of wood ducks at Yazoo National Wildlife Refuge. Pages 269–273 *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, Mo.

Williams, B. K. and F. A. Johnson. 1995. Adaptive management and the regulation of waterfowl harvests. Wildl. Soc. Bull. 23:430–436.