FINAL PERFORMANCE REPORT

WILDLIFE RESEARCH SECTION
FISH AND WILDLIFE RESEARCH INSTITUTE
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PROJECT TITLE:	**PRODUCTIVITY AND HABITAT MODELING OF WOOD STORKS *Mycteria americana* NESTING IN NORTH AND CENTRAL FLORIDA (PID 9292 267 2144)**
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ABSTRACT.—Hydrologic conditions (rainfall and surface water levels), latitude/longitude, and area and types of habitats surrounding wood stork (*Mycteria americana*) colonies in Florida were analyzed at 10 km, 20 km, and 30 km radii around each colony to examine the relationship between stork nesting variables (fledging rate and colony size) during 2003-2005 and available habitat surrounding each colony. Seven variables within 10 km, 14 variables within 20 km, and 6 variables within 30 km of colonies were correlated with fledging rates. Both wetland and non-wetland habitats had significant effects on fledging rate and colony size. Rainfall during the previous 12-24 months had the most constant effect on fledging rates among all the variables. Both larger colonies and colonies in North Florida had higher fledging rates. While some variables and habitats had positive effects and other habitats had negative effects on fledging

rates, results were not consistent across all three distances from colonies suggesting hydrologic and habitat variables may have differential effects with increasing distance from a colony. The size of a stork colony was sensitive to a larger number of variables and the results of modeling were similar among 10, 20, and 30 km distances. Colonies were smaller in the northern part of Florida and coastal colonies were larger than interior freshwater colonies. Because storks preferentially use ephemeral habitats and foraging sites closer to a colony early in the season, these habitats and sites may not be available later in the season, forcing the storks to shift to alternate more distant sites and habitats later in the season. A hypothesis is proposed whereby storks establish their colonies using proximate clues of prey availability based on the effects of past rainfall and certain preferred habitat types within 10 km. These proximate cues to prey availability and foraging substrate surrounding the potential colony are acquired by storks sometime prior to the beginning and during the initial nesting season. However, the long-term stability of a colony ultimately is determined by yearly rainfall patterns and habitat variables >10 km distance, and fledging rates that contribute to future recruitment of nesting birds and the resulting increase in colony size.

INRODUCTION

Historically, the Wood Stork (*Mycteria americana*) was a common breeding species throughout the southeastern United States. However, precipitous declines in the stork's range and population occurred during the mid-1900s (Kushlan and Frohring 1986, Ogden *et al.* 1987). Ultimately, the United States population was listed as endangered in 1984 (USFWS 1984). While the number of stork nests and colonies in Georgia and South Carolina appeared to increase during the 1980s and 1990s, storks are experiencing continued nesting related problems in some regions of Florida, especially South Florida (Coulter *et al.* 1999). The most recent data indicates there were about 7,200 nesting pairs in 22 colonies within Florida during 2001-2005 (Slay and Bryan *et al.* 2001, Brooks and Dean 2008).

Wood storks nesting at the Dee Dot colony, Duval County.

One of the objectives of the Wood Stork Recovery Plan (i.e., 3.3 Monitor productivity of stork populations) is to obtain productivity levels exceeding a minimum standard to ensure continued viability of the U.S. stork population (USFWS 1997, 2000). To assess achievement of this objective, knowledge of the number of fledged young per nest must be determined for a representative number of colonies for a minimum of 3 years. The reclassification from endangered to threatened could be accomplished when there are 6,000 nesting pairs and annual productivity is greater than 1.5 fledglings/nest calculated as a 3-year average. Along with wildlife agencies in North Carolina, South Carolina, and Georgia, the U.S. Fish and Wildlife Service (USFWS) provided a grant to the FWC during 2003-2005 to determine the productivity of storks in Florida (Rodgers 2002, Rodgers *et al*. 2008). These data are currently being used by the USFWS to evaluate the status of the stork population in the United States and determine if the species meets recovery criteria for down-listing (Brooks and Dean 2008, USFWS 2010).

Most researchers have found wood stork fledging success is variable among different years and colonies (Kahl 1964, Ogden *et al*. 1978, Clark 1978, Ehrhart 1979, Hopkins and Humphries 1983, Coulter and Bryan 1995, Rodgers and Schwikert 1997, Rodgers *et al*. 2008) and have suggested food resources are the proximate factor responsible for fledging rates. Wood storks use a variety of wetland habitats for foraging (Coulter *et al*. 1987, Hodgson *et al*. 1988, Bancroft *et al*. 1991, Coulter and Bryan 1993, Gaines *et al*. 1998, Coulter *et al*. 1999, Gaines *et al*. 2000). Of the 45 habitat categories and communities identified in Florida by the FWC (Florida Fish and Wildlife Conservation Commission 2005), at least 15 are continuous or intermittently flooded wetlands. The status of most of these wetland communities (e.g., freshwater marsh and wet prairie, cypress swamp, marine-estuarine, etc.) is classified as poor and declining due to conversion to agriculture and development, ground water withdrawal, incompatible forestry and surrounding land use practices, nutrient runoff, incompatible recreation activities (disturbance to and displacement of wildlife), and effects of sea-level rising on coastal wetlands. The challenge will be to balance protection of our wetland communities for economic, public, and wildlife uses (Florida Fish and Wildlife Conservation Commission 2005). Another objective listed in the Wood Stork Recovery Plan (1.1.2 Locate roosting and foraging habitat) is the task of identifying foraging habitat critical to the recovery of the species (USFWS 1997, 2000). In addition, recovery task 1.2. (Prioritize habitat) recommends developing a prioritization scheme to identify colonies and their foraging habitat with the greatest degree of threat. However, there is little information on the amounts and types of wetlands around each colony available to foraging storks, especially in Florida. Furthermore, there is no published information on the relationship between stork nesting variables (fledging rate and colony size) and amount and types of wetland habitat surrounding each colony in Florida.

Wood storks nesting at the Pelican Island colony, Brevard County.

OBJECTIVES

1. Collect stork nesting data (fledging rate and number of nests) for colonies monitored by

FWC and hydrological data (rainfall and surface water levels) associated with each colony monitored during 2003-2005.
2. Determine the types and area of each habitat class surrounding each colony monitored based on the most recent satellite imagery data.
3. Using the data derived from objectives 1-2, model the relationship between stork nesting variables and hydrological and habitat variables.
4. Prepare a final report for the USFWS.

STUDY POPULATION AND METHODS

Study Area

The study area consisted of stork colonies monitored during a previous study (Rodgers *et al.* 2008, Figure 1, Appendix 1). These colonies were distributed around North and Central Florida, including interior and coastal sites. Center locations of all colonies were delimited with a Wide Area Augmentation System (WAAS) enabled Global Positioning System (GPS) unit. The center of the region occupied by nesting storks was averaged over the study period.

Study Approach

Data on wood stork nesting variables (i.e., dependent variables including fledging rates and colony size) were collected as part of a previous study (Rodgers *et al*. 2008). In summary, either all nests (colonies <100 nests) or a sample of the nests (i.e., 25-50% of nests at larger colonies) were monitored on a biweekly schedule during the March-August breeding season for about 22 colonies each year during 2003-2005. Associations between breeding variables and the independent variables (i.e., hydrologic and habitat variables) were examined using Geographical Information Systems (GIS) and statistical software for the current study.

Hydrologic and Habitat Variables

Hydrologic conditions (rainfall, surface water levels), latitude/longitude location within Florida, and area and types of habitats surrounding a stork colony are hypothesized as being important variables for determining stork colony fledging rates and number of nests. Based on the feeding ecology and flight distances of foraging storks (Coulter *et al*. 1987, Bryan *et al*. 2005, Bryan *et al*. 2008, Borkhataria *et al.* 2008) and the recommended zonal distances used by the USFWS for management guidelines, I used 10 km, 20 km, and 30 km radius distances around each colony to examine the relationships between stork nesting variables and available habitat surrounding each colony (Figure 2). Hydrological data from a recording station within

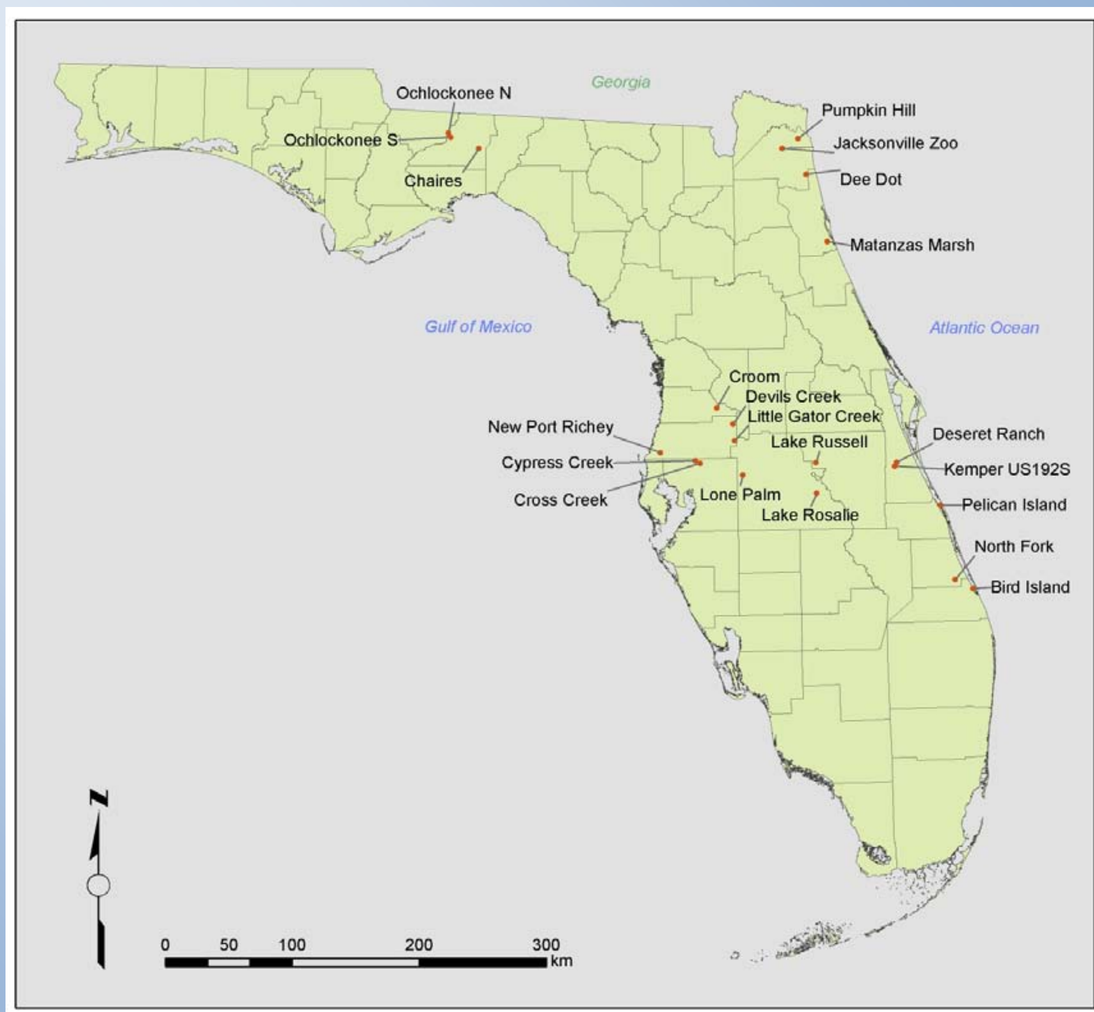

Figure 1. Wood stork colonies monitored during 2003-2005 breeding seasons in North and Central Florida.

15 km of each stork colony were obtained online from the Florida Climate Center (2005) and Hydrologic Data Collection (SJRWMD 2009) databases. These variables included the following:

- cumulative rainfall during the 12 months prior to the start of the nesting season (circa April),
- cumulative rainfall during 12-24 months (termed previous year's rainfall) prior to the start of the nesting season, and
- adjusted surface water level (difference between the current year level and the average of the previous 10 years) at the start of the nesting season.

The area (hectares) and types of habitat within 10 km, 20 km, and 30 km distances surrounding each colony was extracted from the Florida 2003 Vegetation and Land Cover grid using GIS landscape information from the Closing the Gaps Program (Kautz *et al.* 2007). The 2003 landcover dataset has a pixel resolution of 30x30 m (900 m^2). Because the area of habitat within each 10-km annulus around a colony increases as the square of the radius, there are about 314 km^2 within 10 km, 1,256 km^2 within 20 km, and 2,826 km^2 within 30 km of a colony (Figure 2). The types of habitats follow Gilbert and Stys (2004) and are listed in Table 1.

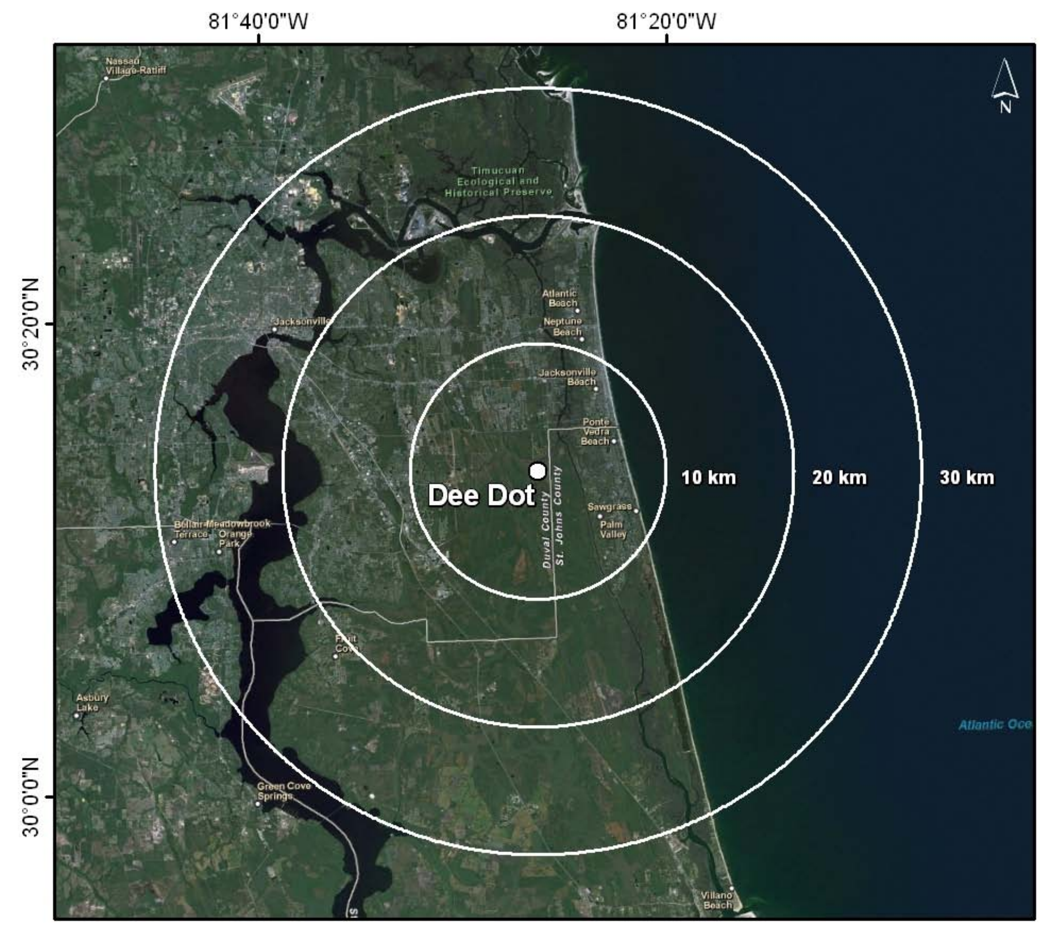

Figure 2. Aerial image of the region surrounding the Dee Dot stork colony with 10 km, 20 km, and 30 km regions delineated.

Because there may be unknown edaphic or geographical factors influencing the productivity of storks at the colony or regional level, each colony also was identified by its latitude and longitude and characterized as being either coastal (≤30 km of the Atla ntic or Gulf coastlines) or interior (>30 km) in location and coded as a bivariate response *Yes* or *No*, respectively. Latitude, longitude, and coastal location were considered fixed variables in the full statistical model.

Statistical Analysis

Data for fledging rate and colony size were analyzed as a colony-year unit. Thus, a colony monitored for 3 years or 3 colonies monitored during 1 year were represented by 3 colony-years. Fledging rates were expressed on a fledglings/nest basis for nests initiated and include nests that failed prior to fledging young.

Prior to initiation of field work in 2003, a power analysis was done to estimate the sample size of stork nests required to detect a difference of 0.25 fledgling/nest in the mean colony reproductive rate, attain a power=80%, with an alpha of 0.05 (Bond 2003, Friendly 2003). Using the mean of 1.29 fledglings/nest and a standard deviation of 1.16 (Rodgers and Schwikert 1997), I estimated a minimum of 38-42 nests (range based on upper and lower confidence intervals) should be monitored each year. I imposed a minimum of 2 years of data per colony for the modeling of stork productivity to avoid any biases associated with too few years of monitoring because I was interested in multiple-year associations *contra* single-year phenomenon.

All statistical analyses were made with the Statistical Analysis System (SAS Institute, Inc. 2003). Unless stated otherwise, values are represented as the mean ± 1 standard deviation. Statistical analyses of reproductive variables were made only for colony-years with ≥38 nests. Prior to pairwise comparisons, the data were tested for normal distribution with the Shapiro-Wilk statistic using the UNIVARIATE procedure and for homogeneity of variances with Bartlett's likelihood ratio test using the DISCRIM procedure. The MEANS procedure was used to calculate standard descriptive statistics including mean, standard deviation, and upper and lower 95^{th} percentile confidence intervals. An inverse variance weighting option was used with the MEANS procedure to account for the uneven sample sizes among colonies. I assumed independence among years and a constant correlation within each colony.

The goal of the stork habitat modeling was to identify associations that may exist between the nesting variables (fledging rate and number of nests) and the wetlands available as foraging habitat surrounding each colony. Hydrologic, habitat, and geographic predictors (x axis) were first displayed with each nesting variable (y axis) in scatter plots (continuous predictors) and box plots (ordinal and categorical predictors) for each colony for visual analysis of simple bivariate patterns. A least-squares fitted simple linear regression trend line for possible linear relationships and a nonparametric Loess-smoothed trend line for possible non-linear patterns of association was overlaid on each scatter plot to characterize the relationship between the dependent (fledging rate and number of nests) and independent (hydrologic variables, area of each habitat type, geographic location) variables. I was especially looking for non-linear relationships among the variables and predictors.

For this study, I assumed that the area of each type of habitat derived from the landcover data in Kautz *et al.* (2007) were constant properties that only needed to be measured once and represented the area of each type of habitat during 2003-2005. If the area of each habitat varied somewhat by year (e.g., annual loss due to development), then these values would be similar to variables measured with Berkson errors (Berkson 1950) when the actual predictor values are more variable than the predictor values used in my study. Berkson errors have been shown to not cause much bias in parameter estimation but they can inflate the apparent power beyond what is probably appropriate (i.e., precision and P-values appear more impressive than they really should be).

Because of the unbalanced design of this study due to no nesting activity at some colonies in certain years, the MIXED procedure was used to model associations between the two nesting variables and hydrologic, habitat, and geographic variables. The MIXED procedure fits mixed linear models (generalizations of standard linear models) using both fixed (hydrologic variables, latitude, longitude, location in respect to coastline, and habitat variables) and random effects (year). Colony and year were used as class variables, and latitude, longitude, and nest numbers were fixed covariates when colony-years were pooled.

Because of the large number of hydrologic, habitat and geographic predictors being considered in the analysis, I used a backward-stepping selection method to reduce the number of non-significant variables from the model (Harrell 2001). For each dependent variable, a full model containing all predictors was first fitted and then the predictor with the highest Type III effect test F-statistic with a P-value > 0.10 was removed from the list of included predictors and then the regression model was refitted (Littell *et al.* 2006). This back-stepping procedure was repeated until all remaining predictor effect P-values are ≤0.05. Final Poisson and negative binomial models without random effects were compared using the small sample version of the Akaike Information Criterion (AICc). Results from the best non-random effect model by AICc and the best random effect model by AICc were summarized for each dependent variable. Standard errors also were computed for each effect estimate. Fit statistics, over-dispersion parameters, and characteristics of the relationship between observed and predicted values for the final models with and without the random effect were calculated.

RESULTS

Fledging Rates

Seven variables within 10 km, 14 variables within 20 km, and 6 variables within 30 km of colonies exhibited significant effects on wood stork fledging rates (Table 1).

TABLE 1. Results of modeling the relationship between wood stork fledging rate with hydrologic, edaphic, and habitat types at 10, 20, and 30 km zones around each colony. Values represent the Pr > | *t* |.[a]

Variable or habitat type	Distance from colony

	10 Km	20 Km	30 Km
Annual rain	0.0422	ns	ns
Previous years rain	0.0425	0.0101	0.0027
Adjusted water level	ns	ns	ns
Colony size	ns	0.0075	ns
Latitude	<0.0001	0.0021	ns
Longitude	ns	0.0014	ns
Coastal location	ns	0.0055	ns
Coastal strand	ns	ns	ns
Sand/beach	ns	ns	ns
Xeric oak scrub	ns	ns	ns
Sand pine scrub	ns	ns	ns
Sandhill	ns	ns	ns
Dry prairie	0.0002	0.0002	ns
Mixed pine-hardwood forest	ns	ns	0.0002
Pinelands	ns	ns	ns
Tropical hardwood hammock	ns	ns	ns
Freshwater marsh and wet prairie	ns	0.0132	<0.0001
Sawgrass	ns	ns	ns
Shrub swamp	ns	ns	ns
Bay swamp	ns	0.0072	ns
Cypress swamp	0.0003	0.0007	ns
Cypress/pine/cabbage palm	ns	0.0236	ns
Hardwood swamp	ns	ns	0.0039
Mixed wetland forest	0.0101	ns	ns
Salt marsh	ns	ns	ns
Mangrove swamp	ns	ns	0.0081
Tidal flat	0.0003	0.0011	
Open water	ns	<0.0001	<0.0001
Shrub and brushland	ns	ns	ns
Grassland	ns	ns	ns
Bare soil/clear cut	ns	ns	ns
Improved pasture	ns	0.0017	ns
Unimproved pasture	ns	0.0022	ns
Agriculture	ns	ns	ns
High impact urban	ns	ns	ns
Low impact urban	ns	ns	ns
AICc	116.1	212.1	158.4

[a]ns=nonsignificant correlation (P<0.05).

The final model for the relationship between stork fledging rate and hydrological and habitat variables within 10 km distance was:

FLEDGING RATE = -12.8021+0.4458 *total annual rainfall* +0.6521 *previous years rainfall* +0.4151 *latitude* +0.0004 *dry prairie* -0.0005 *cypress* +0.0005 *mixed wetland* +0.5964 *tidal flats*.

The final model for the relationship between stork fledging rate and hydrological and habitat variables within 20 km distance was:

FLEDGING RATE = 109.2300 +0.0036 *colony size* +0.8836 *previous years rainfall* +1.4475 *latitude* -1.8502 *longitude* -2.79 *coastal location* +0.0002 *dry prairie* -0.0001 *freshwater marsh* -0.0027 *bay swamp* -0.0001 *cypress* +0.0046 *cypress mixed* +0.0862 *tidal flats* -0.0001 *open water* -0.0001 *improved pasture* +0.0018 *unimproved pasture*.

The final model for the relationship between stork fledging rate and hydrological and habitat variables within 30 km distance was:

FLEDGING RATE = +2.7056 +0.9781 *previous years rainfall* -0.0001 *mixed hardwood hammock* -0.0001 *freshwater marsh* -0.0001 *hardwood swamp* -0.0002 *mangrove* -0.0001 *open water*.

Only previous year's rainfall (i.e., 12-24 months before the beginning of the nesting season) had a significant positive effect on fledging rates within all three distances, while current year's rainfall (i.e.,≤12 months before the current nesting season) exhibited a significant positive effect only within 10 km. Except for improved and unimproved pasture within 20 km, there was no significant negative effect of human altered habitats (e.g., bare soil/clear cut, agriculture, high and low urban) on stork fledging rate. In general, there were more negative correlations between fledging rate and variables with greater distance from a colony (i.e., 10 km with 6 positive and 1 negative correlations, 20 km with 7 positive and 6 negative correlations, and 30 km with only 1 positive but 5 negative correlations).

There was a negative correlation between fledging rate and coastal location (i.e., fledging rate increased with distance) up to 20 km, but thereafter no effect was detected. This is in contrast to the finding of a positive correlation between fledging rate and area of tidal flats within 20 km but consistent with a negative correlation with mangrove within 30 km.

Ambiguous results included the positive effect of dry prairie on stork fledging rate. Dry prairie habitat does not appear to support aquatic prey or suitable foraging habitat for storks. The negative correlations between certain wetland habitats (e.g., cypress, freshwater marsh, and mangrove) and stork fledging rate also were unexpected but suggest these habitats do not drive stork fledging rate.

Colony Size

The size of a wood stork colony was sensitive to more variables and the results of the modeling were similar among 10, 20, and 30 km distances. The final model for the relationship between colony size and hydrological and habitat variables within 30 km distance was:

COLONY SIZE = -34570.00 -453.58 *latitude* +581.78 *longitude* +620.46 *coastal location* -

0.01 *dry prairie* +0.66 *freshwater marsh* +12.59 *sawgrass* -0.0263 *shrub swamp* -0.01 *cypress* -1.21 *cypress mixed* +0.03 *mixed wetland* +0.02 *hardwood swamp* +0.04 *saltmarsh* +0.18 *mangrove* -10.90 *tidal flats* -0.01 *improved pas*ture -0.01 *high urban*.

Colonies were smaller in the northern part of Florida. Coastal colonies also were larger than interior freshwater colonies. Several (e.g., improved pasture and high urban) but not all human-related habitats had negative effects on colony size.

DISCUSSION

Both wetland and non-wetland habitats had significant effects on wood stork fledging rate and colony size. These effects were both positive and negative in direction and varied by distance from a colony. Rainfall during the previous 12-24 months had the most constant effect on fledging rates among all the variables suggesting that nesting success is dependent upon rainfall from 1 to 2 years prior to the start of the current stork breeding season. Neither previous year's nor current year rainfall had an effect on colony size. However, rainfall still may be a factor in the initiation of nesting by storks (Ogden *et al*. 1980). Both larger colonies and colonies in North Florida had higher fledging rates. While some variables and wetland types had positive effects (e.g., cypress, tidal flat) and other habitats had negative effects (e.g., freshwater marsh, cypress, hardwood swamp) on fledging rates, these results were not consistent across all three distances from colonies suggesting these habitats may have differential effects with increasing distance from a colony.

The negative effect of open water (i.e., freshwater lakes and rivers, and marine waters) on fledging rates is probably due to storks not being able to forage in standing water deeper than 30-40 cm. These large areas of unusable habitat may have factored into the decrease in fledging rates at colonies within 20 km from the coastline (see Figure 2). However, the positive correlation between fledging rates and tidal flats within 20 km suggests this habitat maybe important foraging habitat for storks in Florida. Tidal flats have the potential to trap and concentrate prey in small pools during lower tidal cycles. Bryan and Robinette (2008) and Bryan *et al*. (2005) also found storks utilized coastal tidal habitats during lower tidal ranges and suggested these habitats resulted in higher nesting success in Georgia.

There were several ambiguous associations between fledging rate and modeled variables. Certain forested wetland habitats (e.g., cypress, hardwood swamp, bay swamp, and mangrove) may support aquatic prey, but these habitats were not associated with higher fledging success perhaps because storks may not be able to use their tactile foraging method effectively in these heavily vegetated habitats. I have no clear understanding for the negative correlation with freshwater marsh and wet prairie, which appear to be suitable foraging habitat, unless the emergent vegetation in these wetlands is too dense to allow storks to feed. However, the positive correlation with unimproved pasture may be because this habitat often contains many small, ephemeral wetlands, which may not have been accurately detected with the 30x30 m pixel resolution used for the GIS landcover analyses in this study. Storks and other wading birds frequently use these ephemeral wetlands as they draw down and concentrate prey (Kahl 1964; Coulter and Bryan 1993; Bryan *et al*. 2001; Gaines *et al*. 1998, 2000).

There appears to be both positive and negative correlations between wood stork fledging rates and the 3 hydrological, 4 edaphic, and 29 habitat variables considered in this analysis. The breeding responses of storks to these 36 variables varies with their distance from colonies; 6 of 7 positive correlations were within 10 km distance and 7 of 13 positive correlations were within 20 km. This is because storks tend to feed closer to their nesting colony earlier in the breeding season and farther away later in the nesting season (Bryan *et al*. 2008) as they shift their use of foraging sites to reflect the availability of prey. Maintaining the integrity of these important foraging resources and lands surrounding a colony with varying distances or zones will present challenges for land managers.

MANAGEMENT IMPLICATIONS

This study did not examine the spatial distribution and intra-seasonal availability of the individual habitat types, which may actually be driving when and what habitats storks use at various distances and times of the year. These data could be derived from temporal (both seasonal and inter-year) locations and habitats used for foraging storks derived from radio-instrumented birds nesting at selected colonies in Florida. Quantitative prey sampling of the habitats and sites used by foraging storks is needed before specific recommendations for habitat preferences can be made. Ultimately, habitat use by storks and other waterbirds is dependent upon availability of prey interacting with water depth and area of habitat, all of which can vary seasonably and yearly (Ishtiaq *et al*. 2010). Another area of future investigation should be the differential effect of using the 10-30 km management zones of the USFWS around colonies when the colony is near the coast (see Figure 2). These management zones may need to be increases for coastal colonies where a sizeable proportion of the area within a 30 km region is openwater and unusable foraging habitat.

Wood storks are generalists in their selection of foraging habitats and should be expected to exhibit shifting among forging habitats during the breeding season similar to other avian species with variable prey and habitat preferences (Nummi and Poysa 1993, Nolet *et al*. 2002, Davis *et al*. 2009, Rioux *et al*. 2009, Mitchell *et al*. 2010). This habitat shifting is a strategy to use the most profitable food resources and habitats (Madsen 1985). If storks preferentially use ephemeral habitats early in the season, these same habitats may not be available later in the season, forcing the storks to shift to alternate more distant sites and habitats later in the season. These more distant sites with longer hydroperiods may be too deep early in the season but may become suitable as they drawdown later in the season. Some of these habitats may not even be suitable and therefore used during very dry years or when too deep during wet years.

Based on known wood stork foraging ecology and results of this study, I propose a hypothesis for where storks locate their colonies. Storks establish their colonies using proximate cues of prey availability based on the effects of past rainfall and certain preferred habitat types within 10 km. These proximate clues to prey availability and suitable nesting and foraging substrate surrounding the potential colony are acquired by storks sometime prior to the beginning and during the early part of the first nesting season. However, the long-term stability of a colony ultimately is determined by yearly rainfall patterns and variables >10 km distance from the site, including fledging rates that contribute to future recruitment of nesting birds and the resulting increase in colony size. These ultimate factors are acquired by storks later in the breeding season and in subsequent years as they respond to rainfall and the distribution and current year status of foraging habitat surrounding a colony. Since older stork colonies tend to exhibit more nests and greater longevity than first-year colonies (Frederick and Meyer 2008), storks in new and smaller colonies may be still assessing available resources and adapting to the carrying capacity of the foraging habitat surrounding the colony. Colony size is ultimately dependent upon past nesting performance and the amount and quality of certain habitats within an energetically efficient flight distance from the colony.

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APPENDIX 1. Wood stork colonies monitored during 2003-2005 in North and Central Florida.

Colony	County	Latitude Longitude	Number of nests	Site description
Chaires	Leon	30˚ 25.682 84˚ 07.744	216-352	Cypress and black gum-dominated swamp in the eastern part of the Lake Lafayette drainage basin. Mostly rural lands to the north, housing development and landfill to the south. Little or no public access.
Ochlockonee North	Leon	30˚ 32.500 84˚ 22.836	95-150	Black gum swamp on the edge of a natural pond. Surrounded by pine plantation. Railroad track runs along the eastern side. No public access to the private pond but accessible along the railroad right of way.
Ochlockonee South	Leon	30˚ 30.434 84˚ 21.497	46-47	Cypress swamp on the edge of a natural pond. Housing development to the south and east. Railroad track runs along the eastern side. Little public access to the private pond but more accessible along the railroad right of way.
Pumpkin Hill	Duval	30˚ 28.337′ 81˚ 30.333′	0-98	Isolated cypress-dominated domes located on the Pumpkin Hill State Preserve managed by the Florida Park Service. Either a single site or two sites have contained nesting storks. Both sites are prone to dewatering during droughts resulting in no nesting. Colony site is surrounded by pine flatwoods habitat. Little public or no access occurs at the site.
Jacksonville Zoo	Duval	30˚ 24.254′ 81˚ 38.706′	83-91	Several live oak trees within the savannas exhibit of the Jacksonville Zoological Gardens managed by Duval County. Staff has erected artificial structures but few (<3 nests) storks use. Site is surrounded by the zoological gardens and there is considerable public access. However, the storks do not appear to be disturbed by the visitors.
Dee Dot	Duval	30˚ 13.380′ 81˚ 26.749′	125-251	Remnant cypress swamp in an impounded Lake Davis of the private Dee Dot Ranch. Most of the original cypress trees have died due to the prolonged flooding augmented by a well for fisheries enhancement for the lake. Storks now nest almost exclusively in woody vegetation growing in the stumps of dead cypress trees. Site is surrounded by sandhill pine. Little public access to the site.

Matanzas Marsh	St. Johns	29˚ 43.857′ 81˚ 17.349′	18-42	Isolated cypress and gum-dominated dome on the Matanzas Marsh Wildlife Management Area managed by the Florida Division of Forestry, FWC and SJRWMD. The site is prone to dewatering during droughts resulting in no nesting. Cypress dome is surrounded by planted pine. Little or no public access to the site during the nesting season.
Lake Disston	Flagler	29˚ 17.842′ 81˚ 23.465′	0-139	One or two sub-colonies in cypress along the northern edge of Lake Disston. Eastern sub-colony formed first, followed by the occasionally active but smaller western sub-colony. Site is surrounded by pine flatwoods and pastures. Nesting occurs on the lake edge and is accessible by boaters.
Hontoon Island	Volusia	28˚ 59.564′ 81˚ 21.791′	0-67	Primarily cypress with a few gum trees along the shoreline of the St. Johns River. Low river levels result in dewatering during droughts and no breeding. Nest trees probably on private land and is surrounded by bottomland hardwoods and pastures. Nesting occurs on the river edge, which is accessible by boaters.
Croom	Hernando	28˚ 32.276 82˚ 12.204	180-334	Cypress swamp in the Withlacoochee River flood plain. Drainage to the east and frequently dries up. Part of the Croom Wildlife Management Area managed by the Florida Division of Forestry and FWC.
Devils Creek	Pasco	28˚ 25.103 82˚ 05.556	0-14	Isolated oak on a ridge in a cypress swamp. Sustained wind damage to oaks during 2004 hurricane season. Land managed by the SWFWMD. Little public access to the site.
Little Gator Creek	Pasco	28˚ 17.529 82˚ 03.597	0-247	Impounded cypress swamp that drains into the Withlacoochee River. Within the Green Swamp region and managed by the FWC as a wildlife environmental area. Access is controlled during the nesting season to prevent disturbance.
New Port Richey	Pasco	28˚ 12.906 82˚ 40.440	156-226	Remnant cypress swamp in a retention pond surrounding by high density housing. Nutrients in runoff from surrounding housing development and stork guano results in highly enriched, green water. Accessible only by residents but little disturbance.
Cypress Creek	Hillsborough	28˚ 09.766	36-59	Remnant bottomland hardwood-dominated island constructed in a borrow pit for I75-I275 interchange to north. Surrounding land is

		82˚ 23.896		upland and bottomland forest and part of county environmental area. Much of the hardwood nesting substrate has died due to breeding activity. Little or no public access to the site during the nesting season.
Cross Creek	Hillsborough	28˚ 08.547 82˚ 21.119	18-46	Planted small cypress growing in a man-made pond at the entrance to the Cross Creek development. High density development completely surrounds the site. Accessible to the public but little evidence of disturbance.
Lone Palm	Polk	28˚ 03.065 82˚ 00.438	63-171	Remnant bay head island constructed in a borrow pit/lake as part of a private golf course. The nesting substrate has degenerated considerably during the last few years due to guano deposition. The island is adjacent to the 18th green and receives numerous golf balls from golfers. Otherwise, little public access to the site.
Lake Russell	Osceola	28˚ 07.501 81˚ 24.723	63-87	Cypress on the edge of a lake. Probably the result of storks having relocated farther up river along Reedy Creek (hence earlier Reedy Creek colony designation?) drainage during the last decade. Little public access to the current site.
Lake Rosalie	Polk	27˚ 54.602 81˚ 25.324	37-125	Remnant cypress-dominated island created in a dredged extension off of Lake Rosalie. Cypress sustained wind damage during 2004 hurricane season. Little public access to the site.
Deseret Ranch	Brevard	28˚ 06.117′ 80˚ 46.313′	176-254	Brazilian pepper-dominated finger islands in an old borrow pit on the private Deseret Ranch. Individual islands/fingers are separated by deep canals. The site is surrounded by pasture. Little or no public access to the site.
Kemper Ranch	Brevard	28˚ 05.395′ 80˚ 49.209′	74-125	Brazilian pepper-dominated islands in an old borrow pit on the private Kemper Brothers Ranch. Individual islands/fingers are separated by deep canals. The site is surrounded by pasture. Little or no public access to the site. Also known as US192 South colony.
Pelican Island	Indian River	27˚ 47.794′ 80˚ 25.940′	29-78	Mangrove-dominated island within the Pelican National Wildlife Refuge in the Indian River Lagoon. Site is posted and managed by refuge staff but accessible by boaters. Storks have abandoned the site since the mid-2000s.
North Fork	St. Lucie	27˚ 15.872′	68-86	Mangrove-dominated island in St. Lucie River owned by St. Lucie

		80˚ 19.648′		County. Nesting mostly occurs in the interior of the island but is accessible by boaters.
Bird Island	Martin	27˚ 11.416′ 80˚ 11.270′	73-87	Mangrove-dominated spoil island near Sewell's Point. Nesting mostly occurs in the interior of the island but is accessible by boaters. Also known as Sewell Point colony.