

**Species Status Assessment Report
for the
Wood Stork
(*Mycteria americana*)
Version 1.1**



Photo Credit: Christy Hand, South Carolina Department of Natural Resources

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**U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia**

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Photo Credit: South Carolina DNR. Former rice impoundment drawn down for management purposes, ACE Basin, South Carolina.



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EXECUTIVE SUMMARY

This update to the species status assessment, Version 1.1, differs from Version 1.0 as we have updated 2.7.1 Breeding Season Habitat section, current demographic information in Chapter 4, updated the Conservation Actions in Section 5.3, added Section 6.2 - Sea Level Rise - Future Impact analysis by the breeding range, and the updated wetland impacts sections for each breeding region based upon Sweet et al. 2022, and added Section 5.1.2 Changing Climate Conditions which includes the NOAA 2022 Climate Summaries for Florida, Georgia, South Carolina, and North Carolina. These updates did not change or influence the Service's recommendation; however, this SSA provides updated information consistent with the information that led to the recommendation.

The wood stork (*Mycteria americana*) is one of 17 species of true storks in the world, and the only stork species that breeds north of Mexico with breeding populations found in the southeast United States (U.S.), Cuba and Hispaniola, and from Mexico south through Central and South America to Argentina. Wood storks primarily prey upon fish and crustaceans and utilize both fresh and saltwater habitats. The U.S. breeding population was listed as endangered under the Endangered Species Act (ESA) in 1984 because it had declined by more than 75% since the 1930s. This was primarily due to the loss of suitable foraging habitat and colony nesting failures; particularly in the pre-listing core breeding region in south Florida where human actions had reduced wetland areas by about 35%, and construction of canals and ditches drained or changed the hydrology of ecosystems like the Everglades, Lake Okeechobee, Kissimmee River, and Big Cypress Swamp.

Wood storks are colonial nesting birds ("colonial breeders"), typically nesting with conspecifics and other wading bird species within a landscape containing sufficient wetland foraging habitats. In the southeastern U.S., wood storks generally use bald cypress, sweetgum, and mangroves for nesting substrate in various wetlands. In recent years, an increasing number of colonies have been established in wetlands in proximity to human activity such as housing, roads, and active waterways. Wood storks feed in natural and artificial wetlands where prey species are available, water depths are appropriately shallow (< 50 cm, often 10–30 cm), and vegetation is not dense. With a recent increased association of wood stork in human-altered landscapes, there have been observations of wood storks foraging in human impacted and created wetlands, as well as people feeding wood storks "human" food.

The primary threats identified for the U.S. wood storks include habitat loss, conversion, and degradation, and changing climate conditions, such as changes in precipitation, drought, and sea level rise. Land conversion affects wood storks through habitat loss, land use change, fragmentation, and degradation, which directly reduces the availability and quality of all wetland habitat types necessary to wood storks and indirectly impacts food resources in those habitats. Climate change is causing a variety of changes to the various ecosystems and wetland habitats that wood storks depend upon throughout their life cycle, which drive numerous stressors that impact the resources and conditions needed by wood storks, thereby impacting the species' demographic rates (nest success, juvenile survival, sub-adult and adult survival) and resulting viability. Other stressors such as starvation and abandonment of young, predation, disturbance of nesting and roosting sites, contaminants, collisions, poaching/hunting, disease, and fishing line entanglement, are likely impacting individuals, but available evidence does not indicate that these stressors are currently having population-level impacts. However, conservation measures

occurring at state, regional, and federal levels, with specific actions including land acquisition, protection of habitat, restoration and enhancement of habitat, applied research, and public outreach and education, do appear to be having positive population-level effects.

The U.S. breeding population of wood storks is categorized as a single population by genetic analyses; however, wood stork colonies and nest numbers generally cluster into four areas in the southeastern U.S. (northeast, northwest, central and southern). Thus, to assess population resiliency, we used these four U.S. breeding regions as our units of resiliency:

- **South Breeding Region** includes six counties in Florida south of Lake Okeechobee and the Okeechobee Waterway. Southern Florida Coastal Plain ecoregion.
- **Central Breeding Region** includes 15 counties in central peninsular Florida. Southern Coastal Plain ecoregion.
- **Northwest Breeding Region** includes 4 counties in northwest Florida, 6 counties in southwest Georgia and 1 county in east-central Georgia. Southeastern Plains ecoregion.
- **Northeast Breeding Region** includes Atlantic coast counties from northeast Florida (4 counties), Georgia (6 counties), South Carolina (8 counties), and North Carolina (4 counties). Middle Atlantic Coastal Plain ecoregion and Southern Coastal Plain ecoregion.

Demographic factors such as abundance, adult survival, reproductive success, juvenile recruitment, and population growth, influence wood stork resiliency. Influencing these factors are elements of habitat that determine whether the population can grow to carrying capacity, thus increasing the resiliency of populations. A resilient population needs sufficient wetland habitat with diverse resources to support survival and successful breeding. To assess the current and possible future condition of wood storks, we focused on factors that influence the population, and those for which we have sufficient data. These factors include nesting population size (number of pairs/nests), population growth trend, number of large persistent nesting colonies, and a measure of productivity. We then categorically assigned a condition of High, Moderate, or Low to each of these factors for each Breeding Region, and for the population as a whole. Finally, we assessed the current overall resiliency of each Breeding Region based on the average condition of all the demographic factors combined in the table below. Currently, the Northeast breeding region is considered highly resilient, the Northwest breeding region is considered moderately resilient, the central breeding region has moderate-low resiliency, and the south breeding region is considered high-moderately resilient. Collectively, by combining the condition of all the Breeding Regions together we found that the U.S. population is currently categorized as having high-moderate resiliency.

U.S. Breeding Population current demographic condition assessment.

Breeding Region	Population Size	Population Trend	Large Persistent Colonies	Productivity	Overall Demographic Condition
Northeast	High	High	High	High	HIGH
Northwest	Low	Moderate	Low	High	MODERATE
Central	Moderate	Low	Very Low	Moderate	MODERATE-LOW
South	High	Moderate	High	Low	HIGH-MODERATE

U.S. Population	High-Moderate	Moderate	Moderate	High-Moderate	HIGH-MODERATE
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No behavioral, genetic, morphological, or observable variations are within or among the breeding populations of wood storks in the U.S. Distinct Population Segment (DPS), or within the species range-wide. However, current representation is thought to be high in the U.S. DPS due to its historically demonstrated ability to continuously respond to changing habitat conditions and maintain and increase abundance while expanding its range northward. The broad spatial extent covered by the population across the four Breeding Regions reduces the risk to the population posed by any single catastrophic event. Furthermore, the impacts of stressors in one region may be mitigated by the fluid nature of breeding colonies throughout the range, as evidenced by shifts in nesting numbers among the four Breeding Regions in apparent response to varying conditions among the regions.

The future scenarios assessed for this SSA include varying levels and time frames (2050 and 2080) of stressors. Scenarios 1, 2, and 3 are based upon projections of land development changes and sea level rise (SLR) impacts to wetlands, and the likely implementation of conservation actions. All are based on the best scientific and commercial information available at this time. Scenario 1 is a current trends projection of development, NOAA Intermediate SLR projection, regulatory protections of wetlands, and conservation implementation at current or increased levels; Scenario 2 is based upon projecting a moderate increase in stressors, a NOAA High SLR projection, a current trend in development, and no increase to conservation and regulatory implementation (thus current trend); and Scenario 3 is the same as Scenario 2 with the current development trend, a NOAA High SLR along with a significant decrease in regulatory protections, decrease in conservation management due to lower funding levels like wetland restorations not targeting benefits specifically for woods storks. These scenarios consider potential impacts to the wood stork population, to nesting colonies, and to the current core foraging areas (CFA) within each Breeding Region, and thus habitats (wetlands) essential to the breeding ecology of wood storks.

Climate Change	Land Use Change Development	Conservation Actions
Scenario 1 – Low Stressor Increase with Conservation		
Sea-level rise ¹ : NOAA Intermediate (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions at current trends or increase Restoration at current levels or increased
Scenario 2 - Moderate Stressor Increase with Conservation		
Sea-level rise ¹ : NOAA High (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions: current trends Restoration at current levels

Scenario 3 - Moderate Stressor Increase with reduced Conservation		
Sea-level rise ¹ : NOAA High (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions decreased due to changes in regulatory mechanisms or lower funding levels Restoration no longer targets benefits to wood storks

¹Does not account for pre-inundation effects or habitat change.

The current demographic condition of HIGH-MODERATE in the U.S. Breeding Population is used as a proxy of current habitat condition for the future conditions analysis. In Scenario 1 and 2, the current condition of the U.S. Breeding Population range declines to MODERATE-LOW condition, based on habitat loss within the current CFA due to development and sea level rise, in 2050 and 2080. Under Scenario 3, the current condition of the Breeding Region based on habitat lost within the current footprint of the CFA declines to LOW condition in 2050 and in 2080. However, these future condition categories are representative only of habitat loss within the current footprint of the CFA, and does not account for the abundance of suitable habitat still available within the occupied range even considering extreme sea level rise impacts, marsh migration mitigating some of the predicted habitat loss, the creation of new salt marsh habitat due to sea level rise, and the wood stork's demonstrated tendency to establish new or currently unoccupied colony sites to take advantage of optimal environmental conditions.

There are approximately 26.2 million acres of suitable wetland habitat for wood stork within the Southeast U.S. Coastal Plain breeding range of Florida, Georgia, South Carolina, and North Carolina. Forty-two percent, approximately 10.8 million acres (41.2%), represents the current core foraging area that annually supports the current breeding population of approximately 10,000 breeding pairs of wood storks at 100 or more active nesting colonies. We note that within the wood stork breeding range there is an additional (approximately) 15.4 million acres of occupied suitable wetland habitat acres located in between and adjacent to the current occupied core foraging area acres. Suitable wetland habitat does not appear to have limited wood stork recovery.

In 2080 under the High Sea Level Rise projection (Sweet et al. 2022, pp. 11-13), approximately 3.5 million acres, (32.7%) of the breeding season core foraging area is projected to become inundated due to sea level rise, while 7.3 million acres (67.3%) will remain intact and unaffected by sea level rise, and available for wood stork breeding and foraging.

Despite lowered resiliency in some of the breeding regions given certain future scenarios under consideration, we expect that the wood stork will maintain its current level of redundancy in the U.S. Further, if the current trends continue, we would expect that the wood stork's range will continue to expand with the establishment of new nesting colonies due to the growing population and colony turnover. We expect that the wood stork will continue to be represented within the Southeast U.S. Coastal Plain within the current range of Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina. However, any decrease in future resiliency in populations could translate to a modest loss of representation (i.e., decreased resiliency may result in fewer individuals, which provide less opportunity for diversity). Regardless, this species has exhibited

a proclivity to respond to historical habitat changes and pioneering into new habitats, so despite potential losses in resiliency within the four Breeding Regions and the associated implications for representation, we expect that representation will remain relatively high among breeding populations in each of the future scenarios we considered.

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CHAPTER 1 – INTRODUCTION AND ANALYTICAL FRAMEWORK

The wood stork (*Mycteria americana*) is one of 17 species of true storks in the world. They are one of three stork species found in the western hemisphere and are the only stork species that breeds north of Mexico (Coulter et al. 2020, unpaginated). Breeding populations of wood stork are found in the southeast United States (U.S.), Cuba and Hispaniola, and from Mexico south through Central and South America to Argentina (Figure 1). There are no recognized subspecies of wood storks and populations are generally delineated based on their breeding region.



Figure 1. Wood stork range and breeding areas (Coulter et al. 2020, no pagination). Shading represents the current range.

Historically, the wood stork's breeding range extended across the southeast U.S. coastal plain from Texas to South Carolina. When listed, the range included Alabama, Florida, Georgia, and South Carolina with breeding and nesting primarily occurring in south and central Florida with a small number of nesting colonies in north Florida and coastal Georgia and South Carolina. The U.S. population declined from an estimated 20,000 nesting pairs in the 1930s, to about 10,000 pairs by 1960, to a low of approximately 5,000 nesting pairs during the late 1970s and early 1980s. The lowest annual nest/breeding pair count on record was 2,800 nest/pairs in 1978, a period of severe drought in south Florida and many wood storks did not nest (Ogden et al. 1987, p. 752).

The U.S. breeding population (U.S. population) was listed as endangered under the Endangered Species Act (ESA) in 1984 (Service 1984, entire) because it had declined by more than 75% in 50 years since the 1930s. At the time, the Service believed that the U.S. population could approach extirpation by the turn of the century (the year 2000) if it continued to decline at the same rate. The original listing recognized the relationship between the declining population, the loss of suitable foraging habitat, and colony nesting failures; particularly in the primary breeding region in south Florida where human actions had reduced wetland areas by about 35% (Ogden and Nesbitt 1979, p. 512), and construction of canals and ditches drained or changed the hydrology of ecosystems like the Everglades, Lake Okeechobee, Kissimmee River, and Big Cypress Swamp.

The Recovery Plan for the U.S. Breeding Population of wood storks was published in 1986 and was updated in 1997. The major actions needed to accomplish the recovery objective are (1) protect currently occupied habitat; (2) restore and enhance habitat; (3) conduct applied research; and (4) increase public awareness. The primary long-term recovery actions being implemented included large scale wetland ecosystem restorations, enhancement, and management of the Everglades, Kissimmee River Basin, Picayune Strand, Corkscrew Swamp, Greater Charlotte Harbor, Tampa Bay, St. Johns River Basin, Suwanee River-Okefenokee Swamp, Savannah-Ogeechee-Altamaha-Satilla Rivers Basins, and Ashapoo-Combahee-Edisto Basin (ACE).

Due to increases in the wood stork population, breeding range, and range, the 5-year status review (Service 2007, p. 32) recommended that the U.S. breeding population be reclassified from endangered to a threatened status. In 2009, the Service was petitioned to reclassify the U.S. breeding population of wood stork. In 2010, the Service published a 90-day finding that the petition presented substantial information indicating that reclassifying the wood stork may be warranted (75 FR 57426). In 2012, the Service published a 12-month finding that the petitioned action was warranted and concurrently published a proposed rule to reclassify the U.S. breeding population of the wood stork from endangered to threatened and designate this population as a distinct population segment (DPS) (77 FR 75947). The Service requested peer and public review of the proposed rule.

In 2014, when the U.S. breeding population of the wood stork was reclassified from endangered to threatened, its overall range had expanded and included the states of Alabama, Florida, Georgia, North Carolina, Mississippi, and South Carolina; and its breeding range included Florida, Georgia, South Carolina, and North Carolina (79 FR 37077). The best available scientific and commercial data indicated that, since listing in 1984, the breeding population had increased, the overall range had expanded, and its breeding range had expanded significantly.

On June 20, 2019, the Service initiated a 5-year status review (84 FR 28850) for the U.S. population of the wood stork; this SSA report will be used to inform that 5-year status review and an update of the Recovery Plan. The report does not provide decisions; instead, it provides a review of available information related to the wood stork's current and potential future biological condition for consideration when making a status recommendation through the 5-year review process, and for updating the current recovery plan.

The SSA framework (Service 2016, entire; Smith et al. 2018, entire) is the Service's approach for assessing a species' biological condition. It includes an in-depth review of the species' biology, resource needs, and stressors, an evaluation of the species' current status, and requirements for maintaining a long-term viable population. It also includes information on existing and potential future conservation efforts.

Analytical Framework

Using the SSA framework (Figure 2), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Service 2016, entire; Smith et al. 2018, entire).

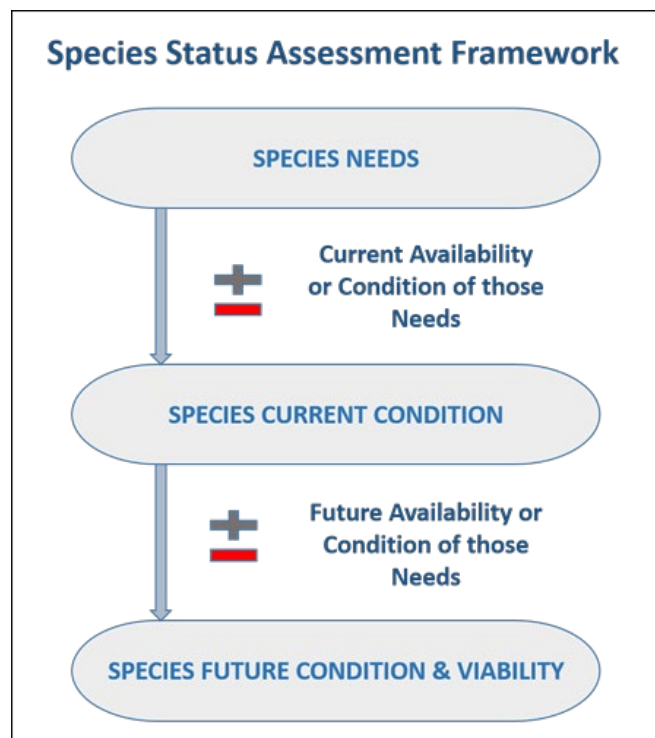


Figure 2: Species Status Assessment Framework.

Viability is the ability of a species to maintain populations in the wild over time. To assess viability, we use the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 308-311). To sustain populations over time, a species must have the capacity to withstand:

- 1) Environmental and demographic stochasticity and disturbances (Resiliency),

- 2) Catastrophes (Redundancy), and
- 3) Novel changes in its biological and physical environment (Representation).

A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

We can best gauge resiliency by evaluating population level characteristics such as demography (abundance and the components of population growth rate—survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are important considerations.

Redundancy is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

Representation is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species need to continually adapt to their changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions, through either plasticity or genetic change (Nicotra et al. 2015, p. 1270; Beever et al. 2016, p. 132). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, pp. 290-291; Sgro et al. 2011, p. 327).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which include measures of inter-population genetic diversity). In assessing the dispersal ability, it is

important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity occupied, and [3] effective population size. In our SSAs, we assess all three facets to the best of our ability based on available data.

The decision whether to list, downlist, or delist a species is based not on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future to account for the uncertainty of the species' future. We evaluate the future biological status of the species by describing future scenarios representing the plausible conditions for the primary factors affecting the species and forecasting the projected future condition for the species in those scenarios, in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the potential future condition for each scenario is too large to individually describe and analyze; therefore, our analysis does not include all possible futures, but those that we consider most reasonably plausible.

CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS

The wood stork is a large wading bird that feeds primarily on fish and other aquatic prey by tactilocation (Figure 3). It forages most efficiently in shallow wetlands where prey is concentrated and its intra-regional movements during the breeding and non-breeding seasons are typically in response to the availability of shallow wetlands. As a wading bird, wood storks are a wetland dependent species and rely on a mosaic of wetlands for nesting, roosting, and foraging.

Ecological information on wood storks detailed in Chapter 2 was drawn from the Birds of the World (formerly Birds of North America) wood stork profile (<https://birdsoftheworld.org/bow/species/woosto/cur/introduction>) and the Recovery Plan (Service 1997) or was otherwise attributed to a specific citation.



Figure 3. Wood storks forage using tactilocation.

2.1 Taxonomy and Genetics

Mycteria americana was first classified by Linnaeus 1758, (Table 1). No subspecies have been determined for this species (Coulter et al. 2020, no pagination).

Table 1. Taxonomic Chart—wood stork.

Kingdom	Phylum	Class	Order	Family	Genus	Species
Animalia	Chordata	Aves	Ciconiiformes	Ciconiidae	<i>Mycteria</i>	<i>americana</i>

Genetic analyses of wood storks nesting in the southeastern U.S. suggests that these birds represent a single population that shows no evidence of discrete subpopulations (Stangel et al. 1990, p. 618; Van Den Bussche et al. 1999, p. 1083; Lopes et al. 2011, p. 1911; Zimmerman et al. 2023, p. 1). An important avenue for on-going and future research on wood storks is the application of modern genetic tools (e.g., single nucleotide polymorphisms, whole genomes) to investigate questions regarding relationships between local and regional breeding colonies (Ramstad 2020, pers. comm.).

2.2 Species Description

Wood storks are long-legged wading birds, standing 85–115 cm (33–45 inches [in]) tall, with wingspans 150–165 cm (59–65 in) in length (Figure 4).



Figure 4. Life stages of wood storks from left to right: eggs in nest, small chicks in nest, large chicks on nest, juvenile “yellow bill” (subadult), and adult.

Adults. Adult plumage is primarily white, except that primaries, secondaries, and short tail feathers are black, with a greenish and purplish sheen. For adults, the head and neck are gray and scaly in appearance and lack feathers. The bill is generally black/gray, and is long and very thick at the base, tapering evenly to its tip and decurved on the distal half. Plumages are similar throughout the year, except that during the breeding season, undertail-coverts are longer and plume-like, and feathers are buff or pinkish on the wing-lining or elsewhere on the plumage. The legs and feet are dark, and the toes are pink during the breeding season (pink may extend up the leg almost to the tarsal joint), fading to flesh color during remainder of the year. Sexes are similar in appearance, although males tend to be slightly larger/heavier than females and have slightly larger bills.

Sub-adults/Nestlings. Sub-adult wood storks (years 1–3 post-hatch) are similar in size and plumage to adults, but their head and neck are covered with grayish feathers. The head and neck feathers are gradually lost as the bird matures. Sub-adults also have pale yellow or straw-colored bills that gradually darken with age. Nestlings are mostly covered in white down, except their heads, and have bright yellow bills.

Sounds. Adults are generally silent, except during displays at the nest. Adults clatter and snap bills during courtship and copulation, and snap bills in defense of their nest.

Begging nestlings raise and lower bills continuously, simultaneously repeating over and over a nasal braying *nyah*. Calls of hatchlings are high-pitched, but pitch becomes lower with age. Choruses of these calls become louder when adults return to the colony, and when the colony is in bright sun, and become muted when no adults are present and when the colony is shaded by clouds. The loud begging calls of many nestlings are audible hundreds of meters away from the colony.

2.3 Global Distribution

The global range of the wood stork includes major portions of North, Central, and South America (Coulter et al. 2020, unpaginated; Figure 1), although the current breeding range in the U.S. is limited to Florida, Georgia, South Carolina, and North Carolina.

Outside the U.S., the breeding range is imperfectly known in Mexico and northern Central America, but includes Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama (Bryan and Borkhataria 2010, entire). In the Caribbean, the wood stork is a rare breeder in Cuba and the Dominican Republic (Coulter et al. 2020, no pagination). In South America, it breeds west of the Andes from Colombia south to western Ecuador; east of the Andes from Colombia south through Amazonas to eastern Peru, northern Bolivia, and northern Argentina, and east to the Atlantic coast through Paraguay and Uruguay north to the Guianas and Venezuela (Coulter et al. 2020, no pagination). Global population size estimates for South America range from 50,000–100,000 wood storks (Byers et al. 1995, p. 14) and approximately 64,000–92,000 breeding adults in Central and North America (Kushlan et al. 2002, p. 64).

2.4 Life History

Wood storks are a relatively long-lived species (Table 2) that exhibit extensive parental care (nesting and brooding lasts approximately four months). Surviving fledglings then undergo a 3-year “sub-adult” (non-breeding) stage before most initiate breeding at 4 years old (Table 2).

Eggs are light brown or olive-buff, overlaid with dark, purplish-brown blotches concentrated primarily at the blunt end. Eggs average 10 cm (3.9 in) long and 6.3 cm (2.5 in) wide.

Figure 4 depicts the four life stages of the wood stork: egg, dependent chick, juvenile (sub-adult), and adult. Sub-adult age includes storks that have fledged through year 3 as wood storks first reproduction occurs at 4 years old.

Wood storks have a lengthy nesting period (> 4 months) when they are associated with their colony site area and afterwards can exhibit intra-regional movements in response to environmental conditions (e.g., availability of shallow foraging habitat; see details in sections 2.5 and 2.5.4 below). Thus, they may have a breeding season “range” as well as a non-breeding season range that may include the colony area, and/or possibly extend through multiple states.

Table 2: Life history stages of wood stork.

Life Stage	Description/Timing
Nest Initiation	Dec-Feb (south Florida) Mar-May (northern range)
Eggs laid	1 egg laid every other day.

	Range 1-5 eggs laid (average 3-4 eggs)
Incubation	28-32 days (both adults)
Fledging	50-55 days
Post-flight period	Up to 85 days post-hatch (15-30 days post-fledging)
Juvenile	85-365 days
Sub-Adult	1-3 years
Adult (sexual maturity)	4-5 years
Life span	10-18 years, but possibly over 22 years

2.5 Breeding Ecology

Wood storks are colonial nesters and nest in association with other wood storks and other wading bird species. Depending on the nesting substrate, wood stork nests can be adjacent to one another, occasionally appearing as nesting “platforms” of multiple nests. Colony size can range from 2–3 nests, to over 1,000 nests, although the majority of U.S. colonies in recent years (past 10 years) have ranged from 50–400 nests (Service 2024, Wood Stork Nesting Database). In 2009, the Corkscrew Swamp colony recorded 1,120 nests and in 2018, 953 nests were recorded at the Jetport colony and 746 nests at the Broad River colony, which is an indication that super colonies (> 500) can still occur in South Florida.

Wood storks exhibit some site fidelity to their natal colony, but an extensive nestling banding/re-sighting effort has also documented wood storks breeding in non-natal colonies (Bryan et al. 2013, pp. 5-6). This finding has been supported by genetic studies. An electrophoretic study of 15 Florida colonies found small genetic distances among colonies, suggesting high levels of gene flow among colonies, and/or colonies of recent origin (Stangel et al. 1990, p. 618). Van Den Bussche et al. (1999, p. 1083) used a combination of DNA fingerprinting and microsatellite analyses, and found low levels of genetic variability and allelic diversity within Georgia and Florida colonies, suggesting a single population of wood storks in the southeastern U.S.

Breeding seasonality varies regionally, generally related to the timing and amount of rainfall. Wood storks generally breed during periods when wetland water levels are decreasing, which concentrates prey during the period when stork nestlings grow at a maximum rate (dependent chick). Wood storks in south Florida typically initiate nesting in the winter (December–February) in response to tropical rainfall patterns which result in a summer rainy period. To the north, in central and northern Florida, Georgia, South Carolina, and North Carolina, wood storks initiate nesting in the March–May period and take advantage of the summer natural recession of water levels to concentrate prey in a variety of freshwater habitats and coastal wetlands that concentrate prey twice a day due to tidal influences.

Wood storks exhibit extensive parental care. There is typically always one parent attending the nestlings until the young reach approximately 30 days of age. Nestlings can fledge at approximately 50–55 days post-hatch, yet they return to the nest for parental feedings for up to 85 days post-hatch. As nestlings grow and the nest becomes crowded, parents often roost in other locations in the colony when they are not out foraging for their young. Parental care is not assumed nor documented away from the nest. Wood storks are generally not territorial but may

defend their nest structure from conspecifics and other wading birds; defense against mammalian predators (e.g., raccoons) is minimal.

Breeding season ranges typically include foraging ranges, which have been widely studied for wood stork. Foraging ranges (maximum distance and area) vary relative to abundance and distribution of foraging habitats surrounding each colony. Breeding season foraging range estimations are primarily based on follow-flights (Bryan et al. 2012, pp. 298-299; Herring et al. 2015, p. 34) and satellite telemetry (Borkhataria et al. 2013, pp. 7-9). In south Florida, wood storks forage 10–74 km away from the colony, generally at distances of 25–50 km; although, maximum flights of 97–130 km have been documented. In north Florida, mean foraging distances averaged 12.1 km from the colony, with > 90% of foraging flights within 25 km; and maximum distance of 65 km (Bryan and Borkhataria 2012, p. 295). In east-central Georgia, mean distance was 12.7 km average with greater than 80% of flights were within 20 km, with maximum greater than 63 km (Bryan and Coulter 1987, p. 158). Overall, foraging distances used by wood storks nesting in coastal Georgia ranged from 0.3 to 38.5 km (Gaines et al. 1998, pp. 46-47). Bryan et al. (2012, p. 293) summarized wood stork follow-flight foraging studies (n = 20+) and found 75–100% of foraging sites were within 20 km of the breeding colonies. Wood storks nesting in south Florida tended to travel greater distances to forage, particularly in earlier studies. The shorter foraging distances suggested by the more recent studies could be due to climatic influences of habitat availability in the single year studies, recent water management activities and/or overall landscape changes associated with the decades of time separating the studies.

2.5.1 Nesting Cycle

Wood storks initiate their nesting cycle with a well-documented courtship period (Coulter et al. 2020, no pagination) that can range from a few hours to a few days (d). Once the pair bond is formed, initial nest construction takes 2–3 days, but construction and/or maintenance occurs throughout the nestling period. After nests are built, timing of breeding is as follows: 6 laying days (typically 3 eggs are laid, one every other day, 28 incubating days, pre-flight nestling period of 50–55 days, and post-flight period of attachment to nest of 15–30 days (Coulter et al. 2020, no pagination). Duration of the nestling period varies among colonies and years. Wood storks generally only fledge one brood per season but may make multiple nesting attempts due to nest failure (e.g., a banded wood stork was observed initiating a total of three different nests in a single season in response to early abandonment/failures) (Bryan and Coulter 1991, p. 687).

It is assumed that some early nesting wood storks in south Florida that abandon nesting efforts may attempt to re-nest in northern/other portions of their range which have appropriate wetlands available later in the season. There is indirect evidence for these occasional regional shifts based on fluctuation of annual nesting numbers (Service 2014, p. 37101; Keyes 2021, pers. comm.; Service 2024, unpublished nesting database).

2.5.2 Productivity

Productivity of the U.S. wood stork breeding population is estimated with two metrics: nest counts and fledging success (average fledged young per nest). The 1997 recovery plan sets the criteria for wood stork recovery; the species would be considered recovered when a 5-year running average exceeds 10,000 wood stork nests, annual regional productivity is greater than

1.5 chicks per nest/year (5-year running average), and a subset of 2,500 nests and 1.5 chicks per nest/year (5 year running averages) in south Florida (Service 1997, p. iii). An average fledging success rate of 1.5 fledged young per nest is thought to be necessary to maintain population viability (Service 1986, p. 5; Service 1997, p. 17) and is based on population data (fledging rate) for the white stork (*Ciconia ciconia*). Conceptually, to maintain a population at a stable level, a productivity rate of 2.0 (two chicks fledged per nest) would be needed in order to keep a population stable, assuming two fledglings survive to breeding age and each pair of adults will reproduce only once in their lifetime. This scenario would result in one-to-one replacement of adults by the new generation. Wood storks are relatively long-lived and generally breed annually, and thus most individuals have multiple chances to replace themselves. As such, a wood stork productivity rate near or even below 1.0 should also lead to a stable or slow-growing population. For example, the 5-year average productivity that had been maintained at the time of recovery for both the bald eagle and the brown pelican, two species similar to the wood stork in diet, aquatic habitat, and longevity, did not exceed 0.9 (74 FR 59444, November 17, 2009; 72 FR 37346, July 9, 2007).

Nest numbers vary annually but have generally increased significantly over the last two decades, resulting in the down-listing of the wood stork from endangered to threatened in 2014 (79 FR 37078). Due to funding constraints, range-wide, statewide, and/or regional monitoring of wood stork productivity has only occurred episodically (e.g., early 1980s and early 2000s). During the 2003–2006 time period, Brooks and Dean (2008, p. 56) indicated the 3-year averages of productivity rate for all colonies monitored in the southeastern U.S. was 1.2 chick/nest attempt (2003–2005); 1.5 chick/nest attempt (2004–2006); and 1.5 chick/nest attempt (2003–2006).

Fledging success rates are typically determined on a per colony basis and vary considerably with local environmental conditions, generally ranging from 0 (total colony failure) to greater than 2.5 fledged young/nest, in optimal conditions. Productivity in peninsular Florida and inland portions of the range exhibit natural fluctuations and can range from high numbers of nests and fledging rates to nesting failure with no fledging (“boom or bust”). In south Florida in particular, timing and amounts of annual rainfall and the consequent impact on sheet flow, local hydrology, and prey availability have generally resulted in occasional “boom” years for wood stork productivity, surrounded by more frequent “bust” years. However, productivity during the “boom” years can be substantial with two or more chicks per nest (South Florida Wading Bird Report 2009–2019, p. 1). The recent South Florida Wading Bird Reports (2009–2019) discuss the variability in annual nesting and productivity in south Florida. In contrast, productivity in colonies along the Atlantic coast in Georgia, South Carolina, and North Carolina tends to be more stable because prey availability is more consistently available from tidal marshes, managed impoundments, and former rice fields; therefore, the species nests near these areas in the breeding range, resulting in increased nest numbers and high productivity (Tomlinson 2009, p. 24) (see Section 4.5).

2.5.3 Survivorship

Threats to survival of wood stork young occur both during their pre-fledging period (egg stage through approximately 55 days post-hatch) and post-fledging (> 55 days post-hatch through sub-adult period [3+ years]) (Table 3). Threats early in the nesting cycle can include predation (e.g., raccoons in a drying colony site) and adult abandonment and/or chick starvation due to foraging habitat declines (e.g., heavy rainfall raising regional water levels). Threats to the older young

(juveniles) are generally related to difficulty finding food (Borkhataria et al. 2012, p. 525) after fledging and during the first winter.

Table 3: Survivorship of wood stork at various life stages.

Life Stage	Survivorship (estimates used in this assessment)
Laying to 14 days	0.73 nestlings/egg
14 – 28 days (hatchling)	0.63 nestlings/egg
28 – 42 days (nestlings 2 weeks old)	0.56 nestlings/egg
42 – 56 days (nestlings 4 weeks old)	0.51 nestlings/egg
56 – 70 days (nestlings 6 weeks old)	0.47 nestlings/egg
70 – 84 days (nestlings 8 weeks old)	0.43 nestlings/egg
Sub-adult (1-3 years)	0.29-0.56 annual
Adult (4+ years)	0.86 annual

At Merritt Island, Florida, nestling mortality was highest during the first two weeks after hatching (Girard 1976, pp. 37-39). In north and central Florida, the largest decrease in survivorship (both fledglings/nest and fledgling/egg) occurred before hatching and the second largest decrease occurred during the nestling period of hatching to 2 weeks of age (Rodgers and Schwikert 1997, p. 85). Survivorship by nesting period for all colony-years was modeled as follows: laying to 14 d, 0.73; to 28 d (hatching), 0.63; to 42 d (nestlings 2 weeks old), 0.56; to 56 d (nestlings 4 weeks old), 0.51; to 70 d (nestlings 6 weeks old), 0.47; and to 84 d (fledging at 8 weeks old), 0.43).

Post-dispersal survival rates of fledglings have been tied to the foraging conditions they encounter upon dispersal. Fledged young from south Florida that dispersed when water levels were high (mean depths > 25 cm) had much lower survival (annual survival rate = 0.15 ± 0.04 standard error [SE]) than those that fledged into more favorable (< 25 cm) water depths (annual survival rate = 0.37 ± 0.06 SE) (Borkhataria et al. 2012, pp. 522-523). Pooled survival rates of juveniles equipped with satellite transmitters at two south Florida and two Georgia colonies were estimated to be 0.29 ± 0.05 SE in their first year, 0.56 ± 0.09 SE in their second year, and 0.87 ± 0.07 SE in their third year (Borkhataria 2009, p. 64).

Adult survival rates estimated for wood storks equipped with satellite transmitters (as adults) varied from 0.54 (first year, post-tagging) to 0.86 (subsequent years), with the difference presumed to be linked to the capture process or harness/transmitter adjustment period (Borkhataria 2009, pp. 64-65). Wood storks are relatively long-lived with frequent band sightings of wood storks in the 10 to 18-year range. The maximum age observed in the wild is over 22 years old (USGS 2024, unpaginated).

2.5.4 Post-Breeding Dispersal

Beginning in late-May, following breeding in south and central Florida, many adults and sub-adults disperse throughout central and north Florida, as well as into Alabama, Mississippi, Georgia, South Carolina, and North Carolina. Individuals from coastal colonies in north Florida, Georgia, and South Carolina also disperse across the nearby Coastal Plain. Occasionally vagrants

wander outside the normal range and have been observed as far as Massachusetts in the east and northern California and southern Idaho and Montana in the west, although the latter wood storks likely originated from Mexico/Central America. Wood storks have also been reported in British Columbia, Colorado, Nebraska, South Dakota, Missouri, Illinois, Michigan, southern Ontario, New York, Maine, and southern New Brunswick (Coulter et al. 2020, no pagination).

Between 1974 and 1979, 788 and 801 nestlings were color-marked in two Everglades National Park colonies and two central Florida colonies (Moore Creek and Pelican Island), respectively. This marking project resulted in 205 reported sightings of living, tagged wood storks. These sightings revealed the following (Coulter et al. 2020, no pagination):

- Juvenile wood storks from south Florida colonies disperse earlier in the calendar year and move farther north than juveniles from central Florida colonies.
- In south Florida colonies, birds displayed major post-breeding dispersal to locations from central Florida north to southeastern and coastal Georgia and coastal South Carolina.
- In central Florida colonies, birds dispersed in all directions.

Satellite telemetry studies of juvenile wood storks from 2002-2005 indicated juvenile birds from south Florida colonies disperse northward primarily in June and July (Hylton 2004, p. 46; Borkhataria 2009, p. 87) (Figure 5). Movements were influenced by Florida Everglades' water levels at the time of dispersal, with juveniles foraging in Everglades wetlands for several days or weeks prior to large-scale dispersal events, in years with favorable water levels for foraging. In years where water levels were too high for effective foraging, wood storks dispersed north immediately (Borkhataria et al. 2012, pp. 523-524). Juveniles captured in south Florida in April 2004 were located in Florida in June; throughout Florida, Georgia, and South Carolina in July and August; and included locations in Alabama in September, with all surviving birds returning to Florida by November. However, not all birds left the state, and not all birds returned to the same regions in subsequent years, supporting that wood storks may have limited natal site fidelity post-dispersal. An analysis of inter-annual home range overlap indicated that home ranges were highly variable among birds and years indicating no set migration pattern (Picardi et al. 2020, p. 11).

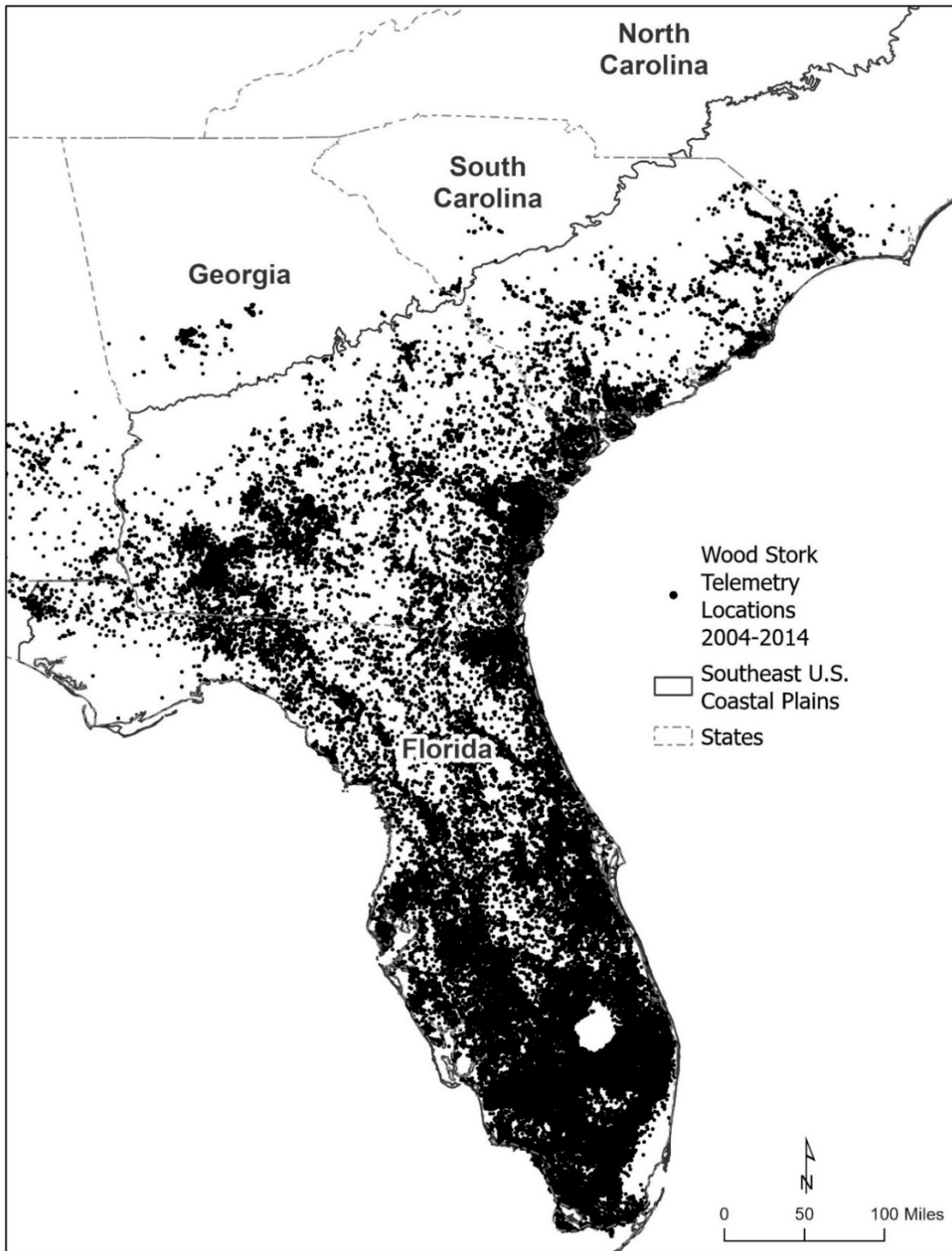


Figure 5. Wood stork satellite tag location data from (2004–2014) (Hylton 2004, p. 46; Borkhataria 2009, p. 87; and Borkhataria et al. 2012, p. 530).

Satellite telemetry studies of adult wood storks captured in south Florida showed the same general movement pattern as juveniles (Borkhataria 2009, p. 86; Picardi et al. 2020, pp. 9-11).

Adults that dispersed out of state returned to winter in Florida, with no locations from November-March recorded outside of Florida from 2006–2011. Some birds remained in Florida all year while others began leaving Florida as early as April in some years, and could be found in Georgia, South Carolina, or North Carolina in April and May, and in Alabama and Mississippi from June-October. Locations were highly variable among years, with all birds returning to Florida by October and all birds remaining in Florida through May.

Seasonal movement patterns of adult birds captured and tagged in Georgia differed from those captured and tagged in south Florida (Comer et al. 1987, p. 165) in that Georgia birds that wintered in Florida generally left Florida earlier in the spring and returned to Florida late in the fall; Florida birds that left Florida, generally did so late spring or early summer and returned to Florida in the early spring. All birds captured in Georgia were located in Florida during December-February from 2006–2011 but could still be found in Georgia during November in most years. Wood storks generally returned to Georgia or South Carolina in March and April, but in some years, birds captured in Georgia could be found in Florida throughout the summer. Adult birds captured in Georgia were not found in Alabama or Mississippi at any time from 2006–2011.

2.6 Non-Breeding Season Ecology

Wood storks are considered partial migrants, with a component of the population shifting from breeding season ranges to non-breeding season ranges annually, another component is generally residential in a single region, and the final component being considered facultative migrants (shift some years, residential the other) (Basille et al. 2019, pp. 8-9; Picardi et al. 2020, pp. 15-16). These shifts are influenced by precipitation/hydrology and its impacts on food resources/availability. Cooler temperatures may also influence wood storks in the northern half of the range to shift south during the winter months. Outside of the U.S., movements between and/or within ranges are not well studied but wood storks are assumed to occur year-round throughout breeding range (Figure 6).

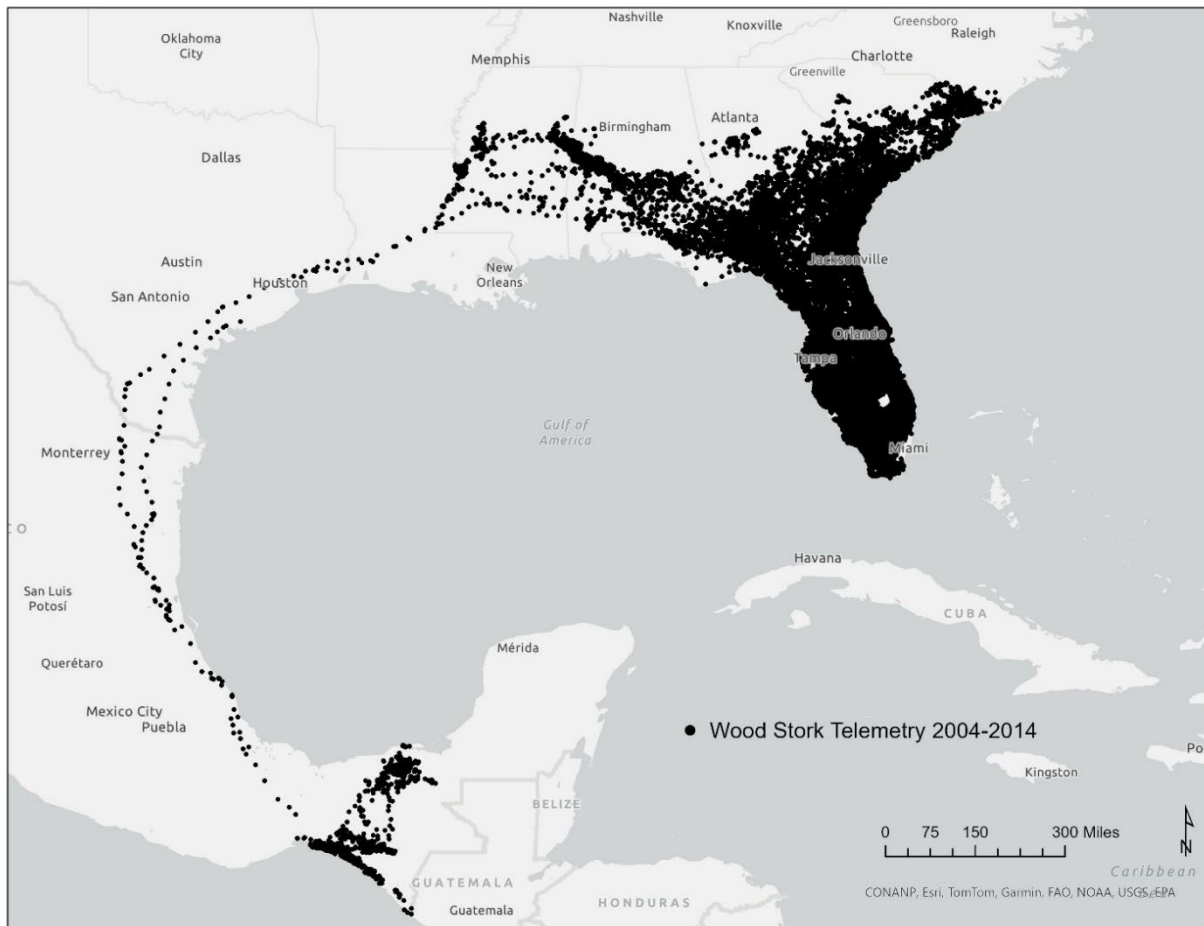


Figure 6. Satellite telemetry locations from 150+ wood storks tagged in Florida, Georgia and South Carolina (compilation of wood stork satellite data: Hylton 2005; Bryan et al. 2008; Borkhataria 2009; Borkhataria et al. 2013; Picardi et al. 2020).

There have been few formal studies of wood stork movement during the non-breeding season. Three adults' radio-tagged in east-central Georgia were later located during the winter in different sites from north to south Florida, and in different sites in different years (Comer et al. 1987, p. 165). Wood storks in coastal Georgia post breeding and winter typically utilized roosts on large estuarine islands and foraged in tidal saltwater wetlands in close proximity (< 2 km) to their roosts (Bryan et al. 2002, pp. 432-433). Individuals in southern Florida move northward and/or westward in pursuit of appropriate foraging conditions after departing their breeding range and can be found in the coastal plain habitats ranging from Mississippi to North Carolina. Birds from northern portions of their range occasionally move westward, but most disperse to salt marsh habitats in South Carolina and Georgia prior to moving into Florida when “winter” temperatures decline.

The non-breeding range of wood storks is presumed to include habitats similar to that of breeding season: almost all freshwater and saltwater wetlands, with prey species and suitable water depths (< 50 cm, often 10–30 cm). Across the southeastern U.S., habitat use by 42 satellite-tagged, non-breeding wood storks was positively correlated with estuarine wetlands, emergent freshwater wetlands, forested freshwater wetlands, and agriculture (Borkhataria 2009,

p. 93); although, non-breeding wood storks also selected areas with abundant canals and ditches and with high habitat heterogeneity. In south Florida, when Everglades and other natural marshes are deeply flooded, wood storks often feed alone or in small groups in ephemeral wetlands or along canals (Coulter et al. 2020, no pagination), or in small or large groups in the Everglades Agricultural Area, located between the Everglades and Lake Okeechobee (Borkhataria et al. 2012, pp. 520-523). In Georgia, foraging wood storks are common in the tidal creeks and marshes during the non-breeding season (Bryan et al. 2002, p. 433). In South Carolina, they make extensive use of coastal tidal marsh and coastal impoundments managed primarily for waterfowl (Murphy and Coker 2008, p. 6).

Wood storks observed in southern Louisiana, lower Mississippi Valley, Texas, southern California, and other western states are presumed to be primarily post-breeders, sub-adults, and immature wood storks from Mexico or Central America (Coulter et al. 2020, no pagination). This hypothesis was based on the following observations: (1) that all U.S. breeding colonies are in the Southeast; (2) that no marked bird from these colonies has been reported west of eastern Mississippi; (3) that marked birds from south Florida colonies move primarily up Atlantic Coast; (4) that large numbers of wood storks have been recorded in Louisiana and lower Mississippi floodplain, with large possible source colonies in Mexico and Central America, and large flocks have been seen flying north along east coast of Mexico in June (Rojas 2015, pers. comm.). Telemetry studies indicate that individuals from the southeastern U.S. colonies may travel to the Mississippi River floodplain in Mississippi and Louisiana during post-breeding season dispersal, and thus that the U.S. and Central American populations “mix” at some level in this region (Bryan et al. 2008, pp. 40-41; Picardi et al. 2018, p. 26; Figure 5 and 6). Although adult wood storks captured in Georgia were not observed to enter Alabama or Mississippi, there is a documented case of a fledgling wood stork from east-central Georgia that traveled to this region and eventually continued into Mexico, where it remained (Picardi et al. 2018, p. 26).

Wood storks are a regular post-breeding visitor (June to early September) to southern end of Salton Sea and adjacent portions of Imperial Valley of southern California, and less commonly to the Colorado River valley of southern California and Arizona; however, these birds are presumed to be from Mexico and/or Central America population/s (Coulter et al. 2020, no pagination).

2.7 Habitat

Wood storks are a wetland dependent species. They use a wide variety of freshwater and estuarine wetlands for nesting, feeding, and roosting throughout their range. The Southeastern United States has nearly 48 million acres of wetlands, which account for more than 43 percent of the Nation’s palustrine and estuarine wetlands (Sucik and Marks 2015, p. 11). Local hydrologic conditions correlate to annual nesting effort (Klassen et al. 2016, pp. 1450-1460).

2.7.1 Breeding Season Habitat

Nesting Colonies

Wood storks are colonial nesting birds, typically nesting with conspecifics and other wading bird species within a landscape containing sufficient wetland foraging habitats. Most wood storks, nest over water in natural and human-altered freshwater and marine-estuarine forested habitats

(Rodgers et al. 1996, pp. 18-19). Inundation of trees prior to and during nesting deters predation at nests, and thus reduces nest abandonment and nest failure, as alligators typically present in these wetlands limit access to nests by mammalian predators, primarily raccoons. Drought conditions can result in drying under the nest trees and increased predation (Herring and Gawlik 2011, entire; Gabel et al. 2021, entire). Estuarine sites usually are flooded by tidal activity or are located on emergent or upland islands.

Freshwater nesting habitats in Florida range from monoculture of bald cypress (*Taxodium distichum*), black gum (*Nyssa biflora*), or southern willow (*Salix caroliniana*) to more heterogeneous bottomland hardwood swamps dominated by cypress and black gum but can also include exotics primarily of Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina equisetifolia*). In central and north Florida, nesting substrates vary by colony and include native trees such as bald cypress, black gum, water tupelo (*Nyssa aquatica*), wax myrtle (*Myrica cerifera*), and dahoon holly (*Ilex cassine*), as well as non-native trees (Rodgers et al. 1996, pp. 2-17). In south Florida, wood storks nest primarily in black mangrove swamps (*Avicennia germinans*), cypress strands and swamps, pond apple (*Annona glabra*), and willow. Colonies are also found in human-impacted areas including artificially impounded waters, on dredge spoil islands (e.g., Grant Farm Island, Brevard Co.; Palm Beach Solid Waste Authority, Palm Beach Co.; El Claire Ranch Hardee Co.) that contain non-native upland species, or in waste-water treatment wetlands (e.g., Wakodahatchee Wetland, Palm Beach Co.; Orlando Wetlands Park, Brevard Co.), and other locations (St. Augustine Alligator Farm, St. Johns Co., Jacksonville Zoo and Gardens, Duval Co.). Wood storks have also nested successfully on artificial nest platforms at the Hillsborough Co. Environmental Lands Acquisition and Protection Program colony (Paul 2020, pers. comm.).

In North Carolina, South Carolina, and Georgia, wood storks generally utilize relatively similar nesting substrate (cypress and black gum) in various wetlands. In coastal Georgia, where many sites are impounded, wood storks' nest in black gum, willow, and buttonbush (*Cephalanthus occidentalis*; Service 1986, p. 3). Other colonies in Georgia, including the Gilman colony (the second largest colony in Georgia) and the Birdsville and Chew Mill Pond colonies (a natural wetland and human-made pond, respectively) nest in elderberry bushes (*Sambucus nigra* ssp. *canadensis*) and in cypress swamps (respectively). Wood storks have nested successfully on artificial nest platforms at the Harris Neck National Wildlife Refuge (NWR) (Robinette et al. 1995, p. 61); however, they have now abandoned the artificial nest structures in favor of cypress that were planted to create natural structure in the area. In South Carolina, nests are located in various substrate in wetlands and/or on islands (Hand 2020, pers. comm.), often in impounded wetlands in privately owned lands (Murphy and Coker 2008, p. 5). In North Carolina, wood storks nest primarily in cypress (Johnson 2020, pers. comm.).

In recent years, an increasing number of colonies throughout their range in the southeastern U.S. have been established in wetlands in proximity to human activity such as housing, roads, and active waterways (Tsai et al. 2016, p. 644).

Nesting Colony Turnover

Wood stork nesting colony turnover has occurred historically, indicating that wood storks move to new colony location when currently occupied colony sites become less suitable than unoccupied suitable habitat (Frederick and Ogden 1997, pp. 320-321; Frederick and Meyer 2008,

entire; Hall et al. 2017, p. 52; Clem et al. 2019, p. 370; Table 4, Figure 7 and 8). Nesting colony turnover is a common trait in wading bird ecology (Frederick and Meyer 2008, entire), potentially due to the ephemeral nature of suitable habitat for colonial waterbirds. Colony turnover can be gradual, potentially taking several years before completion (Frederick and Ogden 1997, pp. 320-321; Figure 8).

Table 4. The number of wood stork nesting colonies during four, 10-year periods from 1982 to 2021 that were active, became active, and became inactive, and the average number of colonies during that timeframe. Note that there have been 322 different nesting sites since 1982.

Wood stork colonies	1982–1991	1992–2001	2002–2011	2012–2021
New	37	90	76	47
Became Inactive	22	34	55	58
10 yr Annual Average	25	43	85	97

From 1982 to 2021, the annual number of active wood stork colonies ranged from 14 to 110. During this period, 332 different wood stork nesting colony sites were monitored, with 250 of these being new sites where nesting did not occur at the beginning of the period, while 160 sites became inactive at some point. Similarly, from 2012 to 2022, wood stork nesting occurred at 182 different sites with an annual average of 101 active colony sites; during that period 47 sites were newly initiated, and 58 colonies became inactive (Service 2024, unpublished database).

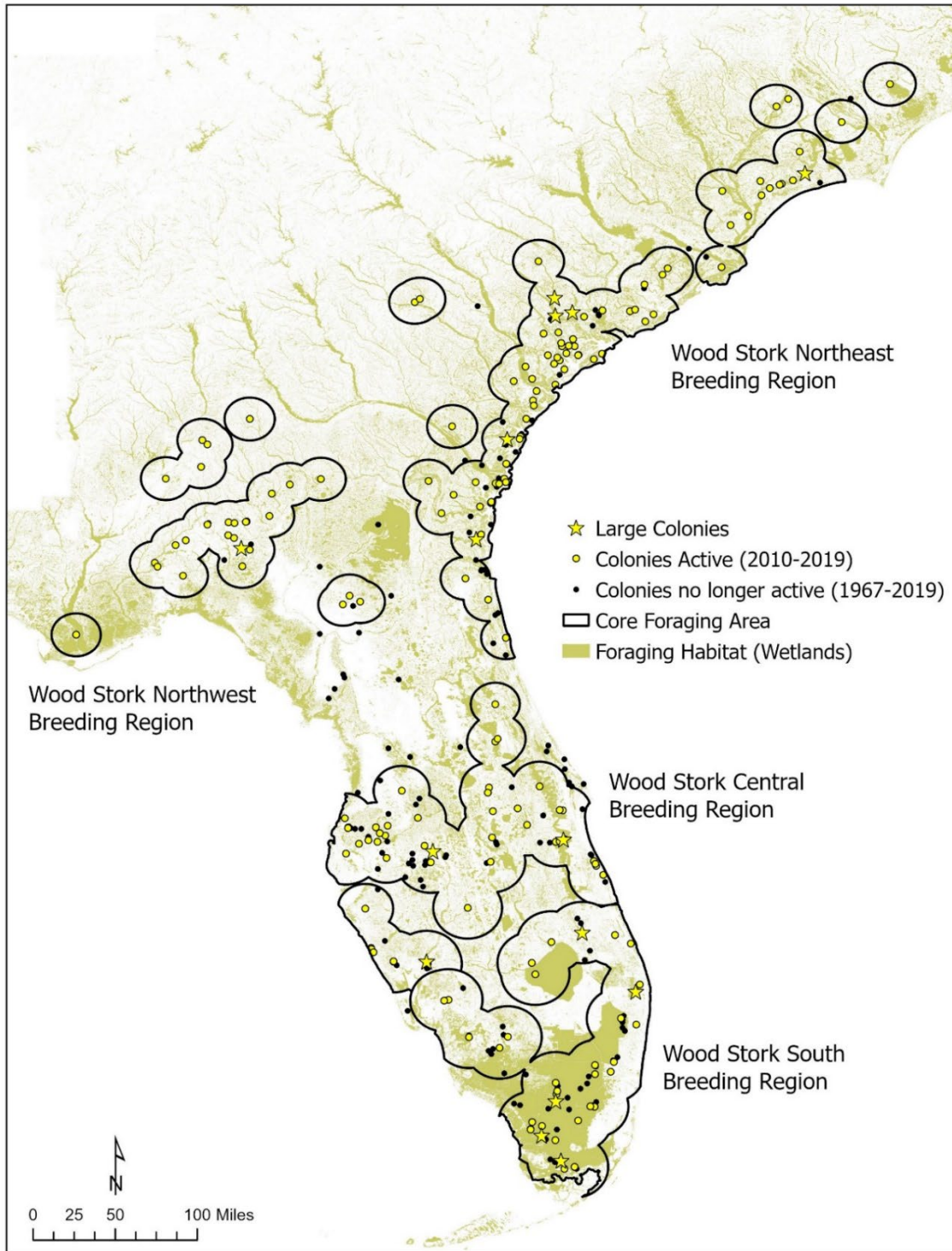


Figure 7. Wood stork (WOST) active (2010–2019) and no longer active colonies (1967–2019) in each breeding region, core foraging area, and across suitable habitat in the United States.

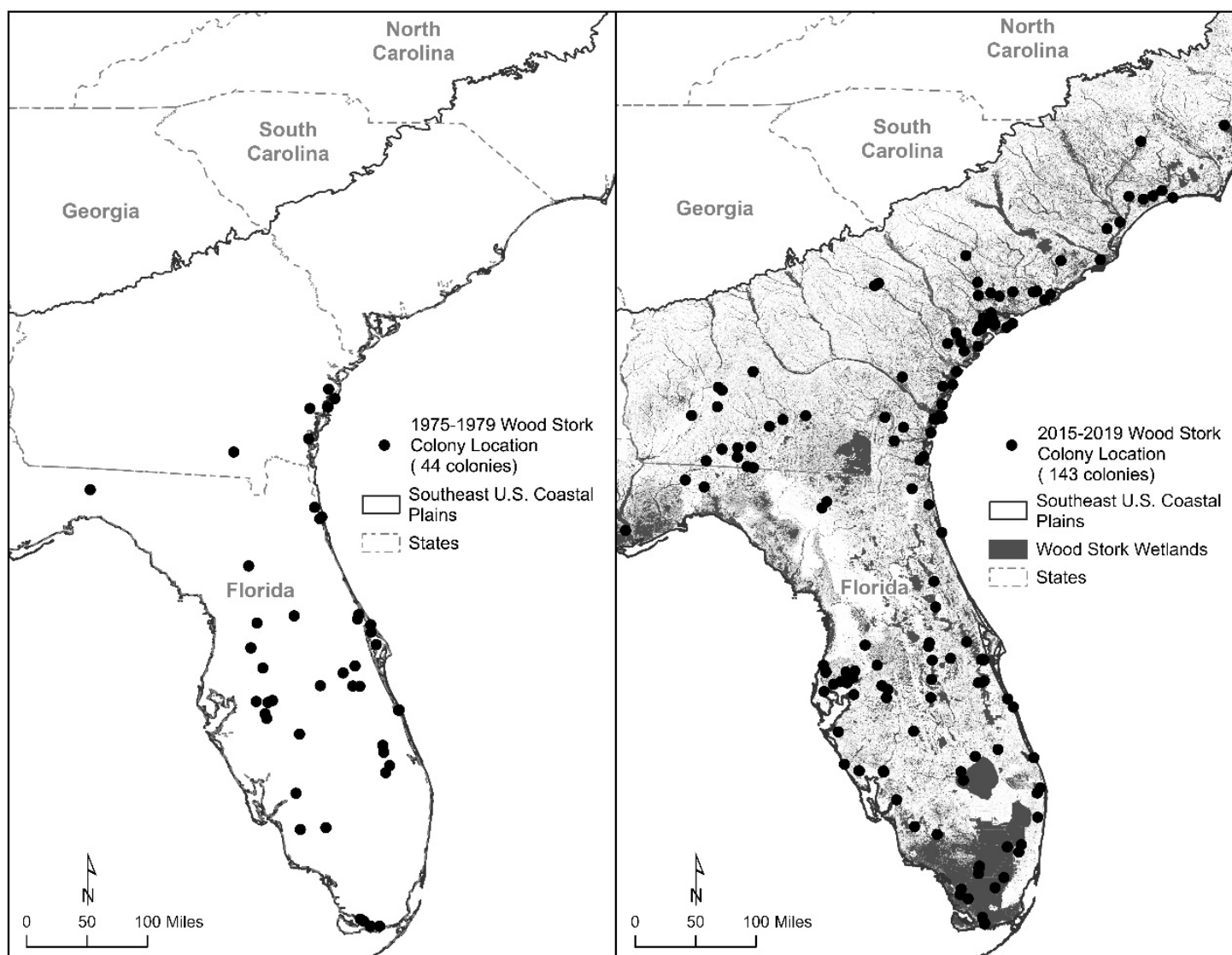


Figure 8. Active wood stork (WOST) colonies from 1975–1979 (left) and 2015–2019 (right); and suitable wetland habitat for wood storks (right).

[illegible]

Foraging Areas

Habitat

September 2025

In coastal Georgia, wood storks feed in both freshwater and saltwater habitats, including freshwater and estuarine marshes (Pearson et al. 1992, p. 36). Within Georgia estuaries, wood storks also feed in tidal creeks and, to a lesser extent, tidal pools during low tide levels (Gaines et al. 1998, pp. 46-47; Bryan and Borkhataria 2013, pp. 845-846). Drought conditions, presumably reducing freshwater habitat availability, result in greater use of tidal wetlands (Gaines et al. 2000, p. 72). Forested wetlands made up between 16–25% of the located coastal foraging sites (Bryan et al. 2012, p. 297). In south-central Georgia, forested wetlands comprised between 41 – 69% of foraging sites (Bryan et al. 2012, pp. 293, 297). In east-central Georgia, wood storks feed in a variety of wetland habitats, including hardwood (27%) and cypress (19%) swamps, human-made ponds (20%), and marshes (9%). In addition, it was observed that wood stork feed more frequently in open canopy wetlands (ponds and marshes) than in closed canopy wetlands (swamps), in relation to availability (Coulter and Bryan 1993, p. 61)

In South Carolina, forested wetlands made up between 36–48% of the located foraging sites; however, wood storks were reported to forage in 43% non-forested wetlands, typically former rice fields, while less than 15% of the foraging sites identified were tidal creeks and other tidal sites (Tomlinson 2009, p. 24). In North Carolina, habitats of the foraging sites included forested wetlands (50%), cutover wetlands/drainages (14%), various ponds (12%), as well as ditches, open wetlands, flooded roads, and tidal creeks (Bryan and Borkhataria 2012, p. 4).

Across the range, With the increased association of wood stork in human-altered landscapes, there have been increased observations of wood storks foraging in garbage dumps and at fish-cleaning stations, as well as of people feeding storks “human” food in both the breeding and non-breeding seasons (Brooks 2020, pers. comm.; Evans and Gawlik 2020, p. 1).

Density

Prey density at south Florida foraging sites averaged 141 items/ m^2 in the Everglades and 40 items/ m^2 in coastal sites as opposed to 10.3 items/ m^2 and 16.8 items/ m^2 at two permanent sampling sites in the Everglades and coastal Florida, respectively (Ogden et al. 1978, pp. 15-16). In a study in Georgia, average density of potential prey at 28 foraging sites were matched with 28 wetlands that were not being used as foraging sites. It was observed that density of potential prey at foraging sites was 14.6 m^2 (36.2 g/ m^2) and density of prey at non-foraging wetlands was 6.8 m^2 (24.2 g/ m^2 ; Coulter and Bryan 1993, pp. 66-67).

Distance

In central Florida, single year follow flight studies of five colonies determined most foraging sites were between 2.5 km - 5.8 km (with a maximum of 10.8 km) from their nesting colony (Bryan et al. 2012, pp. 293, 297). In northeast Florida, habitats used by five radio-tagged storks included palustrine forested (18.2%), estuarine emergent wetland (13.2%), lacustrine emergent wetland (13.2%), and palustrine emergent wetland (11.6%; Rodgers 1987, p. 3). Follow flight studies from two colonies found foraging sites that averaged 14.8 - 18.1 km in distance from their colony with a max distance of 70.3 km (Bryan et al. 2012, pp. 293, 297). Forested wetlands made up between 50 and 76% of the located foraging sites.

A single year follow flight study in south-central Georgia found an average distance of approximately 15 km between the colony and foraging sites with a maximum distance of 47 km

(Bryan et al. 2012, pp. 293, 297). Another single year follow flight study in central Georgia found an average distance of approximately 10 km between the colony and foraging sites with a max distance of 46 km (Bryan et al. 2012, pp. 293, 297). In east-central Georgia foraging sites averaged to be 12 km from the colony site (maximum of 37 km; Bryan et al. 2012, pp. 293, 297).

Follow flight studies of four coastal South Carolina stork colonies averaged between 8.3–13.3 km from their colonies to foraging sites, with a maximum distance of 29 km (Bryan et al. 2012, pp. 293, 297). A single year follow flight study for a colony in coastal North Carolina averaged 11 km between the colony and foraging sites with a maximum of 47 km (Bryan and Borkhataria 2012, p. 4).



Photo Credit: Mark Cook, South Florida Water Management District. Wood stork nesting in a mixed wading bird colony in the Everglades.

For conservation of wood storks in the U.S., the concept of core foraging areas (CFA) for breeding wood storks was derived based on the follow flight studies referred to above. Core foraging areas are suitable foraging wetlands within a set range (30 km) from each colony (Cox et al. 1994, p. 134). Based on wood stork follow flight studies (Bryan et al. 2012, p. 293) suggesting a range smaller than 30 km, the USFWS modified their CFAs regionally: 30 km in south Florida, 25 km in central Florida and 20 km in all other regions/states (Figure 10). However, Borkhataria et al. (2013, pp. 8-9), examined CFAs using satellite telemetry locations of nesting wood storks and noted that 30 km might be more appropriate in south Florida, because non-homogeneous wetland distribution within the proposed circular ranges occasionally resulted in extensive habitat use outside the proposed circular range.

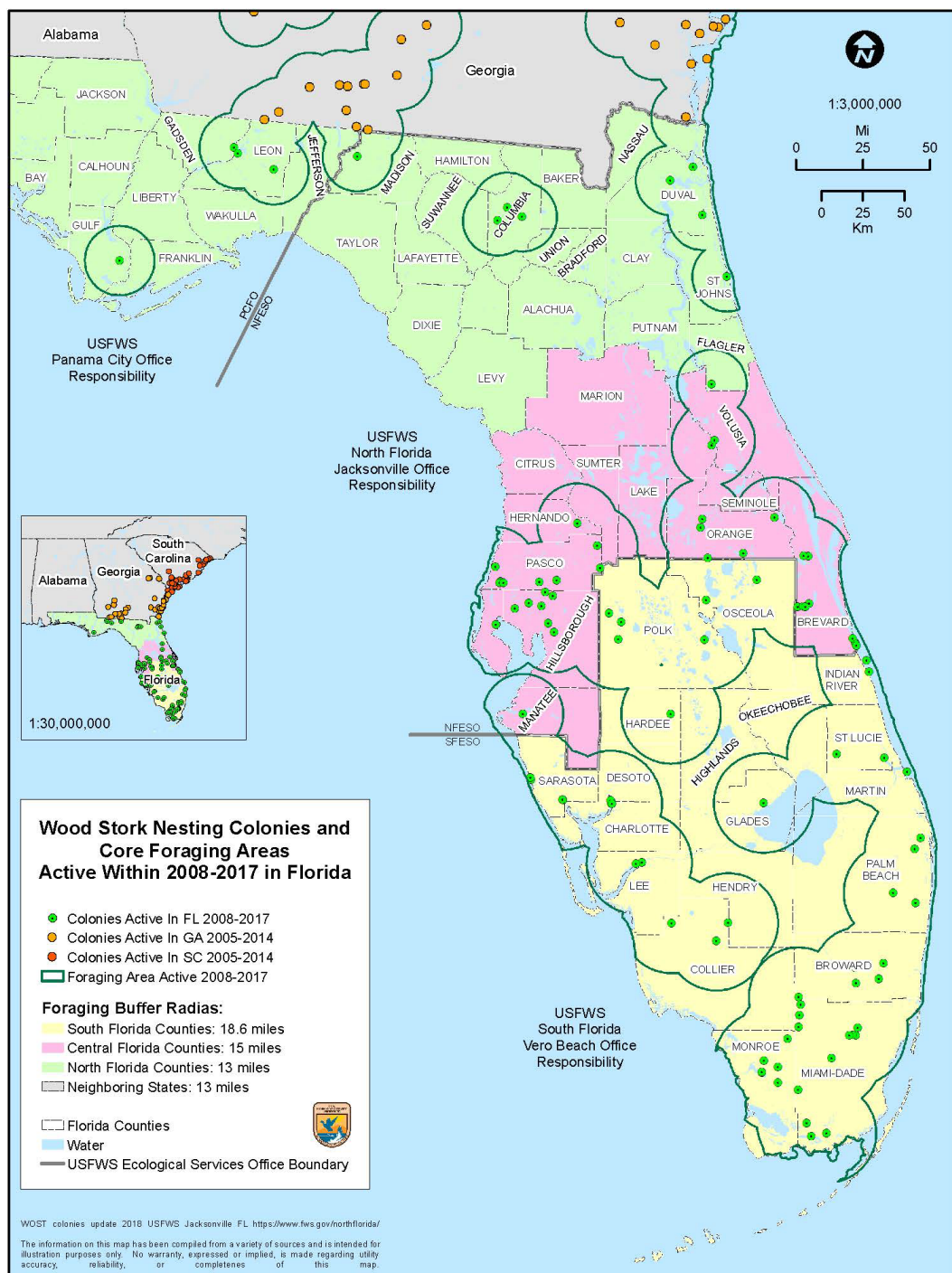


Figure 10. Florida wood stork colonies depicting core foraging area buffers.

2.7.2 Non-Breeding Season Habitats

Roosting Habitat

Wood storks typically roost in trees, generally over or surrounded by water (Pearson et al. 1992, p. 36). Larger roosts, in coastal Georgia, tend to be openings in forested habitats located on large

estuarine islands (Bryan et al. 2002, p. 431), and include a few colony sites. However, wood storks may also roost at foraging sites; but there is no evidence that individuals travel to roost in larger congregations. Wood storks may also roost or rest on the ground (e.g., levees, open grassy fields, mud flats) close to foraging areas.

Foraging Habitat

Non-breeding season foraging habitat is presumed to be similar to breeding season foraging habitat: wetlands with shallow water (< 50 cm) and concentrated prey. Few studies have occurred during the non-breeding season (Bryan et al. 2001, pp. 511-512); however, follow flight and telemetry studies documented roosting wood storks using tidal habitats (e.g., tidal creeks at low tide) for foraging in coastal Georgia (Bryan et al. 2002, p. 433).

2.8 Diet

Wood storks feed by tactilocation, using their bill to bump into prey primarily in the water column (Coulter et al. 2020, no pagination). Major prey species of wood storks vary geographically and include both salt- and freshwater species (Coulter et al. 2020, no pagination). Fish, particularly sunfish (Centrarchidae), are their main prey in freshwater habitats; however, a wide variety of prey items have been identified including: crustaceans (Crustacea: crayfish [Cambaridae], grass shrimp [*Palaemonetes paludosus*], and crabs), amphibians (largely tadpoles), insects (beetles [Coleoptera] and grasshoppers [Orthoptera]), snails (Gastropoda: water snails), reptiles (snakes and small alligators), birds (young rails and grackles) and mammals (woodrats [*Neotoma* spp.], mice [Muridae], and shrews [Soricidae]) (Bent 1926, pp. 62-63; Coulter et al. 2020, no pagination). Wood storks may also consume plant and insect material inadvertently.

In south Florida (Ogden et al. 1976, p. 325; Ogden 1978, pp. 17-20), key prey species include sunfish (Centrarchidae; 14% of individuals, 44% of biomass), yellow bullhead (*Ictalurus natalis*; 2%, 12%), marsh killifish (*Fundulus confluentus*; 18%, 11%), flagfish (*Jordanella floridae*; 32%, 7%), and sailfin molly (*Poecilia latipinna*; 20%, 11%); average length of prey taken was 41 mm at Madeira colony and 54 mm at Lane River colony. Wood storks selected for sunfish and killifish in the Everglades (based on prey consumed relative to potential prey availability) but selectively took Seminole killifish (*Fundulus seminolis*) in coastal areas (Ogden et al. 1976, pp. 325, 327). Differences in the number of prey species eaten by wood storks was observed to be different in various regions of Florida with 11 species eaten in the freshwater Everglades (in 1974) and eight prey species in coastal areas (Kushlan 1979, pp. 135-137). More recent studies (2013-present) have updated data on prey of wood stork. In south Florida, wood stork preyed upon spotted sunfish (*Lepomis punctatus*) as the most common prey item (53%); African jewelfish (*Hemichromis letourneusi*, 26%), dollar sunfish (*Lepomis marginatus*), and brown bullheads (*Ameiurus nebulosus*); non-native fish species comprised 12% of prey items consumed (Klassen and Gawlik 2018, pp. 131-132; Evans and Gawlik 2020, p. 1). The overall mean prey length and bolus mass from nestlings were 5.5 ± 1.0 cm and 44.0 ± 3.6 g, respectively.

In east-central Georgia, prey items documented through a nestling regurgitation study (n = 304 items, 97.4 g; Depkin et al. 1992, pp. 220-221) included: sunfish (74% of individuals, 54% of biomass), bowfin (*Amia calva*; 3%, 13%), redfin pickerel (*Esox americanus*; 6%, 10%), and lake chubsucker (*Erimyzon sucetta*; 3%, 13%); and average length of prey taken was 84.7 mm.

Nestlings in coastal Georgia regurgitated (n = 163 items; Bryan and Gariboldi 1998, p. 153) a mixture of salt water (85% of individuals, 73% of biomass) and freshwater prey (15% of individuals; 65% of biomass). Mummichogs (*Fundulus heteroclitus*), a brackish/saltwater prey item, made up greater than 50% of the individuals and biomass.

CHAPTER 3 – DISTRIBUTION AND ABUNDANCE

The historical and current distribution and abundance of the U.S. breeding population DPS of wood storks are covered in this chapter, although current (2013–2022) conditions are examined in greater detail in Chapter 4. Wood stork nesting and colony numbers have been reported by state where the nesting occurs.

The primary tool for monitoring wood stork has been nest surveys during the peak of breeding season. Surveys provide data on the total number of active nests which can be doubled to estimate the total number of breeding storks in a single year. The approach of reporting the number of nests/breeding pairs provides an overall breeding population estimate but does not account for non-breeding and/or pre-breeding age wood storks.

In this chapter, the concept of wood stork breeding regions is described, as distributions of wood stork nesting colonies suggest that wood stork nesting clusters in four areas in the southeast U.S.

3.1 Historical Trends

The U.S. breeding population of wood storks is located at the extreme northern end of their global range, which extends from northern Argentina north through the southeastern U.S (Figure 1). Historically, it is presumed that the U.S. population was once continuous from Mexico along the Gulf coast to Florida (Coulter et al. 2020, no pagination), but there has been no confirmed stork nesting in Texas, Louisiana, Mississippi, and Alabama in the historical records nor in recent history.

The U.S. breeding population of wood storks experienced a severe population decline in the mid-1900s, presumably due to habitat loss/change in south Florida, where the core of the U.S. population and almost all nesting occurred. The habitat loss/change that occurred during the time of this decline consequently reduced the food base necessary to support breeding colonies of wood storks (Ogden and Nesbitt 1979, p. 521; Ogden and Patty 1981, pp. 99-100; Service 1997, p. 10; Coulter et al. 2020, no pagination). Ogden (1978, p. 143) concluded that the wood stork population in the 1930s was probably less than 100,000 individuals, or between 15,000 and 20,000 breeding pairs. The estimated breeding population declined from 15,000–20,000 pairs, to about 10,000 in 1960, and to a low of between 2,500–5,700 pairs from 1977 - 1980 (Ogden et al. 1987, p. 752). The estimate of a low of 2,500 nesting pairs was from 1978 during the severe drought when many wood storks likely did not breed.

Concurrent with the population decline (from the 1960s - 1980s) was a breeding range expansion to the northern part of the range (i.e. northern Florida, Georgia, South Carolina), presumably in response to declining habitat quality in south Florida (Ogden et al. 1987, p. 752). More specifically, a majority (70%) of the population nested south of Lake Okeechobee and declined from 8,500 pairs, in 1961, to fewer than 500 pairs in the late 1980s. During the same time period, nesting in Georgia increased from 4 to 1,501 pairs and nesting in South Carolina increased from

11 to 829 pairs (Service 1997, p. 10), greatly extending the breeding range north into the Southern Coastal Plain of Georgia and South Carolina. Since the 1980s, surveys documented a population in the Southeast U.S. ranging between 4,073 and 7,853 pairs (Service 1997, pp. 9-10, A1-A9) and continued breeding population increases in Georgia and South Carolina in the early 2000s. Furthermore in 2005, wood storks were observed to have begun nesting in North Carolina (Brooks and Dean 2008, p. 53).

Wood stork nesting records show annual shifts in nesting numbers between regions and states. This is likely in response to habitat and hydrologic conditions in south Florida. As a breeding season initiates in south Florida, large numbers of wood storks will nest when there are normal or optimal habitat and hydrologic conditions, (e.g., a wet or normal rainy season in south Florida, followed by a slow and steady dry down of water levels from January to May), which concentrate prey throughout the entire breeding season. These conditions normally lead to a large and successful breeding season in south Florida. However, as a breeding season initiates in south Florida, if late (February-March) or after nest failures, some wood storks move north to breed in the northern regions in response to sub optimal habitat and hydrologic conditions such as drought conditions or reversals in water levels (e.g., water levels increase due to unseasonal rainfall events dispersing prey). This leads to lower nesting numbers in south Florida and higher nesting numbers in the northern regions.

During the 35-year period since listing under the ESA (1984 to 2022), 27 full surveys of wood stork nesting colonies in the U.S. population's breeding range (Florida, Georgia, South Carolina, and North Carolina) were completed (Table 5). Twenty-three of those surveys resulted in counts exceeding 6,000 pairs. Since 2000, when wading bird considerations began to factor more prominently into water management practices in south Florida, high-nesting years have become more common. Specifically, 18 higher count year have occurred since 2002 (Table 5, Figure 10). Moreover, eight counts of greater than 10,000 pairs have occurred in the past 13 years, and the count of 14,075 pairs in 2009 is the highest on record since the early 1960s. This population estimate along with a conservative estimate of 4,000 pre-breeding age birds suggest a total of 32,000 wood storks were inhabiting the U.S. in 2009 (Bryan and Borkhataria 2010, p. 2). Although population counts vary year-to-year, generally the U.S. population has been increasing since its listing (Figure 10). In addition, though productivity in south Florida generally falls below the target of 1.5 chicks/pair/year (Table 6), and there are on average 300 fewer breeding pairs than the target of 2,500 breeding pairs (Table 5), these metrics show stable trends but with high year-to-year variability.

Table 5. Wood stork nest counts by U.S. (TOTAL), Florida (FL), Georgia (GA), South Carolina (SC), and North Carolina (NC) totals (1975–2022) (Service 2024). Years with no data represent years with incomplete data sets.

YEAR	TOTAL	FL	GA	SC	YEAR	TOTAL	FL	GA	SC	NC
1975	6,920				1999	7,768	6,109	1,139	520	
1976	5,310	5,294	16		2000	7,293	5,491	566	1,236	
1977	5,263	5,125	138		2001	5,582	3,246	1,162	1,174	
1978	2,695	2,595	100		2002	7,855	5,463	1,256	1,136	
1979	4,648	3,800	55		2003	8,813	5,804	1,653	1,356	
1980	5,063	4,766	297		2004	8,379	4,726	1,596	2,057	
1981	4,442	4,156	275	11	2005	5,572	2,304	1,817	1,419	32
1982	3,575	3,420	135	20	2006	11,279	7,216	1,928	2,010	125
1983	5,983	5,600	363	20	2007	4,406	1,553	1,054	1,607	192
1984	6,245	5,647	576	22	2008	6,118	1,838	2,292	1,839	149
1985	5,193	4,562	557	74	2009	12,720	9,428	1,676	1,482	134
1986	5,549	4,781	648	120	2010	8,149	3,828	2,708	1,393	220
1987			506	194	2011	9,579	5,292	2,160	2,031	96
1988			311	179	2012	8,452	4,539	1,905	1,827	181
1989			543	376	2013	11,076	6,948	1,873	2,500	205
1990			709	536	2014	11,238	5,511	2,942	2,501	284
1991	4,073	2,440	969	664	2015	10,058	4,705	2,496	2,496	361
1992	4,084	2,518	1,091	475	2016	10,639	5,223	2,310	2,512	594
1993	6,729	4,262	1,661	806	2017	11,188	6,344	2,027	2,480	337
1994	5,768	3,588	1,468	712	2018	12,105	8,525	1,594	1,858	128
1995	7,853	5,523	1,501	829	2019	8,699	2,921	2,564	3,000	378
1996			1,480	953	2020			2,303		609
1997			1,379	917	2021	12,453	6,002	2,260	3,493	698
1998			1,665	1,093	2022	10,492	3,859	2366	3,928	292

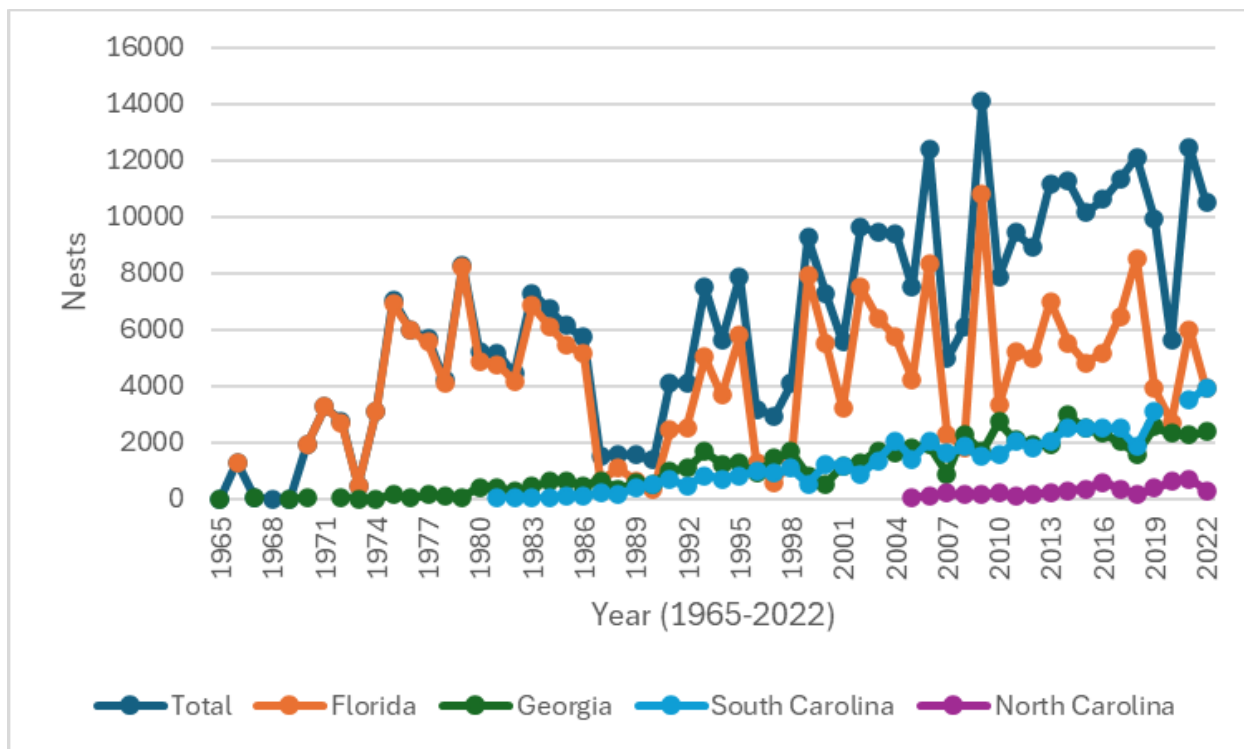


Figure 10. Wood stork nest counts by U.S., Florida, Georgia, South Carolina, and North Carolina totals (1975–2022) (Service 2024, unpublished dataset). Years with no data represent years with incomplete data sets.

At the time when the recovery criteria were developed (Table 6), south Florida (particularly the Everglades) was the epicenter of the U.S. wood stork population and had historically provided the most optimal of the habitat for breeding. This region was particularly prone to environmental stochasticity, altering seasonal wetland ecosystem dynamics, and consequently wood stork rearing and population numbers. Because of this the recovery plan and criteria take into account that many factors can influence species recovery through changes in hydrology, including water management practices that alter the timing and volume of water that flows through wetlands, and large rainfall events that elevate water levels naturally.

Table 6: Criteria for wood stork recovery criteria.

Recovery Criteria	Recovery Description
1 – Nesting Pairs	An average of 10,000 nesting pairs (50% of historical population) calculated over 5 years beginning at time of reclassification.
2 – Productivity	Annual regional productivity greater than 1.5 chicks per nest per year (also calculated over a 5-year average).
3 – Breeding Success	As a subset of the 10,000 pairs, a minimum of 2,500 successful nesting pairs must occur in the Everglades and Big Cypress systems.

3.2 Breeding Regions

The U.S. breeding population of wood storks has been categorized as a single population by genetic analyses to date (see sections 2.1.and 2.5), which has been corroborated by documented

intra-regional movements of breeding-aged individuals and shifts in nesting throughout their range. Within the breeding range, wood stork colonies and nest numbers generally cluster into four areas in the southeastern U.S. (south, central, northwest, and northeast; Figure 11). To identify these clusters, we conducted a density analysis and looked at colonies and nesting numbers at colony locations. A wood stork colony density map was generated through a GIS analysis that clustered colony location points into a specified neighborhood for each of the past five decades (Figure 12).

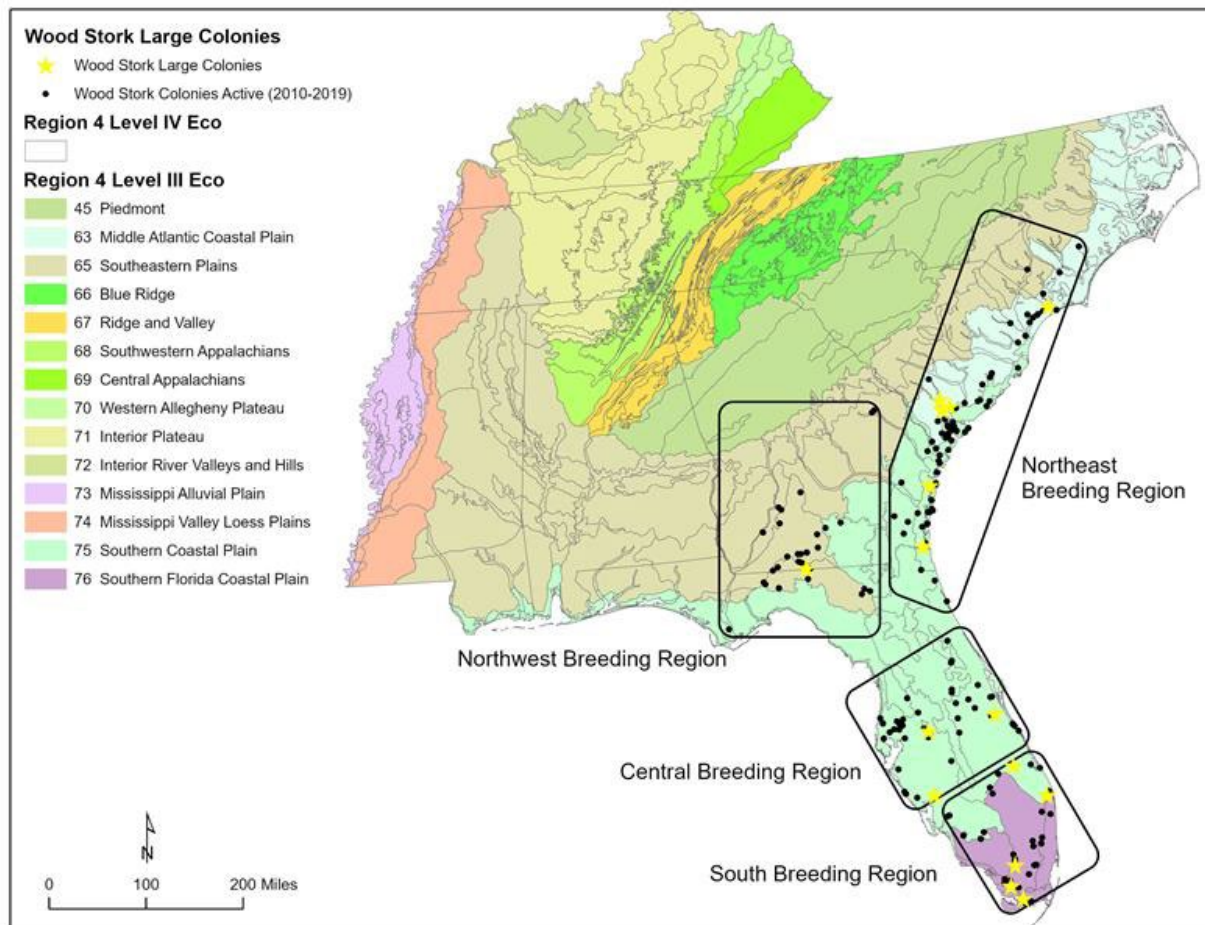


Figure 11. Colony locations within Southeast U.S. Coastal Plain demarking four wood stork breeding regions. Locations of large persistent colonies are highlighted as yellow stars.

Then we looked at nesting density during the past 10 years. This density map was also generated through a GIS analysis that aggregated nest numbers at colonies sites to show where nests are concentrated during a single nesting season. This analysis was systematically calculated for the four highest nesting years during 2009–2019 (Figure 12).

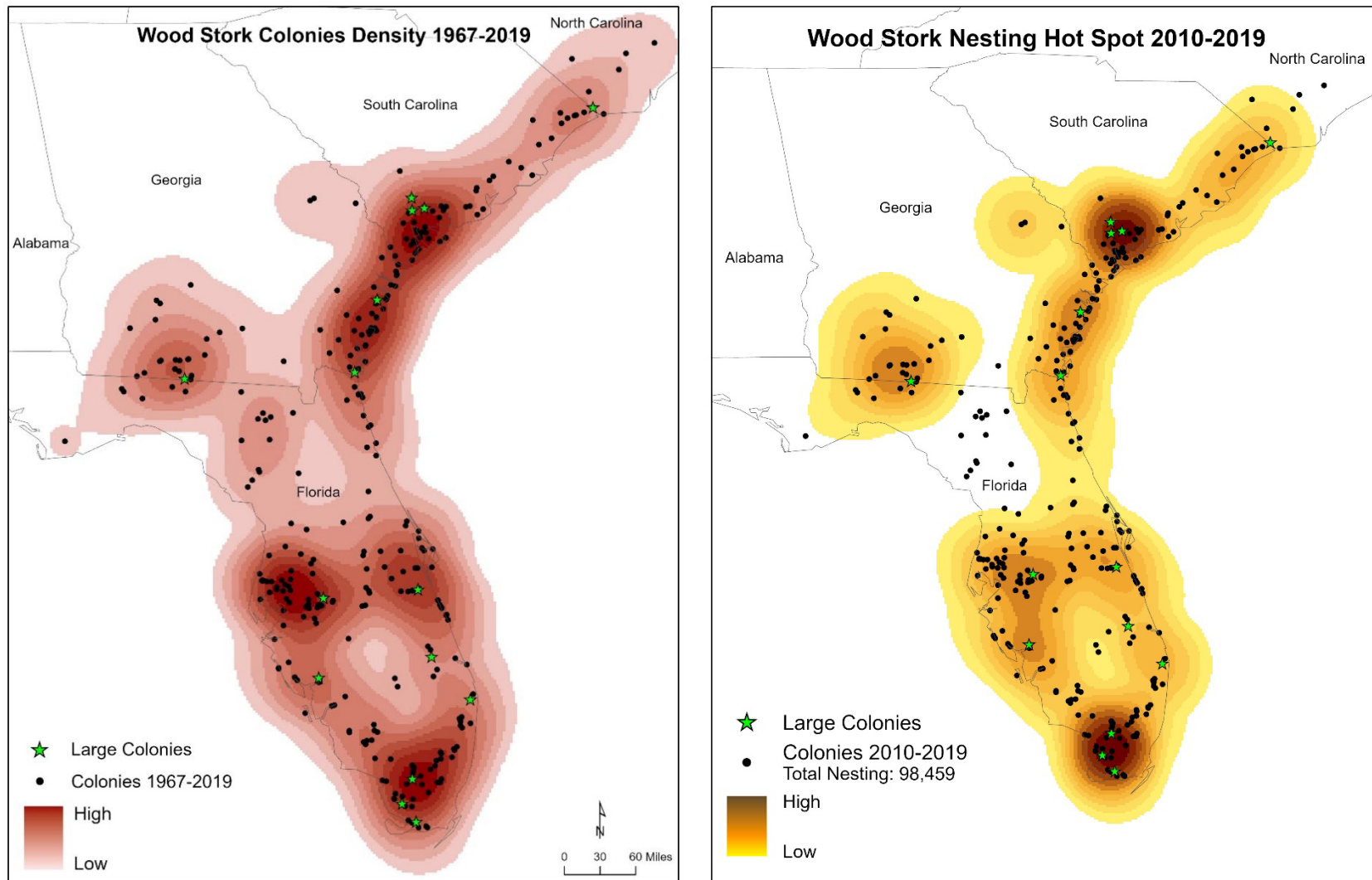


Figure 12 Wood stork colony density map (1967–2019) and nest density by colonies map (2010–2019).

These clusters are defined generally by climate and geography/landscape features, and their influences on wood stork ecology, habitat, and behavior. The breeding regions are henceforward referred to as:

- **South Breeding Region** includes 6 counties in Florida south of Lake Okeechobee and the Okeechobee Waterway. Southern Florida Coastal Plain (Figure 11).
- **Central Breeding Region** includes 15 counties in central peninsular Florida. Southern Coastal Plain (Figure 11).
- **Northwest Breeding Region** includes 4 counties in northwest Florida, 6 counties in southwest Georgia and 1 county in east-central Georgia. Southeastern Plains (Figure 11).
- **Northeast Breeding Region** includes Atlantic coast counties from northeast Florida (4 counties), Georgia (6 counties), South Carolina (8 counties), and North Carolina (4 counties). Middle Atlantic Coastal Plain and Southern Coastal Plain (Figure 11).

Given the four-state breeding range, there is considerable variation in environmental variables including climate, topography/landscape features, and hydrologic regimes, which likely influence these Breeding Regions:

South Florida's weather patterns are classified as "tropical savannah", which includes monsoon seasonality, highly concentrated rainfall during the summer months and a distinct decrease in rainfall throughout the winter months (FCC 2025). Weather patterns in the remaining regions (Central, Northwest and Northeast) are categorized as "humid subtropical", which includes a long, hot, dry summer and a mild, wet winter, and results in availability of habitats during different months than the South Breeding Region. Foraging habitat is commonly rainfall-dependent, and climatic patterns strongly influence foraging habitat availability (wetland conditions), and thus breeding phenology and success. Tsai et al. (2016, p. 643) defined a "latitudinal cline" for stork nest initiation dates (a gradient of breeding onset as you move north in latitude) as follows: south Florida (south of Lake Okeechobee; December), central Florida (south of 29°20' N; January), north Florida and Georgia (north of 29°20' N; February), and South Carolina and North Carolina (March).

Foraging habitats and general landscape (ecoregions) within the Breeding Regions also vary (Figure 12). In the South Breeding Region, colonies occur in the Southern Florida Coastal Plain ecoregion, including wetlands dominated by expansive sheet flow (e.g., Everglades, Big Cypress). In the Central Breeding Region, the colonies are typically located in the Southern Coastal Plain ecoregion, specifically the wetlands in the "flatwoods" habitats. The majority of Northwest Breeding Region colonies are located within the Southeastern Plains ecoregion, including primarily wetlands associated with bottomlands, and depression and agricultural wetlands. Colonies in the Northeast Breeding Region are within the Southern and Middle Atlantic Coastal Plain ecoregions, including similar freshwater habitats as well as tide-influenced wetlands (e.g., salt marsh, managed impoundments, former rice fields, river drainages, etc.).

CHAPTER 4 – CURRENT CONDITION

For this assessment, viability is defined as the ability of the species to sustain populations in the wild over time. Using the SSA framework, we describe the wood stork U.S. breeding population's viability by characterizing the status of this DPS in terms of its resiliency, redundancy, and representation.

The factors used to measure resiliency are primarily demographic and reproductive measures that are influenced by the local and regional environmental conditions. We use these factors as a measure of current condition, and for projecting future conditions. The measures inform how local, regional, and the U.S. population of wood storks are faring within the wetland ecosystems that they depend upon.

4.1 Resiliency

Demographic factors such as abundance, adult survival, reproductive success, juvenile recruitment, and population growth influences wood stork resilience. Influencing these factors are elements of habitat that determine whether the population can grow to carrying capacity, thus increasing the resiliency of populations. A resilient population needs sufficient wetland habitat with diverse food resources to support survival and successful breeding (Figure 13).

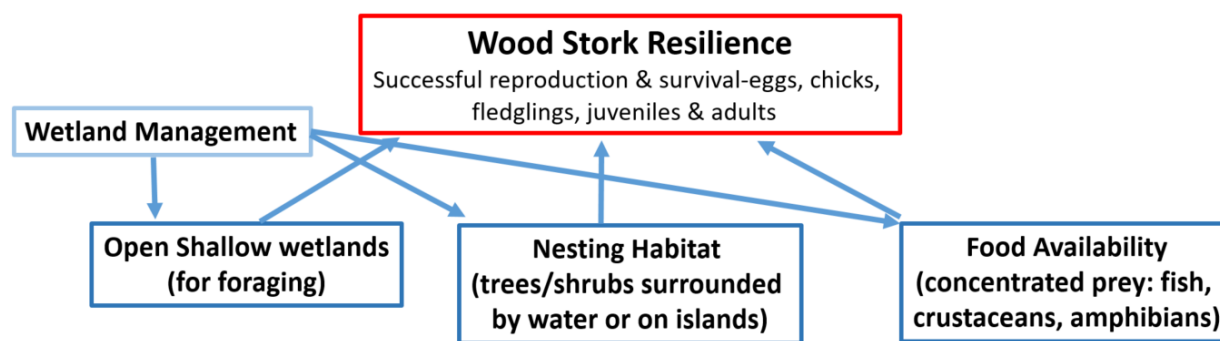


Figure 13. Primary influences on wood stork resiliency: the availability of shallow wetlands for foraging, trees and shrubs emerging from water or surrounded by water for roosting and breeding/nesting, and prey availability.

To assess the current and possible future condition of wood storks, we focused on factors that influence the population and those that we have sufficient data on. These factors include, nesting population size (number of pairs/nests), population growth, number of large persistent nesting colonies, and a productivity measure, are defined in Factors and Trends section (section 4.4). Using the condition category definitions (Table 8), we then assigned a category of High, Moderate, or Low condition to each of these factors for each Breeding Region, and for the population as a whole. Finally, we assessed the current overall resiliency of each Breeding Region based on its average condition of each category of the demographic factors.

4.1.1 Population Resiliency Factors

Breeding Population Size

For the wood stork to be resilient, colonies in the Breeding Regions must be large enough that following a local stochastic event, a sufficient number of individuals survive, or that dispersal from adjacent colonies or Breeding Regions occurs, allowing the nesting population to recover or maintain abundance goals, as described below. The minimum breeding population size needed to be resilient is unknown; however, available data can be used to estimate this value. Long-term, consistent, monitoring of the U.S. population has been conducted since the mid-1970s and includes estimates of various demographic parameters, including breeding population size (Table 5). The Recovery Plan identified a population size of 6,000 nesting pairs (3-year avg.) for down-listing and 10,000 nesting pairs (5-year avg.) for delisting (Service 1986, p. 15; Service 1997, pp. 17-18). Furthermore, as a subset of recovery, the Recovery Plan identified a minimum of 2,500 pairs nesting in the Everglades and Big Cypress ecosystems (South Breeding Region). In a Breeding Region we define “high” condition as a population of 2,500+ pairs; “moderate” condition as 1,500–2,499 pairs, “low” condition as < 1,500 pairs, and an extirpated breeding region is defined as a region consisting of zero active nesting colonies. The conditions are calculated using a 5-year average to account for annual variability in nesting pairs.

Breeding Population Growth Rate

Demographic factors such as birth rate, death rate, and productivity, if documented for a population, can be used to determine a population’s rate of growth. Population growth (λ) is the finite rate of increase of a population over time. A negative (< 1) growth rate indicates a declining population, a growth rate of approximately 1 indicates a stable population, and a positive (> 1) growth rate indicates an increasing population. For this analysis, we consider a growth rate of 0.9-1.1 to be stable and below 0.9 to be declining and above 1.1 to be increasing. Habitat conditions and nesting varies by region and range-wide annually; therefore, a moving average was used to smooth out short-term fluctuations (outliers) and highlight longer-term trends or cycles. As previously stated, the Recovery Plan targeted a 5-year average of 10,000 nesting pairs for delisting. We use a 5-year moving average, across a 10-year time frame, to assess the population change in each breeding region and U.S. breeding population, in this case data from 2008-2022 was used for these calculations.

Large Persistent Colonies

Many colonies are “ephemeral,” because they form and succeed or fail in response to environmental conditions. Relative to colony size (based on nest numbers), we defined colonies that produced over 200 nests more than 5 times during a decade as large persistent colonies. We note the occurrence and abundance of large “persistent” colonies (based on annual nest numbers; Table 7) is another metric of resiliency and redundancy, representing a source of consistent breeding effort (see section 4.4.1 for further information on large persistent colonies).

The occurrence and productivity of large persistent colonies within each wood stork breeding region and range wide was analyzed. In Florida, wood stork colony longevity and size exhibited considerable variability, with younger colonies (< 4 years) exhibiting a higher cessation rate than more persistent colonies (Frederick and Meyer 2008, pp. 15-16). In addition, larger colonies (range-wide) were observed to be less prone to abandonment, and colonies with greater longevity were more likely to be recolonized post-abandonment (Tsai et al. 2016, p. 644). We acknowledge the occurrence of smaller persistent colonies (20-50 nesting pairs) and their contributions to annual breeding productivity but for this analysis we used large persistent

colonies as metric for comparison among Breeding Regions. Large persistent colonies represent approximately forty percent of annual nesting throughout the breeding range.

Table 7. Large persistent colonies by Breeding Region by decade (1980-2019).

Breeding Region	Colony	County	2010s act/size*	2000s act/size*	1990s act/size	1980s act/size*
Northeast	Lay Lake	Columbia (NC)	10/ >200	5/ >100		
	Colony 3	Hampton (SC)	7/ >200	7/ >100	10/ >100	5/ <100
	Colony 6	Colleton (SC)	9/ >200	10/ >300	10 >300	2/ <100
	Colony 20	Colleton (SC)	9/ >200	8/ >200		
	Harris Neck	McIntosh (GA)	10/ >400	10/ >300	10/ >300	5/ <100
	Gilman Paper	Camden (GA)	9/ >200	10/ >100	2/ <100	
Northwest	Blackwater	Brooks (GA)	9/ >200	10/ >100	10 >300	4/ <100
Central	Deseret Ranch	Brevard (FL)	10/ >200	8/ >200	3/ <100	2/ >200
	Morganton North	Charlotte (FL)	8/ >200	1/ <100		
	Lake Somerset	Polk (FL)	10/ >200	9/ <100		
South	Jetport South	Dade (FL)	5/ >400	2/ >100		
	Paurotis Pond	Dade (FL)	9/ >200	10/ >100	7/ <100	
	Broad River	Monroe (FL)	8/ >300			
	PBSWA	Palm Beach (FL)	10/ >300	10/ >200	5/ <100	
	Cypress Creek	St. Lucie (FL)	9/ >200	8/ >100		

*Act = number of times the colony was active. Size = number of nests. Large colonies were defined as having ≥ 200 nests in > 5 years within the decade.

Productivity

The productivity values necessary for population viability at the Breeding Region level are unknown; however, available data were used to estimate condition based upon a few key colonies from each region.

Current Condition

For this SSA we define a Breeding Region current condition based upon population parameters including population size, number of large persistent colonies, productivity, and population trend. Low condition is defined as a population size less than 1,500 nesting pairs; ≤ 1 large persistent colony; average productivity less than 1.3 chicks fledged per nest; and a declining population. Moderate condition is defined as a population size 1,500–2,499 nesting pairs; 2–4 large persistent colonies; average productivity of 1.3–1.7 chicks fledged per nest; and a stable population. High condition is defined as a population size $\geq 2,500$ nesting pairs; ≥ 5 large persistent colonies; average productivity > 1.7 chicks fledged per nest; and an increasing population (Table 8).

Table 8. Population category condition definitions used to assess each Breeding Region’s demographic current condition.

Population Category\Condition	Low (1)	Moderate (2)	High (3)
Population Size (Nests/Pairs)*	<1,500	1,500-2,499	>2,500
Large Persistent Colonies*	0-1	2-4	5 or more
Productivity*and**	<1.3	1.3-1.7	>1.7
Population Trend*	Declining	Stable	Increasing

*We used expert opinion on regional demographic and colony dynamics to determine condition categories measures and ranges.

**A productivity rate of 1.5 fledged young per nest is a recovery goal thought to be sufficient for maintaining a stable population level. We broadened the “moderate” rate to account for variation in monitoring methodologies and general annual variation.

To ascertain the current overall condition of a Breeding Region, each independent population category condition (Low, Moderate, or High) per the definitions (Table 8) are assigned a numeric value of 1, 2, or 3 and each independent Population Category Condition value is averaged to ascertain the Current Condition for a Breeding Region. Table 9 provides a hypothetical example of this calculation.

Table 9. Example of a hypothetical Breeding Region current condition assessment calculation.

Population Size	Population Trend	Large Persistent Colonies	Productivity	Demographic Condition
2,000 pairs Moderate (2)	Declining trend Low (1)	3 colonies Moderate (2)	1.0 fl yng/nest Low (1)	$2 + 1 + 2 + 1 = 6$ $6 / 4 = 1.5$ LOW-MODERATE

4.1.2 Habitat Resiliency Factors

Wood storks are a wetland-dependent species, and because wetland habitat throughout the species’ range is widely available and does not appear to be a limiting factor, we did not include a measure for habitat resiliency factors in the analysis of current condition. We do include a measure of the wetlands within the combined Core Foraging Area for all the nesting colonies for each Breeding Region.

Please see Breeding and Non-Breeding Season Habitats (sections 2.7.1 and 2.7.2) and Breeding Regions (section 3.2) sections above for information regarding habitat needs of the species by Breeding Region, and additional description on how wetland function in each Breeding Region affects habitat use. Please see the Land Conversion and Habitat Loss subsection (section 5.1.1) for information on the stressors impacting the wetland habitats that the wood storks rely upon. Also see Changing Climate Conditions and Sea Level Rise (section 5.1.2) for information on the potential future impacts of climate change to wetland habitats. Note that for the current conditions analysis, we use population demographics to measure the condition of each Breeding Region; and for the future conditions analysis we use habitat condition as a proxy to project a future condition of each Breeding Region.

4.2 Redundancy

The U.S. wood stork DPS is a wide-ranging, single population that breeds in four southeastern states, with all of the breeding occurring in Florida, Georgia, North Carolina, and South Carolina. However, for this SSA we identified four Breeding Regions (section 3.2), as defined by the clustering of nesting colonies and nesting numbers (within and across the geographic borders) among the four states, in order to assess redundancy. Wood stork nest numbers often fluctuate annually and between Breeding Regions due to environmental conditions (e.g., rainfall levels and timing). We note that some breeding adults move between colonies and regions to reproduce due to varying habitat conditions, and that approximately 40-50% of nesting now occurs in the Northeast Breeding Region.

The wide spatial extent covered by the population across the four Breeding Regions reduces the risk to the U.S. population posed by any single catastrophic event, because it is unlikely that a single catastrophic event would impact all four Breeding Regions. Furthermore, the impacts of stressors in one region may also be mitigated by the movement of breeding colonies throughout the range, as evidenced by shifts in nesting numbers across the four Breeding Regions in apparent response to conditions in another region. Moreover, having several large persistent colonies as anchors within each Breeding Region provides redundancy within a Breeding Region and to the overall U.S. breeding population.

4.3 Representation

Maintaining representation in the form of genetic and ecological diversity is important for wood stork to maintain the ability to adapt to future environmental changes. As discussed in section 2.1 Taxonomy and Genetics, the wood stork's U.S. breeding population is considered one genetic population throughout its range. This is supported by all known wood stork population genetic studies that have been conducted to date (Stangel et al. 1990, p. 618; Van Den Bussche et al. 1999, p. 1083; Lopes et al. 2011, p. 1911). Individuals of the U.S. population do overlap with individuals from the Mexico and Central America populations during the non-breeding season; however, genetic exchange between the populations is currently considered minimal (Service 2014, p. 37087), as it has been documented only once (Bryan and Borkhataria 2010, p. 2).

Ecological diversity is also an indication of representation. Wood storks use a mosaic of wetland habitats for nesting, roosting, and foraging. These include shallow and persistent (i.e., short and long hydroperiod) wetlands, marshes, and shallow open water habitats (including freshwater, brackish, and saltwater habitat associated with natural and anthropogenic landforms) which are found in the coastal plain regions of the southeastern U.S. Negative impacts to the Everglades and other wetlands in south Florida from development and agriculture caused the population decline that led to the listing of the U.S. wood stork population, but also may have influenced the regional shift in abundance of nesting wood storks north into Georgia and South Carolina. As conditions deteriorated and dried in south Florida, the extensive salt marshes, coastal wetlands, and old rice impoundments of Georgia and South Carolina, with their greater stability, became better options for foraging during the breeding season and the population center shifted north. Thus, the breeding range shift and expansion northward may demonstrate an innate behavioral and adaptive response to deteriorating habitat conditions in south Florida (Hitch and Leberg 2007, p. 534).

Movement data of adult wood storks tagged with satellite transmitters indicate that some exhibit migratory movements within the southeast U.S. between breeding and non-breeding seasons, some are “residential” (remain in one area all year), and others employ both strategies. In response to climatic conditions in fall and winter, most wood storks move south into Florida, especially towards South Florida, or to coastal habitats if residing in South Carolina and Georgia. All of these patterns indicate an ability to respond to current environmental conditions and to move (or not) depending on local resource availability.

Wood storks also use human-made wetlands such as canals, ditches, impounded ponds and lakes, and more urban habitats range-wide, which they were not known to use historically. Few studies have examined the potential risks associated with wood storks foraging in urban wetlands (e.g., contaminants, disturbance, and parasites/diseases) (Martin 2010, p. 61). Historically wood storks were described as secretive and perceived as intolerant of human disturbance, particularly in colonies (Bent 1926, p. 57; Burleigh 1958, p. 119); however, with the recent increase of use of urban habitats (Klassen and Gawlik 2018, p. 126; Evans and Gawlik 2020, p. 1), wood storks appear more tolerant of human activity to the extent that they will nest and forage in highly urbanized areas like storm water retention ponds in housing developments, commercial shopping areas, and along busy roads. Wood storks seek and use suitable foraging wetlands and nesting habitats which are found in a variety of natural and human influenced and created habitats.

As mentioned previously, representation is the ability of a species to adapt to both near-term and long-term changes in its physical and biological environment. Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Nicotra et al. 2015, p. 1270; Beever et al. 2016, p. 132). Thus, representation reflects the ability of the species to respond and adapt to changing conditions, either by changing themselves, or by responding to changes around them. Representation is often measured in the genetic, morphological, ecological, behavioral, or other types of diversity present among populations, but as noted previously there is little evidence of these types of differences among populations of wood stork. However, the wood stork’s innate behavioral capacity to respond to deteriorating and changing wetland conditions on a daily, seasonal, annual, and long-term basis, and to exploit novel habitat types such as human made wetlands, indicates adaptive capacity. The U.S. population of wood storks has gradually shifted and expanded its breeding range (e.g., northward into three new states) and increased its habitat use (e.g., to include urban wetlands, impounded wetlands and coastal salt marshes of Georgia and South Carolina) in response to changing conditions, and thus ultimately demonstrates some degree of adaptive capacity despite a lack of evidence showing genetic diversity within the species. Thus, we interpret this to mean that representation is at least adequate, and possibly even high for this species.

4.4 Factors and Trends

To assess the current resiliency for each of the four Breeding Regions, we quantified the demographic factors described in the Population Resiliency Factors section (section 4.1.1) and Table 8 above, which provide the condition measures for population size, large persistent colonies, productivity, and population trend that are used to determine overall condition of each Breeding Region and for the U.S. Breeding Population.

4.4.1 Large Persistent Colonies

Relative to colony size (based on nest numbers), we defined colonies that produced over 200 nests more than five times during 2013–2022 (Table 10) as the current condition measure for large persistent colonies.

To identify colonies that meet this definition, colony persistence was examined relative to wood stork colony size and longevity within the four Breeding Regions in multiple decades (Table 7; 1980–2019). While focused on the most recent larger colonies, we also note the regional nesting activity patterns of other, often smaller, colonies, less consistent colonies (e.g., colonies that pulsed > 200 nests during a lower number of years), as well as “legacy” colonies of historical significance (e.g., Corkscrew). Pulses in nesting activity are in response to changing environmental and hydrological conditions.

Longevity of colony occupancy expectedly varies with Breeding Region as the regions to the north generally have a shorter history of wood stork colony presence than southern regions of the breeding range (see description in section 3.2 Breeding Regions). Each Breeding Region contains at least one “large” colony with a history spanning four decades (longevity). Large colony size is a key factor for persistence that leads to longevity in colonies (Frederick and Meyer 2008, p. 16; Tsai et al. 2016, p. 644). Large and/or persistent colonies within each Breeding Region provide redundancy within the overall U.S. population.

Table 10. Large persistent colonies total nests/pairs by Breeding Regions and (2013–2022).

Breeding Region	State	Colony Name	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northeast	North Carolina	Lay's Lake	125	184	211	244	244	114	239	416	443	147
	South Carolina	Colony 3	195	267	268	283	254	225	333		309	0
	South Carolina	Colony 6	368	442	368	314	291	204	429		292	474
	South Carolina	Colony 20	205	315	207	177	281	208	312		284	452
	Georgia	Harris Neck	334	387	442	509	400	474	450	626	671	477
	Georgia	Gilman	250	347	300	399	409	314	340	265	378	415
Northwest	Georgia	Blackwater	185	322	370	248	236	208	360	275	240	280
Central	Florida	Deseret Ranch	390	165	235	180	195	230	75		110	80
	Florida	Morganton	175	0	200	230	155	220	110		115	90
	Florida	Lake Somerset	432	178	231	48	74	88	82	105	80	52
South	Florida	Cypress Creek	280	230	230	220	0	16	0			
	Florida	Palm Beach Co. SWA	413	304	255	255	155	365	72	100	190	194
	Florida	Jetport South	463	400	0	0	857	953	0	275	631	
	Florida	Broad River	150	300	193	340	545	746	550	370	849	245
	Florida	Paurotis Pond	500	270	285	230	326	682	170	70	157	0
All Large Persistent			4,465	4,111	3,795	3,677	4,422	5,047	3,522		4,961	3,213
Percent Southeast U.S.			40	37	38	35	40	42	41		40	31
Southeast U.S. Total			11,076	11,238	10,058	10,639	11,188	12,105	8,699		12,453	10,492

4.4.2 Productivity

Wood stork annual productivity/breeding success directly influences wood stork abundance and population growth. As a wide-ranging species, it can be extremely difficult and/or costly to monitor wood stork relative to this metric. Wood stork colonies vary considerably in their remoteness from human habitation, occurring in urban sites as well as remote sites, requiring aircraft or watercraft to observe. In addition, their breeding “season” (nest building through nestling fledging) can require four months, and thus monitoring breeding success can be a considerable time/financial commitment depending on the methodology employed.

Breeding success estimates numbers of young surviving through the nestling period and reaching the free-ranging juvenile period. These estimates can be accomplished via ground and aerial survey methods, although the ground-based monitoring is generally more accurate. The most common ground-based monitoring involves visiting the colony and observing specific nests every 10–14 days throughout the breeding season (Rodgers 1995, entire). For individual nests, observations are made on the number of nestlings reaching 50–55 days post-hatching, the age at which the young can fly (fledging). These numbers are averaged to estimate breeding success (fledged young/nest) of the colony. In most years, a number of nests may not have young reach fledging age (e.g., nest may be abandoned or be lost due to predation). Breeding success may also be averaged for successful nests (only those nests that fledge young).

In some instances, but especially for aerial monitoring, single counts of older (fledge-aged) nestlings in nests are used to estimate success per nest. This monitoring is similar to ground-based averages of successful nests in that an estimate of fledged young/nest is attained, but some of the information pertaining to the breeding year (e.g., nest failures and their causes) is lost. Some agencies/institutions also employ aerial photography in their monitoring, taking a series of overlapping photographs, using software to merge them into an image and then counting nests/young to estimate breeding success. While less field time is employed in this method, it does require extensive time to examine the colony photography.

As discussed in section 2.5.2 Productivity, annual wood stork breeding success varies considerably among years, geographic regions, and colonies, generally in response to changes in environmental conditions which ultimately alter predation risk. Current (2013–2022) breeding success rates are productivity rates (average number of fledged chicks per nest for a colony) and we noted that productivity rates for wood stork colonies have been derived using different methodologies and productivity varies annually and among Breeding Regions (Table 11).

Table 11. Productivity rates and averages for large persistent colonies by Breeding Region.

Breeding Region	State	Colony \ Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northeast	GA	Gilman Paper	0.6	1.8	2.0	1.8	1.9	2.1	1.6	1.8	1.8	2.0
		Harris Neck	1.5	2.1	2.0	1.7	2.2	2.1	1.6	1.4	1.7	1.8
	SC	Colony 6	1.4	2.4	2.3	1.2	1.5	1.8	1.9	ns	2.1	2.2
		Colony 20	1.5	2.6	2.5	2.1	2.2	1.6	2.1	ns	1.9	2.0
		Average	1.3	2.2	2.2	1.7	2.0	1.9	1.8	1.6	1.9	2.0
		5 yr. Average	1.5	1.6	1.7	1.7	1.9	2.0	1.9	1.8	1.8	1.8
Northwest	GA	Blackwater	ns	ns	ns	0.8	1.3	2.0	ns	ns	ns	ns
		Chew Mill Pond*	0.8	ns	ns	ns	1.5	2.1	2.3	ns	1.3	ns
		Camilla	ns	ns	1.8	0.6	2.0	1.6	ns	ns	ns	ns
		Average	0.8	nd	1.8	0.7	1.6	1.9	2.3	ns	1.3	nd
		5 yr. Average	1.0	1.3	1.3	1.0	1.2	1.5	1.7	1.6	1.6	
Central	FL	Lake Somerset	1.6	1.9	1.7	2.0	ns	1.2	ns	2	1.6	ns
		Dot Dash*	1.8	1.7	1.9	ns	2.0	1.5	ns		2	1.7
		Lake Russell*	0.4	0.7	2.0	1.3	2.0	2.2	1.8	ns	1.6	0.3
		Average	1.3	1.4	1.9	1.7	2.0	1.6	1.8	2.0	1.7	1.0
		5 yr. Average	1.5	1.4	1.5	1.5	1.7	1.7	1.8	1.8	1.8	1.6
South	FL	PBSWA	0.5	ns	ns	ns	1.0	2.1	0.2	ns	2.1	0.9
		Paurotis Pond	ns	1.7	0.2	0.7	1.6	1.5	0.0	nd	1.5	na
		Tamiami West	1.9	0.4	0.7	0.0	2.1	0.0	0.0	0.8	1.5	0.0
		Average	1.2	1.1	0.5	0.4	1.6	1.2	0.1	0.8	1.7	0.4
		5 yr. Average	0.8	0.7	0.8	0.7	1.0	1.0	0.8	0.8	1.1	0.8

Note: Large colonies = > 200 nests/year for > 5 years during the 2013-2022 period. *nd (no data) indicates the large colony was not monitored for breeding success that year, therefore, there is no data to average. DotDash, Lake Russell, and Chew Mill are smaller (~100 - 200 nests) but consistently monitored colonies. Note: No productivity data was collected for the Northwest breeding region in 2022. 2020 COVID protocols precluded a survey of all the nesting colonies in 2020. Thus, the averages in 2020, 2021, and 2022 are based off of incomplete data sets (in some cases 5 years averages are used with 4 data points divided by 4), but represent the best available information.

4.5 Current Demographic Conditions

Condition of Breeding Regions and the U.S. population of wood storks are described using the demographic factors defined and described earlier in this chapter. Those include: 1) population size, 2) breeding population trend, 3) large persistent colonies, and 4) productivity. The condition value for each the demographic factors are averaged to ascertain the Current Condition of each Breeding Region, and the four Breeding Region conditions are averaged to rate overall resiliency for the U.S. population. Demographic conditions are described as High, Medium, and Low, per definitions presented earlier in this chapter. To determine overall condition, these condition ratings were assigned values 3, 2, and 1 for High, Medium, and Low, respectively.

4.5.1 South Breeding Region

Breeding Population Trend

Annual nest counts (1965–2022, 57 years) show a great deal of variability. The long-term trend (1965-2022) has an increasing (High) population growth (Figure 14; $\lambda = 0.97$), and the short-term trend (2013-2022) has a stable (Moderate) population trend ($\lambda = 0.97$).

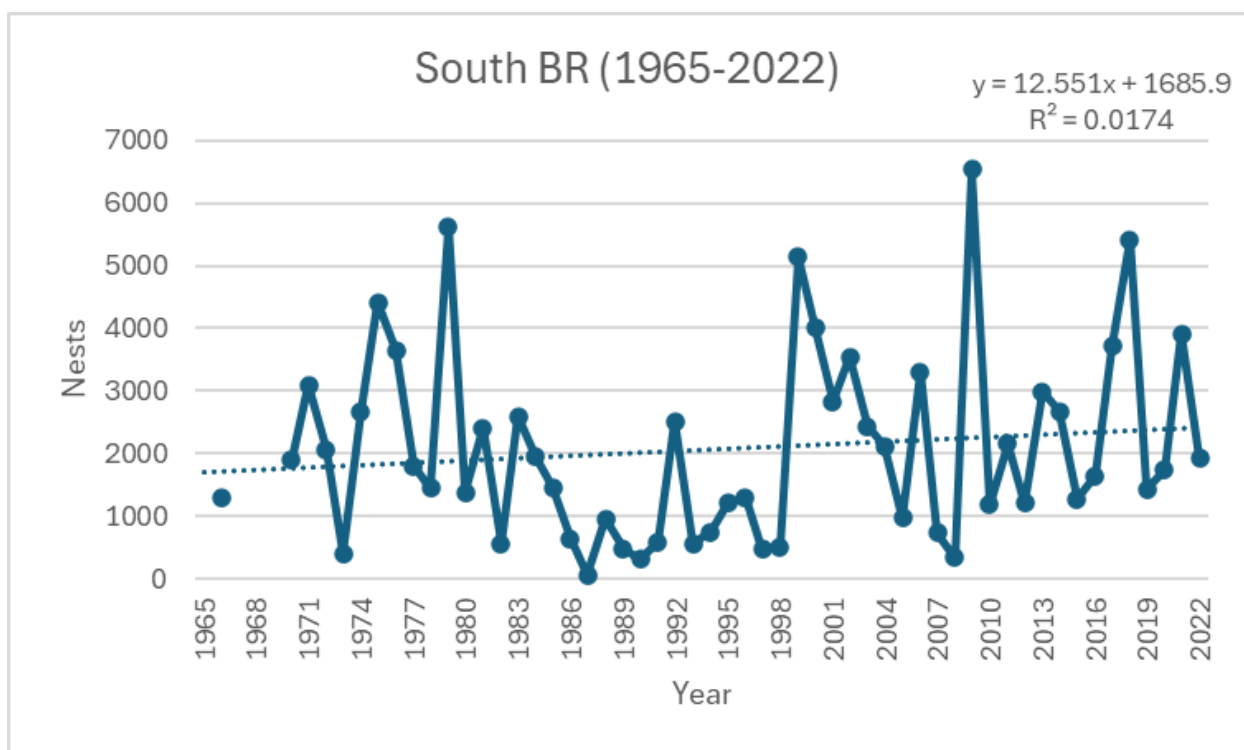


Figure 14. Annual wood stork nesting in the South Breeding Region with regression analysis.

Breeding Population Size

The current 10-year average (2013–2022) is 2,673 pairs/nests. The current 10-year average of the 5 year moving averages is 2,608. The five-year moving averages during the past 10 years (calculated using data from 2013–2022) ranged from 1,961–3,242 nests/pairs. The Recovery Criteria metric (five-year moving average of 2,500 nests; Table 12) was met 6 of 10 years.

Table 12. Annual nest totals and five-year moving averages of the number of nesting pairs of wood storks in the South Breeding Region from 2013–2022.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Year Total	2,995	2,676	1,276	1,649	3,720	5,423	1,428	1,732	3,907	1,926
5-Year Average	2,980	2,045	2,063	1,961	2,463	2,949	2,699	2,790	3,242	2,883

Large Persistent Colonies

Within the South Breeding Region, there were 31 active colony sites during 2013–2022 and were in seven counties (for historic comparative purposes, there were 12 active colonies in 1975–1985). Six colonies met the criteria as a large persistent colony; these colonies were located in four counties. Four of the six large persistent colonies occur on publicly managed conservation lands. Only one of these colonies (Palm Beach Solid Waste Authority colony) met the criteria in the previous decades (and was present at lower nesting numbers in the 1990s). There were several additional colonies that produced > 200 nests but did not meet the parameter of being persistent (< 5 years in a decade), including: Corkscrew and Baron Collier colonies (Collier Co.), Jetport and Tamiami West colonies (Dade Co.), and Lostmans Creek (Monroe Co.). There are also “legacy colonies” (e.g., Corkscrew) with active histories dating back several decades which include pulses of > 1000 nests.

Productivity

From 2013 to 2022, 23 breeding success estimates (productivity) were made for the three large persistent colonies (Table 13); seven estimates had productivity of ≥ 1.5 fledged young/nest. The annual average productivity ranged from 0.1 to 1.7 fledged young/nest and the 10-yr average of five-year running averages was 0.9 and ranged from 0.7 to 1.1 (Table 13).

Table 13. Productivity averages from (number of fledged young/nest (fl yng/nest) for large persistent colonies for the South Breeding Region.

Productivity\Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Average	1.2	1.1	0.5	0.4	1.6	1.2	0.1	0.8	1.7	0.4
5 yr. Average	0.8	0.7	0.8	0.7	1.0	1.0	0.8	0.8	1.1	0.8

Demographic Condition

The current (2013–2022) demographic condition of the South Breeding Region is HIGH-MODERATE (Table 14).

Table 14. South Breeding Region current demographic condition assessment.

Years	Population Size	Population Trend	Large Persistent Colonies	Productivity	Demographic Condition
2010-2019	Moderate (2,106 pairs)	Moderate (stable)	High (5 colonies)	Low (0.8)	MODERATE
2013-2022	High (2,883 pairs)	Moderate (stable)	High (5 colonies)	Low (0.8)	HIGH-MODERATE

4.5.2 Central Breeding Region

Breeding Population Trend

The long-term trend (1971–2022, 51 years, $\lambda=8.93$) is increasing. It is important to note the high variability of nesting in this breeding region throughout time and note that the years included in the short-term (2013–2022, $\lambda=0.67$) are not as low as several years throughout the long-term trend. (Figure 15).

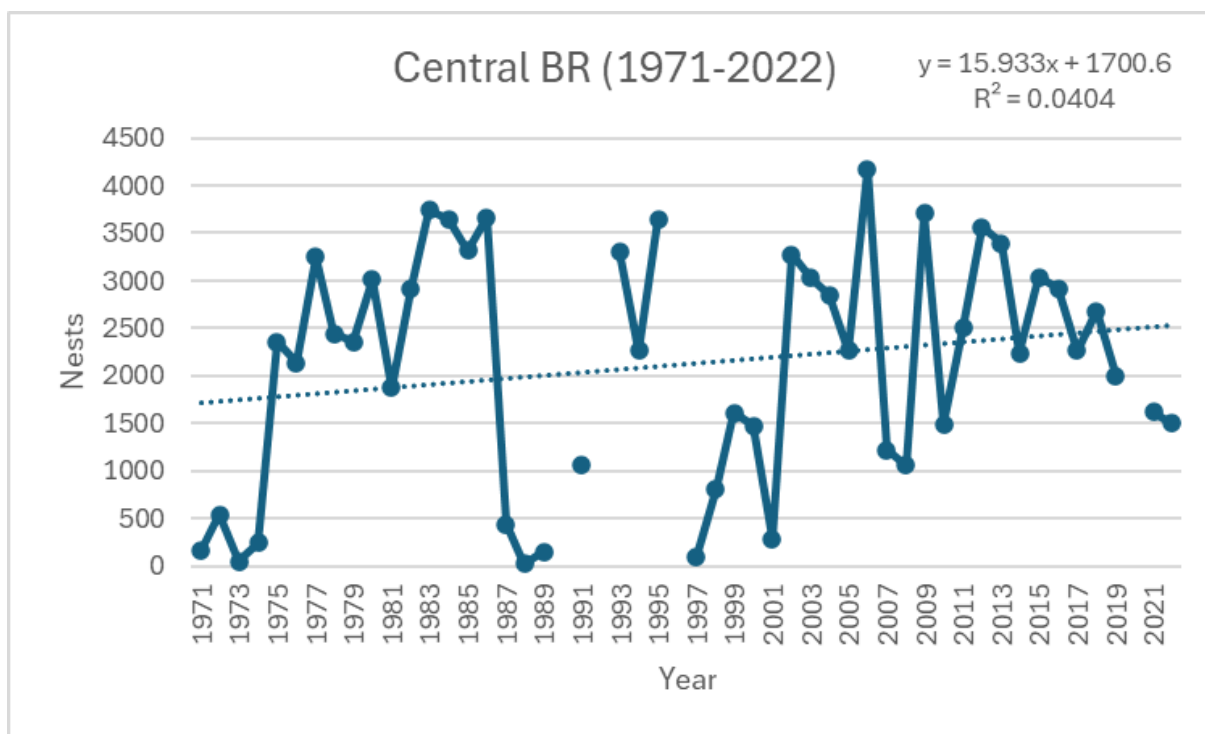


Figure 15. Annual wood stork nesting in the Central Breeding Region with regression analysis

Breeding Population Size

The current 10-year average (2013–2022) is 2,405 pairs/nests. The current 10-year average of the 5 year moving averages is 2,607 pairs/nests. Five-year moving averages during the past 10 years (2013–2022) ranged from 1,950–3029 pairs/nests (Table 15). The Recovery Criteria metric (five-year moving average of 2,500 nests) was met 7 of 10 years.

Table 15. Annual nest counts and five-year moving averages of nest counts in the Central Breeding Region.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Year total	3,390	2,236	3,034	2,921	2,263	2,677	2,002	n/a	1,622	1,499
5-yr avg.	2,932	2,637	2,945	3,029	2,769	2,626	2,579	2,466*	2,141*	1,950*

Large Persistent Colonies

There were 47 active wood stork colony sites in 2013–2022 (for historic comparison there were 36 active colonies in 1975–1985). No colonies met the greater than 200 nests for at least five years, although, three averaged greater than 150 nests. Ten colonies were active in all years and an additional 10 were active nine out of ten years. One of these colonies (Deseret Ranch) met the criteria in three years and often since 2000 and has a very long persistence (although smaller number of nesting pairs) in the 1990s and 1980s. Two additional colonies (El Claire in Hardee

Co. and Morganton North in Charlotte Co.) generally produce greater than 150 nests and occasionally 200 nests during 2013–2022.

Productivity

From 2013 to 2022, 23 breeding success estimates (productivity) were made for the three large and/or persistent Central colonies; 18 (78%) had an estimated productivity of ≥ 1.5 fledged young/nest. The 10-year annual average productivity was 1.6 and ranged from 1.0 to 2.0 fledged young/nest (Table 16). The 10-year 5-year running average was 1.6 and ranged from 1.4 to 1.8 (Table 16).

Table 16. Productivity averages from (number of fledged young/nest) for large persistent colonies for the Central Breeding Region.

Productivity\Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Average	1.3	1.4	1.9	1.7	2.0	1.6	1.8	2.0	1.7	1.0
5 yr. Average	1.5	1.4	1.5	1.5	1.7	1.7	1.8	1.8	1.8	1.6

Demographic Condition

The current (2013-2022) demographic condition of the Central Breeding Region is MODERATE-LOW (Table 17).

Table 17. Central Breeding Region current demographic condition assessment.

Years	Population Size	Population Trend	Large Persistent Colonies	Productivity	Demographic Condition
2010-2019	High (2,740 pairs)	High (increasing)	Moderate (3)	High (1.8)	HIGH-MODERATE
2013-2022	Moderate (1,950 pairs)	Low (declining)	Low (0)	Moderate (1.6)	MODERATE-LOW

4.5.3 Northwest Breeding Region

Breeding Population Trend

The long-term trend (1977–2022) shows annual nest counts increasing ($\lambda = 4.31$) (Figure 16). The short-term trend (2013-2022) is stable ($\lambda = 0.93$).

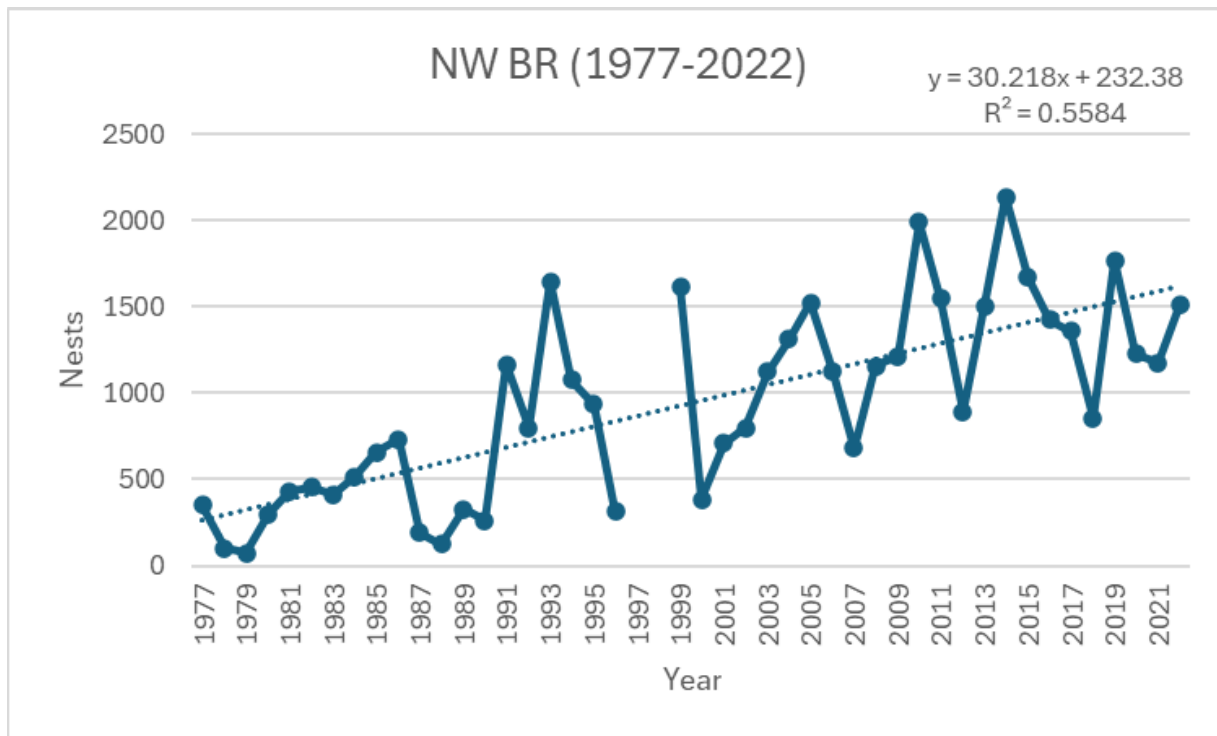


Figure 16. Annual wood stork nesting in the Northwest Breeding Region with regression analysis.

Breeding Population Size

The current (2013-2022) 10-year average is 1,491 pairs/nests, and the current 10-year average of the 5-year moving averages is 1,417 (Table 18). Five-year moving averages during the past 10 years range from 1,291-1,621 pairs/nests (Table 18). The Recovery Criteria metric (5-year moving average = 2,500 nests) has not been met for this breeding region.

Table 18. Annual nest counts and five-year moving averages in the Northwest Breeding Region.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual	1,507	2,137	1,673	1,426	1,360	855	1,772	n/a	1,176	1,509
5 yr avg.	1,431	1,616	1,552	1,527	1,621	1,490	1,417	1,353*	1,291*	1,328*

Large Persistent Colonies

This region includes counties in both Florida (n = 4) and Georgia (n = 6). There were 20 active colony sites from 2013–2022 (for historic comparative purposes, there were 3 active colonies in 1975–1985). Two colonies within the northwest region (Blackwater, Brooks Co. and Camilla, Mitchell Co., Georgia) met the criteria of a large persistent colony and they are located on private lands, but they did not meet the criteria in the previous decade. The Duck Lake colony (Leon Co., Florida) was active all 10 years (2013-2022) with greater than or equal to 150 nests and three years with greater than 200 nests. The Chaires colony (Leon Co., Florida) produced greater than 200 nests only once in 2013; this multiple decade large colony is now mostly inactive.

Productivity

From 2013 to 2022, 12 breeding success estimates (productivity) were made for the three large and/or persistent Northwest colonies; 6 (50%) had an estimated productivity of greater than or equal to 1.5 fledged young/nest (Table 19). The annual average productivity, that we had data for, was 1.5 and ranged from no data to 0.8 to 2.3 fledged young/nest. The average of 5-year running averages was 1.5 and ranged from 1.0 to 1.7 from 2013–2022. The 2021 10-year average was 1.6.

Table 19. Productivity averages from (number of fledged young/nest) for Northwest Breeding Region large persistent colonies.

Productivity\Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Average	0.8	n/a	1.8	0.7	1.6	1.9	2.3	n/a	1.3	n/a
5 yr. Average	1.0	1.3	1.3	1.0	1.2	1.5	1.7	1.6	1.6	n/a

Demographic Condition

The current (2013–2022) demographic condition of the Northwest Breeding Region is MODERATE (Table 20).

Table 20. Northwest Breeding Region current demographic condition assessment.

Years	Population Size	Population Trend	Large Persistent Colonies	Productivity	Demographic Condition
2010-2019	Low (1,417)	High (increasing)	Low (1)	High (1.7)	MODERATE
2013-2022	Low (1,328)	Moderate (stable)	Low (2)	High (1.6)	MODERATE

4.5.4 Northeast Breeding Region

Breeding Population Trend

The long-term trend (1965–2022, 57 years) shows annual nest counts increasing ($\lambda = 1389.5$) (Figure 17). The short-term trend during the past 10 years (2013–2022) shows annual nest counts increasing ($\lambda = 1.69$).

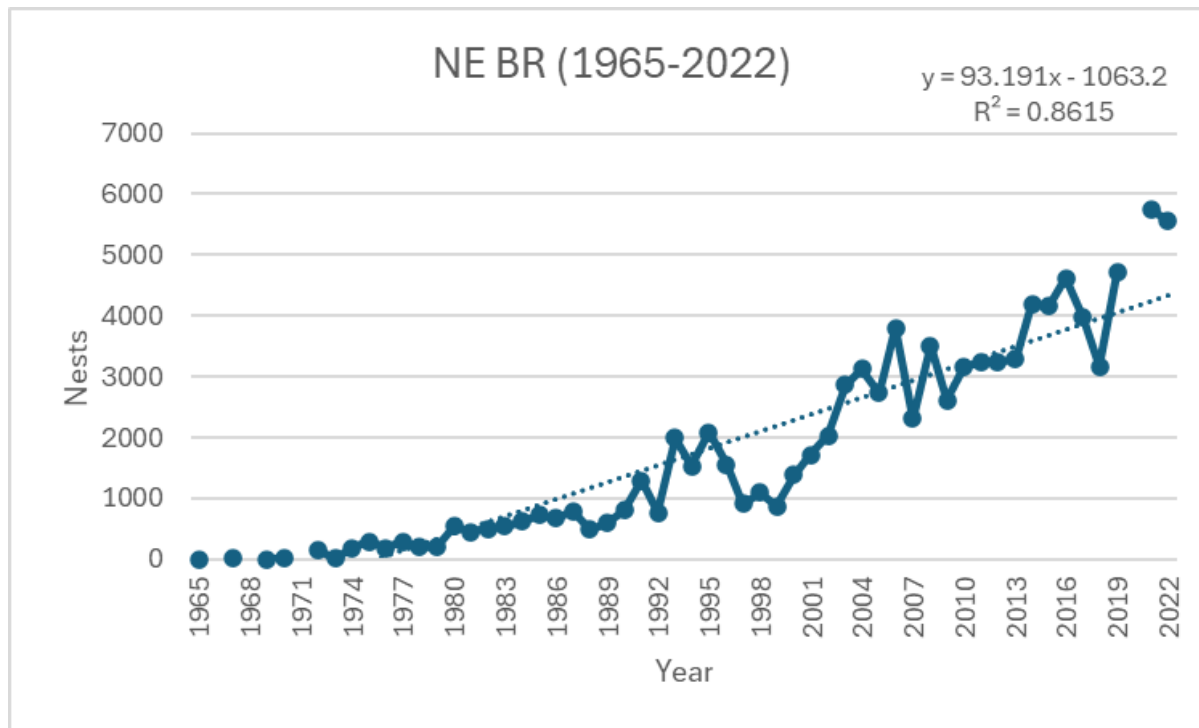


Figure 17. Annual wood stork nesting in the Northeast Breeding Region with regression analysis.

Breeding Population Size

The current 10-year average is 4,381 nests/pairs and the current 10-year average of the 5-year moving average is 3,958 nests/pairs. Five year moving averages during the past 10 years range from 3,110-4,794 nests/pairs (Table 21). The Recovery Criteria metric (five-year moving average = 2,500 nests) was met all 10 years from 2013-2022.

Table 21. Annual nest counts and five-year moving averages of nest counts in the Northeast Breeding Region.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual	3,284	4,203	4,173	4,620	3,972	3,162	4,709	1,896	5,748	5,558
5 yr avg.	3,110	3,427	3,628	3,905	4,050	4,026	4,127	4,116*	4,398*	4,794*

Large Persistent Colonies

The northeast breeding region is more expansive than the others, including counties in Florida (n = 4), Georgia (n = 6), South Carolina (all, n = 8), and North Carolina (all, n = 4). There were 68 active colony sites in this region from 2013–2022 (for historic comparative purposes, there were 17 active colonies in 1975–1985). Seven colonies met the criteria of a large persistent colony, including two in Georgia, four in South Carolina, and one in North Carolina (Table 10). Only one of these colonies is located on publicly managed conservation lands. Harris Neck NWR and Gilman Colony 6 and Colony 20 (both Colleton Co., South Carolina) met the criteria in the previous decade and Colony 6 met the criteria in the 1990s. Both Colony 6 and Harris Neck NWR had a wood stork nesting presence dating back into the 1980s.

Productivity

From 2013 to 2022, 40 breeding success estimates (productivity) were made for the large and/or persistent Northeast colonies; 34 (85%) had an estimated productivity of greater than or equal to 1.5 fledged young/nest. The annual average productivity ranged from 1.3 to 2.2 fledged young/nest and the 10-year average was 1.9 (Table 22). The 2022 5-year running average was 2.0 and ranged from 1.5 to 2.0 from 2014–2022, and the 2022 10-year average was 1.8.

Table 22. Productivity averages and 5-yr averages for large persistent colonies for the Northeast Breeding Region.

Productivity\Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Average	1.3	2.2	2.2	1.7	2.0	1.9	1.8	1.6	1.9	2.0
5 yr. Average	1.5	1.6	1.7	1.7	1.9	2.0	1.9	1.8	1.8	1.8

Demographic Condition

The current (2013–2022) demographic condition of the Northeast Breeding Region is HIGH (Table 23).

Table 23. Northeast Breeding Region current demographic condition assessment.

Years	Population Size	Population Trend	Large Persistent Colonies	Productivity	Demographic Condition
2010-2019	High (4,187)	High (increasing)	High (6)	High (1.9)	HIGH
2013-2022	High (4,794)	High (increasing)	High (7)	High (1.8)	HIGH

4.5.5 U.S. Breeding Population

Breeding Population Trend

The long-term trend (1974–2022, 49 years) shows an increasing population ($\lambda = 3.37$) (Figure 18). The current trend during the past 10 years (2013-2022) shows increasing (High) population ($\lambda = 1.05$).

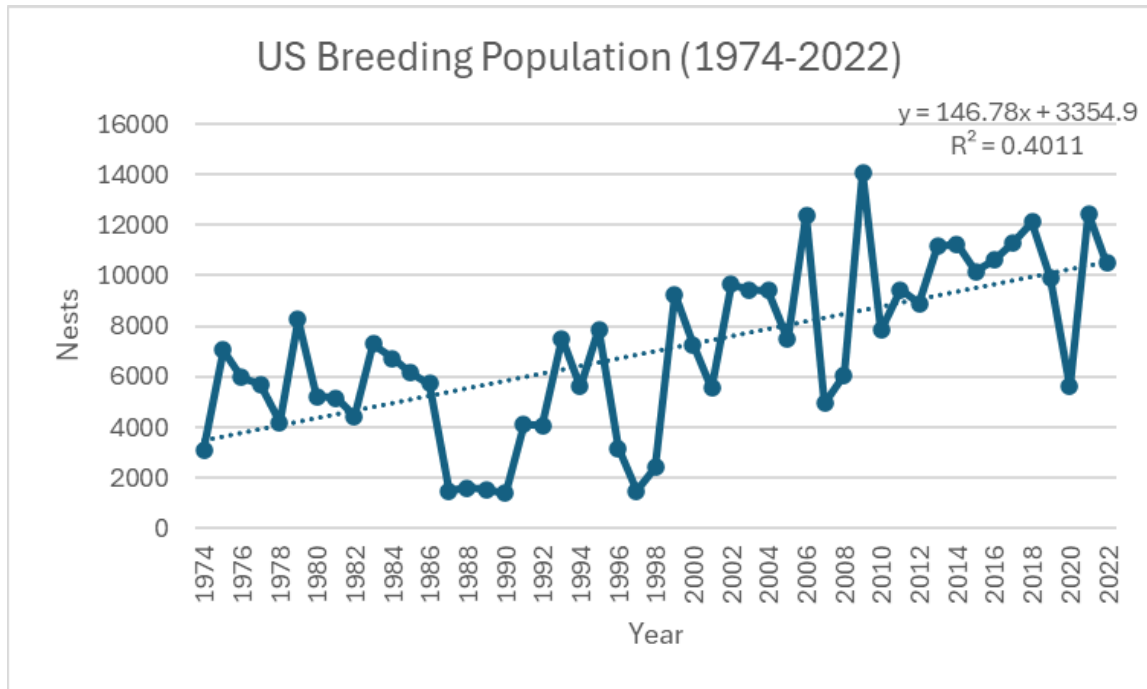


Figure 18. Annual wood stork nesting in the U.S. Breeding Population with regression analysis.

Breeding Population Size

The current 10-year average is 11,054 nests/pairs with a high of 12,453 nests/pairs (Table 24). The current 10-year average of the 5-year moving averages is 10,636 pairs/nests. Five-year moving averages during the past 10 years (2013-2022) ranged from 9,725 – 11,091 nests/pairs (Table 24). Recovery criteria metric (five-year moving average of 2,500 nests) was met nine out of 10 years.

Table 24. 5-year moving averages of nest counts in the U.S. Breeding Population.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual	11,176	11,252	10,156	10,616	11,315	12,117	9,911		12,453	10,492
5yr avg	10,453	9,725	10,188	10,422	10,903	11,091	10,822	10,725*	11,072*	10,955*

*2020 COVID protocols precluded a survey of all the nesting colonies in 2020. Thus, the averages in 2020, 2021, and 2022 are 4-year averages using the appropriate 5-year timeframe but lacking data from 2020.

Large Persistent Colonies

Large and/or persistent colonies within each Breeding Region provides redundancy within the overall U.S. breeding population.

Productivity

Out of 103 breeding success estimates among all wood stork colonies, 60 (69%) had estimated productivity greater than or equal to the 1.5 fledged young/nest presumed necessary for population recovery (Table 25).

Table 25: Productivity averages and 5-yr averages for each Breeding Region in the U.S. Breeding population.

Breeding Region	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northeast	1.5	1.6	1.7	1.7	1.9	2.0	1.9	1.8*	1.8*	1.8*
Northwest	1.3	1.3	1.3	1.0	1.2	1.5	1.7	1.6*	1.6*	n/a
Central	1.4	1.4	1.5	1.5	1.7	1.7	1.8	1.8*	1.8*	1.6*
South	0.6	0.7	0.8	0.7	1.0	1.0	0.8	0.8*	1.1*	0.8*

Note: No productivity data was collected for the Northwest breeding region in 2022.

*2020 COVID protocols precluded a survey of all the nesting colonies in 2020. Thus, the averages in 2020, 2021, and 2022 are based off of incomplete data sets, but represent the best available information.

Demographic Condition (Resilience)

The current (2013–2022) Demographic Condition and resilience of the U.S. Breeding population is HIGH-MODERATE (Table 26b).

Table 26a. U.S. Breeding Population current demographic condition assessment (2010-2019).

Breeding Region	Population Size	Population Trend	Large Persistent Colonies	Productivity	Overall Demographic Condition
Northeast	High	High	High	High	HIGH
Northwest	Low	High	Low	High	MODERATE
Central	High	High	Moderate	High	M-H
South	Moderate	Moderate	High	Low	MODERATE
U.S Population	M-H	M-H	M-H	M-H	M-H

Table 26b. U.S. Breeding Population current demographic condition assessment (2013-2022).

Breeding Region	Population Size	Population Trend	Large Persistent Colonies	Productivity	Overall Demographic Condition
Northeast	High	High	High	High	HIGH
Northwest	Low	Moderate	Low	High	MODERATE
Central	Moderate	Low	Very Low	Moderate	MODERATE-LOW
South	High	Moderate	High	Low	HIGH-MODERATE
U.S Population	High-Moderate	Moderate	Moderate	High-Moderate	HIGH-MODERATE

4.6 Summary of Current Resiliency, Redundancy, and Representation

As previously described, the Southeast U.S. DPS of the wood stork is a wide-ranging, single population, with all breeding occurring in Florida, Georgia, South Carolina, and North Carolina, which the Service grouped into four breeding regions to assess wood stork redundancy (Figure 11). The wood stork experiences increased redundancy in the Northeast Breeding Region due to 40–50 percent of wood stork nesting now occurring in this region, compared to historical trends. The wood stork also has increased redundancy across the four breeding regions due to the wide

spatial extent of the range of wood stork and the fluid nature of breeding throughout the range making it unlikely that a single catastrophic event or stressor would impact all four breeding regions. In addition, having several large, persistent, colonies as anchors within each breeding region provides resiliency within a region and represents a form of redundancy for the Southeast U.S. DPS of the wood stork.

Representation is often measured in the genetic, morphological, ecological, behavioral, or other types of diversity present among populations, but, as noted previously, there is little evidence of these types of differences among populations of wood stork. However, the wood stork's innate behavioral capacity to respond to changing and deteriorating wetland conditions on a daily, seasonal, annual, and long-term basis, and to exploit novel habitat types such as human-influenced and -created wetlands, indicates adaptive capacity. Wood storks in the Southeast U.S. DPS have gradually shifted and expanded their breeding range northward and increased their habitat use to include urban and suburban wetlands, managed wetlands, impounded wetlands, restored wetlands in response to changing conditions. Ultimately, these responses demonstrate a degree of adaptive capacity despite a lack of evidence showing genetic diversity within the wood stork.

Resiliency is measured through demographic factors such as abundance, reproductive success, juvenile recruitment, and population growth. Throughout the tracking of wood stork nest count data, it has been observed that wood stork experiences a great deal of annual variability. As described above in the south breeding region, nest counts in the long-term (1965–2022) and short-term (2013–2022) population growth is stable, and the five-year moving averages from 2013–2022 ranged from 1,961–3,242 nests/pairs. In the central breeding region, the long-term trend (1971–2022) indicates increasing population growth; however, the short-term trend (2013–2022) indicates a decreasing trend. The five-year moving averages have ranged from 1,950–3,029 pairs/nests. The northwest breeding region long-term trend (1977–2022) shows annual nest counts increasing ($\lambda = 4.31$), with the short-term trend being stable, and the five-year moving averages range from 1,291–1,621 pairs/nests. In the northeast breeding region, the long-term trend (1965–2022) and short-term trend (2013–2022) show population growth increasing, and the five-year moving averages range from 3,110–4,794 nests/pairs. Overall, the current (2013–2022) demographic condition and resilience of the U.S. Breeding population is HIGH-MODERATE (Table 26b).

CHAPTER 5 – STRESSORS AND FACTORS AFFECTING VIABILITY

Note to the reader, the only changes in this Chapter from Version 1.0 to 1.1 is the NOAA Climate Change State Summaries were added in 5.1.2 Changing Climate Conditions and updated 5.3 Conservation Actions section.

In this chapter, we evaluate the current and future stressors that may affect wood stork long-term viability. The discussion does not include a comprehensive overview of all past factors that contributed to the species historical decline. Current and potential future stressors, along with current and future expected distribution and abundance, determine viability and vulnerability to extinction. We discuss stressors, factors, and sources that will influence impacts on wood stork future viability, as well as stressors that were not carried forward into our analysis because of lack of evidence that the stressor will impact wood stork populations or viability.

Stressors or threats are defined as any action or condition that is known to, or is reasonably likely to, negatively affect individuals of a species (Figure 19). This includes those actions or conditions that have a direct impact on individuals, and those that affect individuals through alteration of their habitat or required resources. Some threats, while present and acting on individuals, may not rise to the level of affecting the population.

Each threat is considered in terms of its scale, intensity, and duration, as well as potential direct or indirect impacts it may have on the species or its habitat across life history stages. Some threats may be affecting the species at all life stages, or all individuals within the population, or possibly affecting the species only within a particular Breeding Region. It is possible that a threat may be specifically affecting a single resiliency factor, such as the amount of suitable habitat or a specific life stage. Factors influencing current condition can be both negative (e.g., contaminants) and beneficial (e.g., appropriate water management). Consideration and analysis are also given to the cumulative effects of these factors on the species' overall viability including population resilience, species redundancy, and representation.

The most influential resource needs were identified earlier under sections 2.5 and 2.6 breeding and non-breeding seasons. We identified stressors and their cause and effect upon those needs and the species as a whole through: (1) a meeting with state wildlife agencies (Florida Fish and Wildlife Conservation Commission (FWC), Georgia Department of Natural Resources (Georgia DNR), South Carolina Department of Natural Resources (South Carolina DNR), and North Carolina Wildlife Resources Commission (NCWRC) agency species experts in November 2019, (2) a meeting with South Breeding Region species experts in November 2019, (3) reviewing the published literature, and (4) reviewing unpublished reports.

The primary threats (in order from greatest to least current effect on the subspecies) identified for the U.S. wood storks include:

- habitat loss/conversion/degradation (current)
- changing climate conditions: drought, precipitation, sea level rise (future)

which altered the hydrologic regimes of the Everglades and Big Cypress ecosystems. Extensive loss of short hydroperiod wetlands in Southwest Florida has decreased high water foraging habitat. Wetlands were also drained and converted for agricultural production, although this type of habitat conversion has slowed in recent years.

Although habitat has been reduced and become increasingly fragmented, habitat conversion has increased the abundance and distribution of human-made wetlands that provide food resources and nesting habitat for wood storks. Wood storks use habitat opportunistically and frequently exploit urban and suburban wetland habitats; however, many important parts of their range include wetlands that are protected through public ownership (refuges, parks, wildlife management areas, military bases, and wetland management buffer areas). Furthermore, wood stork habitat is protected through water and wetland protection laws, and state sovereign submerged lands protections. Also, many large- and small-scale wetland restoration, enhancement, and conservation easements are being implemented, and future projects are being identified due to the importance of water and wetland resources.

Land conversion resulting from development has negatively impacted wood storks due to the construction of roads, buildings, power lines, and cell phone towers. The expansion of cities, towns, and suburban communities directly alters, as well as fragments, wood stork habitat. Large metropolitan areas such as Miami, Ft. Myers, Orlando, Tampa, St. Petersburg, Tallahassee, and Jacksonville in Florida, Savannah in Georgia, and Charleston and Myrtle Beach in South Carolina, make hundreds of square miles far less suitable for wood stork use, as do smaller towns located throughout the range (Figure 20).

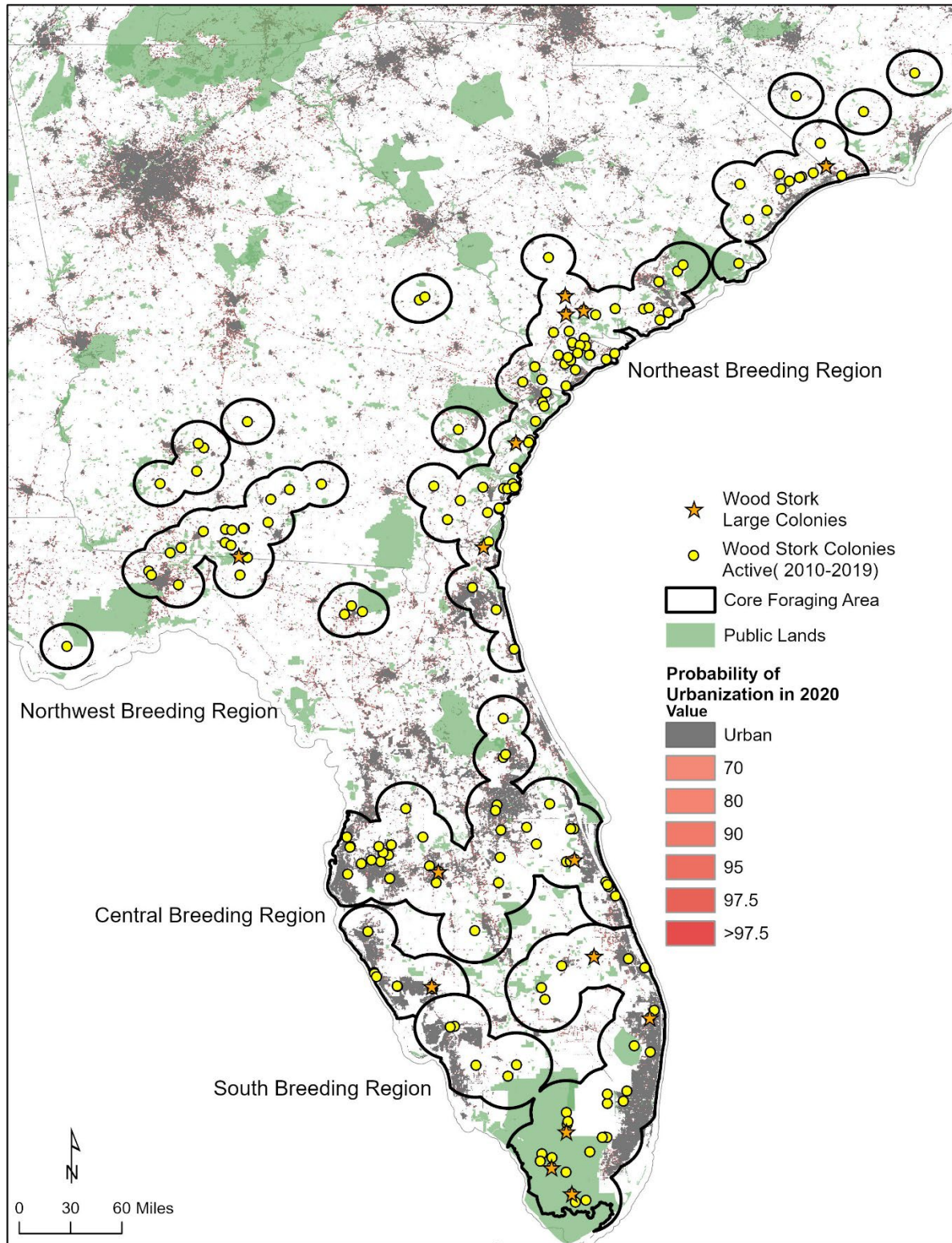


Figure 20. Map of wood stork nesting colonies, core foraging areas, publicly managed lands, and current condition of development (SLEUTH 2020).

Conversion and loss of habitat may exacerbate the normal effects of periodic drought on wood storks, which do poorly in all aspects of their life cycle when conditions become drier. Industrial and agricultural lands consumptive use of water may also change hydrologic conditions of adjacent wetlands as large withdrawals can impact the water table and reduce water levels in wetlands, which increases the risk of woody vegetation encroachment and succession to upland.

Human population growth along the southeast U.S. coast results in an increase in development and is encroaching upon salt marsh and adjacent habitats. This development could limit suitable foraging, nesting, and roosting habitat, and the potential for range expansion of the species. As urban development continues, if additional land is not protected, the potential for the wood stork population to find sufficient suitable habitat to offset the loss of historical habitat, may be limited.

A factor worth noting (but not analyzed here) is future demand for water to meet the demand from the growing human population of the southeastern U.S. and for agriculture/industrial uses. Both will impact ground and surface water availability, which will impact wetland availability and health across southeastern U.S. (i.e. potentially reducing available water to the shallow, short hydroperiod wetlands). It is noted that high-water use aligns with wood stork nesting season in South Florida (Clem 2020, pers. comm.). More studies are needed to quantify and predict potential impacts of urban development and associated water use to wood stork and specifics on water minimum flows and water table level necessary for wood stork.

Another related emerging threat is woody vegetation encroachment into suitable foraging habitats due to changes in hydrological regimes and reduced fire frequency, which is indicative of dryer wetland conditions during the annual hydrologic cycle. This has been described as a current ongoing issue at Corkscrew Swamp Sanctuary and Corkscrew Regional Ecosystem Watershed (Hall et al. 2017, p. 52; Clem et al. 2019, p. 370), within Everglades National Park (Dean 2019, pers. comm.), and within the St. Johns River Basin (Hall et al. 2017, entire).

Despite the negative impacts to wetland habitats described above, wetlands of the Southeast Coastal Plain are extensive (Lang et al. 2024, p. 10) and there are significant large- and small-scale wetland restoration efforts underway and being identified throughout this Southeast U.S. wood storks are responding to changes in wetland conditions in ways related to both timing of reproduction, and the spatial extent of where they reproduce.

5.1.2 Changing Climate Conditions

Climate change is causing a variety of changes to the various ecosystems and wetland habitats that wood storks depend upon throughout their life cycle. This source drives numerous stressors that impact the resources and conditions needed by wood storks, thereby impacting the species' demographic rates (nest success, juvenile survival, sub-adult and adult survival) and resulting viability. Below we discuss stressors resulting from the overarching source of climate change. These stressors include warming temperatures, precipitation changes, drought, and sea level rise (SLR). Many of these can exacerbate the stressors caused by human development, described above. Figure 19 above provides an overview of how climate change relates to these stressors, resources/habitat needed for the wood stork, demographics, and, ultimately, viability. We note that environmental and climatic changes may result in both negative and positive affects under certain scenarios.

State Climate Summaries (NOAA National Centers for Environmental Information)

Climate summaries including “key messages” and statements regarding temperature, precipitation, drought, rainfall, sea level rise projections for Florida, Georgia, and South Carolina are provided below.

FLORIDA

The following is an excerpt from (<https://statesummaries.ncics.org/chapter/fl/>).

Key Messages: Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century. Rising temperatures will likely increase the intensity of naturally occurring droughts in this area because of increases in rate of loss of soil moisture. The number of landfalling hurricanes in Florida is highly variable from year to year; however, hurricane rainfall rates are projected to increase as the climate continues to warm. Global sea level has risen about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100, causing increases in coastal flooding and contributing to saltwater contamination of coastal groundwater reservoirs.

- Temperatures in Florida have increased about 1 °F since the beginning of the 20th century
- Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century
- Increases in extreme precipitation and drought are projected
- Hurricane rainfalls are expected to increase for Florida as the climate continues to warm
- Sea level is projected to rise another 1 to 4 feet by 2100 as a result of both past and future emissions from human activities, with large associated increases in tidal flood days
- Updated sea level is projected to rise up to 10 feet by 2100 under the Extreme projection (Sweet et al. 2017, pg. 14, 21)

GEORGIA

The following is an excerpt from (<https://statesummaries.ncics.org/chapter/ga/>).

Key Messages: Georgia, like much of the southeastern United States, is one of the few regions globally that has not exhibited an overall warming trend over the 20th century. However, under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century, including increases in heat wave intensity and decreases in cold wave intensity. Higher temperatures will increase the rate of loss of soil moisture during dry spells, which could lead to more intense droughts and increased competition for the state’s water resources. Global sea level has risen by about 8 inches since 1880 and is projected to rise another 1 to 4 feet by 2100. Sea level rise will increase the frequency, extent, and severity of coastal flooding, a grave risk to developments along Georgia’s coastline.

- Georgia, like much of the southeastern United States, is in one of the few regions globally that has not exhibited an overall warming trend in surface temperatures over the 20th century

- Georgia currently receives frequent precipitation throughout the year; however, precipitation projections for Georgia are uncertain.
- The Bermuda High, a semi-permanent high-pressure system off the Atlantic Coast, plays an important role in the summer climate of the state
- Thunderstorms are common in Georgia, particularly in the spring and summer months, and often bring heavy rains, which can cause severe flooding
- Although Georgia rarely experiences direct landfall of hurricanes, tropical storm system remnants can bring heavy rains and strong winds to the state
- Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century
- Georgia is at extreme risk for SLR due to its low elevation along the coast
- Updated sea level is projected to rise up to 10 feet by 2100 under the Extreme projection (Sweet et al. 2017, pg. 14, 21)

SOUTH CAROLINA

The following is an excerpt from (<https://statesummaries.ncics.org/chapter/sc/>).

Key Messages: Average temperature for South Carolina has increased about 0.5 °F since the early 20th century, less than half that of the United States as a whole. Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century, including increases in extreme heat events. Future changes in precipitation are uncertain, but extreme precipitation is projected to increase. In addition, projected increases in temperature will likely increase the intensity of naturally occurring droughts. Sea level has risen by 1.3 inches per decade at Charleston since reliable record keeping began in 1921, nearly double the global SLR. Global sea level is projected to rise another 1 to 4 feet by 2100, with greater rises for South Carolina. Rising sea levels pose widespread and continuing threats to both natural and built environments in coastal South Carolina.

- Temperatures in South Carolina have increased about 0.5 °F since the beginning of the 20th century.
- Annual precipitation has been below average during most years in the 2000s (12 of 16 years during 2000–2015). Little change in average annual precipitation is projected over the 21st century.
- Since the start of the 21st century, the state has experienced a below normal number of extreme precipitation events.
- Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century.
- Since 1921, the sea level at Charleston has risen by 1.3 inches per decade, nearly double the global SLR of 0.7 inches per decade.
- Global sea level is projected to rise another 1 to 4 feet globally by 2100 as a result of both past and future emissions from human activities and greater rises are likely for South Carolina following historical trends. Updated sea level is projected to rise another up to 10 feet by 2100 under the Extreme projection (Sweet et al. 2017, pg. 14, 21).

The Intergovernmental Panel on Climate Change (IPCC) has devised a system to project plausible future greenhouse gas concentrations in various scenarios (termed “representative

concentration pathways” or RCPs). Climate change predictions suggest overall warming temperatures throughout North America under all greenhouse gas emission scenarios (IPCC 2022, pp. 4-19). An increase of 3.6 °F (2 °C) compared to pre-industrial levels (IPCC 2019, pp. 23–24) is more likely than not to be exceeded by the year 2100 under the RCP4.5 climate scenario, and likely to be exceeded under the RCP6.0 and RCP8.5 scenarios. Some habitat and ecological changes, such as sea level rise, increased intensity of storm events, and range expansion northward beyond the historical breeding range, have already been observed.

If we examine current projections under plausible future greenhouse gas concentrations, termed RCPs, relative to 1981-2010, over 2050-2074 the 50th percentile (median) for the South Atlantic-Gulf Region (Southeast U.S.; Wood Stork U.S. population range), annual mean maximum air temperature warms by 3.9 °F (2.2 °C) in RCP 4.5, whereas the region warms by 5.7 °F (3.2 °C) in RCP 8.5 (Alder and Hostetler 2013, entire). Similarly in the Ogeechee-Savannah watershed (Georgia and South Carolina), temperature increases by 4.0 °F (2.2 °C) and 6.0 °F (3.3 °C) in RCP 4.5 and RCP 8.5, respectively. In the Everglades watershed over the same period, temperature changes are smaller with projected increases of 2.7 °F (1.5 °C) and 4.1 °F (2.3 °C) in RCP 4.5 and RCP 8.5, respectively. Projected annual mean of monthly maximum temperature for the Atlantic-Gulf Region from 2006 through 2074 is presented in Figure 22.

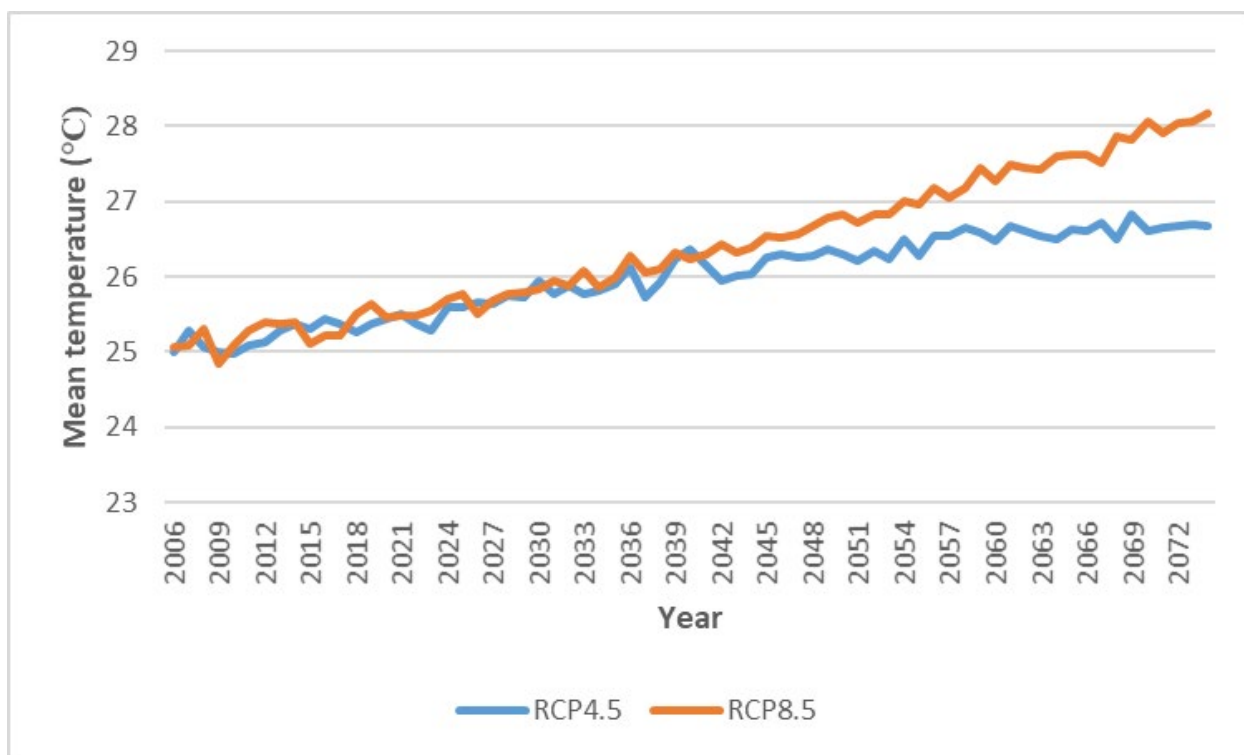


Figure 22. Annual mean of 30 Coupled Model Intercomparison Projects (CMIP) 5 models for maximum monthly temperature projected under future greenhouse gas concentrations (Representative Concentration Pathways (RCP 4.5 and RCP 8.5) for the Atlantic-Gulf Region (Alder and Hostetler 2013, entire).

Precipitation Changes

The wood stork breeding range lines up with areas with the higher average annual precipitation within Southeast U.S. These higher precipitation areas occur along the Atlantic coast and across

the Florida Peninsula (Figure 23). Hurricanes and tropical storms can also contribute significantly to annual precipitation totals (Knight and Davis 2009, p. 1).

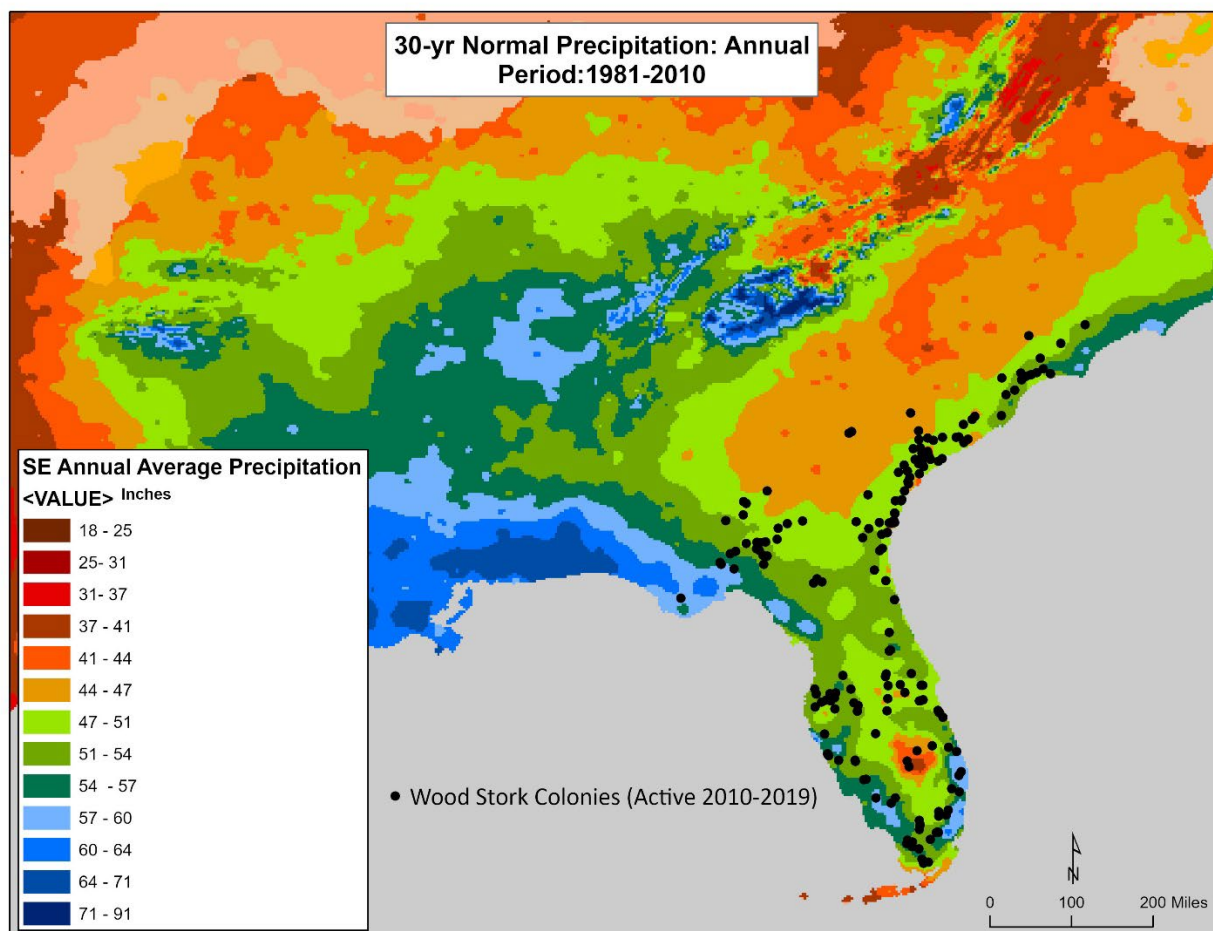


Figure 23. Southeast U.S. Annual Average Precipitation map and current wood stork nesting colony locations.

Climate change is also expected to change precipitation patterns throughout the species' range, but the impacts vary among the key habitat types. An overall increase in rainfall due to climate change is expected throughout much of the range. Relative to 1981–2010, over 2050–2074 the 50th percentile (median) for the South Atlantic-Gulf Region, annual mean precipitation increases by 0.3 in (7.6 mm) per month in RCP 4.5 and by 0.2 in (5.1 mm) per month in RCP 8.5 (Alder and Hostetler 2013, entire). Similarly in the Ogeechee-Savannah watershed, precipitation increases by 0.3 in (7.6 mm) and 0.4 in (10.2 mm) per month in RCP 4.5 and RCP 8.5, respectively. Precipitation change is slightly lower in the Florida Everglades compared to the Ogeechee-Savannah watershed over the same period, with projected increases of 0.1 in (2.5 mm) and 0.3 in (7.6 mm) per month in RCP 4.5 and RCP 8.5, respectively. Projected annual mean of monthly precipitation for the Atlantic-Gulf Region from 2006 through 2074 is presented in Figure 24.

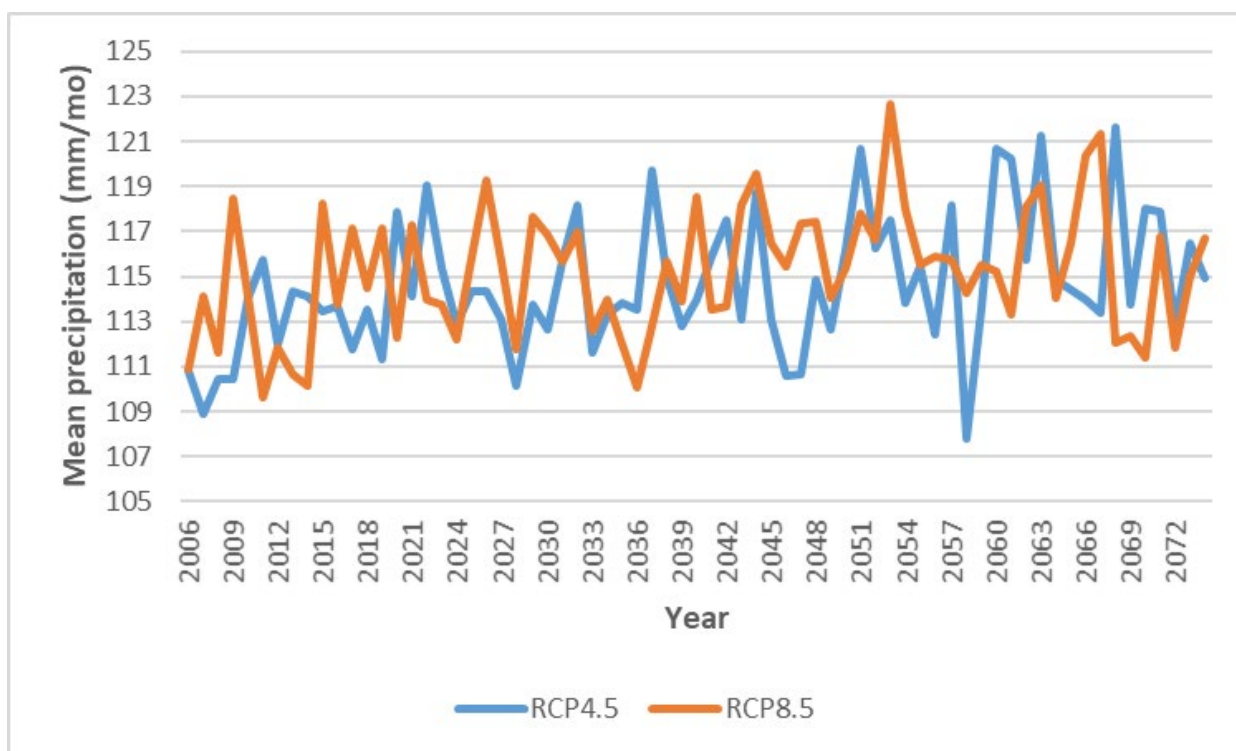


Figure 24. Annual mean of 30 Coupled Model Intercomparison Projects (CMIP5) models for monthly precipitation projected under future greenhouse gas concentrations (RCP 4.5 and RCP 8.5) for the Atlantic-Gulf Region (Alder and Hostetler 2013, entire).

Drought

Rising temperatures are expected to increase evaporation. If warmer temperatures are not counter-balanced by increased precipitation, wood storks could face increased drought-like conditions. The evaporative deficit is a measure of water balance that reflects the difference between actual and potential evapotranspiration. In the time period between 2050–2074, the 50th percentile (median) evaporative deficit across the South Atlantic-Gulf Region show drier conditions with a slight deficit increase in RCP 4.5 and RCP 8.5, relative to 1981–2010 (Alder and Hostetler 2013, entire). For example, the deficit increases by 0.2 in (5.1 mm) per month in the Ogeechee-Savannah watershed under both scenarios during the same time period. Similarly, the deficit increases by 0.2 in (5.1 mm) and 0.3 in (7.6 mm) in the Florida Everglades in RCP 4.5 and RCP 8.5, respectively. Projected annual mean of monthly precipitation for the Atlantic-Gulf Region from 2006 through 2074 is presented in Figure 25.

There is low confidence in observed trends in drought at the global scale (IPCC 2014, p. 53). At smaller scales, standardized precipitation index data from 2000-2015 suggest that extended periods of dry weather are likely going to increase in the future throughout Florida, particularly in the northern part of the state (i.e., panhandle) and areas around Lake Okeechobee (Collins et al. 2017, p. 585). In Georgia and South Carolina, even if average annual precipitation remains constant, higher temperatures lead to greater drought intensity.

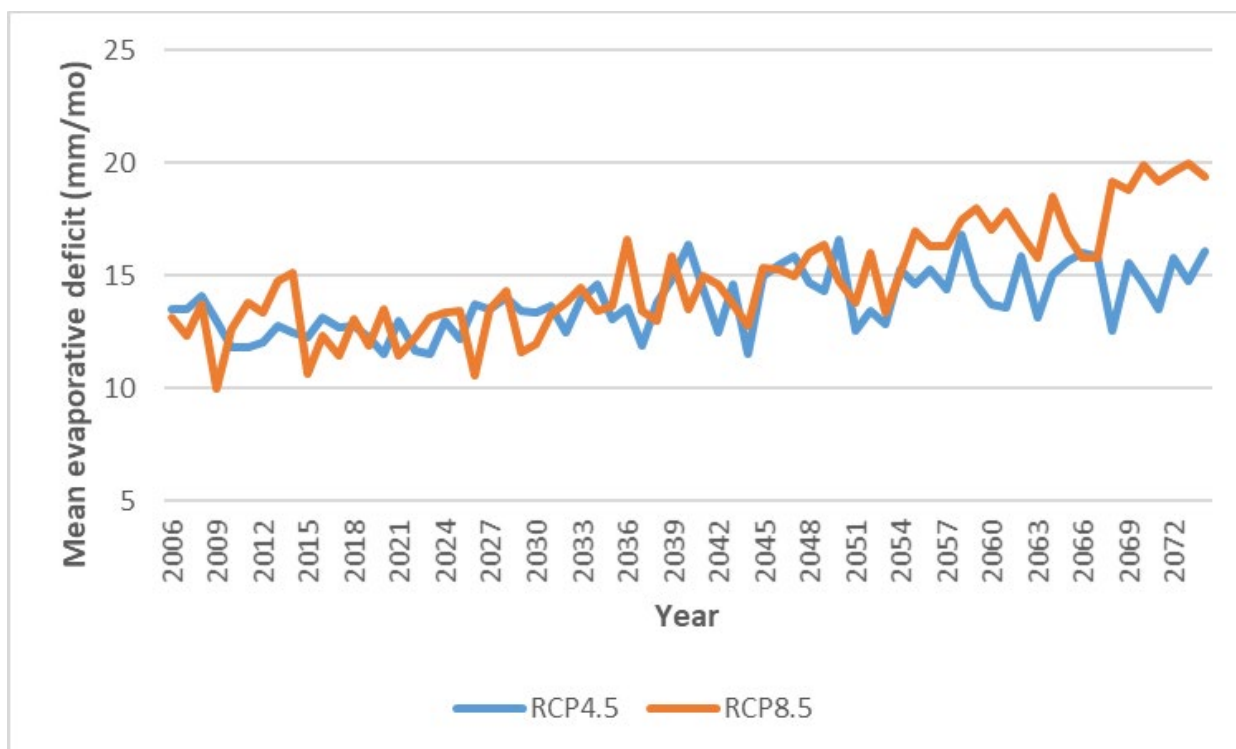


Figure 25. Annual mean of 30 CMIP5 models for monthly evaporative deficit projected under future greenhouse gas concentrations (RCP 4.5 and RCP 8.5) for the Atlantic-Gulf Region (Alder and Hostettler 2013, entire).

Hurricanes

Climate change effects that increase the intensity of extreme storm events over historical patterns or that would cause a general drying of wetland habitats would threaten the species (Service 2007, p.19; Service 2021, p.65). Overall, the effects of climate change will likely increase the frequency and intensity of heavy precipitation events in North America (IPCC 2014, p. 53). In terms of tropical cyclones, the projected warmer climate will potentially decrease the frequency, but increase the intensity, of events when they occur in the Atlantic Basin (Collins et al. 2017, p. 610). For example, statistically downscaled models demonstrated a two- to seven-fold increase in the frequency of Hurricane Katrina-level events with a 1 °C (1.8 °F) rise in global temperature (Grinsted et al. 2013, entire). Direct mortality effects tend to be low, and though damage to nesting vegetation at colony sites has been documented, nesting generally continues in following years. Hurricanes also commonly act as an erosional agent and deliver significant volumes of sediment to the marsh surface, which could aid wood stork resiliency by increasing vertical accretion of salt marsh habitat (Staro et al. 2021, p. 1). There are many examples of breeding seasons following hurricane landfalls that have been very productive (e.g., 2018 breeding season in south Florida following Hurricane Irma in September 2017) (Cook 2019, p. 1).

Sea Level Rise (SLR)

This following section comes from SSA v1.0 (Service 2021, pp. 66-69) and was based upon the 2017 NOAA Technical Report on Sea Level Rise (Sweet et al. 2017, entire). In 2022, NOAA updated this Technical Report (Sweet et al. 2022, entire) and we used that update to assess

potential future impacts to wood stork habitat. The updated SLR projections (Sweet et al. 2022, entire) lowered near mid-century estimates and removed the Extreme scenario. See section 6.2 Sea Level Rise – Future Impacts to see how the Service updated the analysis and incorporated into future condition scenarios and analysis regarding the projected future condition of wood stork habitats.

One impact of warming temperatures, coupled with other climatic factors such as melting of continental ice, is SLR. Documentation of SLR is based upon several sources of information and now includes predictive future scenarios (Figure 26). Sea level rise and flooding of coastal wetlands is a significant concern for the wood storks, as this results in the loss and degradation of both foraging and nesting habitats. Coastal salt marsh habitat, coastal managed impoundments, and former rice fields, especially in Georgia and South Carolina, are important to individuals from coastal colonies for foraging during the breeding season, and to residents and short-term migrants for foraging during the non-breeding season (Tomlinson 2009, p. 24). Sea level rise is also very likely to increase the storm surge potential along major coastlines (Collins et al. 2017, p. 611). Storm surge is the rise in water level during a storm, measured as the height of the water above the normal predicted astronomical tide, and is primarily caused by a storm's winds pushing water onshore and can cause flooding.

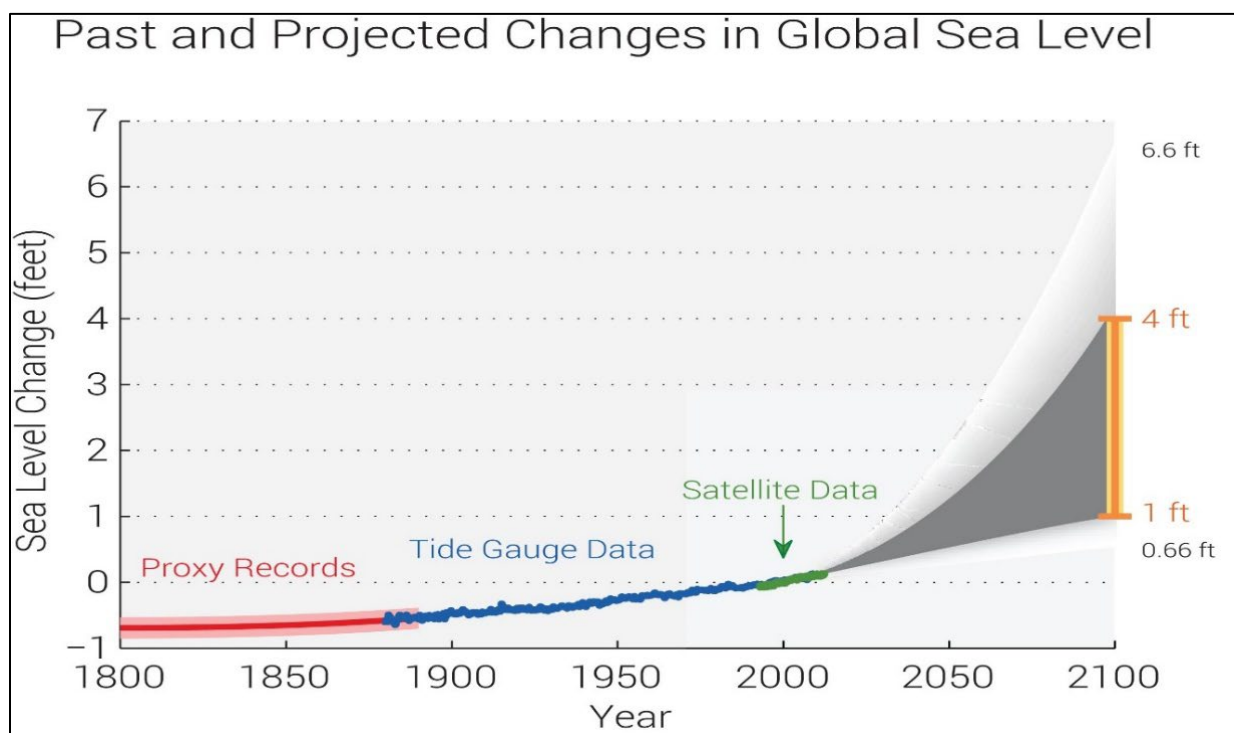


Figure 26. A graphical representation of sea level rise (SLR) indicating how sea level has been measured through time: proxy, tidal gauges, satellite, future forecasting (Parris et al. 2012, entire; Melillo et al. 2014, p. 45).

Because wood storks mainly forage in water < 0.5 m (20 in) deep, a projected SLR that could exceed 0.99 m (39 in) by the end of the century would make much of the current coastal range unusable for foraging. The threat of SLR on tidal foraging habitat will be covered in greater detail in the Future Scenarios section and will likely have more impacts to the Northeast

Breeding Region. For the remainder of this section, we refer to threats to breeding habitat, specifically inundation of colony sites.

Sea level rise threats were assessed using six projections compiled by NOAA (Sweet et al. 2017, entire). If we examine these scenarios under a set of possible future greenhouse gas concentrations, the NOAA Low model has a 98% and 100% chance of being exceeded in 2100 under RCP 4.5 and RCP 8.5, respectively (Sweet et al. 2017, p. 22). The NOAA Intermediate-Low scenario has a 73% and 96% chance of being exceeded in 2100 under RCP 4.5 and RCP 8.5, respectively (Sweet et al. 2017, p. 22). Therefore, these two scenarios were not considered to be plausible and were eliminated from further analysis. The remaining four scenarios (NOAA Intermediate, NOAA Intermediate High, NOAA High, and NOAA Extreme) were considered plausible and incorporated into the inundation model. The NOAA Intermediate and NOAA Intermediate High reflect decreasing greenhouse gas emission scenarios by 2060 and 2080, respectively. The NOAA High scenario reflects business as usual with no decrease in future greenhouse gas emissions. Finally, the NOAA Extreme scenario reflects rapid ice melt with no decrease in future greenhouse gas emissions (Sweet et al. 2017, entire).

The relative sea level change scenarios for Virginia Key (Florida) are shown in Figure 27 (Collini et al. 2018, entire). The projected SLR under the NOAA High scenario is 2.5 ft (0.8 m) and 5.6 ft (1.7 m) in 2050 and 2080, respectively. Sea level rise of 2 ft and 6 ft in the South and Central Breeding Regions would impact 8–9 and 10–16 colonies, respectively. Although impacts from flooding and tides may impact these colonies prior to inundation, complete inundation, thus impacted loss, would be expected by approximately 2050 (8–9 colonies; 2 ft threshold) and 2080 (10–16 colonies; 6 ft threshold) under the NOAA High scenario, regardless of potential habitat changes.

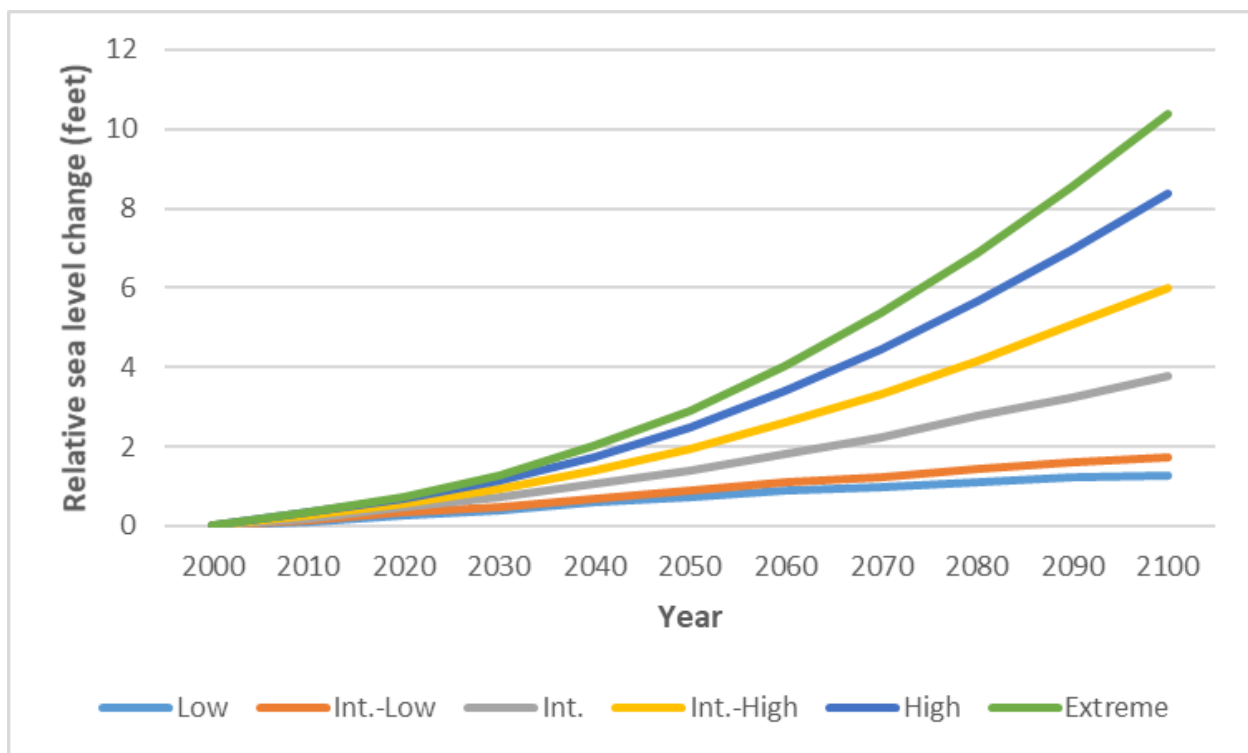


Figure 27. Relative sea level change scenarios for Virginia Key (Florida). Data source: NOAA Technical Report NOS CO-OPS 083; Site: 1006452795.

Similarly, the projected sea level change in Fort Pulaski (Georgia) under the NOAA High scenario is 2.6 ft (0.8 m) and 5.8 ft (1.8 m) in 2050 and 2080, respectively (Figure 28; Collini et al. 2018, entire). However, colonies in Georgia are not as susceptible to inundation compared to Florida, particularly at lower thresholds. Within the Northeast Breeding Region a large number of colonies are inundated, thus impacted/lost, (e.g., 15 colonies at 3 ft by 2050 High scenario and 43 colonies at 6 ft 2080 High scenario).

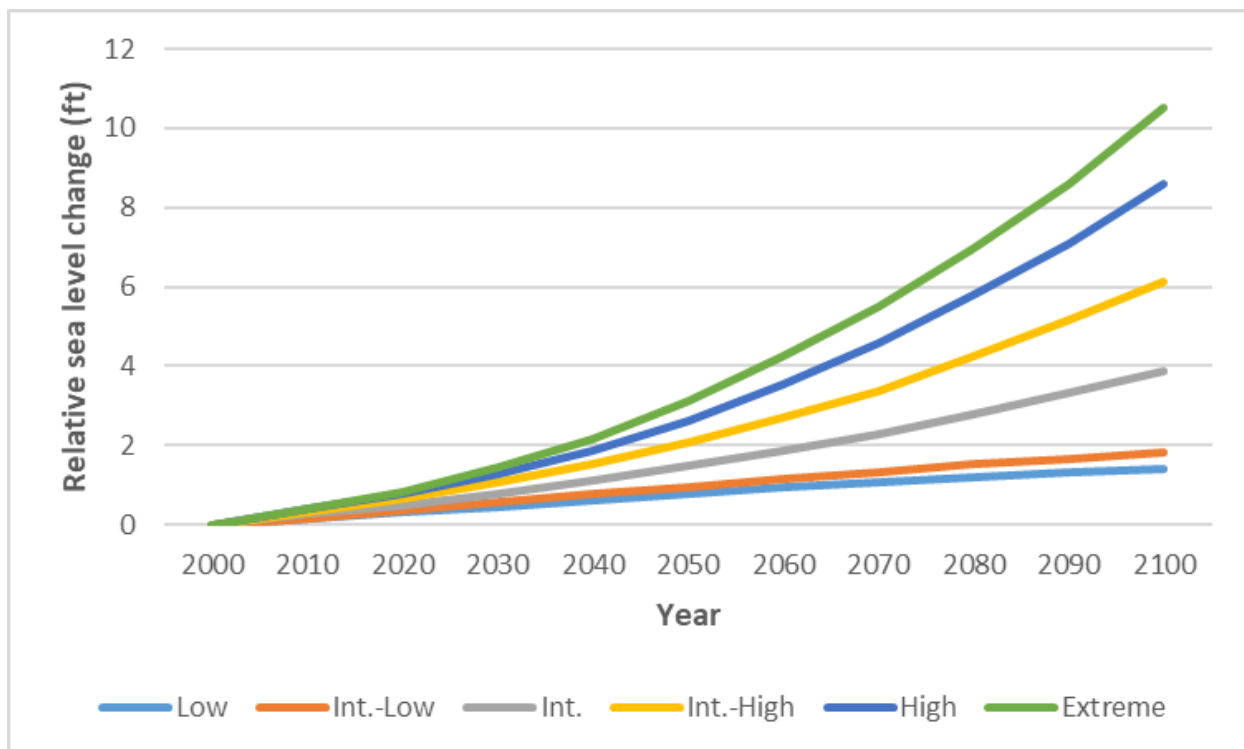


Figure 28. Relative sea level change scenarios for Fort Pulaski (Georgia). Data source: NOAA Technical Report NOS CO-OPS 083; Site: 1005852785.

Climate Effects on Wood Storks

Predicted climatic changes that could impact future wood stork populations include precipitation, temperature, and SLR. The influence of precipitation, hydroperiod, and drying conditions on wood stork foraging and breeding habitat abundance and quality have been noted earlier in this chapter. However, these environmental changes can and will vary considerably relative to local landscape conditions associated with individual colonies such as wetland type, abundance, and connectivity, as well as topography. Predicted future climatic changes (precipitation, temperature, drying) will likely be highly variable, potentially on a local or per colony basis, and these predicted changes could result in either positive or negative impacts on breeding success; therefore, we have limited our future climatic impact scenario to SLR.

- Rainfall timing coupled with warming temperatures could increase the occurrence and severity of drought and wetland drying. Long term drought could negatively impact breeding and survival demographics.
- Changes to the quantity and intensity of precipitation (including hurricanes), depending on timing, will alter foraging habitat availability and associated wetland food resources for wood storks, however these factors could have a positive or negative affect on demographics.
- Warming temperatures contribute to increased SLR, which is expected to result in the loss of coastal foraging habitat, with the greatest impacts on the Northeast Breeding Region, and thus likely loss of foraging, nesting, and roosting habitats.

5.2 Stressors Considered and Not Included in Viability Analysis

Starvation and/or Abandonment of Young

Starvation and abandonment of nestlings is generally associated with poor rainfall scenarios and/or water management that results in reductions of foraging habitat used to support the growing young. As discussed above, timing and amount of precipitation influences prey dispersion and availability. Excessive rainfall and/or water management resulting in high water levels during the breeding season generally has a negative effect on wood stork young due to prey being dispersed which can result in starvation/nest abandonment. Furthermore, extensive droughts similarly reduce prey abundance/availability during the nestling-rearing period.

There have been rare occasions when heavy rainfall that soaks young nestlings with cool/cold temperatures, results in nestling mortality (e.g., Harris Neck NWR [Service 2006, entire]). Sudden decreases in temperature during unusually mild winters with early nesting in South Carolina have twice led to abandonment (Hand 2020, pers. comm.).

Predation

Adult wood storks have few predators, but the eggs and nestlings of breeding birds can be vulnerable in certain scenarios. Alligator presence in colony waters typically reduce/limit nest predation by terrestrial predators (Burtner and Frederick 2017, pp. 697-698); however, on occasions when water levels drop in breeding sites, raccoons and other potential terrestrial predators can access nests and prey on wood stork nestlings, impacting colony productivity (Rodgers et al. 1987, p. 155; Coulter and Bryan 1995, p. 237). There is also concern of fish crow (*Corvus ossifragus*) predation when adult wood storks are disturbed from the nest with eggs/small chicks, however this has never been documented.

Exotic Burmese pythons (*Python molurus bivittatus*), through eDNA analysis, have been documented widely throughout the Florida Everglades (Orzechowski et al. 2019, p. 1), and they have been observed to act as predators in wading bird colonies, including wood storks (Dove et al. 2011, p. 128), at approximately 4% of monitored nests (Orzechowski et al. 2019, p. 1). Burmese pythons tend to cue in on prey abundance (e.g., nestlings in colonies) and can potentially consume large volumes of prey (i.e., young/eggs from several nests in a single event). In addition to predation of nestlings in colonies, pythons are fully capable of consuming adult wood storks, which not only removes an individual from the population but also the individual's potential breeding productivity over time, however, this is likely a rare occurrence.

The Asian swamp eel is another emerging species that has been observed to outcompete and reduce populations of forage fish species that wading birds, including wood storks, prey upon (Service 2018, entire; Pintar et al. 2023, entire). Current data indicates that the Asian swamp eel's geographic distribution in the United States is limited by thermal tolerance (Service 2018, p. 4). Therefore, while the Asian swamp eel is present in some areas of Florida, it is not present in the other States that make up the majority of the wood stork's range, and the long-term establishment of its invading populations may not extend north of Florida. At this time, it is not clear how much of the wood stork's range the Asian swamp eel could invade, or whether or not an invasion would significantly impact prey resources of the wood stork to the extent that would result in wood stork population decline.

Disturbance

Disturbance can occur at nesting and roosting sites either during single/occasional events, or at a more "chronic"/continuous rate. Occasional disturbance, i.e. flushing parents from the nest, may result in some loss of wood stork young, due to resulting predation of small nestlings; where as, chronic disturbance could potentially result in full colony abandonment. Disturbance has been associated with island colony sites that attract boats and people for recreational and ecotourism activities. Grant Farm Island, Florida, experienced a loss of 15 nests and eventual colony abandonment in 1985 due to human disturbance (Rodgers et al. 1987, p. 155). Pelican Island experienced loss of 33 of 132 nests in 1985 as result of beach-landing and associated fish crow depredation of eggs. As a result, buffer zones of 60 to 65 m around a nesting colony was recommended to protect nesting wood storks from foot traffic and boat approaches, respectively (Rodgers and Smith 1995, p. 94).

Wood storks feeding in tidal creeks are more sensitive to disturbance than those feeding in more open estuarine areas (Bratton 1990, pp. 125-126); however, disturbance to foraging sites is not likely to result in nestling mortality unless it is widespread and frequent throughout a colony's core foraging area. In order to minimize disturbance to foraging sites a minimum buffer zone of 100 m around foraging sites was recommended (Rodgers and Smith 1997, p. 144).

It should be noted that wood storks have appeared to acclimate to the presence of humans, including colonies in the Jacksonville Zoo and St. Augustine Alligator Farm, and an overall increase in the number of colonies in urban areas throughout the range. In areas where wood storks initiate nesting in the presence of humans, disturbance does not seem to be as impactful as in more remote colonies that are already established.

Contaminants

Contamination threats, including both mercury (Hg) and organochlorines/organophosphates (OC/OP), to wood storks and other wading birds, have occurred in the southeastern U.S. during the last several decades. Wood storks accumulate environmental Hg, primarily from consumption of fish. Higher trophic level prey fish from South Carolina shallow wetlands (Carolina Bay foraging habitat) typically have higher Hg concentrations, and pose the greatest risk to wood stork nestlings, than lower trophic level prey (Brant et al. 2002, p. 410). Prey species in south Florida, specifically Everglades National Park, contain levels of Hg that exceed levels of concern for sensitive avian species (Rumbold et al. 2008, pp. 635-636). Nestling regurgitations (all species; collected in 1995) in Georgia contained low levels of Hg, with

concentrations higher in freshwater species of fish than in estuarine species (Gariboldi et al. 1998, p. 404). Analyses of Georgia nestling feathers for Hg indicated a regional difference, with inland nestlings typically having higher Hg than coastal nestlings (Gariboldi et al. 2001, pp. 1553-1554). Stable isotope analyses were used on Georgia nestling feathers to determine foraging habitats and linked Hg concentrations to habitat types (inland Hg > coastal Hg) (Romanek et al. 2000, p. 593; Bryan et al. 2012b, p. 150). Long-term (16 years) analyses of stable isotopes and Hg at a coastal Georgia colony indicated that Hg in nestlings was associated with freshwater habitat use and is additionally linked to higher rainfall amounts in the 23 months prior to breeding (Bryan et al. 2014, p. 2714). Nestling feather samples from the Tamiami West colony in southeastern Florida averaged approximately 8 and 2 ppm in 2002 and 2003, respectively (Borkhataria et al. 2012, pp. 522, 593). Nestling feather samples from another southeastern Florida colony averaged 2.3 and 1.7 ppm in 2004 and 2005, respectively (Borkhataria et al. 2012, p. 522) and averaged approximately 4 ppm in 2012 (Bryan et al. 2015, p. 224).

Blood and feather samples from 20 post-fledging storks of various ages analyzed for Hg were generally higher than those of nestling storks, presumably due to feather growth/molting patterns and/or dietary differences (Bryan et al. 2001b, p. 280). Feather Hg concentrations from free-ranging storks in coastal South Carolina (n = 9) and north Florida (n = 10) averaged approximately 4 ppm (Bryan et al. 2015, p. 224).

A long-term study analyzed consumption of Hg concentrations in wild caught prey and found long-term consumption of Hg could result in behavioral anomalies and reduced productivity for other wading bird species, such as the white ibis (Frederick and Jayasena 2010, p. 1851). It should be noted that this study occurred in a captive setting because it would be difficult to determine the effects of long-term Hg consumption in wild birds due to exposure to other confounding factors that influence productivity.

Contamination events can be triggered by stochastic events, such as hurricanes or flooding, that expose concentrations of contaminants. For example, from November 1998 through early April 1999, a bird mortality event occurred on the north shore of Lake Apopka, Florida, on former farmlands that had been purchased by the St. Johns River Water Management District and Natural Resources Conservation Service (NRCS). An estimated 676 birds died on-site, mostly white pelicans (*Pelecanus erythrorhynchos*) and various species of wading birds, including wood storks. Of the estimated 1,991 wood storks present in the area, 43 died on-site and an unknown number of birds (Rauschenberger 2007, p. 16). The cause of death was attributed to organochlorine pesticide (OC) toxicosis (Rauschenberger 2007, p. 16). The birds were exposed to OCs by eating OC-contaminated fish, which became easy prey as fish moved from ditches into the flooded fields, located in the eastern part of the restoration area (Rauschenberger 2007, p. 16). However, generally, legacy pesticide contamination has not been documented to adversely affect wood stork reproduction (Ohlendorf et al. 1978, p. 616; Bowerman et al. 2007, p. 1506).

Few studies have examined the potential risks associated with wood storks foraging in urban wetlands. Wood storks nesting at the Jacksonville Zoo colony are known to use urban wetlands via satellite telemetry studies (Martin 2010, entire). This colony is one of the most productive in north Florida. Prey from 30 sample sites, as well as dead or moribund chicks from this colony, were analyzed for 18 inorganic elements, 46 polycyclic aromatic hydrocarbons, and a suite of

eight organophosphate and 29 organochlorine pesticides. This study found that all of the contaminant levels measured in prey items were below the lowest reported effect levels, indicating that risk of effect-level, contaminant exposure to wood storks is unlikely (Martin 2010, p. 61).

Collisions

A small number of wood storks are killed annually by collisions with vehicles and powerlines, although neither of these stressors appear to impact population or recovery numbers; however, collision impacts could potentially increase as wood storks continue to move into urban landscapes. The wind power industry may also pose a mortality risk to wood storks in the future from wind turbine collisions and additional infrastructure (transmission lines). Deng and Frederick (2001, p. 423) observed no nocturnal collisions but documented that wood storks were flying regularly over the power lines at night.

Poaching/Hunting

A small number of wood storks have been shot by hunters, or by aquaculture managers trying to keep wood storks from consuming fish in commercial ponds; however, there is no evidence that these sources of mortality are significant enough to impact wood stork population growth or recovery numbers.

Disease

Avian malaria (*Plasmodium* and *Haemoproteus*) has been documented in wood storks in the southeastern U.S. and in other countries (Zabransky et al. 2008, p. 1178; Villar et al. 2013, p. 522; Bryan et al. 2015, p. 222). It is generally more prevalent in adult birds than nestlings, presumably due to greater exposure risk over time. However, malaria has not been documented at levels of concern in wood storks and thus it is not thought to impact population growth or recovery numbers.

Eustrongylidosis is a parasitic disease that primarily impacts wading birds, including wood storks (Spalding et al. 1993, p. 327). It is caused by three species of roundworms of the genus *Eustrongylides* and typically occurs in eutrophic waters with high nutrients and minerals, particularly those receiving agricultural and/or urban run-off. *Eustrongylidosis* is typically contracted by wading birds who consume infected fish and can result in mortality, although is currently no evidence that this source of mortality is significant enough to have population-level impacts on wood stork.

Fishing Line Entanglement

Annually, a small number of wood storks are documented (generally photo-documentation) with fishing line entanglements or with fishing hook injuries. Few are rescued, rehabilitated, and released. There is no evidence that this source of injury and mortality are significant at a population level for wood stork.

Note that through the Migratory Bird Treaty Act program, permits issued to wildlife rehabilitators in the Southeast U.S., report annually 50–80 wood storks brought to wildlife rehab facilities for care. In some cases, the causes of injury or death are identified.

5.3 Conservation Actions

A recovery plan for the U.S. breeding population of wood storks was published in 1986 (Service 1986, entire) and later revised in 1996 (Service 1997, entire). In addition, wood storks were included in the South Florida Multi-Species Recovery Plan (MSRP 2001, entire), and the Comprehensive Everglades Restoration Plan (CERP 2000). Primary actions identified in these documents that were deemed necessary for recovery are described in Table 27.

Table 27. Primary conservation actions for wood storks from the wood stork recovery plans.

CONSERVATION ACTION	DESCRIPTION
Protect current habitats	• Utilize existing laws/regulations to prevent loss of current habitats including ESA, Migratory Bird Treaty Act (MBTA), and Clean Water Act (CWA; see also Section 1.3)
Create, restore, and enhance habitats	• Work with land managers to create new habitats (e.g., wastewater treatment systems, National Audubon Society (NAS) Kathwood foraging ponds, Disney Wildlife Preserve wetlands) • Restore suitable wetlands (e.g., willow/woody plant removal projects) • Enhance wetlands for stork use (e.g., managing extensive networks of South Carolina tidal impoundments to make prey available at needed times; drawdown of impoundments adjacent to colony at Harris Neck NWR) • Comprehensive Everglades Restoration Plan (re-establishment of more natural hydrology in Everglades/Big Cypress systems)
Applied research	• Better understand movement patterns of breeding and non-breeding storks in response to environmental conditions (annual and seasonal) • Monitor productivity/survivorship to assess population viability • Continue monitoring for, and determining potential impacts of, contaminants (primarily Hg) and diseases/parasites • Employ new genetic techniques to examine inter-relatedness of population components
Public education/outreach	• Make public aware of the uniqueness of the species and its ecological needs • Educate landowners on actions they can take (e.g., guidelines)

The long-term survival and recovery of this species requires the presence of a mosaic of wetland habitats for breeding, foraging, and roosting scattered throughout their range during varying climatic and seasonal conditions. Management actions for foraging and breeding habitats include maintenance/protection of existing wetlands, creation of new wetland habitats, and restoration of previously impacted habitats.

Land Acquisition and Conservation Easements

Lands being purchased for conservation through federal, state and private acquisition programs contribute to wood stork recovery (Figure 29).

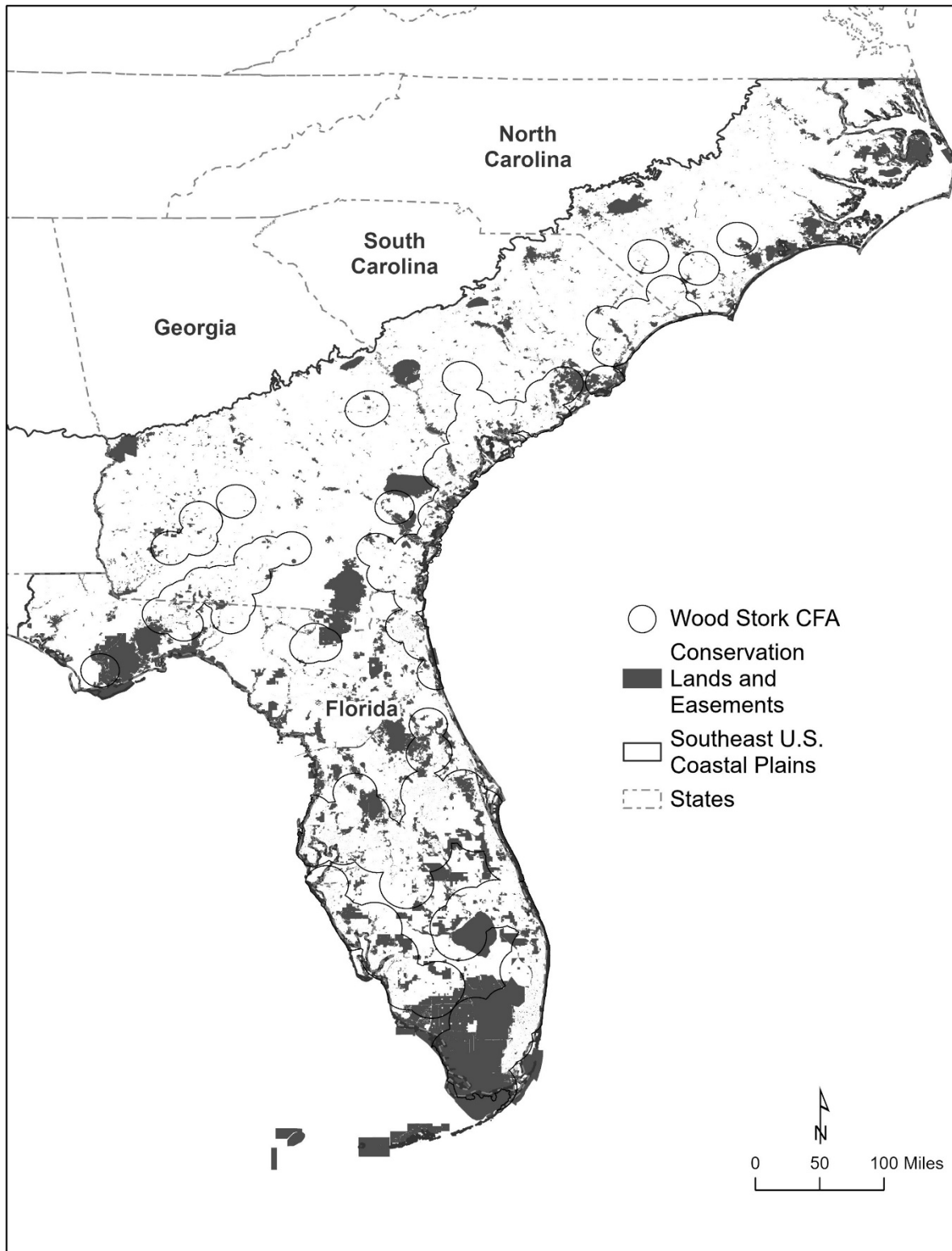


Figure 29. Conservation lands and easements within the U.S. breeding range of the wood stork occupy 17.4 million acres, including 9.2 million acres of wetlands.

On March 11, 2024, the Department of Interior and the Service announced the newest large-scale initiative, the Everglades to Gulf Conservation Area (EGCA), which will help to facilitate conservation within 4,045,268 acres of southwest Florida using tools including voluntary conservation easements. “Conservation Areas” are national wildlife refuges that consist primarily or entirely of conservation easements on private lands in cooperation with landowners. The EGCA is expansive and spans 12 Florida counties, west of Lake Okeechobee from Lakeland south to Naples. It borders the Everglades Headwaters National Wildlife Refuge Conservation Area and Florida Panther National Wildlife Refuge. This Conservation Area will enhance and support the conservation objectives of the Everglades Restoration program. In addition, initiated in 2012, the Everglades Headwaters National Wildlife Refuge and Conservation Area includes 2.6 million acres of grassland savannah with wet and dry prairie that encompasses the Kissimmee River Valley in Florida. Conservation easements and acquisition purchases for the 150,000-acre approved boundary are underway and will provide additional conservation benefits to wood storks.

Florida’s Wildlife Corridor facilitates partnerships that result in conservation land acquisitions (Florida Wildlife Corridor 2022, entire; FSWAP 2022, entire). *Florida Forever* is the largest state public land acquisition program of its kind in the U.S. with approximately 10 million acres managed for conservation in Florida and 2.6 million acres purchased under the *Florida Forever* and *Preservation 2000* programs (<https://floridadep.gov/lands/environmental-services/content/florida-forever>). Listed species, wetlands quality, and other attributes that affect wood storks are considered in the ranking criteria for lands purchased in these programs.

Within the southeastern U.S. states in wood stork range, additional natural resource agency acquisition programs include the Georgia Land Conservation Program, South Carolina Land Legacy and Conservation Bank Act, North Carolina Natural Heritage Trust Fund, Parks and Recreation Trust Fund, Clean Water Management Trust Fund, Agricultural Development and Farmland Preservation Trust Fund, and Alabama Forever Wild Trust Fund.

Natural wetlands are being targeted for acquisition to be protected through the management of public lands for wildlife and water conservation (NRCS 2006, p. 1); also see *Recovery Task (1) Protect currently occupied habitat* in the Recovery Plans section.

Wetland Habitat Restoration, Management, and Protection

Approximately 9.2 million acres of wetlands occur on Federal and state lands including the Service’s National Wildlife Refuges, National Park Service lands, National Forests, Department of Defense lands, National Aeronautics and Space Administration lands, State Parks, State Wildlife Management Areas, and State Forests (Figure 29). Wetlands in these areas are currently and will continue to be afforded some protection from development and other large-scale habitat disturbance through Federal and state regulations. These regulations include the Coastal Zone Management Act, Rivers and Harbors Act, National Environmental Policy Act (NEPA), National Forest Management Act, the National Wildlife Refuge System Improvement Act, the Sikes Act, among others. Mitigation and wetland restoration may also be regulated through the National Wetlands Mitigation Action Plan (2022) and the Executive Order (EO) 11990 Protection of Wetlands (1977).

Each state within wood stork range has developed plans to monitor wildlife and associated habitat through State Wildlife Action Plans (SWAP; FSWAP 2022, entire; GSWAP 2015, entire; SCSWAP 2015, entire; NCSWAP 2015, entire; ASWAP 2015, entire; MSWAP 2015, entire), which receive Federal funding through the State and Tribal Wildlife Grants program. A primary theme in each SWAP throughout the wood stork's range is wetland conservation, which is further developed by each state in a State Wetland Management Program (SWMP; EPA 2024, entire). These plans summarize the status of wetlands in each state and include information on how wetlands are regulated, and efforts developed to restore and/or mitigate wetland loss. In many states, wetlands are regulated through the Clean Water Act (CWA), and 404 permitting through the U.S. Army Corps of Engineers (USACE). The CWA regulates the discharge of fill material into waters of the United States (WOTUS), including wetlands.

Florida has different regulations in that the state has authority to regulate wetlands apart from the CWA. On February 15, 2024, a Federal court in the District of Columbia issued a ruling formally vacating the EPA's December 2020 decision to allow the State of Florida to assume permitting authority for section 404 of the CWA and the Service's biological opinion related to that decision. Accordingly, implementation of the CWA and NEPA again rests with the EPA and the U.S. Army Corps of Engineers. However, the United States is currently appealing the District Court's decision.

The Comprehensive Everglades Restoration Program (CERP) is a large-scale watershed and wetland ecosystem restoration and protection program in south Florida that aims to restore the natural hydrology of the Everglades and Big Cypress ecosystems (South Florida Ecosystem Restoration Task Force 2021, p. i). Through CERP the first of three cells in the 6,500-acre Everglades Agricultural Reservoir was filled to store and clean water from Lake Okeechobee. The water will go south to restore natural freshwater flow through the Florida Everglades and other wetland ecosystems. The South Florida Wading Bird Report (2020, pp. 1-3) reveals that several wood stork nesting responses have improved over the past 20 years, while others have shown no change or are getting worse. There have been improvements of nesting at coastal colonies, but that remains below the restoration target. Despite improved nesting, the late timing of nesting has not changed to an earlier time frame and thus annual nesting success often is below that necessary to sustain the local population, while in some years nesting success can also be high. The ratio of tactile to visual foragers in the Everglades has improved since the mid-2000s but remains an order of magnitude below the restoration target set by CERP. It is noted that all targets are not expected to be met until full restoration has been implemented. Other restorations efforts apart of CERP include the Kissimmee River Restoration Project (Central Breeding Region) which has restored over 40 square miles of river and floodplain ecosystem including 43 miles of meandering river channel and 27,000 acres of wetlands (<https://www.sfwmd.gov/our-work/kissimmee-river>). In addition, the Upper St. Johns Basin Restoration Project (Northeast Breeding Region) has enhanced and restored 150,000 acres of marsh (SJRWMD 2007, p. 1-4), and the Lake Apopka project has restored 15,000 acres of wetlands on former farms. The Altamaha River Watershed, Lower Savannah River Watershed, and Ashepoo-Combahee-Edisto Rivers Basin have had over 160,000 acres of upland and wetland habitat protected.

Localized wetland restoration projects on individual public, private, industrial, and agriculture properties within the range of the wood stork have and continue to improve wood stork habitat.

A smaller scale project, The Wetlands Reserve Program (WRP), has restored over 200,000 acres of wetlands in Florida including a site that supports a nesting colony. In addition, over 125,000 acres in Alabama, Georgia, and South Carolina have been restored over the past 20 years. Other restoration programs include the National Coastal Wetlands Program, Partners for Wildlife, Forest Stewardship Program, North American Waterfowl Management Plan, and North American Wetlands Conservation Act (77 project across several states affecting 250,000 acres of wetlands), and the Food Security Act. On private agricultural lands, wetlands are protected through the Food Security Act by removal of incentives for farmers to convert wetlands to crop fields.

Specific Actions – Foraging Habitats

Suitable foraging wetlands have been and continue to be created with diked “impoundments”, modifications of existing impoundments, restoration of impacted wetlands, and creation of shallow short hydroperiod wetlands through hydrologic management. Feeding impoundments created for storks at National Audubon Society’s Silver Bluff Plantation Sanctuary (Kathwood Ponds, Jackson, South Carolina) in the Northwest Breeding Region have successfully attracted large numbers of adult and immature wood storks in late summer/early fall (Coulter et al. 1987, pp. 205-207). These impoundments primarily provide habitat for fledglings dispersing from multiple Georgia colonies (Bryan et al. 2000, pp. 55-56). At the Harris Neck NWR (coastal Georgia, Northeast Breeding Region), the Snipe Pond impoundment is lowered to foraging depth for wood stork adults to provision their young from the adjacent Woody Pond colony site and later for fledglings to forage in.

In coastal South Carolina, where managed tidal impoundments (e.g., former rice fields) are managed throughout the year to provide winter habitat for waterfowl, concentrations of greater than 100 storks are often found foraging during water drawdowns (Murphy and Coker 2008, p. 6). In brackish impoundments, the management cycle often involves draining the wetlands during January, burning undesirable vegetation during February or March and then promptly flooding the wetlands until May or June (Folk et al. 2016, p. 33). When water levels are temporarily lowered during the late spring and summer to allow for the germination of desired vegetation, fish within the wetlands are concentrated into perimeter ditches where they can be easily captured by wood storks and other wildlife. Additional brief drawdowns occur during the late summer and fall as water is circulated among impoundments. By staggering the timing of these drawdowns instead of draining all of the wetlands simultaneously, it is possible to provide concentrated prey throughout the breeding and post-breeding seasons. The South Carolina DNR coordinates with public land managers and local landowners to time these drawdowns during periods of nestling growth and when fledglings are dispersing from coastal colonies, to maximize benefit to wood storks.

Waste-water treatment ponds and flow through marshes facilities are increasing in numbers and acreage within the southeastern region, and they are now being utilized by wood storks as both foraging and breeding habitats. Examples in Florida (South and Central Breeding Region) with documented stork use include facilities in Orlando Wetlands Park, Lakeland (“Se7en” Wetlands), and Wakodahatchee Wetlands Park.

Wastewater treatment flow through marshes and other manmade wetland features are increasing within the southeastern United States and are used by wood storks as both foraging and breeding

habitats. For example, in Florida, management for wastewater treatment now supports 200 acres of wetlands at Viera Wetlands and 125 acres of wetlands at Sweetwater Wetlands Park; and wastewater treatment wetlands now support a wood stork nesting colony each at Wakodahatchee Wetlands (50 acres of wetlands), Orlando Wetlands (1,200 acres of wetlands), and at Se7en Wetlands (1,600 acres of wetlands). Each of these managed wetland systems have been documented to support a large variety of wetland dependent species including wood stork (with nesting now occurring at three sites). As noted above, the 6,500-acre Everglades Agricultural Area Reservoir will store and clean water from Lake Okeechobee, which will provide wood stork foraging habitat along the reservoir's edges and in shallow areas during periods of drawdown and will improve conditions of wetlands with appropriately timed water releases in the Everglades.

Efforts have been made to improve herbaceous foraging wetlands negatively impacted by encroaching woody plants (e.g., willows) due to drier wetland conditions in southwest Florida (Clem et al. 2019, pp. 369-370) and the St. John's River basin (SJRWMD 2017, entire). Woody wetland vegetation encroachment has been identified as an issue in interior Everglades National Park (Dean 2019, pers. comm.). Combining herbicide and mechanical methods, while costly, have opened-up impacted habitats and made them available for wood stork use in the Corkscrew Swamp watershed (Hall et al. 2017, p. 52; McCollom et al. 2022, p. 54).

Specific Actions – Breeding Habitat

Many wood stork breeding sites exist on managed impoundments (e.g., Harris Neck NWR) or associated backwaters inland from the effects of tides (e.g., Colonies 6 and 20 in South Carolina) and rely on rainfall to create suitable water levels. Maintenance of water levels during the breeding season limits predation by terrestrial predators, however, during drought years, these colonies may become unsuitably dry.

Some colony sites that were once altered to the point of abandonment have been restored, resulting in stork re-colonization of the sites. For example, wood stork nesting in the Gator Creek colony in Florida (Central Breeding Region) became active again following work over 10-years to correct the hydrology. Similarly, birds returned to nest in a formerly drained colony site on St. Simons Island, Georgia (Northeast Breeding Region), after repaired levees reflooded the site (Robinette et al. 1995, p. 62). Wood storks also returned to the Colony 8 site in South Carolina (Northeast Breeding Region) after the water control system was repaired, a year-long process. A 2006 WRP restoration of 200 acres of farmland (with wetlands) in Camilla, Georgia (Northwest Breeding Region) now supports a growing wood stork colony with over 100 nesting pairs annually. Wood storks have nested successfully on artificial nesting platforms erected for the species at Harris Neck NWR, Georgia (Robinette et al. 1995, p. 61). Sapling cypress trees planted on small islands at the same time these platforms were constructed (year) are now being used for nesting structure instead of the platforms (Bryan 2021, pers. comm.). Wood storks have also used nesting structures in the Cypress Creek colony in west-central Florida (Paul 2020, pers. comm.) and in a colony near Okatie, South Carolina.

Conservation Lands

With regard to important wood stork wetland habitats, a number of the nesting colonies occur on federal conservation lands (e.g., USFWS refuges, National Park Service [NPS], Department of

Defense, National Aeronautics and Space Administration) and are consequently afforded protection from development and large-scale habitat disturbance. Wood stork colonies also occur on a variety of state-owned properties, and existing state and federal regulations provide protection on these sites. However, approximately half of known wood stork colonies occur on private lands. Through conservation partnerships, colonies can be protected through the owners' stewardship. In an effort to minimize potential loss of colony sites, partnerships have been developed through conservation easements, wetland restoration projects, and other conservation means. Also, the wetland areas near nesting colonies play a vital role in the success of a nesting colony. Due to the regulatory status of wetlands, conservation of wetlands shown to be important to wood storks can be largely achieved through the application and improved implementation of existing wetland laws and mitigation practices, such as the Clean Water Act (33 U.S.C. 1251 et seq.) and the interagency cooperation provisions under section 7 of the Act (although, protections under section 7 only apply if the species is listed under the Act).

CHAPTER 6 – FUTURE SCENARIOS AND CONDITIONS

To analyze species' viability, we considered the current demographic condition and future availability or condition of resources important to wood storks.

To examine the potential future condition of the wood stork, we developed three future scenarios that focus on a range of conditions based on projections for land development, SLR, impacts of changing climate conditions, and beneficial conservation actions (as described in sections 5.1.1 and 5.1.2 on Human Development and Changing Climate Conditions, respectively). The range of what may happen in each scenario is described based on the current condition of nesting colonies and their associated core foraging areas, and how resiliency, representation, and redundancy would be expected to change within each Breeding Region and U.S. breeding range. It is important to note, we do not model how population demographics will change under future conditions, nor do we model how wood storks will respond to changing habitat conditions. Simply stated, the future scenarios are a habitat-based analysis, that project the future condition of the current core foraging areas in each Breeding Region. However, habitat suitable which is currently occupied by wood storks exists outside of the current core foraging areas, and we expect that wood storks will continue to respond to changing environmental and habitat conditions, including degradation, conversion, and creation of wetland habitats, as they have in recent history.

We chose 30- and 60-years (approximately 2050 and 2080) as the timeframes for the future analysis. These time elements are within the predictive range of the model used to project future development for the southeastern U.S. coastal plain and are also within the climate change forecasts that cover the southeastern U.S (Sweet et al. 2017, entire; Sweet et al. 2022, entire). These scenarios allow for general representation of largescale stressors that have the potential to impact wood storks range-wide. Potential future impacts associated with changing climatic conditions (i.e., estimates for precipitation, drought levels, temperature, and SLR) were based on climate model projections downscaled for Florida, Georgia, and South Carolina. To forecast future urbanization, we considered future scenarios that incorporate the SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model. This model simulates patterns of urban expansion that are consistent with spatial observations of past urban expansion and transportation networks (Terando et al. 2014, entire).

Biologically, we note 30- and 60-year timeframes cover seven and 15 wood stork generations, respectively, assuming a generation time of four years (Coulter et al. 2020, no pagination). These future projected timeframes allow for considered effects to several wood stork generations and therefore allow adequate time to detect a downward population trend, and time to formulate responses with appropriate conservation actions.

6.1 Future Scenarios

The future scenarios assessed for this SSA include varying levels and time frames (2050 and 2080) of stressors, that relate primarily to climate change and urban development but also include conservation actions that aim to mitigate impacts from stressors (Table 28). These scenarios consider potential impacts to the wood stork population, to nesting colonies, and to the core foraging areas within each Breeding Region, and thus habitats (wetlands) essential to the breeding ecology of wood storks. Scenarios 1, 2, and 3 are based upon projections of land development changes and SLR impacts to wetlands, and the likely implementation of conservation actions. All are based on the best scientific and commercial information available at this time. Scenario 1 is a current trends projection of development, NOAA Intermediate SLR projection, regulatory protections of wetlands, and conservation implementation at current or increased levels; Scenario 2 is based upon projecting a moderate increase in stressors, a NOAA High SLR projection, a current trend in development, and no increase to conservation and regulatory implementation (thus current trend); and Scenario 3 is the same as Scenario 2 with the current development trend, a NOAA High SLR along with a significant decrease in regulatory protections, decrease in conservation management due to lower funding levels like wetland restorations not targeting benefits specifically for woods storks.

Predicted future climatic changes (precipitation, temperature, drying) will likely be variable on regional and local scales, and it would be difficult to project comparable impacts to different types of wetland ecosystems at 30- and 60-year time frames. Further, these predicted changes could result in either positive or negative impacts on wood stork breeding success. Therefore, we have limited our future climatic impact scenario to SLR, while also considering impacts of development, and conservation implementation.

Table 28. Future scenarios for wood stork and metrics for evaluating resilience (Sweet et al. 2022).

Climate Change	Land Use Change Development	Conservation Actions
Scenario 1 – Low Stressor Increase with Conservation		
Sea-level rise ¹ : NOAA Intermediate (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions at current trends or increase Restoration at current levels or increased
Scenario 2 - Moderate Stressor Increase with Conservation		
Sea-level rise ¹ : NOAA High (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions: current trends Restoration at current levels

Climate Change	Land Use Change Development	Conservation Actions
Scenario 3 - Moderate Stressor Increase with reduced Conservation		
Sea-level rise ¹ : NOAA High (number of colonies impacted and wetland loss within core foraging areas by 2050 and 2080)	SLEUTH 2050 & 2080 Nesting colony Core Foraging Area habitat impacted by development (70 percent probability or greater) by 2050 and 2080	Wetland habitat regulatory protections-conservation management-acquisitions decreased due to changes in regulatory mechanisms or lower funding levels Restoration no longer targets benefits to wood storks

¹Does not account for pre-inundation effects or habitat change.

6.2 Sea Level Rise – Future Impacts

Sea Level Rise – Based on projections discussed in Sweet et al. 2017

We examined the effects of different rates of SLR (NOAA Intermediate, NOAA High; Sweet et al. 2017, entire) on colonies sites, current Core Foraging Areas (CFAs), and wetland habitat within Breeding Regions for the years 2050 and 2080 (approximately 30- and 60-year projections). Sea level rise impacts on wood stork Breeding Regions were assessed by calculating the average rise for each scenario, rounding to the nearest foot, and mapping out those levels of sea level rise on each wood stork Breeding Region's current CFAs and other wetlands within the Breeding Regions (using ArcGIS shapefiles supplied by NOAA and USFWS, Table 29). All mapping analyses were completed in ArcGIS Desktop 10.6.

Table 29. Projected sea level rise (SLR) rates for representative locations within Breeding Regions based on SLR scenarios established by National Oceanic and Atmospheric Administration – NOAA VLM: 0.00075 feet/year (Sweet et al. 2017).

Sea Level Rise Projections (rounded to the nearest foot)		
South Breeding Region	Intermediate	High
2050	1 ft	2 ft
2080	3 ft	6 ft
Central Breeding Region		
2050	1 ft	2 ft
2080	3 ft	6 ft
Northeast Breeding Region		
2050	1 ft	3 ft
2080	3 ft	6 ft
Northwest Breeding Region		
2050	1 ft	2 ft
2080	3 ft	5 ft

Anticipated Future Impacts

- Negative impacts (habitat conversion and loss) by both development and SLR varied considerably among Breeding Regions. Loss of salt marsh and managed tidal

impoundment (former rice impoundments) habitats due to SLR is projected to have a significant negative impact in the Northeast Breeding Region.

- The potential for salt marsh to elevate through accretion and the creation of new salt marsh in response to SLR is not well understood and will be likely be variable and dependent upon the rate of SLR. Changes to the salt marsh and managed tidal impoundments in Georgia and South Carolina are expected to be significant.
- Kirwan et al. (2010, pp. 3-4) indicated that marshes within a larger single wetland system can be affected by SLR differently based on the amount of suspended sediment (<https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2010GL045489>).
- Sea level rise is expected to cause salt marshes to extend upstream at the expense of freshwater wetlands, dramatically altering the intertidal landscape. Salinization reduces primary production, reduces plant species diversity, decreases respiration, and leads to loss of marsh elevation. <https://lternet.edu/findings/sea-level-rise-alters-wetland-function/>.
- Tidal freshwater marshes will decline in area as saltwater intrudes, and brackish marshes migrate inland to replace them. Already existing salt marshes may convert to open water if their rate of vertical accretion relative to brackish and tidal freshwater marshes prevents them from keeping pace with accelerated SLR (Craft et al. 2009, unpaginated). For salt marshes to persist despite rising waters, they must grow at a rate equal to or greater than the rate of SLR. This scenario requires that the marsh surface increases in height. The two processes by which this can occur are: 1) accumulation of root material in marsh soils, and 2) trapping of sediment that is carried into the marsh during flood tides. Though marsh habitat will be lost in some areas, marsh migration models that apply to the region where wood storks breed predict and overall net gain in marsh habitat (Kirwan et al. 2016a, p. 253; Kirwan et al. 2016b, p. 4366).
- When coastal impoundment dikes breach, the functionality of the entire impoundment or impoundment complex may be lost. Increasingly severe storm events combined with sea level rise could result in the loss of substantial acres of wetlands within the managed impoundments and former rice fields. Unlike salt marsh habitat, managed tidal impoundments will not migrate or be replaced through accretion.
- There are a limited number of documented wood stork colony losses, primarily due to anthropogenic factors (e.g., draining). These colony losses did not likely result in losses of individual storks but rather in no nesting and/or a shift of nesting to nearby sites in subsequent years (e.g., St. Simons Island colony, Savannah Airport colony, and South Carolina Colony 8). Wood storks may shift habitat use in response to future inundation of coastal colonies from SLR, or they may respond differently because changes associated with SLR tend to be more gradual in nature than those caused by other anthropogenic factors.

Sea Level Rise – Future Impacts based on projections in (Sweet et al. 2022)

After the SSA Version 1.0 analysis was completed in 2021 using the Sweet et al. 2017 SLR projections, new sea level rise projections were published and our understanding of high tide flooding thresholds changed. The updated SLR report (Sweet et al. 2022, pp. 11-13) changed projected SLR estimates and removed the Extreme scenario. Additionally, the NOAA inundation layers that we used in SSA Version 1.0 to determine habitat effects were updated using higher

resolution elevation data and/or tidal datums (NOAA 2024a, unpaginated). The improved land elevation data and tidal datums resulted in greater and lesser estimates of inundation.

Flooding from above normal high tides is referred to as “high tide flooding” (HTF) or “nuisance flooding.” Sea level rise will push tides higher, and the frequency of flooding will increase. HTF thresholds were developed to indicate the severity of impacts to the public from a flooding event (Sweet et al. 2022, p. 29). These HTF thresholds are relative to current mean higher high water (MHHW; i.e., the wet-dry land delineation) and are at a fixed elevation (Sweet et al. 2022, p. 29). They do not represent exceedances of future SLR projections of MHHW. Once sea level rises to the elevation of the HTF threshold, then the threshold becomes null (K. Serafin 2024, pers. comm.). As such, we clarify in this SSA, Version 1.1, that HTF thresholds are not additive to future sea level rise projections (K. Serafin 2024, pers. comm.).

Essentially, high tide flooding is an aspect of sea level rise and is incorporated into future sea level rise estimates. However, we can use the frequency projections to evaluate how soon species or habitats may be affected from sea level rise. This is limited to the near-term, before local sea level rise projections (i.e., future MHHW) reach the local HTF threshold. Currently, we do not have predictions for exceedances of future high tides.

In this SSA Version 1.1 we have updated the future conditions analysis using the latest SLR projections from Sweet et al. 2022 (pp. 11-13) projected out to 2050 and 2080 (Table 30). Our future conditions analysis of SLR include (1) intermediate and (2) high scenarios (NOAA 2024b, unpaginated) of SLR for each breeding region. All SLR estimates in 10-year increments up to 2100 are provided.

Table 30. Sea Level Rise comparison of the 2017 and 2022 NOAA SLR model projections (Sweet et al. 2017; Sweet et al. 2022). Thirty-year (2050) and 60-year (2080) Intermediate and High projections are rounded to the nearest foot.

Breeding Region and Year	2017 SLR Projections		2022 SLR 2022 Projections	
South Breeding Region	Intermediate	High	Intermediate	High
2050	1 ft	2 ft	1 ft	2 ft
2080	3 ft	6 ft	2 ft	4 ft
Central Breeding Region				
2050	1 ft	2 ft	1 ft	2 ft
2080	3 ft	6 ft	2 ft	4 ft
Northeast Breeding Region				
2050	1 ft	3 ft	1 ft	2 ft
2080	3 ft	6 ft	3 ft	5 ft
Northwest Breeding Region				
2050	1 ft	2 ft	1 ft	2 ft
2080	3 ft	5 ft	1 ft	4 ft

Suitable Breeding Habitat - There are approximately 26.2 million acres of suitable wetland habitat for wood stork within the Southeast U.S. Coastal Plain breeding range of Florida, Georgia, South Carolina, and North Carolina (Table 31). Forty-two percent, approximately 10.8

million acres (41.2%), represents the current core foraging area that annually supports the current breeding population of approximately 10,000 breeding pairs of wood storks at 100 or more active nesting colonies (Figure 30).

Table 31. Southeast U.S. Coastal Plains Wood Stork (WOST) Breeding Range Suitable Wetland Habitat by 2080 under High Sea Level Rise (SLR) of 4–5 ft: total suitable wetland habitat and habitat either impacted or unimpacted by SLR

Southeast Coastal Plains Wood Stork Wetlands	Total WOST Wetlands acres	SLR Inundated WOST Wetlands acres	Remaining WOST Wetlands acres
Breeding Range Total	26,245,187	5,715,903 (22%)	20,529,284 (78%)
Breeding Range current CFA Total	10,808,704	3,531,743 (33%)	7,276,961 (67%)
Total outside current CFA	15,436,483	2,184,170 (14%)	13,252,323 (86%)

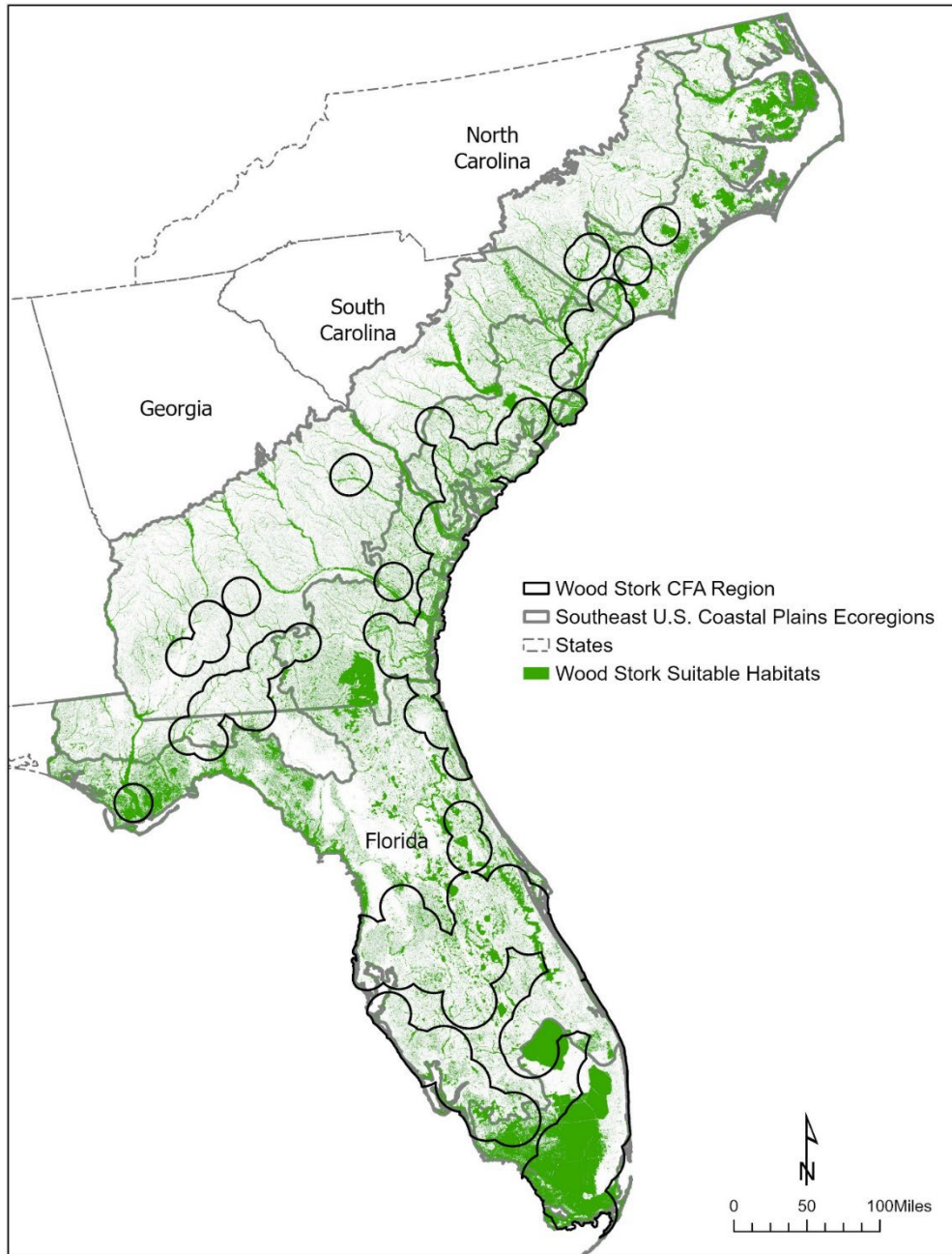


Figure 30. Current condition of Southeast U.S. Coastal Plains Wood Stork (WOST) Suitable Wetland Habitat and current CFA polygons around active colonies (2010-2019).

In 2080 under the High Sea Level Rise projection (Sweet et al. 2022, pp. 11-13), approximately 3.5 million, (33%) of the breeding season core foraging area will be inundated, while 7 million acres (67%) will remain intact and unaffected by SLR, and available for wood stork breeding and foraging. We note that within the wood stork breeding range there is an additional (approximately) 13 million acres of occupied suitable wetland habitat acres located in between and adjacent to the current occupied core foraging area acres (Table, 31, Figure 31).

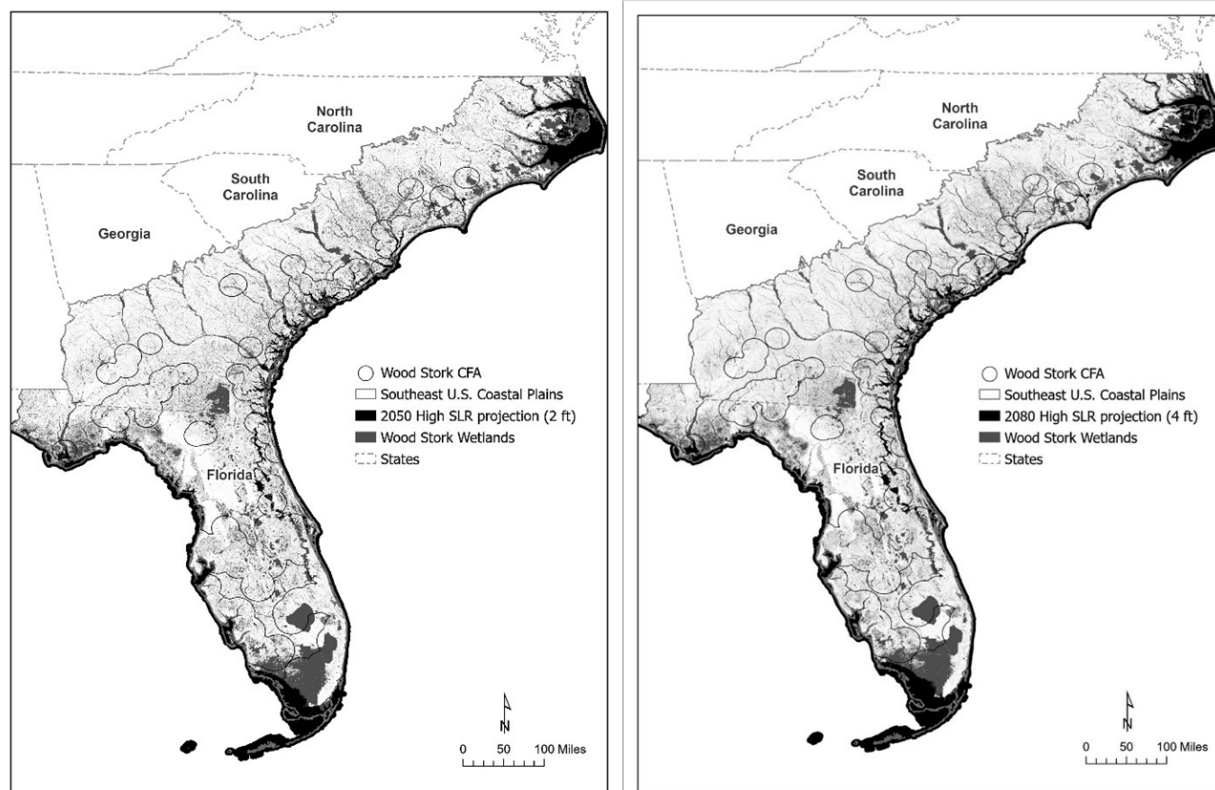


Figure 31. Suitable wetland habitat available in 2050 (2 feet) and 2080 given high (4 feet) sea level rise projections across the wood stork's breeding range in the southeast U.S. coastal plains.

Suitable wetland habitat does not appear to have limited wood stork recovery. The wood stork nesting record of colony turnover demonstrates that when a breeding colony site is no longer suitable or offers less favorable conditions, wood storks will shift to exploit more favorable conditions at adjacent suitable wetland habitat that is available within their occupied range. We project that the wood stork population will continue to grow into the foreseeable future, even though there is expected to be some loss and gain in wetlands due to SLR, upslope migration of coastal wetlands, and some change from saltwater to freshwater wetlands due to climate change.

Gains and losses of salt marsh habitat

Determining the expected future stability and resiliency of salt marsh habitat depends on the balance between land elevation, primary productivity, and sediment accretion (Weston et al. 2023, pp. 1-2). Several studies find a direct correlation between the salt marsh sediment budget and the amount of vegetated/unvegetated ratio, indicating that sediment accretion/loss is a good indicator of salt marsh resiliency to future sea level rise (Ganju et al. 2017, pp. 4-5; Windom and Palmer 2022, pp. 518-522).

While sea level rise is expected to cause the degradation and loss of existing coastal wetland habitats in some areas, marsh migration models also project that new salt marsh habitat will be created as coastal marshes migrate upslope along the coastal upland and water interface (Kirwan et al. 2016a, p. 253), resulting in a net expansion of salt marsh habitat in response to sea level rise in some areas (Kirwan et al. 2016b, p. 4366). In some areas, coastal marsh habitat may

remain stable or transgress upslope, and freshwater marshes may be converted into brackish or salt marsh depending upon whether the rate of horizontal erosion of the salt marsh from the ocean side (trailing edge) due to rising water is compensated or exceeded by the rate at which material accumulates vertically (e.g., trapping of sediment carried by flood tides, accumulation of root material in marsh soils), which causes its landward expansion upslope (Colombano et al. 2021, p. 1639). As such, in some areas, wetland habitat will shift and elevate rather than be lost, as sea level rise causes wetland migration landward, with seaward erosion and upslope transgression shifting the location and extent of each coastal wetland habitat type (Colombano et al. 2021, p. 1639).

In contrast, model simulations using the IPCC mean SLR estimates show a 20% decrease in salt marsh habitat but a 2% increase in tidal freshwater marsh habitat. The Georgia coast in particular experiences meso-tidal intrusion of 2.3 m which buffers against moderate SLR and may consequently increase vertical accretion to compensate (Craft et al. 2009, pp. 77-78).

Although we can project through modeling where wood stork habitat within the current core foraging area (CFA) is likely to be inundated by sea level rise, it is less clear where and how much brackish and saltmarsh habitat suitable for wood stork use will be created and/or lost in the future as coastal estuarine marshes migrate in response to sea level rise (Craft et al. 2009, entire; Kirwan et al. 2016a, p. 258; Fagherazzi, et al. 2020, entire).

The Service acknowledges that SLR could consequently shift biotic relationships in wetland habitat, which could pose a threat to prey availability for wood storks (Lorenz and Serafy 2006, entire; Crotty et al. 2019, entire). However, through review the Service found no evidence that SLR will impact prey availability that will result in population level impacts to wood storks. We also note that the wood stork has expanded into new habitats and been able to exploit new food sources that historically have not been exploited (Evans et al. 2023, pp. 12-15). The Service expects wood stork to continue to adapt to potential changes in biotic community, such that prey availability is not limiting wood stork resiliency.

6.3 Temperature, Precipitation, Drought – Future Impacts

The future impacts of climate variables including temperature, precipitation, evaporation deficit, drought, and hurricanes, to wood stork breeding regions was not modeled for this SSA. These climate factors are all inter-related to hydrologic conditions of the wetlands within a Breeding Region. Good hydrologic conditions generally lead to increased wood stork nesting and productivity, while drought conditions generally lead to lower and sometimes no wood stork nesting and productivity (Figure 32). The timing of wet or dry hydrologic condition affects when impacts to annual wood stork reproduction will occur, in the current or future breeding years. Initially, a drought can concentrate prey and lead efficient foraging and good productivity (Frederick and Ogden 2001, entire), but drought also lowers prey productivity and availability in future years and can negatively impact future nesting and productivity. Large rain events and hurricanes can have negative and positive effects as well. Hurricanes generally occur after the breeding season and the direct impacts can damage the colony nesting structure. However, the large amount of rain associated with hurricanes can rehydrate wetlands and produce positive affects in the next breeding season. Large rain events can also offset drought conditions. Because of the uncertainty around how these climatic variables would ultimately impact wood stork viability into the future, we did not carry them forward in our analysis of future viability. Where

available, downscaled climate models should be assessed to determine localized impacts and develop future management options to support wood stork breeding ecology in a Breeding Region.

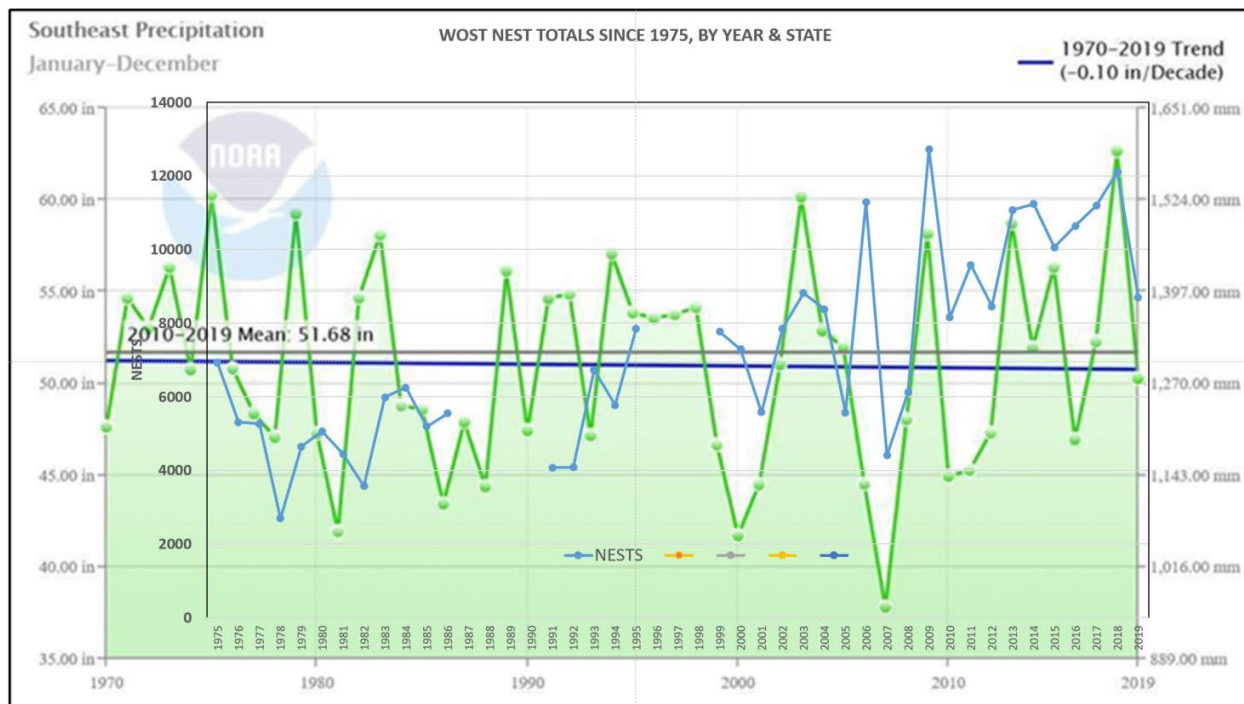


Figure 32. Annual precipitation in the Southeast U.S. 1970–2019 (NOAA 2020) indicated by the green solid line and Wood Stork total nests in the U.S. Breeding Population (1975–2019) indicated by the periodically broken blue line.

Temperature: Climate change predictions suggest overall warming temperatures throughout North America under all greenhouse gas emission scenarios (IPCC 2014, p. 58). Projections for the southeastern U.S., from 2050–2074, indicate annual mean maximum air temperature warms by 3.9 °F (2.2 °C) in RCP 4.5, whereas the region warms by 5.7 °F (3.2 °C) in RCP 8.5 (Alder and Hostetler 2013, entire).

Precipitation: Climate change is also expected to change precipitation patterns throughout the wood stork’s range, but the impacts vary among the key habitat types. An overall increase in rainfall due to climate change is expected throughout much of the range. In the southeastern U.S., annual mean precipitation increases by 0.3 in (7.6 mm) per month in RCP 4.5 and by 0.2 in (5.1 mm) per month in RCP 8.5 (Alder and Hostetler 2013, entire).

Drought: Projections of drought in the southeastern U.S., from 2050–2074, indicate drier conditions across the region, with a slight evaporative deficit increase in RCP 4.5 and RCP 8.5 (Alder and Hostetler 2013, entire). Periods of evaporative deficit result in drier soils, and result in decreased inflow and maintenance of water levels in wetlands.

South Breeding Region: In the South Breeding Region over the same period, temperature changes are smaller with projected increases of 2.7 °F (1.5 °C) and 4.1 °F (2.3 °C) in RCP 4.5 and RCP 8.5, respectively. Precipitation change is slightly lower in the South Breeding Region over the same period, with projected increases of 0.1 in (2.5 mm) and 0.3 in (7.6 mm) per month

in RCP 4.5 and RCP 8.5, respectively. The evaporative deficit increases by 0.2 in (5.1 mm) and 0.3 in (7.6 mm) in the South Breeding Region in RCP 4.5 and RCP 8.5, respectively.

Central Breeding Region: In the Central Breeding Region over the same period, projected temperatures show increases of 3.2 °F (1.8 °C) and 4.8 °F (2.7 °C) in RCP 4.5 and RCP 8.5, respectively. In the Central Breeding Region, annual mean precipitation increases by 0.3 in (7.6 mm) in both scenarios. In the Central Breeding Regions, the evaporative deficit increases by 0.1 in (2.5 mm) and 0.2 in (5.1 mm) under RCP 4.5 and RCP 8.5, respectively.

Northwest Breeding Region: The Northwest Breeding Region projections increase by 4.1 °F (2.3 °C) and 6.0 °F (3.3 °C) in RCP 4.5 and RCP 8.5, respectively. Projections in the Northwest Breeding Region show increases of 0.2 in (5.1 mm) in both RCP 4.5 and RCP 8.5. In the Northwest, the evaporative deficit increases by 0.1 in (2.5 mm) and 0.2 in (5.1 mm) under RCP 4.5 and RCP 8.5, respectively.

Northeast Breeding Region: The Northeast Breeding Region projections increase by 4.0 °F (2.2 °C) and 6.0 °F (3.3 °C) in RCP 4.5 and RCP 8.5, respectively. In the Northeast Breeding Region, precipitation increases by 0.3 in (7.6 mm) and 0.4 in (10.2) per month in RCP 4.5 and RCP 8.5, respectively. The evaporative deficit increases by 0.2 in (5.1 mm) per month in the Northeast Breeding Region under both scenarios during the same time period.

Anticipated Future Impacts

- Rainfall timing coupled with warming temperatures could increase the occurrence and severity of drought and wetland drying.
- Changes to the quantity and intensity of precipitation (including hurricanes), depending on timing, will alter foraging habitat availability and associated wetland food resources for wood storks, but this could have both positive and negative effects.
- Climate models for south Florida suggest a scenario for increased evapotranspiration and overall decreased rainfall, which when applied to the Everglades would lower median water depths and shorten inundation duration periods and have significant impacts on wetland hydrology and ecology (Nungasser et al. 2015, pp. 763-764; Obeysekera et al. 2015, p. 760).
- Warming temperatures contribute to increased SLR, which is expected to result in the loss of coastal foraging habitat, with the largest impacts likely in the Northeast Breeding Region, as described in section 6.2 Sea Level Rise - Future Impacts.
- Colonies in impounded backwaters (coastal South Carolina and Georgia) are vulnerable to infrastructure damage during extreme rainfall events.

6.4 Development—Future Impacts

Future development projections include the loss or conversion of uplands and wetlands, and possible degradation of adjacent wetland habitats used for nesting, foraging, and roosting, and are likely to occur across the range of the wood stork (Figure 33). The 30-year development projection was calculated by overlaying SLEUTH 70% projections (i.e., identifying all areas with a 70% or greater probability of being converted from non-urban land uses to developed land types) over the current CFA habitat buffers of the nesting colonies within each Breeding Region (Table 49, Figure 33). The overall measure shows an increase in development within all the

current CFAs from a current condition (2020) of 4,845,165 ac developed (16%) to 6,726,896 ac developed (22%) by the year 2050 (Table 49, Figure 33). The current trend of development projects a 60-year increase from the current condition of 4,845,165 ac developed (16%) to 8,596,051 developed (28%) by 2080 (Table 49, Figure 33).

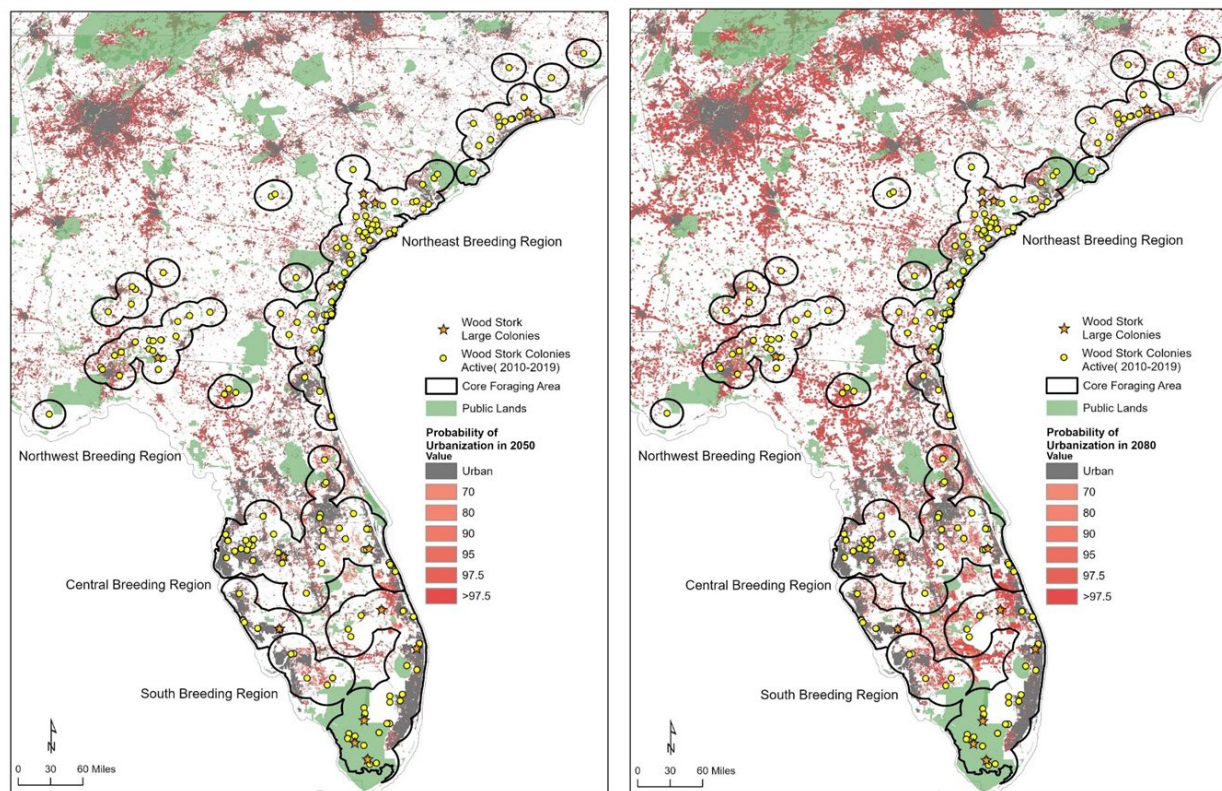


Figure 33: Maps of wood stork nesting colonies, core foraging areas showing future projections of development at 30-year (2050; left) and 60-year (2080; right) projections based on current trends (SLEUTH). See Table 49 for amount of developed lands future projections of development within the current CFAs.

6.5 Conservation—Future Impacts

The loss of wood stork habitat projected is mitigated when acquisitions, easements, and conservation actions focused on wood stork biological needs are included in the future development formula. A significant segment of conservation actions in Florida will be within the Everglades restoration and Everglades Headwaters NWR and Conservation Area, and through the Florida Forever Program. There are many focal restoration and acquisition areas throughout the wood stork's range, including: Kissimmee River basin, Picayune Strand, Corkscrew Swamp, Greater Charlotte Harbor Watershed, Tampa Bay, St. Johns River basin, Suwannee River-Okefenokee Swamp, Savannah-Ogeechee-Altamaha-Satilla Rivers basins, and Ashapoo-Combahee-Edisto Basin (ACE), Santee River basin, Winyah Bay-Focus Area. Regulatory review, acquisitions, easements, and conservation actions included in the conservation scenarios are expected to moderate the impacts of potential future development projected in the SLEUTH models. These conservation efforts would provide some protection for the current CFAs and lessen the impact over the next 30- and 60-years.

6.6 Future Conditions of Breeding Regions

We projected impacts of future condition under the three scenarios for each Breeding Region and for the U.S. wood stork population's range. Periodicity and amounts of rainfall and temperatures will vary in the future but impacts to individual colony sites and foraging habitats will be dependent on an extensive range of local conditions, thus these impacts are less predictable. Therefore, we focused on potential impacts of development and two possible levels of SLR on wood stork breeding and foraging habitats, specifically within current CFAs associated with wood stork colonies as defined under current conditions. The current resiliency condition is measured by population size, population trend, the number of large persistent colonies, and productivity Table 32.

Table 32. U.S. Breeding Population current condition per a demographic assessment measured by population size, population trend, productivity (Chapter 4).

Breeding Region	Current Demographic Condition
Northeast	HIGH
Northwest	MODERATE
Central	MODERATE-LOW
South	HIGH-MODERATE
U.S. Population	HIGH-MODERATE

For our wood stork future condition analysis, we measured changes in the current CFA habitat that support wood stork nesting colonies within each Breeding Region resulting from 1) SLR impacts to the current CFA, 2) future development within the current CFA, 3) SLR impacts to the wetlands within the current CFA, 4) SLR impacts on nesting colony sites, 5) SLR impacts on large persistent colony sites, and 6) different levels of conservation implementation. Habitat condition categories of High, Moderate, Low, and Very Low are classified by the percentage of acreage remaining after projected urbanization impacts on the current CFA (Table 33); percentage of the wetlands within the current CFA remaining after SLR; the percentage of nesting colonies remaining after SLR; the number of large persistent colonies remaining after SLR; and a high, medium, and low level of conservation implementation (Table 33).

Table 33. Future Habitat Condition categories represented by the percent of current Core Foraging Areas impacted or lost and colonies impacted-lost after assessing future changes of each condition category.

Percent Remaining	Percent Impacted/Lost	Future Habitat Condition
91-100	10	high (3)
71-90	11-30	moderate (2)
41-70	31-60	low (1)
0-40	61-100	very low (0)

This analysis only accounts for changes to habitat within the current CFA of a Breeding Region. This analysis does not predict the response of wood storks to changing habitat conditions such as whether wood storks would relocate to other occupied areas outside the current CFA to exploit more favorable conditions (e.g., find new colony sites, expand the current CFAs or Breeding Regions, etc.). However, historical evidence related to wood stork response to the ditching and draining the wetlands of the Everglades and south Florida indicates that wood storks often relocate in the face of declining habitat conditions to take advantage of more optimal conditions elsewhere.

The future Overall Condition for each Breeding Region in our analysis is based upon current CFAs and losses for each parameter due to either development or SLR. Even though we could not model for future impacts from temperature, precipitation, drought, and hurricanes, anticipated impacts are noted in Section 6.3 Temperature, Precipitation, Drought and are also included in the summary of each Breeding Region Future Conditions.

To ascertain the future Overall Condition of habitat within the current boundary of the CFA in a Breeding Region, per the definitions above, each of the habitat categories is assigned a condition (Very Low, Low, Moderate, or High). Using numeric values (Table 34), the six condition categories are averaged (rounding to the nearest half integer) to ascertain future changes to a Breeding Regions current CFA under SLR and development projections, and conservation implementation. To calculate the Overall Future Condition for a Breeding Region, the current condition from section 4.5 Current Demographic Conditions, is used as proxy for the baseline habitat condition. The assumption is that habitat condition reflects demographic conditions and vice versa. By applying parameters presented in Table 34 to the Breeding Region's current condition, we then determine the Overall Future Condition. A hypothetical calculation is presented in Table 35.

Table 34. Future condition calculator to determine Overall Future Condition of habitat within the current CFA footprint using Current Condition as the baseline to measure change.

Future Habitat Condition Categories Average	Breeding Region Overall Future Condition
High (3)	Current condition remains the same
High-Moderate (2.5)	Current condition declines 0.5 category
Moderate (2)	Current condition declines 1 category
Moderate-Low (1.5)	Current condition declines 1.5 categories or Very Low
Low (1)	Current condition declines 2 categories or Very Low
Low-Very Low (0.5)	Current condition declines 2.5 categories or Very Low
Very Low (0)	Current condition declines Very Low

Table 35. Hypothetical calculation of a Breeding Region Future Overall Condition due to impacts from SLR on the current CFA, Wetlands, Colonies, Large Persistent Colonies, Development within the current CFA, and Conservation Implementation. Hypothetically, the current condition is High-Moderate. By applying the High-Moderate Future Habitat Condition average, the current condition of High-Moderate declines by 0.5 to a Future Condition of MODERATE.

Category	Condition
Current CFA	20 percent lost due to SLR Moderate (2)
Wetlands	18 percent lost due to SLR Moderate (2)
Colonies	11 percent lost due to SLR Moderate (2)
Large Persistent Colonies	5 percent impacted/lost due to SLR High (3)
Current CFA developed	25 percent of the CFA is developed Moderate (2)
Conservation	Conservation implemented at current or higher levels High (3)
Calculation Future Habitat Condition	$2+2+2+3+2+3=14$; $14/6 = 2.33333$; round to 2.5 High-Moderate
Current Condition Future Calculation Future Overall Condition	High-Moderate Current Condition declines by 0.5 category MODERATE

6.6.1 South Breeding Region

Currently, there are 3,840,486 acres of wetland habitat within the South Breeding Region current CFA that support 36 colonies, of which five are designated as large, persistent colonies. The overall future habitat condition is measured by changes as it relates to development and to SLR impacts (Sweet et al. 2022) to the current CFA, current CFA wetlands, current nesting colony locations (2010-2019), and the level of conservation implementation (Figure 34; Tables 36 and 37).

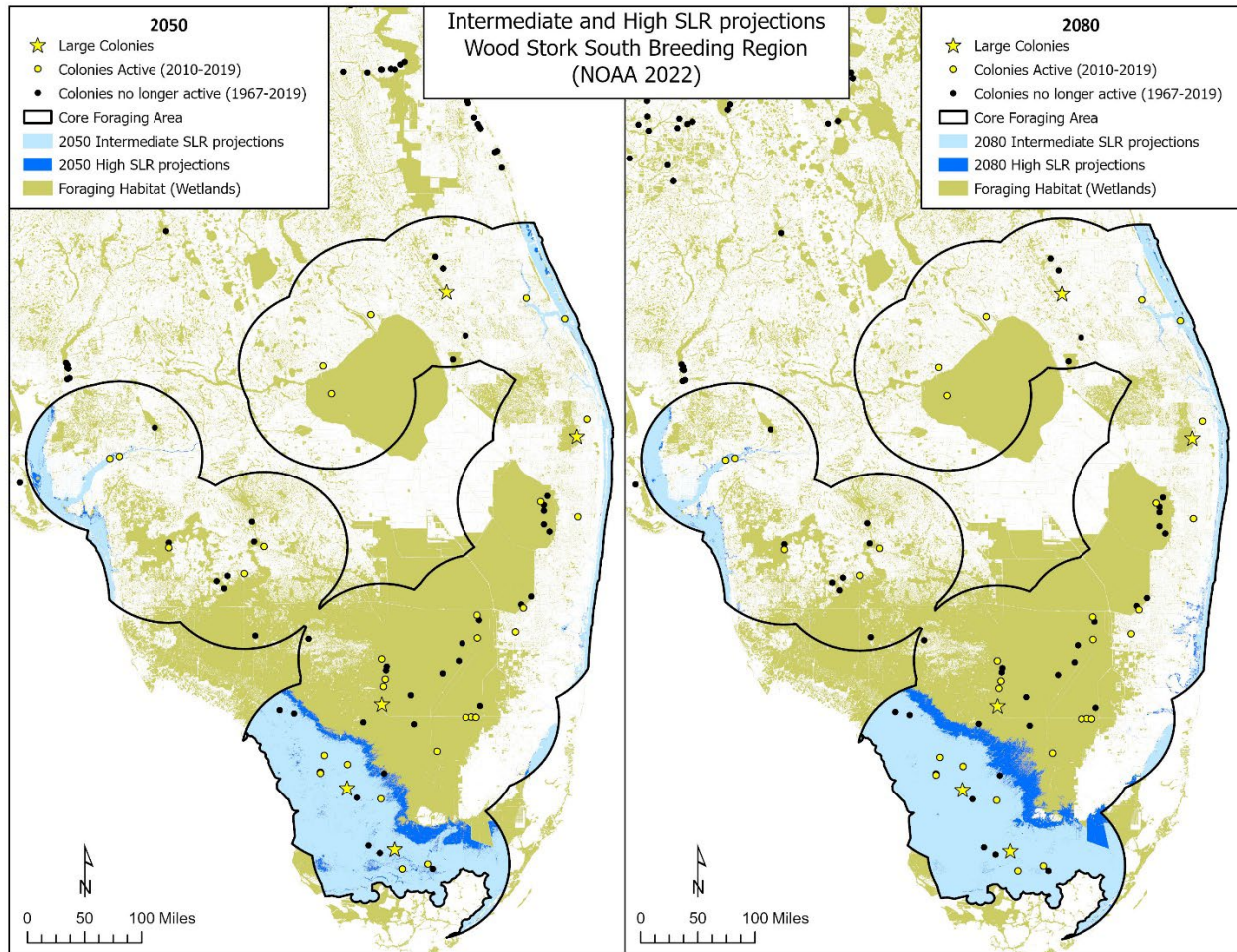


Figure 34. Map of Wood Stork South Breeding Region with colony locations, current CFA buffer of 20km with Intermediate and High SLR projections at 2050 (left panel) and Intermediate and High SLR projections at 2080 (right panel).

Table 36. Wood Stork South Breeding Region current Core Foraging Area (CFA), measures of current CFA wetlands, development, nesting colonies, and changes due to sea level rise (Sweet et al. 2022).

South Breeding Region			
SLR Projections Impacts to current CFA	CFA Acres	Percent Remaining	Habitat Condition
2020 current CFA	7,577,090	100	current
2050 Intermediate	6,501,081	86	moderate
2080 Intermediate	6,352,507	84	moderate
2050 High	6,352,507	84	moderate
2080 High	6,146,663	81	moderate
SLR Projections Impacts to current CFA Wetlands	CFA Wetland Acres	Percent Remaining	Habitat Condition
2020 current CFA Wetlands	3,840,486	100	current
2050 Intermediate	3,181,680	83	moderate
2080 Intermediate	3,038,266	79	moderate
2050 High	3,038,266	79	moderate
2080 High	2,870,501	75	moderate
Current CFA Development Projections	CFA Developed Acres	Percent Developed	Habitat Condition
SLEUTH 2020	1,367,663	18	current
SLEUTH 2050	1,799,967	24	moderate
SLEUTH 2080	2,301,608	30	moderate
SLR Projections Impacts to CFA Nesting Colonies	CFA Colonies	Percent Remaining	Habitat Condition
2020 Colonies	36	100	current
2050 Intermediate	24	67	low
2080 Intermediate	24	67	low
2050 High	24	67	low
2080 High	23	64	low
SLR Projections Impacts to CFA L. Persistent Colonies	CFA Large Persistent Colonies	Percent Remaining	Habitat Condition
2020 Large Persistent Colonies	5	100	current
2050 Intermediate	3	60	low
2080 Intermediate	3	60	low
2050 High	3	60	low
2080 High	3	60	low
Conservation Implementation			Conservation Condition
2050 and 2080 Scenario 1			high
2050 and 2080 Scenario 2			moderate
2050 and 2080 Scenario 3			low

Table 37. South Breeding Region future Core Foraging Area (CFA) habitat conditions in 2050 and 2080 for Scenarios 1, 2, and 3 (Sweet et al 2022).

	Scenario 1		Scenario 2		Scenario 3	
SOUTH	2050	2080	2050	2080	2050	2080
Current CFA	M	M	M	M	M	M
Wetlands	M	M	M	M	M	M
Colonies	L	L	L	L	L	L
L.P. Colonies	L	L	L	L	L	L
Development	M	M	M	M	M	M
Conservation	H	H	M	M	L	L
Average	M	M	M-L	M-L	M-L	M-L

Resiliency Future Condition Summary

The current resiliency condition for the South Breeding Region is HIGH-MODERATE (section 4.5) and is measured by demographics: population size, population trend, the number of large persistent colonies, and productivity. In the future condition analysis, we use the current condition of a Breeding Region as a proxy for the current condition of habitat, and thus as the baseline of where this analysis of future condition begins. The future condition is measured by changes to the current CFA habitat, development and sea level rise impacts to the current CFA wetlands and current nesting colony locations including large persistent nesting colonies, and also conservation implementation levels projected in two future time frames (2050 and 2080) and under the three future scenarios.

Temperature and precipitation increases are projected for the South Breeding Region. An increase in evaporative deficit can lead to drought conditions and will impact wetland habitats and foraging resources. The evaporative deficit is projected to increase in the South Breeding Region. Projected drought and stronger hurricanes will directly impact the South Breeding Region's wetlands and individual colony sites. A change in evaporative deficit could affect nesting both negatively and positively and overall will contribute to the variability in annual nesting success, but as such could not be modeled accurately and is not included in the future condition calculation. Downscaled climate models for the South Breeding Region should be assessed to predict localized impacts and develop future management options to support wood stork breeding ecology in this region.

Under Scenario 1, SLR is projected to impact 17 and 21 percent of the wetlands within the current footprint of the CFA by 2050 and 2080, respectively; and that area impacted by (and potentially lost to) SLR will include 12 of the 36 colony sites (33 percent) by 2050 and 2080. Two of the current five (40 percent) large, persistent colonies will be impacted by SLR in both the 2050 and 2080 timeframes. Land conversion will increase from 18 percent to 24 and 30 percent of the current CFA under the 2050 and 2080 timeframe projections, respectively. However, as stated previously, habitat does not appear to be a limiting factor for wood stork resiliency. Conservation efforts, such as wetland conservation easements and regulatory mechanisms to avoid/minimize/mitigate impacts to wetlands, remain at least at current levels under Scenario 1, making Scenario 1 similar to Scenario 2, and better than Scenario 3, in terms of conservation efforts and regulatory mechanisms.

Under Scenarios 2 and 3, SLR is projected to result in loss of 21 and 25 percent of wetlands within the current footprint of the current CFA by 2050 and 2080, respectively. Of the current 36 active colony sites, 12 and 13 (33 and 36 percent) will be impacted by (and potentially lost to) SLR in both the 2050 and 2080 timeframe projections. Two of the current five (40 percent) large, persistent colonies will be impacted by SLR in either timeframe. Land conversion in the current CFA will increase from 18 percent to 24 percent and 30 percent by 2050 and 2080, respectively. Conservation efforts are maintained under Scenario 2 and reduced under Scenario 3. However, in this breeding region the conservation efforts under Scenario 2 would not likely counteract the other negative influence factors considered (e.g., habitat loss within the current CFA due to SLR and development trends) and therefore are not likely to have a significant influence over the difference in overall future condition between Scenarios 2 and 3 in the South Breeding Region.

The current demographic condition of HIGH-MODERATE in the South Breeding Region is used as a proxy for current CFA habitat condition in the future condition analysis. In Scenarios 1 and 2 the current condition of the Breeding Region current CFA declines a full category in 2050 and in 2080, so that the overall CFA habitat condition for the South Breeding Region is projected to decline to a MODERATE-LOW condition in 2050 and in 2080 (Table 38). Under Scenario 3, the current CFA habitat condition of the Breeding Region declines 1.5 categories in the 2050 and 2080-year time frames, so that the overall current CFA habitat condition for the South Breeding Region CFA is expected to decline to a LOW condition (Table 38).

Table 38. The South Breeding Region Overall future condition (at 2050 and 2080, under Scenarios 1, 2, and 3 (Sweet et al. 2022)) of habitat within the current footprint of the wood stork core foraging area (CFA).

	2050	2080
Scenario 1 CFA Condition	MODERATE-LOW	MODERATE-LOW
Scenario 2 CFA Condition	MODERATE-LOW	MODERATE-LOW
Scenario 3 CFA Condition	LOW	LOW

The South Breeding Region’s Scenarios 1-3 project a MODERATE-LOW to LOW condition for current CFA habitat in 2050 and 2080, with a reduction in suitable habitat within the current footprint of the CFA due to sea level rise and development (Table 38). However, this projection does not account for suitable habitat available outside the current CFA, how wood storks respond to the changing habitat conditions, or that a portion of the population may pioneer new colony sites and foraging habitats within the currently occupied South Breeding Region or into new areas that provide habitat to support wood stork reproduction.

6.6.2 Central Breeding Region

Currently, there are 2,302,543 acres of wetlands in the Central Breeding Region current CFA that supports 48 colonies, of which three are designated as large, persistent colonies. The overall future condition is measured by changes related to development, SLR impacts to the current CFA (Sweet et al. 2022), current CFA wetlands, current nesting colony locations, and the level of conservation implementation (Table 39 and 40, Figure 35).

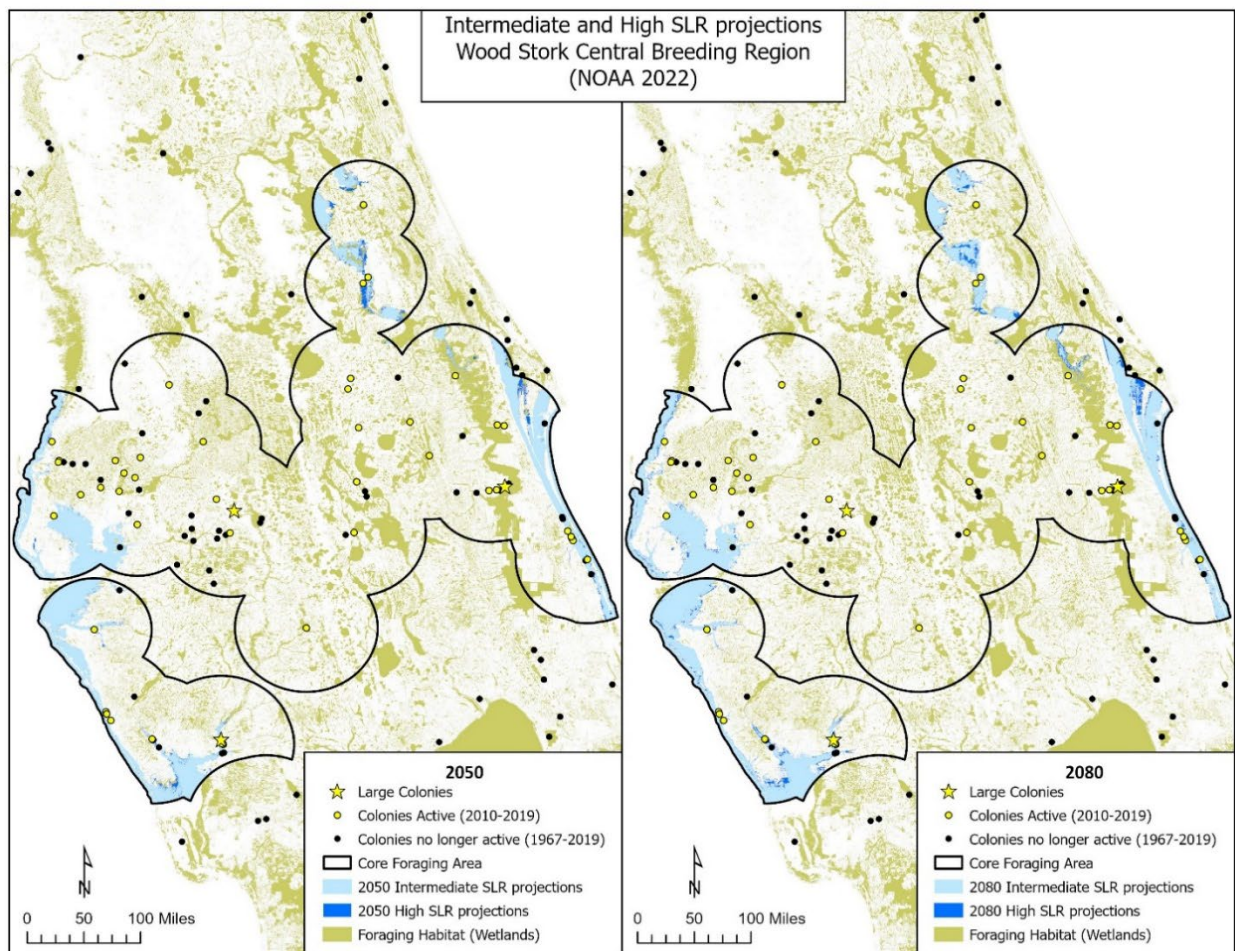


Figure 35. Map of Wood Stork Central Breeding Region with colony locations, current CFA buffer of 20km with Intermediate and High SLR projections at 2050 (left panel) and Intermediate and High SLR projections at 2080 (right panel).

Table 39. Wood Stork Central Breeding Region current Core Foraging Area (CFA), measures of current CFA wetlands, development, nesting colonies, and changes due to sea level rise (Sweet et al. 2022).

Central Breeding Region			
SLR Projections Impacts to Current CFA	CFA Acres	Percent Remaining	Habitat Condition
2020 Current CFA	8,270,482	100	current
2050 Intermediate	7,527,537	91	high
2080 Intermediate	7,463,953	90	moderate
2050 High	7,463,953	90	moderate
2080 High	7,360,553	89	moderate
SLR Projections Impacts to Current CFA Wetlands	CFA Wetland Acres	Percent Remaining	Habitat Condition
2020 Current CFA Wetlands	2,302,543	100	current
2050 Intermediate	2,113,174	92	high
2080 Intermediate	2,058,538	89	moderate
2050 High	2,058,538	89	moderate
2080 High	2,008,170	87	moderate
Current CFA Development Projections	CFA Developed Acres	Percent Developed	Habitat Condition
SLEUTH 2020	2,045,622	25	current
SLEUTH 2050	2,649,284	32	low
SLEUTH 2080	3,224,819	39	low
SLR Projections Impacts to CFA Nesting Colonies	CFA Colonies	Percent Remaining	Habitat Condition
2020 Colonies	48	100	current
2050 Intermediate	34	71	moderate
2080 Intermediate	33	69	low
2050 High	33	69	low
2080 High	32	67	low
SLR Projections Impacts to CFA L. Persistent Colonies	CFA Large Persistent Colonies	Percent Remaining	Habitat Condition
2020 Large Persistent Colonies	3	100	current
2050 Intermediate	2	67	low
2080 Intermediate	2	67	low
2050 High	2	67	low
2080 High	2	67	low
Conservation Implementation			Conservation Condition
2050 and 2080 Scenario 1			high
2050 and 2080 Scenario 2			moderate
2050 and 2080 Scenario 3			low

Table 40. Central Breeding Region future Core Foraging Area (CFA) habitat conditions in 2050 and 2080 for Scenarios 1, 2, and 3.

	Scenario 1		Scenario 2		Scenario 3	
CENTRAL	2050	2080	2050	2080	2050	2080
Current CFA	H	M	M	M	M	M
Wetlands	H	M	M	M	M	M
Colonies	M	L	L	L	L	L
L.P. Colonies	L	L	L	L	L	L
Development	L	L	L	L	L	L
Conservation	H	H	M	M	M	L
Average	M	M	M-L	M-L	M-L	M-L

Resiliency Future Condition Summary

The current resiliency condition for the Central Breeding Region is MODERATE-LOW (section 4.5) and is measured by demographics including population size, population trend, the number of large persistent colonies, and productivity. In this future condition analysis, we use the current condition of a Breeding Region as a proxy for the current condition of habitat and thus the baseline of where this analysis of future condition begins. The future condition is measured by changes to the current CFA habitat, development and sea level rise impacts to the current CFA wetlands and current nesting colony locations including large persistent nesting colonies, and also conservation implementation levels projected in two future time frames (2050 and 2080) and under the three scenarios.

Temperature and precipitation increases are projected for the Central Breeding Region. An increase in evaporative deficit can lead to drought conditions and will impact wetland habitats and foraging resources. The evaporative deficit is projected to increase and be the same under RCP 8.5 compared to RCP 4.5 in the Central Breeding Region. Projected drought and stronger hurricanes will directly impact the South Breeding Region's wetlands and individual colony sites. A change in evaporative deficit could affect nesting both negatively and positively and overall will contribute to the variability in annual nesting success, but as such could not be modeled accurately and is not included in the future condition calculation. Downscaled climate models for the Central Breeding Region should be assessed to predict localized impacts and develop future management options to support wood stork breeding ecology in this region.

Under Scenario 1, SLR is projected to impact 8 and 11 percent of the wetlands within the current CFA by the 2050 and 2080 future timeframe projections, respectively. The area impacted (and therefore potentially lost to) by SLR will include 14 of the 48 (29 percent) currently active colony sites in the 2050 projection, and 15 of the 48 (31 percent) current colony sites in the 2080 projection. One of the current three large, persistent colonies (33 percent) will be impacted by (and potentially lost to) sea level rise in both future timeframe projections. Land conversion will increase from 25 percent to 32 and 39 percent of the current CFA under the 2050 and 2080 timeframe projections, respectively. Conservation efforts are maintained at least at current levels

under Scenario 1, making the future condition in terms of conservation under Scenario 1 similar to that under Scenario 2 and better than that under Scenario 3.

Under Scenarios 2 and 3, SLR is projected to result in losses of 11 and 13 percent of wetlands within the current CFA by 2050 and 2080, respectively. Of the 48 currently active colony sites, 15 (31 percent) and 16 (33 percent) are projected to be impacted by (and potentially lost to) SLR by 2050 and 2080, respectively. One of the current three large, persistent colonies will be impacted by (and potentially lost to) sea level rise in both future timeframe projections. Land conversion in the current CFA will increase from 25 percent to 32 percent and 39 percent by 2050 and 2080, respectively. Conservation efforts are maintained under Scenario 2 and reduced under Scenario 3. In the Central Breeding Region, conservation efforts under Scenario 2 would partially mitigate negative influence factors, resulting in a slightly better future condition in terms of conservation and regulatory mechanisms under Scenario 2 when compared with Scenario 3.

The current demographic condition of MODERATE-LOW in the Central Breeding Region is used as a proxy for the current CFA habitat condition. In Scenario 1, the current condition of the Breeding Region declines one full category, resulting in the overall current CFA habitat condition for the Central Breeding Region to decline to a LOW-VERY LOW condition in 2050 and 2080 (Table 41). Under Scenarios 2 and 3, the current condition of the Breeding Region declines 1.5 categories in the 2050 and 2080 timeframes, making the overall current CFA habitat condition for the Central Breeding Region decline to VERY LOW condition in 2050 and 2080 (Table 41).

Table 41. The Central Breeding Region: Overall future condition (at 2050 and 2080, under Scenarios 1, 2, and 3 (Sweet et al. 2022)) of habitat within the current footprint of the wood stork core foraging area (CFA).

	2050	2080
Scenario 1 Current CFA Condition	LOW-VERY LOW	LOW-VERY LOW
Scenario 2 Current CFA Condition	VERY LOW	VERY LOW
Scenario 3 Current CFA Condition	VERY LOW	VERY LOW

The Central Breeding Region's Scenarios 1-3 project a LOW-VERY LOW to VERY LOW condition for current CFA habitat in 2050 and 2080, with a reduction in suitable habitat within the current footprint of the CFA due to sea level rise and development (Table 41). However, this projection does not account for suitable habitat available outside the current CFA, how wood storks respond to the changing habitat conditions, or that a portion of the population may pioneer new colony sites and foraging habitats within the currently occupied Central Breeding Region or into new areas that provide habitat to support wood stork reproduction.

6.6.3 Northwest Breeding Region

Currently, there are 1,286,773 acres of wetlands within the Northwest Breeding Region current CFA that supports 30 colonies, of which one is designated a large, persistent colony. The overall future habitat condition is measured by changes related to development, to SLR (Sweet et al.

2022) impacts to the current CFA, current CFA wetlands, current nesting colony locations, and the level of conservation implementation (Table 42 and 43, Figure 36).

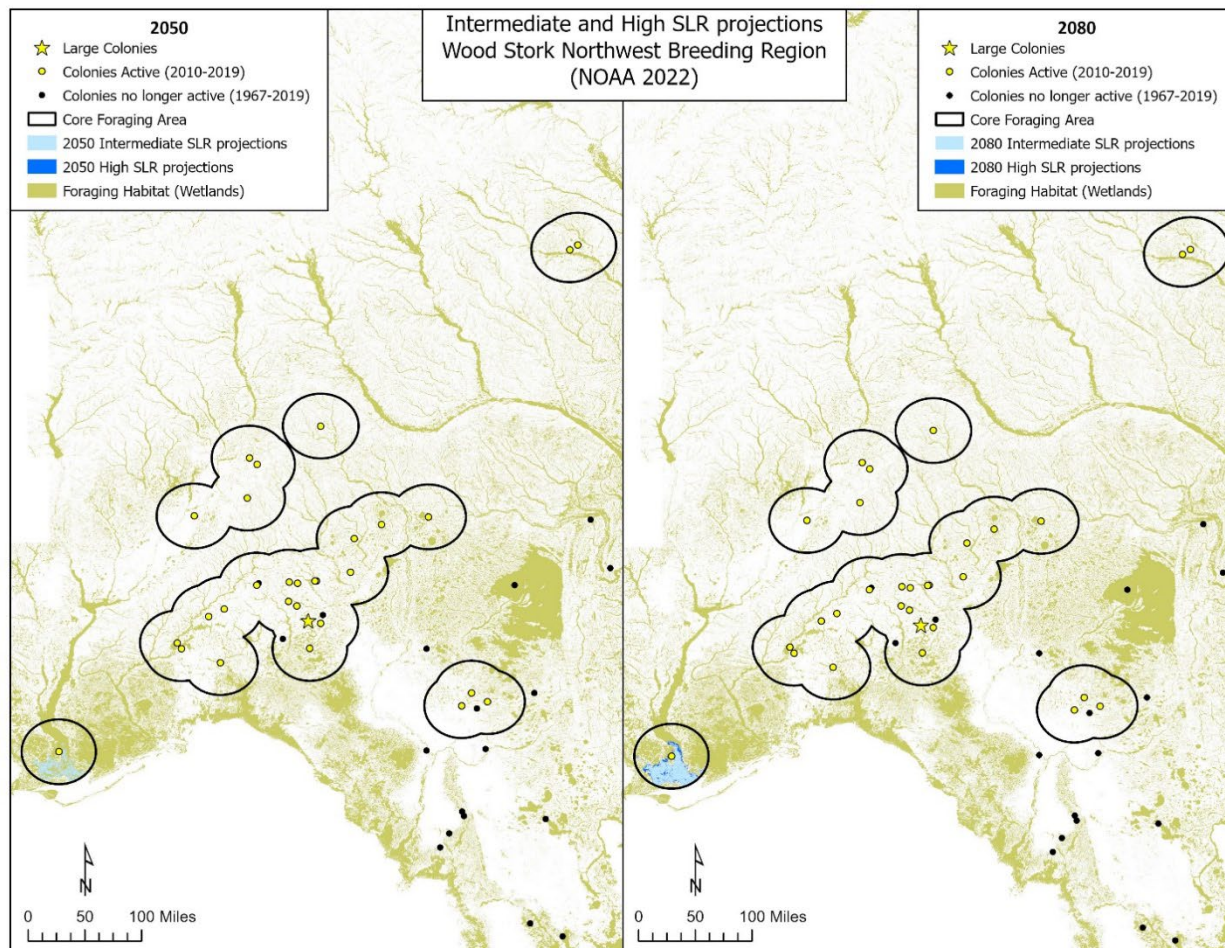


Figure 36. Map of Wood Stork Northwest Breeding Region with colony locations, current CFA buffer of 20km with Intermediate and High SLR projections at 2050 (left panel) and Intermediate and High SLR projections at 2080 (right panel).

Table 42. Wood Stork Northwest Breeding Region current Core Foraging Area (CFA) measures of current CFA wetlands, development, nesting colonies, changes due to sea level rise (Sweet et al. 2022).

Northwest Breeding Region			
SLR Projections Impacts to Current CFA	CFA Acres	Percent Remaining	Habitat Condition
2020 Current CFA	5,306,878	100	current
2050 Intermediate	5,261,469	99	high
2080 Intermediate	5,228,389	99	high
2050 High	5,261,469	99	high
2080 High	5,207,100	98	high
SLR Projections Impacts to Current CFA Wetlands	CFA Wetland Acres	Percent Remaining	Habitat Condition

2020 Current CFA Wetlands	1,286,773	100	current
2050 Intermediate	1,243,924	97	high
2080 Intermediate	1,211,248	94	high
2050 High	1,243,924	97	high
2080 High	1,191,879	93	high
Current CFA Development Projections	CFA Developed Acres	Percent Developed	Habitat Condition
SLEUTH 2020	397,523	8	current
SLEUTH 2050	793,629	15	moderate
SLEUTH 2080	1,175,536	22	moderate
SLR Projections Impacts to CFA Nesting Colonies	CFA Colonies	Percent Remaining	Habitat Condition
2020 Colonies	30	100	current
2050 Intermediate	30	100	high
2080 Intermediate	30	100	high
2050 High	30	100	high
2080 High	30	100	high
SLR Projections Impacts to CFA L. Persistent Colonies	CFA Large Persistent Colonies	Percent Remaining	Habitat Condition
2020 Large Persistent Colonies	1	100	current
2050 Intermediate	1	100	high
2080 Intermediate	1	100	high
2050 High	1	100	high
2080 High	1	100	high
Conservation Implementation			Conservation Condition
2050 and 2080 Scenario 1			high
2050 and 2080 Scenario 2			moderate
2050 and 2080 Scenario 3			low

Table 43. Northwest Breeding Region future Core Foraging Area (CFA) habitat conditions in 2050 and 2080 for Scenarios 1, 2, and 3.

	Scenario 1		Scenario 2		Scenario 3	
NORTHWEST	2050	2080	2050	2080	2050	2080
Current CFA	H	H	H	H	H	H
Wetlands	H	H	H	H	H	H
Colonies	H	H	H	H	H	H
L.P. Colonies	H	H	H	H	H	H
Development	M	M	M	M	M	M
Conservation	H	H	M	M	L	L
Average	H	H	H-M	H-M	H-M	H-M

Resiliency Future Condition Summary

The current resiliency condition for the Northwest Breeding Region is MODERATE (section 4.5) and is measured by demographics including population size, population trend, the number of large persistent colonies, and productivity. In this future condition analysis, we use the current condition of a Breeding Region as a proxy for the current condition of habitat, and thus as the baseline of where this analysis of future condition begins. The future condition is measured by changes to the current CFA habitat, development and sea level rise impacts to the current CFA wetlands and current nesting colony locations including large persistent nesting colonies, and also conservation implementation levels projected in two future time frames (2050 and 2080) and under the three scenarios.

Temperature and precipitation increases are projected for the Northwest Breeding Region. An increase in evaporative deficit can lead to drought conditions and will impact wetland habitats and foraging resources. The evaporative deficit is projected to increase to similar levels under RCP 8.5 and RCP 4.5 in the Northwest Breeding Region. Projected drought and stronger hurricanes will directly impact the Northwest Breeding Region's wetlands and individual colony sites. A change in evaporative deficit could affect nesting both negatively and positively and overall will contribute to the variability in annual nesting success, but as such could not be modeled accurately and is not included in the future condition calculation. Downscaled climate models for the Northwest Breeding Region should be assessed to predict localized impacts and develop future management options to support wood stork breeding ecology in this region.

Under Scenario 1, SLR is projected to impact three and six percent of wetlands within the current CFA by 2050 and 2080, respectively. The area impacted by SLR will not include any of the 30 currently active colony sites in either future timeframe projection. The one currently active large, persistent colony in this region will not be impacted by SLR in either future timeframe projection. Land conversion will increase from eight percent to 15 and 22 percent of the current CFA under the 2050 and 2080 timeframe projections, respectively. Conservation efforts are at least at current levels under Scenario 1, making the future outlook in terms of conservation and regulatory mechanisms under Scenario 1 similar to that under Scenario 2, and better than that under Scenario 3.

Under Scenarios 2 and 3, SLR is projected to result in the loss of three and seven percent of wetlands within the current CFA in the 2050 and 2080 time projections. Of the 30 currently active colony sites, none are projected to be impacted by SLR in either future timeframe. The one currently active large, persistent colony will not be impacted by SLR in either future timeframe projection. Land conversion in the current CFA will increase from eight percent to 15 percent and 22 percent by 2050 and 2080, respectively; though suitable habitat is widely available, and it does not appear that habitat is a limiting factor for wood stork resiliency. Conservation efforts are maintained at least at current levels under Scenario 1 and Scenario 2, and reduced under Scenario 3. However, in this breeding region conservation efforts would not likely counteract the other negative influence factors considered (e.g., habitat loss within the current CFA due to sea level rise and development trends), and therefore are not likely to have a significant influence over the difference in overall future condition between Scenarios 2 and 3 in the Northwest Breeding Region.

The current demographic condition of MODERATE in the Northwest Breeding Region is used as a proxy for current CFA habitat condition. In Scenario 1, the current condition of the Breeding Region remains High in 2050 and 2080, so that the projection of overall CFA habitat condition for the Northwest Breeding Region remains MODERATE in 2050 and 2080 (Table 44). Under Scenario 2 and 3, the current condition of the Breeding Region declines a half category in the 2050 and 2080 timeframes, and the overall CFA habitat condition for the Northwest Breeding Region declines to MODERATE-LOW condition in 2050 and in 2080 (Table 44).

Table 44. The Northwest Breeding Region overall future condition (at 2050 and 2080, under Scenarios 1, 2, and 3 (Sweet et al. 2022)) of habitat within the current footprint of the wood stork core foraging area (CFA).

	2050	2080
Scenario 1 Current CFA Condition	MODERATE	MODERATE
Scenario 2 Current CFA Condition	MODERATE-LOW	MODERATE-LOW
Scenario 3 Current CFA Condition	MODERATE-LOW	MODERATE-LOW

The Northwest Breeding Region’s Scenarios 1-3 project a MODERATE to MODERATE-LOW condition for current CFA habitat in 2050 and 2080, with a reduction in suitable habitat within the current footprint of the CFA due to sea level rise and development (Table 44). However, this projection does not account for suitable habitat available outside the current CFA, how wood storks respond to the changing habitat conditions, or that a portion of the population may pioneer new colony sites and foraging habitats within the currently occupied Northwest Breeding Region and into new areas that provide habitat to support wood stork reproduction.

6.6.4 Northeast Breeding Region

Currently, there are 3,607,715 acres of wetlands within the Northeast Breeding Region current CFA that supports 76 colonies, of which 6 are designated large, persistent colonies. The overall future habitat condition is measured by changes related to development, to SLR impacts to the current CFA, wetlands, current nesting colony locations, and the level of conservation implementation (Table 45 and 46, and Figure 37).

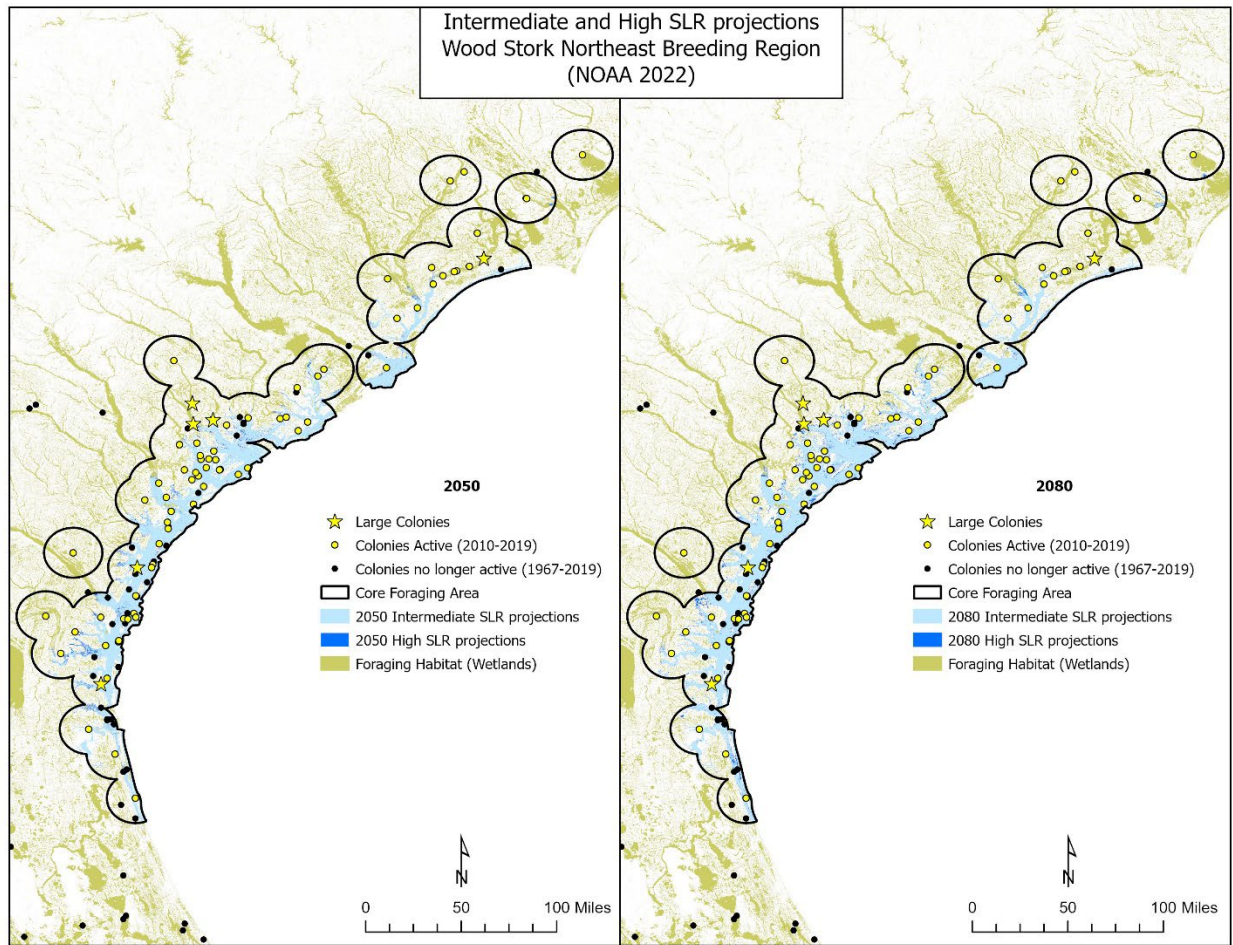


Figure 37. Map of Wood Stork Northeast Breeding Region with colony locations, current CFA buffer of 20km with Intermediate and High SLR projections at 2050 (left panel) and Intermediate and High SLR projections at 2080 (right panel).

Table 45. Wood Stork Northeast Breeding Region current Core Foraging Area (CFA), measures of current CFA wetlands, development, nesting colonies, and changes due to sea level rise (Sweet et al. 2022).

Northeast Breeding Region			
SLR Projections Impacts to Current CFA	CFA Acres	Percent Remaining	Habitat Condition
2020 Current CFA	9,204,711	100	current
2050 Intermediate	7,414,773	81	moderate
2080 Intermediate	7,139,703	78	moderate
2050 High	7,260,621	79	moderate
2080 High	6,888,413	75	moderate
SLR Projections Impacts to Current CFA Wetlands	CFA Wetland Acres	Percent Remaining	Habitat Condition
2020 Current CFA Wetlands	3,607,715	100	current
2050 Intermediate	2,452,386	68	low
2080 Intermediate	2,262,323	63	low
2050 High	2,328,098	65	low
2080 High	2,156,723	60	low
Current CFA Development Projections	CFA Developed Acres	Percent Developed	Habitat Condition
SLEUTH 2020	1,034,357	11	current
SLEUTH 2050	1,484,016	16	moderate
SLEUTH 2080	1,894,088	21	moderate
SLR Projections Impacts to Current CFA Nesting Colonies	CFA Colonies	Percent Remaining	Habitat Condition
2020 Colonies	76	100	current
2050 Intermediate	74	97	high
2080 Intermediate	65	86	moderate
2050 High	72	95	high
2080 High	49	64	low
SLR Projections Impacts to Current CFA Large Persistent Colonies	CFA Large Persistent Colonies	Percent Remaining	Habitat Condition
2020 Large Persistent Colonies	6	100	current
2050 Intermediate	6	100	high
2080 Intermediate	6	100	high
2050 High	6	100	high
2080 High	6	100	high
Conservation Implementation			Conservation Condition
2050 and 2080 Scenario 1			high

2050 and 2080 Scenario 2			moderate
2050 and 2080 Scenario 3			low

Table 46. Northeast Breeding Region future Core Foraging Area (CFA) habitat conditions in 2050 and 2080 under Scenarios 1, 2, and 3 (Sweet et al. 2022).

	Scenario 1		Scenario 2		Scenario 3	
	2050	2080	2050	2080	2050	2080
NORTHEAST						
Current CFA	M	M	M	M	M	M
Wetlands	L	L	L	L	L	L
Colonies	H	M	H	L	H	L
L.P. Colonies	H	H	H	H	H	H
Development	M	M	M	M	M	M
Conservation	H	H	M	M	L	L
Average	H-M	M	M	M	M	M-L

Resiliency Future Condition Summary

The current resiliency condition for the Northeast Breeding Region is HIGH (section 4.5) and is measured by demographics including population size, population trend, the number of large persistent colonies, and productivity. In this future condition analysis, we use the current condition of a Breeding Region as a proxy for the current condition of habitat, and thus the baseline of where this analysis of future condition begins. The future condition is measured by changes to the current CFA habitat, development and sea level rise impacts to the current CFA wetlands and current nesting colony locations including large persistent nesting colonies, and also conservation implementation levels projected in two future timeframes (2050 and 2080) and under the three scenarios.

Temperature and precipitation increases are projected for the Northeast Breeding Region. An increase in evaporative deficit can lead to drought conditions and will impact wetland habitats and foraging resources. The evaporative deficit is projected to increase and be the same under RCP 8.5 compared to RCP 4.5 in the Northeast Breeding Region. Projected drought and stronger hurricanes will directly impact the Northeast Breeding Region's wetlands and individual colony sites. A change in evaporative deficit could affect nesting both negatively and positively and overall will contribute to the variability in annual nesting success, but as such could not be modeled accurately and is not included in the future condition calculation. Downscaled climate models for the Northeast Breeding Region should be assessed to predict localized impacts and develop future management options to support wood stork breeding ecology in this region.

Under Scenario 1, SLR is projected to impact 32 and 37 percent of the wetlands within the current footprint of the current CFA by 2050 and 2080, respectively; the area impacted by (and potentially lost to) SLR will include two of the 76 (3 percent) currently active colony sites in the 2050 projection, and 11 of the 76 (14 percent) current colony sites in the 2080 projection. None of the currently active large, persistent colonies in this region will be impacted by SLR in either future timeframe projection. Land conversion will increase from 11 percent to 16 and 21 percent of the current CFA under the 2050 and 2080 timeframe projections, respectively. Conservation

efforts are maintained at least at current levels under Scenario 1, making the future outlook in terms of conservation and regulatory mechanisms under Scenario 1 similar to that under Scenario 2 and better than that under Scenario 3.

Under Scenarios 2 and 3, SLR is projected to result in loss of 35 and 40 percent of wetlands within the current footprint of the CFA by 2050 and 2080, respectively. The area impacted by (and therefore potentially lost to) SLR will include four of the 76 (5 percent) currently active colony sites in the 2050 projection, and 27 of the 76 (36 percent) current colony sites in the 2080 projection. None of the currently active large, persistent colonies will be impacted by SLR by 2050 or 2080. Land conversion in the current CFA will increase from 11 percent to 16 percent and 21 percent by 2050 and 2080, respectively. Conservation efforts are maintained under Scenario 2 and reduced under Scenario 3. However, in this breeding region, the conservation efforts under Scenario 2 would not likely counteract the other negative influence factors considered (e.g., habitat loss within the current CFA due to SLR and development trends), and therefore are not likely to have a significant influence over the difference in overall future condition between Scenarios 2 and 3 in the Northeast Breeding Region.

The current demographic condition of HIGH in the Northeast Breeding Region is used as a proxy for current CFA habitat condition. In Scenario 1, the current condition of the Breeding Region declines a half category in 2050, and a full category in 2080, resulting in the overall CFA habitat condition for the Northeast Breeding Region being HIGH-MODERATE to MODERATE in 2050 and 2080, respectively (Table 47). Under Scenario 2, the current condition of the Breeding Region declines a full category in the 30-year and 60-year time frame, and thus the overall CFA habitat condition is MODERATE (Table 47). Under Scenario 3, the current condition of the Breeding Region declines a full category under the 30-year projection making the overall CFA habitat condition MODERATE, and under the 60-year projection the current condition drops by 1.5 categories making the overall CFA habitat condition MODERATE-LOW in 2080 (Table 47).

Table 47. The Northeast Breeding Region overall future condition (at 2050 and 2080 under Scenarios 1, 2, and 3 (Sweet et al. 2022)) of habitat within the current footprint of the wood stork core foraging area (CFA).

	2050	2080
Scenario 1 Current CFA Condition	HIGH-MODERATE	MODERATE
Scenario 2 Current CFA Condition	MODERATE	MODERATE
Scenario 3 Current CFA Condition	MODERATE	MODERATE-LOW

The Northeast Breeding Region’s Scenarios 1–3 project a HIGH-MODERATE to MODERATE-LOW condition for current CFA habitat in 2050 and 2080, with a reduction in suitable habitat within the current footprint of the CFA due to sea level rise and development (Table 47). However, this projection does not account for suitable habitat outside of the current CFA, how wood storks respond to the changing habitat conditions, or that a portion of the population may

pioneer new colony sites and foraging habitats within the currently occupied Northeast Breeding Region or into new areas that provide habitat to support wood stork reproduction.

6.6.5 U.S. Breeding Population Range

Currently, the total area within the U.S. Breeding Population's current CFA is 30,359,161 acres, which includes 11,037,517 acres of wetlands (36% of the current CFA), 4,845,165 developed acres (16% of the current CFA), and 190 colonies of which 15 are designated as large-persistent colonies (Figure 30).

In this future analysis, we use the current condition of a Breeding Region as a proxy for the current condition of habitat and thus the baseline of where this analysis of CFA future condition begins. The future CFA habitat condition for the U.S. Breeding Population is measured by changes to the current footprint of the CFA as it relates to development and to sea level rise impacts to the CFA wetlands and current nesting colony locations, and to conservation implementation levels projected in two future time frames (2050 and 2080) and under the three scenarios (Tables 48 and 49). Future Scenario 1 projects current trends will continue, with an Intermediate level of sea level rise, and conservation implementation will continue at a High level. Scenario 2 projects a High level of sea level rise, continued development, and conservation efforts at current trends levels. Scenario 3 is the same as Scenario 2 in 2050 and 2080, except that conservation efforts are reduced, as this scenario assumes that conservation, management, restoration, and acquisitions, are significantly constrained due to issues such as reduced budgets, funding, or other conservation priorities.

Table 48. Wood Stork U.S. Breeding Population current core foraging area (CFA), and measures of current CFA wetlands, projected development, nesting colonies, and changes due to sea level rise (Sweet et al. 2022).

U.S. Breeding Population Range-wide			
SLR Projections Impacts to current CFA	CFA Acres	Percent Remaining	Habitat Condition
2020 Current CFA	30,359,161	100	current
2050 Intermediate	26,705,577	89	moderate
2080 Intermediate	26,185,269	86	moderate
2050 High	26,339,267	87	moderate
2080 High	25,603,446	84	moderate
SLR Projections Impacts to current CFA Wetlands	CFA Wetland Acres	Percent Remaining	Habitat Condition
2020 Current CFA Wetlands	11,037,517	100	current
2050 Intermediate	8,991,164	82	moderate
2080 Intermediate	8,570,375	78	moderate
2050 High	8,668,826	79	moderate
2080 High	8,227,273	75	moderate
Current CFA Development Projections	CFA Developed Acres	Percent Developed	Habitat Condition
SLEUTH 2020	4,845,165	16	current
SLEUTH 2050	6,726,896	22	moderate
SLEUTH 2080	8,596,051	28	moderate
SLR Projections Impacts to current CFA Nesting Colonies	CFA Colonies	Percent Remaining	Habitat Condition
2020 Colonies	190	100	current
2050 Intermediate	162	85	moderate
2080 Intermediate	152	80	moderate
2050 High	159	84	moderate
2080 High	134	71	moderate
SLR Projections Impacts to current CFA Large Persistent Colonies	CFA Large Persistent Colonies	Percent Remaining	Habitat Condition
2020 Large Persistent Colonies	15	100	current
2050 Intermediate	12	80	moderate
2080 Intermediate	12	80	moderate
2050 High	12	80	moderate
2080 High	12	80	moderate
Conservation Implementation			Conservation Condition
2050 and 2080 Scenario 1			high
2050 and 2080 Scenario 2			moderate
2050 and 2080 Scenario 3			low

Table 49. Future habitat conditions within the current footprint of the U.S. Breeding Population Core Foraging Area (CFA) in 2050 and 2080 for Scenarios 1, 2, and 3 (Sweet et al. 2022).

	Scenario 1		Scenario 2		Scenario 3	
	2050	2080	2050	2080	2050	2080
RANGE-WIDE						
Current CFA	M	M	M	M	M	M
Wetlands	M	M	M	M	M	M
Colonies	M	M	M	M	M	M
L.P. Colonies	M	M	M	M	M	M
Development	M	M	M	M	M	M
Conservation	H	H	M	M	L	L
Average	M	M	M	M	M	M

The current demographic condition of HIGH-MODERATE in the U.S. Breeding Population is used as a proxy of current habitat condition for the future conditions analysis. Overall, when considering all factors analyzed, the future condition of the habitat that makes up the current footprint of the CFA in the range-wide U.S. Breeding Population is projected to be to Moderate in both the 30- and 60-year projections under all three future scenarios (Tables 50 and 51).

Table 50. The U.S. Breeding Population Current CFA Overall Future Condition 2050 and 2080 under Scenarios 1, 2, and 3 based on future sea level rise impacts to currently occupied CFA habitat (Sweet et al. 2022).

	2050	2080
Scenario 1 Current CFA Condition	MODERATE	MODERATE
Scenario 2 Current CFA Condition	MODERATE	MODERATE
Scenario 3 Current CFA Condition	MODERATE	MODERATE

Table 51. The Northeast, Northwest, Central, South Breeding Regions and the U.S. Breeding Population Conditions (Demographic - Habitat) in 2020, and projected future condition of the current CFA in 2050 and 2080 (Sweet et al. 2022). It is noted that this analysis predicts how the current footprint of the CFA will change due to sea level rise and development; however, new colony sites and habitat outside of the current footprint of the CFA which becomes occupied by wood storks during future expansion is not accounted for in this analysis.

	Scenario 1		Scenario 2		Scenario 3	
Breeding Region	2050	2080	2050	2080	2050	2080
Northeast	H-M	M	M	M	M	M-L
Northwest	H	H	H-M	H-M	H-M	H-M
Central	M	M	M-L	M-L	M-L	M-L
South	M	M	M-L	M-L	M-L	M-L
U.S. Population	M	M	M	M	M	M

While we project in our future condition analysis based on the current CFA that sea level rise will result in the loss of some occupied habitat within the current CFA, as described above, a substantial amount of suitable habitat remains in the CFA (see chapter 6.2). Further, we estimate that even under the highest sea level rise projections there will remain ample occupied, suitable breeding and foraging habitat outside the current CFA that will be available for wood storks to use (Figure 38). Thus, habitat loss due to sea level rise is not likely to limit the resiliency of wood storks in the foreseeable future (see chapter 6.2).

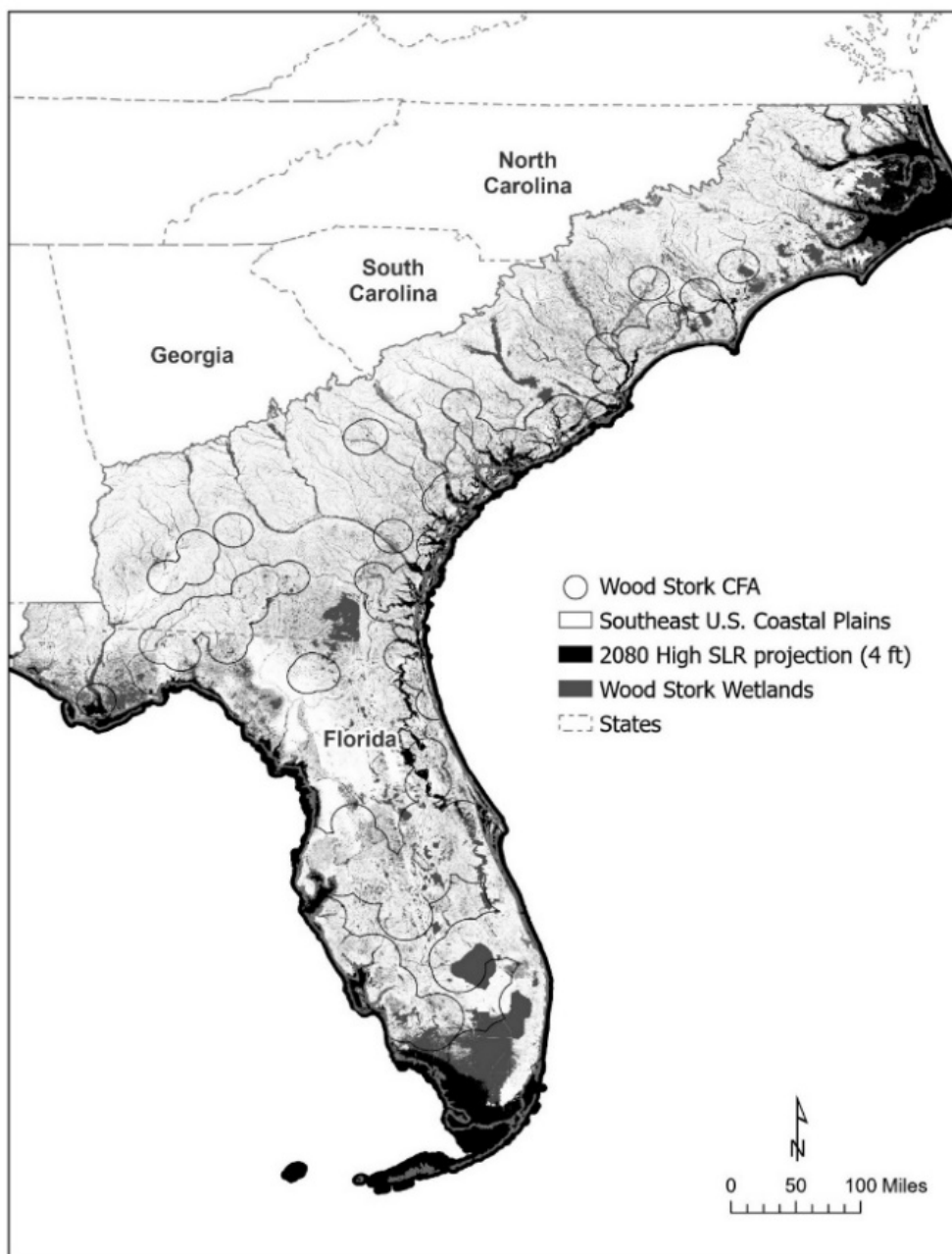


Figure 38. Map of U.S. Population of Wood Storks Breeding Regions with wetlands, current nesting colony locations, current CFA buffer of 20 km, and High SLR projection at 2050 (Sweet et al. 2022).

Further, the ecological record shows that wood storks respond to environmental change. The wood stork's nesting colony site record shows that they will abandon a colony site when it is no longer suitable, or when other suitable potential colony sites provide more advantageous conditions than do currently occupied sites (see chapter 2.7.1). Wood storks may shift their habitat use in response to future inundation of coastal colonies from sea level rise; therefore, the projected loss of existing colony sites in the following future condition discussion may not result

in an equivalent reduction in the number of actual colony sites in the future, or in a reduction in the number of breeding pairs present range-wide, but rather a shift in location of individuals from current to new colony sites in some cases. We expect that this phenomenon will continue to occur and that the wood stork population and breeding range will continue to grow, shift, and expand into the available suitable habitat that is currently occupied by wood storks but outside the current footprint of the CFA.

6.7 Synthesis

U.S. Breeding Population Resiliency Future Condition

The U.S. breeding population of the wood stork has expanded its range from the historical south Florida stronghold northward into Georgia and the Carolinas in the 1980s and 1990s in response to declining environmental conditions. We expect that the habitat and behavioral plasticity characteristics of this species will continue to allow it to respond to a dynamic and constantly changing environment into the future despite changes that occur within the current footprint of the CFA. Habitat conditions within the current footprint of the CFA are expected to be moderate in the future, with some loss of habitat due primarily to development and sea level rise. However, even given extreme scenarios of climate change, adequate suitable habitat for the wood stork will be available within the current CFA, and an abundance of suitable habitat will be available in currently occupied habitat outside the current CFA, indicating sustained resiliency of wood stork populations into the foreseeable future.

U.S. Breeding Population Redundancy Future Condition

If current trends continue it would be expected that the wood stork's range will continue to expand, increasing redundancy. Overall, the future scenarios project either the continuation of current conditions or some deteriorated conditions within each of the four Breeding Regions. We project that overall wood stork breeding conditions will be adequate (i.e., resource needs will be met), and the Breeding Regions will be maintained despite varying degrees of potential habitat loss, conversion, or degradation, prolonged droughts, reduced reproductive success, and increased mortality in eggs and young. Thus, despite lowered resiliency in some regions given certain future scenarios under consideration, we expect that the wood stork will maintain its current level of redundancy in the U.S. DPS, (i.e., maintaining at least one large persistent nesting colony and several other colonies in each of the four Breeding Regions), with no major reduction in its overall range even with some habitat and colonies lost due to sea level rise, and no extirpation of any Breeding Regions. While local losses due to environmental, anthropogenic, or stochastic changes at currently occupied colony sites and foraging areas may continue to cause changes in habitat use as they have in the past, we expect that wood storks will likely continue the trend of range shift or expansion into existing or into new colonies sites to replace colonies that are impacted-lost or otherwise rendered unsuitable. As such, we expect the maintenance of all four existing breeding regions into the future, and therefore a degree of redundancy in the future which is comparable to that which exists today.

U.S. Breeding Population Representation Future Condition

No behavioral, genetic, morphological, or observable variations have been described within or among the breeding populations of wood storks in the U.S. DPS, or within the species range-

wide. However, current representation is thought to be high in the U.S. DPS due to its historically demonstrated ability to continuously respond to changing habitat conditions and maintain and increase abundance while expanding its range northward. Within this expanded range, the species has also exhibited the ability to employ different annual movement strategies. Annual nesting data suggests that some wood storks will shift within and between regions relative to environmental conditions. As a result, some individuals will use separate breeding- and non-breeding season ranges in response to changing resources (e.g., food availability), while others will remain “residential” (staying in one range for both seasons), and still others employ both strategies, presumably in response to resource availability. This behavioral flexibility suggests that the species has the ability to respond accordingly and remain resilient despite changing conditions into the future. Other notable aspects of flexibility in this species are their use of natural and human made/influenced habitats, nesting in fresh and estuarine habitats, nesting in native and exotic vegetation, and foraging on native, exotic, and novel prey/forage. All of these characteristics indicate robust adaptive capacity, and therefore a high degree of representation.

The current breeding range, which extends across four states, is projected to maintain at least a moderate degree of resiliency into the future, and thus we expect that the wood stork will continue to be represented within the Southeast U.S. Coastal Plain within the current range of Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina. However, any decrease in future resiliency in populations could translate to a modest loss of representation (i.e., decreased resiliency may result in fewer individuals, which provide less opportunity for diversity). Regardless, this species has exhibited a proclivity to respond to historical habitat changes, so despite potential losses in resiliency within the four Breeding Regions and the associated implications for representation, we expect that representation will remain relatively high among breeding populations in each of the future scenarios we considered.

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