Longevity and Size of Wood Stork (*Mycteria americana*) Colonies in Florida as Guides for an Effective Monitoring Strategy in the Southeastern United States

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Abstract.—Wood Storks (*Mycteria americana*) breed in colonies widely dispersed across approximately 3,350 km^2 within the United States, and effective monitoring of this population presents immediate tradeoffs between coverage, accuracy, and cost. Here, we summarize surveys in Florida 1991-2005 as a first step towards improving existing survey strategies. In order to determine whether counts from aircraft are a suitable technique for quantifying nests, we compared aerial and ground counts at the same eleven colonies in 2004. Across all colonies, aerial counts averaged 8.1% more nests, probably as result of either better visibility or mistakenly including Great Egret (*Ardea alba*) nests in the count. During the period 1991-2005, statewide totals in Florida ranged from 2,211-6,449 nests, with an apparently increasing trend through time. Annual modal colony size fluctuated from 65-144 nests, with significantly smaller modal size in 2001-2004, suggesting that colony size has decreased over time. Current survey practices are to visit all previously active colonies and all new ones that are reported or that are encountered during flights between known colonies. Surveys are not systematic, and the number or importance of novel, undetected colonies is unknown. In south Florida, where past and potential colony sites have been systematically surveyed annually, turnover (proportion of colony sites different in two surveys) increased rapidly with interval between surveys, and within ten y, >80% of colony sites differed. Annual turnover rates were not uniform across years, and young colonies appeared to have higher turnover than older ones (up to four y). Novel systematic aerial transects across suitable habitat in central Florida revealed approximately one novel colony/525 km^2. Thus, abandonment of old colonies and formation of new ones is a typical and fairly rapid process in this species. Throughout the state, larger colonies were more persistent, and were surveyed more often than small colonies. The bias of the current nonsystematic survey strategy is towards visiting older colonies that are likely to disappear within 15 y, and against finding newer, growing colonies. This is likely to bias estimates of total population downwards compared to true values. We strongly recommend that surveys be geographically systematic, even if this reduces coverage. We suggest these systematic surveys be located in large blocks (hundreds or even thousands of km^2) in areas with suitable habitat and historically high colony densities.

Key words.—Florida, *Mycteria americana*, reproduction, Wood Stork.

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Breeding aggregations of Wood Storks (*Mycteria americana*) in the United States are widely dispersed over approximately 334,000 km^2 in four states. Effective monitoring of this federally endangered species must, therefore, be at a large geographic scale, making tradeoffs between cost, accuracy and coverage of immediate concern. Searches and surveys for stork colonies over large areas have usually been accomplished using fixed-wing or rotary aircraft (Ogden 1978; 1994; Nesbitt *et al.* 1982; Kushlan and Frohring 1986; Ogden *et al.* 1987; Rodgers *et al.* 1987). While the accuracy of aerial counts of wading birds can be high (Frederick *et al.* 2003), storks tend to nest in the tops of trees, and are large, white targets. Rodgers *et al.* (1995) found that by comparison with ground counts, aerial counts of populations of stork colonies underestimated numbers of nests by 10.1%, though counts at individual colonies were considerably more inaccurate.

Since the area over which storks nest is too vast to be covered completely by systematic aerial surveys, most survey attempts have been focused on repeat visits to colonies discovered in the past. New colonies are added as they are encountered on routes between existing colonies, or as a result of citizen or biologist reports of activity (Nesbitt *et al.* 1982; Ogden *et al.* 1987; Rodgers *et al.* 1987; Coulter *et al.* 1999). While these surveys probably account for the majority of large, conspicuous colonies, this strategy may induce bias into both the size of colonies discovered, and the resulting population estimates. The extent of this bias is unknown, in part because the colonies missed by nonsystematic surveys have never been quantified.

Although Wood Storks are relatively philopatric by comparison with other wading birds in the southeastern U.S. (Frederick and Ogden 1997), their colonies are not permanent. Some colonies are known to be continuously active for over 60 years (Coulter *et al.* 1999), others are active for only a year or two. However, colony turnover has never been measured for the species. Colony turnover is of importance for designing a conservation strategy for colony sites and their associated foraging areas. An understanding of the biological factors leading to either abandonment or retention of a colony site also will be useful for prioritizing colonies for conservation or survey effort.

In this study, we use surveys in Florida to assess the accuracy of aerial counts, to measure colony turnover rates, and to document the formation of new colonies. The Florida surveys are relevant for this purpose because they encompass a large part of the U.S. nesting range (approximately 45% of land area) and breeding population (approximately 40%), include many kinds of habitats, and have a relatively long sampling period (35 years for many colonies).

METHODS

Numbers of stork nests in Florida colonies reported between 1991 and 2006 were analyzed, with additional information from the Everglades going back in some cases to the 1970s. In the Everglades, stork colony surveys were, until 1986, aimed at visiting all previously active sites. After 1986, surveys were systematic, with 100% coverage of the entire Everglades from Loxahatchee National Wildlife Refuge in the north to Florida Bay in the south. Systematic survey flights were flown in east-west oriented transects at 240 m altitude and approximately 200 km/h airspeed with one observer on either side of the aircraft so that visual overlap occurred between transects, which were spaced 2.6 km apart.

The statewide surveys were conducted annually from 1991 through 1995, 1999, and 2001 through 2005. From 1991-1995 and 1999-2001, approximately half the previously identified colonies were surveyed per year, whereas from 2002-2005, nearly all (>95%) were visited each year. Surveys generally followed the south to north gradient of nesting initiation dates, with earliest surveys in March in the south and latest in June in the north.

Aerial surveys were generally accomplished in a Cessna 172 single-engine fixed-wing aircraft. The coordinates of the targeted colonies were programmed prior to take-off into a handheld GPS receiver with an external, windshield-mounted antenna, and colonies were visited in a way that minimized total travel time. Each colony was approached at an altitude of 300 m above ground level, followed by a descent to 150-200 m when close to the site. If a colony was active, storks usually were visible somewhere in the vicinity (flying, perching, or attending nests). If no birds were seen on approach, the search gradually circled outward from the colony site as the observers scanned for birds within an area of about 10 km^2. At each active colony, two observers counted the storks and estimated the number of occupied nests (i.e., with adults, eggs, or young). If no nests were observed, the site was declared inactive and the observers proceeded to the next nearest colony.

In 2004 eleven stork colonies were counted in central peninsular Florida from both aircraft and from the ground. On the ground, stork nests were counted while walking slowly through the colony in a fashion that systematically covered the area of nests.

In addition, systematic aerial surveys were performed in central Florida to estimate the number of novel colonies that might be missed by visiting only previously known colony sites. Wood Stork colonies were searched for in three rectangular plots in central Florida in May and June 2003, and the surveys were repeated at two of these plots in 2004. The plots were positioned to include as much suitable nesting habitat as possible. Each plot was 50 km long (aligned east/west) and 21 km wide, and was surveyed in five or six parallel transects spaced 3.0 km apart at an altitude of 300 m above ground level and an airspeed of about 160 km/h between 08.30 and 15.45 h. Two observers seated on opposite sides of the airplane directed their continuous scan 90 degrees to the transect axis for a distance of 1.5 km away from the aircraft. Diversions from the transect were taken in order to inspect any white birds seen on the ground within that distance. If nesting Wood Storks were present, the colony was circled to count the nests as done during the regular colony counts. If complete visual coverage is assumed, a total of 1,640 km^2 was searched.

In 2005, in addition to conducting visual counts as described above, each colony was photographed with a digital 35 mm single-lens reflex camera with a 100-400 mm lens equipped with an electronic image stabilizer. The visual and photographic counts were compared for 25 colonies in central Florida.

Colony turnover rates were expressed as the proportion of colonies that were different in two comparison years, using the formula of Buckley and Buckley (2000):

$$T = \frac{(S_1 + S_2)}{(N_1 + N_2)t'}$$

where S_1 = the number of sites used only in the first census year of the comparison pair; S_2 = the number of sites used only in the second census year; N_1 = the total number of sites used in the first year; N_2 = the total number of sites used the second year; t' = the number of years between the censuses, and T = the turnover rate.

In the Everglades, where all active and inactive colonies were systematically detected (as above), colony turnover rates were tallied as a function of interval between surveys. All pairs of years in the record were compared to generate a series of intervals. This gave a picture of the proportion of previously recorded colonies that might be expected to be active if survey effort were noncontinuous or spaced over intervals of a given number of years.

RESULTS

A total of 406 active colonies were tallied in Florida during 1991-2005, during 678 checks of colonies. Mean colony size overall was 116.2 nests (SD = 209.5). Statewide totals ranged from 2,211-6,916 nests, with an apparently increasing trend through time (Figure 1). Annual modal colony size fluctuated from 65-144 nests, with significantly smaller mean size in 2001-2004 (55.6, SD = 24.01) than in 1991-1995 (109.3, SD = 30.55, $t = 3.1$, $p < 0.02$).

Accuracy of Aerial Survey Methods

In total, 1,428 nests were counted from the air, and 1,480 from the ground at eleven colonies in 2004, representing a 3.6% difference for all colonies combined (average error 25 nests, SE = 6, range of error at individual colonies 5-65%). Error at individual colonies was higher, averaging 25 nests (18.5%). Visual estimates were fairly close to counts of photographs of the same colonies. The total visual count of 25 colonies in 2005 was 1,260 nests, while the total count from photographs was 1,180. The difference for the population of 25 colonies was 6.8% (average error 20 nests, SE = 6, range 0-270%).

Colony Persistence and Turnover Rate Characteristics

Occupancy rate (proportion of years a colony was occupied by any storks, given that the colony was checked for occupancy) of newly discovered colonies in the statewide survey declined markedly during the first three years, followed by an increase in occupancy rate thereafter (Figure 2). Larger colonies survived longer (Figure 3).

In the Everglades data set, annualized colony turnover rate decreased rapidly as the hypothetical interval between surveys increased (Figure 4), and stabilized at a low and fairly consistent level after about four years. The proportion of the population found in different colonies in any two comparison years in the Everglades was computed. There was no relationship between the proportion of the population in different colonies with increasing interval between survey years (Figure 5). However, as the interval between survey years reached 14 years, the proportion of the measurable population in different colonies approached 100%.

New colonies were often discovered in the surveys. For example, eleven colony locations novel to the dataset were detected in 2004 with a mean of 36 (23.0 SD, range 4-65) nests per colony. The 400 nests in these eleven colonies represented 7.7% of the total

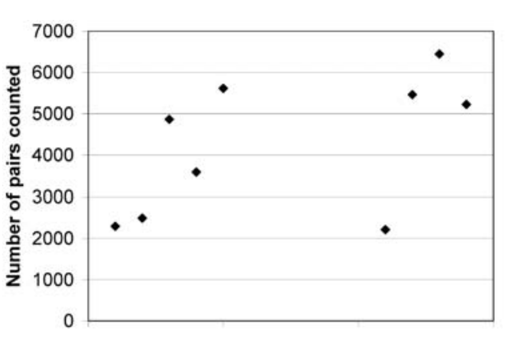

Figure 1. Numbers of nesting pairs of storks in Florida statewide surveys, 1991-2006. The trend is probably increasing, since 2001 was an incomplete survey in a very dry year, and 2005 was generally a poor year for nesting.

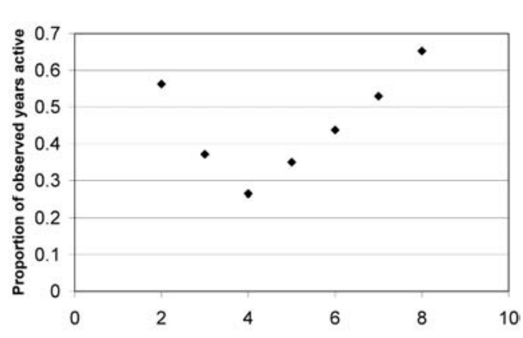

Figure 2. Occupancy rate (proportion of years active given the colony was surveyed) as a function of number of years since colony was discovered, in Wood Stork colonies throughout Florida, 1991-2005.

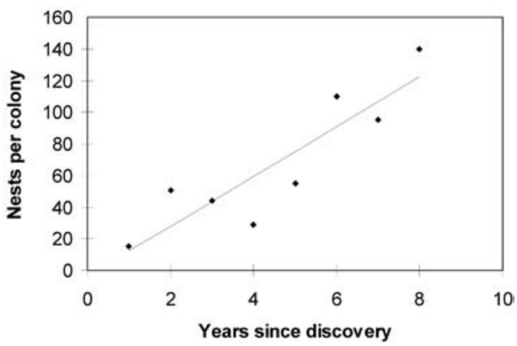

Figure 3. Size of Wood Stork colony in relation to maximum age of colony since discovery. Longevity increased with age, $R^2 = 0.796$, $p < 0.002$).

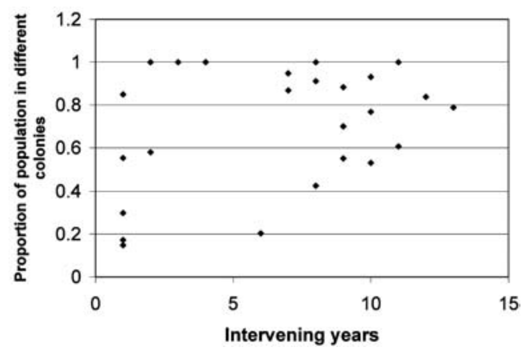

Figure 5. Raw (not annualized) proportion of the Wood Stork population in the Everglades that is in different colonies, by interval between surveys. There is no significant relationship between the two variables ($R^2 = 0.03$, $p = 0.14$), though the proportion in different colonies does appear to converge on 100% by the twelve to 14 y. interval.

5,214 nests found in 2004. This is particularly noteworthy considering that most of these colonies were found opportunistically, not as a result of a large-scale systematic search. In systematic surveys for novel colonies in central Florida in 2004, two novel colonies were found in approximately 1,050 km^2 of suitable habitat surveyed, or about one novel colony per 525 km^2.

DISCUSSION

This 15-year history of aerial surveys for storks in Florida provides evidence to suggest that the nesting population in the state is increasing (see also Borkhataria *et al.* 2007, this volume for more quantitative assessment), that colonies are widespread throughout the state and highly variable in size, and that they are declining in size over time. The decline in size is not likely to be a function of increased survey effort, since the time spent surveying or the type of survey strategy has not changed appreciably during the study period. Instead, this trend probably reflects the increasingly fragmented nature of Florida wetlands, and a decreasing carrying capacity for most colony sites (Gibbs 1991).

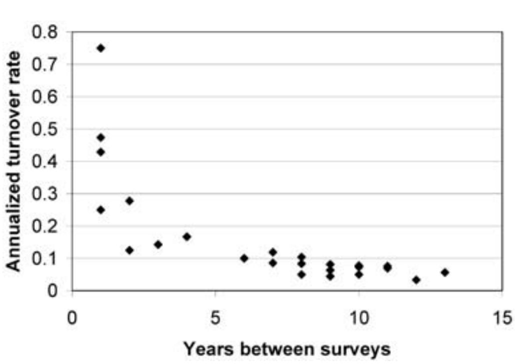

Figure 4. Annualized turnover rate of Wood Stork colonies in the Everglades of Florida, USA (see methods for calculation of turnover) in relation to the number of years between surveys. This distribution was generated using all possible pairs of years in the dataset and reflects the likelihood of finding colonies to be active after a specified interval.

Despite Wood Storks having been identified as relatively philopatric among ciconiiform birds (Frederick and Ogden 1997), turnover rates were surprisingly high in this species, with 80% of even large colony locations being different within ten years of their initiation. The most robust of the evidence for frequent turnover comes from areas of the Everglades that are largely protected from human disturbance and significant habitat fragmentation, suggesting that relatively frequent changes of colony locations may be typical of this species. However, the Everglades has seen considerable change in hydrologic conditions during the study period and is also considered naturally hypervariable among ecotypes (Sklar *et al.* 2005). It is therefore not clear how applicable these turnover rates might be to other areas, nor of how representative they might be of the species prior to human modifications of the landscape.

The turnover in colony locations implies that some colonies may often go undetected by the "check previously known colonies" strategy that has been used in Florida and the southeastern US for many years. Our results suggest that while some inactive colony sites are re-used, there are a substantial number of novel locations each year. In the case of central Florida, we found at minimum one novel colony/525 km^2.

The actual extent of bias resulting from nonsystematic surveys is difficult to estimate. Presumably, novel colonies would be younger and smaller on average than established ones, and therefore would collectively represent a small proportion of the total population at any one time. Thus missing them might not have a large effect on the population estimate. Until the size of novel colonies can be quantified, however, it is impossible to estimate the effect further.

Stork colonies are often discovered by means other than aerial survey, including reports by biologists and the public, flightlines noted from the air on other types of biological surveys, etc. The degree to which these sources account for the efficient discovery of new colonies is unknown, but they could be very important in areas of high human population density and/or activity by biologists. However, unsolicited reports are typically unreliable in both space and time, and probably should not be counted upon as an integral part of a regular, quantitative field survey effort.

There is some evidence that older and larger colonies have higher survival rates than do younger smaller ones. This comes both from statewide surveys, and from the more systematic Everglades information. In statewide surveys, checked colony sites of less than four years of age had successively decreasing probabilities of occupancy, whereas older colonies had increasing occupancy rates. This observation was bolstered by the Everglades data, where annualized turnover rates appeared to stabilize after three to five years. There is some suggestion, therefore, that if a colony survives more than a few years, the survival rate increases considerably. There also appears to be a direct relationship between size of colony and longevity, suggesting that larger colonies are also more stable breeding sites.

Future Survey Design

There are several ramifications of this information for improved design of a monitoring program for breeding storks in the United States. First, it seems clear that there are substantial numbers of colonies that are undetected by the current survey protocol, and that the effect on the total population estimate cannot be known without at least occasionally locating colonies systematically. This argues directly for a systematic survey design.

Second, there may be important biases inherent in the nonsystematic surveys. Colony encounters are biased towards larger and older colonies. If older colonies go extinct at some nontrivial rate, and novel locations are under-represented in any annual survey, it will result in a perceived population trend that is lower than the true trend. The interval between surveys is also of interest. The stork population has typically been monitored throughout the range annually for five years, with intervals of approximately five years between monitoring periods. The statewide and Everglades information both suggest that after five years a substantial proportion of colonies will be novel; starting such a survey series with a target of checking "old" and partially defunct colonies may exacerbate the bias discussed above. The bias in trend is inherent in the nonsystematic survey method, and also argues strongly for a systematic methodology.

The objectives of any stork monitoring program in the southeastern United States should be to detect changes in population size, trend, and geographic shifts in nesting distribution. Any such monitoring plan for Wood Storks must be at a large enough scale to encompass the large breeding range and dispersed pattern of nesting typical of the species.

Our findings indicate that the aerial survey technique is efficient and reasonably accurate at estimating numbers of birds nesting in a population of colonies, once colonies have been located. Our error at estimating population (3.8%) is similar in magnitude to that of Rodgers *et al.* (1995; 10.1%), although it should be clear that error at estimating individual colonies in both studies was much higher. Aerial survey is therefore likely to be useful for estimating the size of populations only because of errors at individual colonies canceling one another. However, as above, the nonsystematic survey design has variable encounter rates of colonies of different size and age characteristics, and probably leads to biases in estimation of both total population size, and trend.

Complete-coverage aerial surveys throughout the entire range would certainly correct these biases, but would be so expensive and time consuming as to be infeasible.

Monitoring of stork populations therefore poses a common and fundamental problem of tradeoffs between coverage and quality of information (Lawler and O'Connor 2004). We suggest that accuracy in estimating trend and local population size are probably more important in managing this species than is continuous (but low quality) geographic information. In order to accomplish a systematic survey design without huge increases in total survey effort, systematic surveys necessarily would need to be focused in smaller areas. Although this means that total population size must be extrapolated from these smaller areas to the entire range, it should be remembered that nonsystematic survey effort in effect requires large and probably unjustifiable assumptions in order to estimate true population size as well.

It makes logistical sense to focus such systematic surveys in areas of historically high colony (and population) density. Ideally, the area surveyed should be large enough to encompass a population of both large and small colonies as they fluctuate in space over time, and large enough to be representative of a geographic region (e.g., coastal plain of Georgia, the Everglades, etc.) in order to detect major geographic shifts. We suggest that these characteristics will generally require an area of hundreds to 1,000 km^2 within any one region. For Florida, areas that include historically high densities of stork colonies include the Everglades, southwest Florida, the area immediately east of Tampa Bay, and

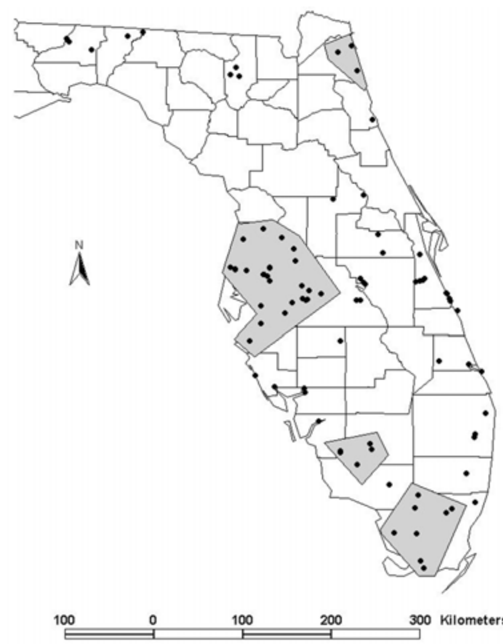

Figure 6. Areas of high Wood Stork colony density in Florida (shaded) as possible systematic survey areas for detecting population trend and shifts between major geographic areas. Dots represent known Wood Stork colonies.

coastal northeast Florida (Figure 6). These areas constitute collectively approximately 18,590 km^2, and contained between 88% (2003) and 54% (2004) of all stork nesting identified in Florida. We estimate that systematic, 100% coverage surveys in these areas would require approximately the same amount of flight time as the current nonsystematic statewide surveys do.

LITERATURE CITED

Buckley, P. A. and F. G. Buckley. 2000. Patterns of colony-site use and disuse in saltmarsh-nesting Common and Roseate Terns. Journal of Field Ornithology 71: 356-69.

Coulter, M. C., J. A. Rodgers, J. C. Ogden and F. C. Depkin. 1999. Wood Stork. Pages 1-28 *in* The Birds of North America (A. Poole and F. Gill, Eds.). The Birds of North America, Inc., Philadelphia, Pennsylvania.

Frederick, P. C. and J. C. Ogden. 1997. Philopatry and nomadism: contrasting long-term movement behavior and population dynamics of White Ibises and Wood Storks. Colonial Waterbirds 20: 316-23.

Frederick, P. C., B. A. Hylton, J. A. Heath and M. Ruane. 2003. Accuracy and variation in estimates of large numbers of birds by individual observers using an aerial survey simulator. Journal of Field Ornithology 74: 281-87.

Gibbs, James P. 1991. Spatial relationships between nesting colonies and foraging areas of Great Blue Herons. Auk 108(4): 764-70.

Kushlan, J. A. and P. C. Frohring. 1986. History of the southern Florida Wood Stork population. Wilson Bulletin 98: 368-386.

Lawler, J. J. and R. J. O'Connor. 2004. How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? Condor 106(4): 801-14.

Nesbitt, S. A., J. C. Ogden, H. W. Kale II, B. W. Patty and L. A. Rowse. 1982. Florida atlas of breeding sites for herons and their allies: 1976-1978. U.S. Fish and Wildlife Service, Office of Biological Services, FWS/OBS-81/49. 450 pp.

Ogden, J. C. 1978. Recent population trends of colonial wading birds on the Atlantic and Gulf coastal plains. *In* Wading Birds (A. Sprunt IV, J. C. Ogden and S. Winckler, Eds.). Research Report No. 7. National Audubon Society, New York.

Ogden, J. C. 1994. A comparison of wading bird nesting dynamics, 1931-1946 and 1974-1989 as an indication of changes in ecosystem conditions in the southern Everglades. Pages 533-570 *in* Everglades: the Ecosystem and its Restoration (S. Davis and J. C. Ogden, Eds.). St. Lucie Press, Delray Beach, Florida.

Ogden, J. C., D. A. McCrimmon, Jr., G. T. Bancroft and B. W. Patty. 1987. Breeding populations of the Wood Stork in the southeastern United States. Condor 89: 752-759.

Rodgers, J. A., S. B. Linda and S. A. Nesbitt. 1995. Comparing aerial estimates with ground counts of nests in Wood Stork colonies. Journal of Wildlife Management 59: 656-66.

Rodgers, J. A., A. S. Wenner and S. T. Schwikert. 1987. Population dynamics of Wood Storks in North and Central Florida, USA. Colonial Waterbirds 10: 151-56.

Sklar, F. H., M. J. Chimney, S. Newman, P. McCormick, D. Gawlik, S. L. Miao, C. McVoy, W. Said, J. Newman, C. Coronado, G. Crozier, M. Korvela and K. Rutchey. 2005. The ecological-societal underpinnings of Everglades restoration. Frontiers in Ecology and the Environment 3(3): 161-69.