Improving Wood Duck Survival Estimates in the Mid-Atlantic Region by Using Nest Box Banding Programs

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Abstract: Previous work by LeMaster and Trost (1994) and Otis (1994) developed and evaluated statistical models for incorporating wood ducks (*Aix sponsa*) banded between 15 April and 30 June into band recovery analyses to estimate survival and recovery rates. In this study, we analyzed wood duck band recovery data from 1982–1992 in the proposed mid-Atlantic wood duck management unit and evaluated the impact of past early season banding on precision of the estimates. Based on statistics compiled from the wood duck nest box program in South Carolina, we then used computer simulation to evaluate potential impact of state and regional scale banding of adult females in nest box programs. Additional early season banding in the mid-Atlantic region could slightly improve estimates of annual and summer survival rates for adults, but replacement of preseason banding with early season banding to achieve banding quotas can result in substantial decreases in precision of some parameters.

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Wood duck populations in the Atlantic and Mississippi flyways represent an important wildlife resource both aesthetically and as a source of recreational hunting. This species is consistently second only to mallards (*Anas platyrhynchos*) in numbers harvested each year (Gamble 1990, Serie and Chasko 1990). However, the biology of the wood duck makes it extremely difficult to generate reliable estimates of population numbers or trends (U.S. Fish and Wildl. Serv. Off. of Migratory Bird Manage. unpubl. rep.). Their unique biology contributes to the general failure of states to achieve banding quotas suggested by the U.S. Fish and Wildlife Service (USFWS) Office of Migratory Bird Man-

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agement. Inadequate numbers of banded cohorts have produced survival and recovery rate estimates that have poor precision. Because estimates are key to optimum management of a species, Sparrowe (1990) suggested that increased banding effort should be a priority in future efforts to improve management of wood duck populations.

In response to the challenge to increase sample sizes of banded wood duck cohorts, LeMaster and Trost (1994) proposed that the traditional preseason banding period of 1 July–15 September be extended to include the early season period 15 April–30 June. They modified the usual band recovery models developed by Brownie et al. (1985) by adding a survival rate for a summer period (late May to early August), and they estimated annual and summer survival rates for adults. Precision of these estimates increased only slightly by adding summer banded cohorts. Otis (1994) subsequently developed methodology for optimum allocation of banding effort between the 2 periods, and concluded that the relative cost of banding early vice preseason birds had to be small to make early season banding cost effective.

Intensive artificial wood duck box programs have been used extensively throughout the United States to increase population productivity (Bellrose 1990). South Carolina has maintained one of the most ambitious of these programs for more than 20 years (Prevost et al. 1990). Most wood ducks in the mid-Atlantic and southern regions of the United States complete breeding before the traditional preseason banding season (Haramis 1990). Therefore, banding of nesting females in concert with nest box check programs that are normally conducted to monitor use and associated productivity of nest boxes would serve to increase sample sizes of early season cohorts only. The objective of this work was to investigate the potential benefits, in terms of improved estimates of survival and recovery parameters, of banding nesting females that use artificial nest boxes.

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Methods

Band Recovery Data

We obtained band recovery data from the Bird Banding Laboratory of the U.S. Department of Interior. We requested information on all wild wood ducks banded from 1982 to 1992 in Delaware, Maryland, New Jersey, North Carolina, South Carolina, Virginia, and West Virginia. This collection of states was identified as the mid-Atlantic region in the recent redefinition of wood duck management units (USFWS Off. of Migratory Bird Manage., unpubl. rep.). Information on recovery of these birds was restricted to birds shot or found dead during the hunting season.

Nest Box Data

Information on numbers of nest boxes currently maintained in South Carolina was compiled by contacting all organizations known to be involved in nest box programs, including the South Carolina Department of Natural Resources (DNR), the USFWS Carolina Sandhills National Wildlife Refuge, the USFWS Santee National Wildlife Refuge, the Savannah River Site of the Department of Energy, and the South Carolina Waterfowl Association. Although total nest box effort in South Carolina likely exceeds other states in the mid-Atlantic region, these numbers were applied to other states in subsequent analyses performed on a regionwide scale. In this sense, these analyses represented a best case scenario for the potential of nest box programs.

Analysis and Computer Simulation

Recovery data for juveniles and adults banded during the preseason in the mid-Atlantic region were stratified by sex and analyzed using Program BROWNIE (Brownie et al. 1985). Selection of a most appropriate model to estimate survival for each sex was made using the likelihood ratio and goodness of fit tests in BROWNIE, and this model was used to construct specific estimation models for 2 age classes, similar to those used by LeMaster and Trost (1994) and Otis (1994) for adults only. We used these models in Program SURVIVE (White 1983) to analyze combined recovery data from birds banded during either the early or preseason periods.

The potential contribution of additional early season banding was evaluated using the Monte Carlo simulation capabilities of SURVIVE. The empirical data on existing numbers of nest boxes, combined with estimates of occupancy rates, capture success rates, and ability to check boxes on private property were used to produce estimated upper and lower bounds on numbers of adult females that could be banded each year in each state, assuming that data from South Carolina is reasonably representative of the states in the mid-Atlantic region. If each state is given equal weight, multiplication of these bounds by the number of states in the region (7) represents upper and lower bounds on a regional scale. Numbers of birds under several different scenarios were added to the actual numbers banded in the mid-Atlantic region between 1982 and 1992, and estimates of increased precision in parameter estimates were obtained by simulation. Values for survival and recovery rates in the simulation were taken from results of the earlier analysis of the actual band recovery data from 1982–1992. With this approach, we are assessing the theoretical impact of supplementary early season banding of adult females during the past 11 years.

The recent study proposal for the Wood Duck Population Monitoring Initiative (USFWS Off. of Migratory Bird Manage., unpubl. rep.) provides banding quotas for each state and population management unit. These quotas were developed to produce estimates of average adult survival rates with 10% coefficients of variation (CVs) for a 5-year period. For the mid-Atlantic region, the female quotas are 2,000 and 7,280 AHY (adult) and HY (immature) birds, respectively. Using methodology developed by Otis (1994), sample size combinations were calculated for preseason and early season adults that produce CVs of 10% and 5% for average AHY survival. Values for survival and recovery rates in these calculations were again taken from the results of analyzing the actual band recovery data between 1982 and 1992.

Results

Band Recovery Data

Numbers of birds banded during the early and preseason periods from 1982–1992, and total numbers that had been recovered through the 1992 hunting season, are listed in Table 1. Note that a much greater number of AHY females are banded in the early season than in the preseason, yet these birds are not used in standard band recovery analyses.

Nest Box Estimates

Our best estimate of the number of nest boxes in South Carolina in 1992 is 23,111. Of these boxes, only 3,030 were deemed as suitable for potential banding based on the criteria that a location must have at least 90 boxes present and that the property be either under management by a natural resource agency or part of a cooperative agreement with a private conservation organization. Occupancy rates of nest boxes are highly variable within the wood duck's breeding range (Soulliere 1990). Factors that affect these rates include location, box age, box condition, box density, habitat, renesting rates, social behavior, and climatic conditions. In the 3 South Carolina studies cited by Soulliere (1990), occupancy rates ranged from 34% to 96%, and averaged 60%. We used 60% as a lower bound for occupancy rate; the upper bound was 100%. Reliable estimates of capture efficiency of nesting females are unavailable. Information obtained from the Savannah River Ecology Laboratory (B. Kennamer, unpubl. data) and Carolina Sandhills National Wildlife Refuge (K. McCutcheon, un-

Table 1. Numbers of wood ducks banded and recovered in the mid-Atlantic region from 1982–1992.

Age and sex class[a]	*N* banded in early season	*N* banded in preseason	*N* recovered
AHY males	2,308	2,655	260
HY males	284	8,035	576
AHY females	4,074	2,525	165
HY females	213	5,875	270

[a]AHY = adult; HY = immature.

publ. data), suggest capture rates of approximately 30–45%. Therefore, we arbitrarily chose 50% upper and 30% lower bounds for capture rates. These values result in minimum and maximum estimates of 545 (3,030 × .60 × .30) and 1,515 (3,030 × 1.00 × .50) additional adult females banded in the early season in South Carolina in a typical year. If we assume that these numbers could be banded in each of the 7 states in the region, then we have minimum and maximum estimates of 3,815 and 10,605 additional birds banded on a regional scale each year. Because nesting in this region is usually completed before the beginning of the preseason banding period (Soulliere 1990), we assumed that additional bands are added only during the early banding period.

Survival and Recovery Rate Estimates from Preseason Data

Survival and recovery rates for males were estimated using Model H_1, in which both sets of parameters vary by year. This model fit the observed recovery data well ($P = 0.638$). For females, Model H_{02}, which has constant survival rate and year specific recovery rates, was chosen as the best model ($P = 0.776$). Year specific survival rates for males are very imprecise (Table 2), and the 11-year average survival rates for both age classes are not overly precise ($CV_{AHY} = 8.9\%$, $CV_{HY} = 11.9\%$). Precision of average annual survival rates for females (Table 2) also is not small ($CV_{AHY} = 6.8\%$, $CV_{HY} = 15.3\%$), considering the 11-year time span that was used. For each sex, precision also is poor for year specific recovery rates. Average recovery rates are estimated with CVs between 5% and 10%. Poor precision resulted from inadequate samples of banded cohorts of both sexes during the past 15 years.

Survival and Recovery Rate Estimates Using Supplemental Early Season Banding

We used Program SURVIVE to construct a model that assumed 1) a summer survival rate for adults banded in the early season that was constant for all years, 2) an age specific annual survival rate, also constant for all years, and 3) age and time specific annual recovery rates. We decided to use constant survival rates for both sexes because females are the more important sex in these analyses. Additionally, although a model with constant survival rates was not chosen as the best model for males, the goodness of fit for such a model was not poor ($P = 0.148$).

For both sexes, there were negligible differences between precision of recovery rate estimates produced by this dataset and the preseason only dataset. These results (Table 3) are consistent with those of LeMaster and Trost (1994). The standard error of the annual survival rate for AHY males has been substantially decreased from 0.054 to 0.021, but most of this decrease was from assuming that survival rates are constant in the combined dataset and not to the additional information provided by AHY males banded in summer. When Model H_{02} was used only with the preseason data, the estimated standard error of the annual AHY survival rate is 0.023. Precision of the estimated annual survival rate for HY males was slightly decreased. Survival rate estimates for both AHY

Table 2. Survival ($\hat{S}_i$) and recovery ($\hat{f}_i$) rate estimates of wood ducks in the mid-Atlantic region, based on preseason banding data from 1982–1992.

	Males								Females							
	AHY				HY				AHY				HY			
Year	$\hat{S}_i$	s.e.($\hat{S}_i$)	$\hat{f}_i$	s.e.($\hat{f}_i$)	$\hat{S}_i$	s.e.($\hat{S}_i$)	$\hat{f}_i$	s.e.($\hat{f}_i$)	$\hat{S}$	s.e.($\hat{S}$)	$\hat{f}_i$	s.e.($\hat{f}_i$)	$\hat{S}$	s.e.($\hat{S}$)	$\hat{f}_i$	s.e.($\hat{f}_i$)
1982	.483	.212	.028	.014	.504	.148	.055	.009	.529	.036	.008	.008	.463	.071	.055	.011
1983	.791	.291	.045	.012	.994	.284	.062	.009			.029	.008			.057	.010
1984	.479	.230	.030	.008	.396	.182	.076	.010			.024	.006			.050	.010
1985	.378	.180	.021	.009	.559	.210	.042	.013			.011	.004			.016	.009
1986	.647	.219	.025	.008	.479	.144	.034	.008			.020	.006			.028	.008
1987	.719	.229	.039	.010	.430	.128	.048	.008			.021	.006			.031	.007
1988	.446	.138	.030	.007	.319	.096	.036	.006			.021	.005			.030	.007
1989	.865	.298	.032	.008	.994	.303	.028	.006			.015	.004			.018	.006
1990	.383	.138	.023	.006	.266	.089	.020	.004			.019	.004			.021	.005
1991	.864	.457	.041	.010	.595	.324	.031	.006			.017	.004			.023	.006
1992			.015	.007			.027	.006			.017	.004			.017	.005
$\overline{X}$	.605	.054	.030	.003	.554	.066	.042	.002			.018	.002			.032	.002

Table 3. Estimates of annual ($\hat{S}$) and summer ($\hat{S}'$) survival rates produced by combining early and preseason banding data.

Sex and age class[a]	$\hat{S}$	s.e.($\hat{S}$)	$\hat{S}'$	s.e.($\hat{S}'$)
AHY male	.621	.021	.846	.108
HY male	.554	.055		
AHY female	.551	.032	.662	.108
HY female	.462	.070		

[a]AHY = adult; HY = immature.

Table 4. Simulated percent coefficient of variation (CV) of average annual adult ($\hat{S}_{AHY}$) and young ($\hat{S}_{HY}$) female survival rates, and average adult summer ($\hat{S}'_{AHY}$) female survival rate when M additional adult females are banded during each early season from 1982–1992.

M	$\hat{S}_{AHY}$	$\hat{S}_{HY}$	$\hat{S}'_{AHY}$
0[a]	6.8	15.3	
A[b]	5.8	15.2	16.3
A+545	4.6	15.6	13.2
A+1,515	3.6	15.1	11.5
A+3,815	2.4	15.3	11.1
A+10,605	1.5	15.3	10.9

[a]Actual 1982–1992 preseason numbers only.
[b]A = Actual early season numbers from 1982–1992.

and HY females were not appreciably improved. For both sexes, summer survival rate estimates have large standard errors.

Simulation of Additional Early Season Banding

Simulation of average annual and summer female survival rates for the mid-Atlantic region produced by adding varying numbers of early season banded adults to the actual numbers of preseason birds banded between 1982 and 1992 shows that some gains in precision of AHY rates are realized (Table 4), and, as would be expected, there is no improvement in precision of HY annual survival rate. As before, recovery rate estimates were unaffected and are therefore not presented.

Simulation of Alternative Banding Quota Strategies

When the USFWS preseason banding quotas are satisfied, simulated CVs of average annual AHY survival and HY survival were 5.0% and 8.2%, respec-

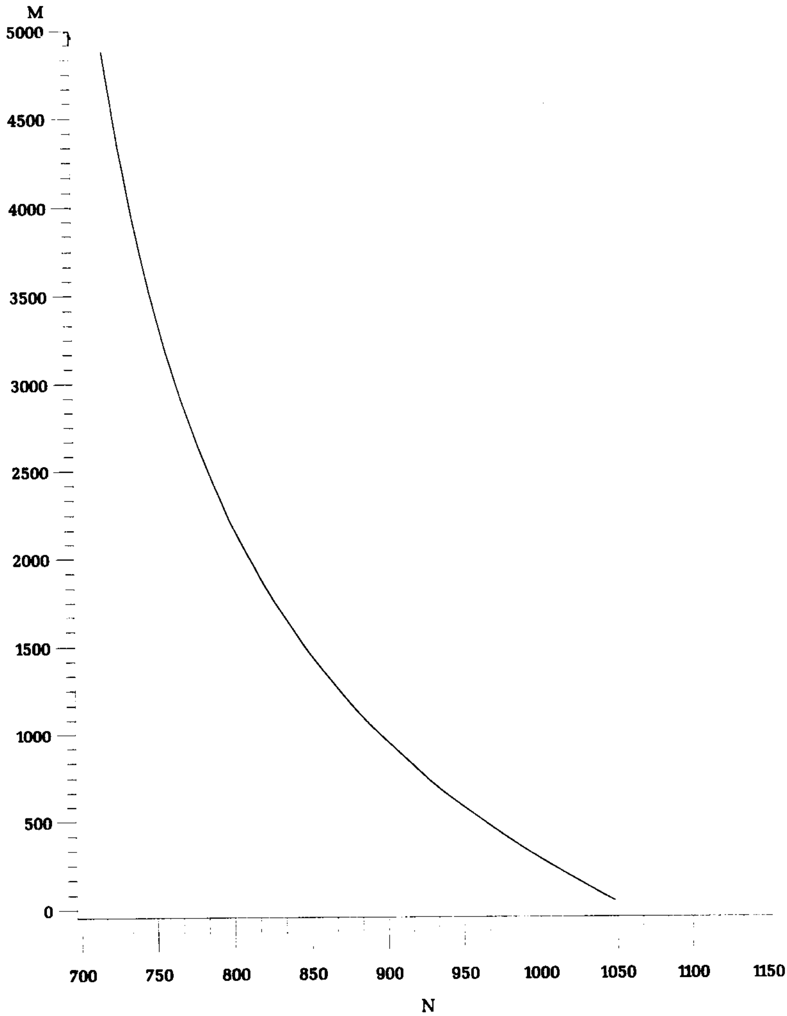

Figure 1. Sample size combinations for preseason (N) and early season (M) adult females, that will produce a CV = .10 for 5-year average survival rate.

tively. The CV for AHY survival is less than the target level of 10% because USFWS calculations were based on slightly different assumed values for survival and recovery rates and on a slightly different estimation model. Our results indicate that approximately 1,100 and 4,200 adult females need to be banded in the preseason to produce CVs of 10% and 5%, respectively (Figs. 1, 2). If early season banding is done to reduce required preseason banding, then several early season individuals must be banded to replace each individual not banded in the preseason. For example, if a CV of 10% is desired, a reduction of 100 birds in the preseason must be offset by banding approximately 500 adults in the early season. Although this number is certainly feasible given our estimates of females

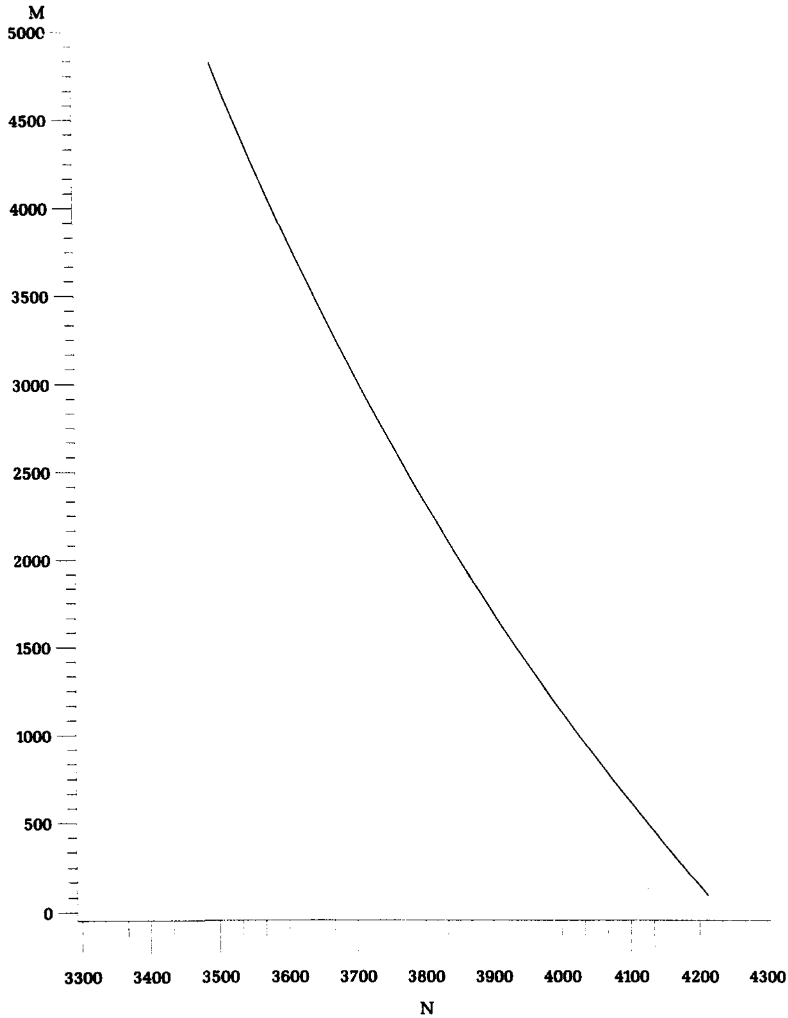

Figure 2. Sample size combinations for preseason (N) and early season (M) adult females, that will produce a CV = .05 for 5-year average survival rate.

that could be banded in nest boxes, it seems unlikely that such a tradeoff would be cost effective.

Discussion

Although comparisons are somewhat confounded by slightly different time frames and a redefinition of the Southeastern management unit proposed by Bowers and Martin (1975) to the mid-Atlantic unit proposed by the USFWS Office of Migratory Bird Management, empirical survival and recovery estimates obtained from our dataset are similar to those reported by Nichols and Johnson (1990). However, our estimates for adult recovery rates of 0.030 and 0.018 for males and females, respectively, were significantly less than the corresponding estimates of 0.046 and 0.034 reported by Nichols and Johnson (1990), (z-test (males) = 3.77, $P < 0.001$; z-test (females) = 4.44, $P < 0.001$). Whether these decreases indicate a recent decline in adult harvest rates or reporting rates is unknown. Summer survival rate estimates are higher than those reported by LeMaster and Trost (1994), and female mortality during summer appears much larger for females than males. However, the large standard errors of summer survival rates preclude declaration of any statistically significant differences. Improvements in female summer survival estimates could be made with additional early season banding (Table 4), and therefore this practice could be justified if summer mortality is an important issue for improved wood duck management.

If the objective is to improve estimates of annual female survival and recovery rates in the mid-Atlantic region, then our results suggest that incorporating additional banding effort into wood duck nest box programs on a regional scale can reduce CVs of adult annual survival rates. However, if this effort detracts from amount of effort devoted to traditional preseason banding, then precision of estimates of both AHY and HY survival rates will decline. We encourage natural resource agencies and their cooperators in the mid-Atlantic and southern states to increase their preseason banding efforts to achieve the quotas suggested by the USFWS, so that management of this important waterfowl species will be based on reliable knowledge of its current population biology.

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