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COMPARISON OF AERIAL AND GROUND TECHNIQUES FOR DISCOVERY AND CENSUS OF WADING BIRD (CICONIIFORMES) NESTING COLONIES[1]

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Among wetland animals, populations of colonially-nesting wading birds have shown great utility as bioindicators of contaminants (Custer et al. 1991), condition of prey stocks (Frederick and Spalding 1994), and ecosystem behavior (Ogden 1994).

However, the estimation of breeding populations of these birds can be problematic. Censuses of colonies from the ground are difficult, expensive, and may disturb reproduction (Werschkul et al. 1976, Tremblay and Ellison 1979), and the employment of flight-line counts is too unreliable to be of use (Erwin and Ogden 1979, Erwin 1980, 1981). Consequently, aerial survey at low altitudes has become the most common method for discovering and censusing colonies of wading birds, particularly in regional surveys (Spaans 1975, Nesbitt et al. 1982, Runde et al. 1991).

Some bias is inherent in this methodology, since dark-colored species are much less visible than light-colored species, and because aerial methods are poor at quantifying nests that are under the vegetative canopy. Caughley (1977) and Pollock and Kendall (1987) have shown that aerial censuses of large animals often produce considerable underestimates of the true population, even when animals are clumped. Pollack and Kendall (1987) suggest that aerial counts are usually difficult to correct using any generic bias estimator and that corrections should be determined empirically in each study, using ground counts.

A number of studies have estimated the accuracy of counting nests of colonially-nesting ciconiform birds from the air. Employing ground counts as a standard, Gibbs et al. (1988) found that aerial surveys consistently underestimated colony sizes of Great Blue Herons by an average of 13%, and suggested that correction factors could be applied to derive true population size from aerial surveys alone. Rodgers et al. (1995) found that aerial counts were inaccurate for census of colonies of Wood Storks (*Mycteria americana*), probably because of visual confusion with Great Egrets (*Ardea albus*). Dodd and Murphy (1995) assessed nine techniques (including aerial counts and aerial photography) for counting Great Blue Heron colonies in South Carolina, and found that when used alone, all methods resulted in wide confidence intervals for the statewide nesting population.

Here, we compare the size, species composition, and efficiency of colony discovery in the central Everglades of Florida using systematic aerial survey techniques alone, with information derived over a four-year period from a combination of aerial and ground search methods. Because the habitat in the study area is open and aerial viewing conditions excellent, this comparison constitutes a test of the aerial method at its greatest possible advantage.

METHODS

STUDY AREA

During 1992–1995, we performed systematic ground and aerial surveys over Water Conservation Areas 2 and 3 (291,477 ha) in the central Everglades of southern Florida. The central Everglades is flat, and the vegetation is predominantly open, wet-prairie slough interdigitated with sawgrass strands (*Cladium jamaicensis*) and tree-islands of various types (Loveless 1959, Gunderson and Loftus 1993). The study area is entirely freshwater marsh, and is vegetatively homogeneous.

SYSTEMATIC AERIAL SURVEYS

We searched for colonies by flying east-west oriented transects spaced 2.6 km apart over the study area. We used a Cessna 172 high-wing single engined aircraft at 244 m above ground level, and at approximately 185 kph airspeed. This combination of altitude and transect spacing was derived empirically by flying by known colonies at various horizontal distances with naive observers. Detection reached 100% at 1.5 km from the colony, and the 2.6 km spacing of transects therefore allowed considerable overlap between transects. One

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observer on each side of the aircraft looked for groups of birds in tree islands; coverage was designed to be 100% of the study area. One observer (PCF) participated in all of the surveys, whereas the other observer was consistent within any year but changed between years. Survey flights were performed only on days with good visibility between sunrise and 12:00 EST, at least once during every month between January and July of each year. Each survey of the entire area took between eight and ten hours of flight time over two or three days.

When a group of birds was located, it was overflown at various altitudes between 300 and 100 m to allow repeated counts by both observers. At least one low pass (70 m) was made to ascertain the presence of rare or dark-colored species, to confirm species composition, and to ascertain stage of nesting. The location of all colonies was determined with a Global Positioning System (GPS) on board the aircraft, with a stated accuracy of 300 m. Raw counts were typically of numbers of adult birds. These counts were converted to numbers of nests according to stage of nesting—if in courtship or nestbuilding, both members of the pair are likely to be present, and raw counts were divided in half to estimate numbers of nests. If in incubation, numbers of birds were considered roughly equivalent to numbers of nests. Unless a colony exhibited more than one distinct pulse of nesting of any species, the peak count of nests between January and June was taken to be the total number of nest starts for that year.

SYSTEMATIC GROUND SEARCHES

We performed systematic searches for colonies of wading birds using airboats, which provided access to all wetted marsh in the study area. We conducted the surveys between early April and late May of every year (coinciding with the peak period of incubation for all species) by approaching all tree islands in the study area in an airboat, a method that reliably flushes any birds that are present. Using an on-board GPS, we systematically searched the study area in north-south belt transects of 0.9 km width and confirmed search progress on a gridded map. Once a colony had been located, we circled the colony to within 50m to flush any birds present. If stage of nesting could not be determined from the boat, or if the colony was large (area of nesting greater than approximately 75 m), the colony was entered on foot, and nests counted. Raw counts of birds were converted to estimated numbers of nests by the same methods as with aerial counts (above).

If the colony site was very large (> 200 m in any dimension), nests were counted by two or more observers walking through the colony. With the exception of the small day-herons, nests were distinguishable to species if eggs or young were present (McVaugh 1975). Nests of Tricolored Herons (*Egretta tricolor*), Snowy Egrets (*E. thula*) and Little Blue Herons (*E. caerulea*) are indistinguishable during incubation. In these cases, we assumed that the relative numbers of adults of each species that flushed were proportional to the percentage of nests of each species. In most cases, however, we were able to return to these colonies during the nestling period, when differences in chick plumage allowed positive species identification.

We found that the best possible estimates of nesting had to be assembled using information from both aerial and ground surveys. Early-season aerial surveys, for instance, were used to estimate numbers of Great Egret nests that were abandoned prior to initiation of ground visits; because this species nests in open vegetation and is quite conspicuous, these counts are likely to have been accurate. In very large colonies of conspicuous, white-plumaged species (> 1,500 nests) we found it difficult to be systematic in counting the spatially extensive colonies and considered aerial surveys superior under these circumstances. Aerial surveys also were used in several instances to supplement ground information when separating Little Blue Heron nests from those of other dark-colored species, because the chicks are white-plumaged.

We combined information from both aerial and ground counts to give the best estimate of the number of colonies (defined as aggregations of > 10 nests) and number of nest starts in any given year. We then compared these estimates with those derived only from the information recorded during aerial surveys, in order to examine the efficiency of the aerial method in locating colonies and estimating nest starts. Values presented are means ± SD.

RESULTS

We found that use of the aerial method alone gave estimates of numbers of nests of 9 species that were 70% of the total derived from both aerial and ground surveys (range 55–86% among years), and estimates of numbers of colonies that were an average of 21% of the total (range 13–32%, see Table 1).

The accuracy of the aerial method alone varied considerably among the ten species (range for aerial accuracy of nest and colony counts among species was 0–99.8%). Means of species-specific annual accuracies averaged across white species (Great Egrets [*Ardea albus*], White Ibises [*Eudocimus albus*], Snowy Egrets, Cattle Egrets) was 80 ± 0.18% for nests and 73.5 ± 13.7% for colonies. Colonies of dark-colored species (Little Blue Herons, Tricolored Herons, Great Blue Herons [*Ardea herodias*], Black-crowned Night Herons [*Nycticorax nycticorax*], and Glossy Ibises [*Plegadis falcinellus*]) were much more infrequently discovered, and total numbers were inefficiently counted using aerial methods alone (nests: $\bar{x}$ = 17.0 ± 21.8%, colonies: $\bar{x}$ = 15.0 ± 14.3%).

The error in the aerial method stems both from not finding colonies as well as from underestimation of nests at known colonies. At colonies that were counted using both aerial and ground methods, the aerial method underestimated nests by an average of 28.3% (all species combined, across years). Again, the light colored species had low mean annual error (0–49%) relative to the dark colored species (47–91%). The total percentage of nests missed due to miscounts varied considerably between years (5–53%), and there is no obvious consistent explanation for the inter-annual differences. The contribution of this counting error to total error varied between 19 and 86% among years.

DISCUSSION

Even though the aerial surveys were relatively efficient at quantifying the nests and colonies of the numerically most important species in the study area, the average

TABLE 1. Best estimates of actual numbers of nests (aerial plus ground counts, see Methods) and colonies of ciconiiform wading birds during four years in the central Everglades, with estimates of the accuracy of the aerial method alone.

			GE[1]	WI	LB	TC	SE	CE	GB	BC	GI	Total
1992	Aerial plus ground	nests	21,871	13,365	975	1,513	1,734	200	117	127	30	39,932
		colonies	29	7	40	40	13	1	58	11	2	201
	Aerial accuracy[2]	nests	0.784	0.993	0.509	0.231	0.908	0	0.034	0.394	0	0.857
		colonies	0.690	0.857	0.650	0.050	0.615	0	0.017	0.182	0	0.323
1993	Aerial plus ground	nests	1,879	0	564	368	162	430	325	166	0	3,894
		colonies	34	0	22	22	5	7	185	3	0	278
	Aerial accuracy	nests	0.831	n.a.	0.191	0.796	1.000	0.640	0.052	0.060	n.a.	0.623
		colonies	0.765	n.a.	0.364	0.455	1.200	0.857	0.032	0.667	n.a.	0.230
1994	Aerial plus ground	nests	2,527	100	764	1,043	287	345	346	112	3	5,527
		colonies	52	1	29	54	10	3	232	14	1	396
	Aerial accuracy	nests	0.928	1.000	0.325	0.014	0.697	0.377	0.009	0.063	0	0.552
		colonies	0.769	1.000	0.241	0.056	0.300	0.667	0.009	0.143	0	0.152
1995	Aerial plus ground	nests	3,027	780	479	629	369	2,176	489	174	40	8,163
		colonies	52	2	24	39	8	6	355	6	1	493
	Aerial accuracy	nests	1.020	1.000	0.077	0.024	0.664	0.987	0.084	0.006	0	0.782
		colonies	0.750	1.000	0.083	0.026	0.500	0.833	0.037	0.000	0	0.134
Mean aerial accuracy												
	nests	mean	0.891	0.998	0.276	0.266	0.817	0.504	0.045	0.131	0.000	0.703
		SD	0.105	0.004	0.185	0.367	0.163	0.422	0.032	0.177	0.000	0.140
	colonies	mean	0.743	0.952	0.335	0.146	0.654	0.589	0.024	0.248	0.000	0.210
		SD	0.037	0.082	0.240	0.206	0.387	0.402	0.013	0.290	0.000	0.087

[1] GE = Great Egret, WI = White Ibis, LB = Little Blue Heron, TC = Tricolored Heron, SE = Snowy Egret, CE = Cattle Egret, GB = Great Blue Heron, BN = Black-crowned Night Heron, GI = Glossy Ibis.
[2] Aerial estimates/aerial and ground estimates.

annual error of the aerial method alone for all species (30% of nests, 61% of colonies) is probably unacceptable for most studies. The use of correction factors to predict true counts also seems unacceptable, given the high interannual variability in accuracy of the aerial method. Use of aerial methods alone therefore seems most appropriate for studies in which it is known *a priori* that large, conspicuous colonies of purely or largely white-colored species predominate, and in which novel colony locations are likely to be conspicuous.

The error of aerial estimates in total numbers of nests derives from at least two main sources of error—miscounting dark-colored species, and not finding colonies. The error contributed by each source appears to average out at close to half the total error, but the differences among years is extreme (19–95% across years). It seems likely that the interannual differences are related both to the number of small, novel colonies and the species that predominate (large white species are more likely to be counted accurately).

For the dark-colored species, the aerial method alone was very poor at determining numbers of nests and colonies. To some extent, the relative rarity of some of the species must have played a part. Using our best estimates, Glossy Ibises and Black-crowned Night Herons were less than 1.5% of total nests, and all dark colored species represented less than 21% of all nest starts. In addition, Little Blue Herons, Tricolored Herons, and Great Blue Herons also tended to nest in the smaller colonies and were likely to be found in colonies occupied only by other dark-colored species (Frederick 1995). Among dark-colored species, aerial surveys had their highest efficiency with Little Blue Herons. This is probably a result of the fact that the young of Little Blue Herons are white plumaged and are easily detected from the air after chicks have hatched.

In our comparisons, the estimates of birds and colonies compiled from ground and aerial methods together are treated as the standard for comparison. It should be clear that there must be biases inherent even in this combination of methods and that the true estimate of breeding population size must be some higher figure than we report. Given the systematic nature of ground searches and the almost complete accessibility of the entire area to airboats, we feel that the ground search method must have been very efficient at locating colonies. However, there is no obvious way to assess the accuracy of ground counts for determining true numbers of nests.

The study area in the central Everglades is homogenous habitat with only isolated tree islands and generally excellent visibility for aerial surveys. In situations with less open conditions, the biases of aerial surveys that we have quantified are likely to be even more severe. We recommend aerial survey as an important tool in quantifying numbers of colonies and nests of colonially-nesting waterbirds, but one that should almost never be used without additional information from systematic ground surveys and censuses.

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AN EXPERIMENTAL TEST OF THE FUNCTION OF STICKS IN THE NESTS OF HOUSE WRENS[1]

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Key words: House Wren; nest building; sex roles in nest building; nesting success; Troglodytes aedon.

Males of several species of wrens (Troglodytidae) participate to varying degrees in nest building, some even building multiple nests (Kendeigh 1941, Verner 1965, Collias and Collias 1984, Kennedy and White 1992). The Northern House Wren (*Troglodytes aedon*) is a monomorphic, insectivorous, secondary cavity nesting species which is seasonally monogamous although polygyny does occur (Kendeigh 1941, Drilling and Thompson 1988, Johnson and Kermott 1991). Male House Wrens build multiple nests within their territories by placing sticks into several cavities (Kendeigh 1941, McCabe 1965, Finch 1989), while one cavity is the focus of the male's attention and receives the most sticks (Kendeigh 1941, Belles-Isles and Picman 1986). Soon after a female arrives on the male's territory she constructs a soft nest of rootlets, grass, and feathers on top of the stick foundation into which she deposits her eggs (Kendeigh 1941, Kennedy and White 1992). Although females insert some sticks into cavities (Kendeigh 1941, McCabe 1965), it is the male that expends the most effort filling nesting cavities with sticks (Kendeigh 1941, Kennedy and White 1992).

Two hypotheses advanced (Kendeigh 1941) to explain the function of this behavior were territorial claim and female choice. Since competition for suitable nesting sites may be high for cavity-nesting species (Yahner 1983/1984, Brawn and Balda 1988, Gustafsson 1988), by placing sticks into cavities first, early arriving males may outcompete later arrivals for a favorable nest site. In many monomorphic species, males may be subject to stronger sexual selection which may manifest itself in behavioral rather than morphological consequences (Andersson 1994). Females may therefore select males based on the extent to which the stick foundation is completed (Kendeigh 1941), and may evaluate a male's commitment to her and the nest site similar to the Black Wheatear, *Oenanthe leucura* (Moreno et al. 1994), perhaps reducing her chances of being a secondary female if mated with a polygynous male. The extent to which the sticks serve a specific function with regard to the nest structure itself has not been tested.

By preventing males from filling treatment nest boxes with sticks, I tested two hypotheses. First, if filling a nest box with sticks by males is necessary for courtship and mating, then stick removal from boxes should preclude pair-bond formation. Second, if having a stick foundation enhances fledgling success in some way, than pairs with sticks removed should be less successful in rearing and fledging young.

METHODS

I studied an unbanded population of House Wrens at the Edmund Niles Huyck Preserve and Biological Research Station on the Helderburg Plateau, southwest Albany County, New York (elev. 370–500m, 42°10′N, 74°10′W). I used 70 nest boxes during the summers of 1992 and 1993 and 40 in 1994. Nest boxes were spaced at least one acre apart in preferred wren habitat (Parren 1991). The boxes measured 10 × 14 × 20 cm internally, with an entrance hole 3 cm. in diameter and were painted either dark brown or forest green. Boxes were attached to a tree or metal post with the entrance hole approximately 1.5 m. above the ground and opened from the front to facilitate nest examination and stick removal.

Nest boxes were randomly assigned each year to treatment or control groups prior to the arrival of wrens

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