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MITIGATION FOR THE ENDANGERED WOOD STORK ON SAVANNAH RIVER SITE

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Abstract. A proposed change in facility operations at the U.S. Department of Energy's Savannah River Site in the early 1980s potentially threatened Wood Storks, a recently classified federally endangered species that foraged on that facility. The resulting interagency consultation was highly successful in that the impacted habitat was "replaced" by an approximately equal amount of foraging impoundments, managed specifically for this species, that were used extensively by the birds. Ecological studies conducted in support of this mitigation strategy provided invaluable information addressing many of the "tasks" listed in the Wood Stork recovery plan as important to the recovery of the species.

Key Words: Department of Energy, endangered species, foraging habitat, mitigation, *Mycteria americana,* Wood Stork, Savannah River Site.

The Wood Stork (*Mycteria americana*) is a large wading bird that nests and forages in wetland habitats. In 1984, the species was listed as federally endangered as a result of population declines believed to be related to the loss of foraging habitat (USFWS 1986). Unlike many wading birds that feed visually, Wood Storks forage by tactilocation, requiring shallow wetlands with high densities of their aquatic prey to forage efficiently (Kahl 1964). High densities of prey in shallow freshwater wetlands are typically present as a result of decreasing water levels due to seasonal variation in rainfall and evapotranspiration patterns (Coulter 1988). As wetland acreages have declined in the 1900s, particularly in southern Florida, so have populations of Wood Storks.

Concerns increased for this species as population estimates declined by approximately 60–80% through the mid-1900s (Ogden and Patty 1981, Kushlan and Frohring 1986). Concurrent with the population decline, the "center" of the population's breeding range shifted northward (Ogden et al. 1987), with breeding first documented in both Georgia and South Carolina in the 1970s and 1980s, respectively (Harris 1995, Murphy 1995).

The U.S. Department of Energy's (DOE) Savannah River Site (SRS) occupies approximately 78,000 ha of upper coastal plain/sandhill habitat in west-central South Carolina, and is bounded on its south-western border by the Savannah River. The primary function of the SRS was to operate nuclear reactors to produce plutonium and tritium to meet national defense needs for nuclear weapons. Since the mid-1950s water used to cool these reactors has been discharged into several streams feeding into the Savannah River. The discharged cooling waters altered many downstream aquatic habitats due to high water temperatures and fluctuating flow rates, including the creation of deltas where these streams entered the swamp system associated with the river (Savannah River Swamp System, SRSS). The L-reactor, which had discharged cooling water effluent into Steel Creek since 1953, was placed on standby status in 1968. Due to an increased need for nuclear materials, in 1980 the DOE decided to initiate the process of restarting the L-reactor. This process included the evaluation of potential environmental impacts on the Steel Creek delta, downstream of the L-reactor.

Wood Storks have been observed in the central Savannah River drainage, which includes the SRS, since the early 1900s. Murphey (1937) reported that although storks did not breed in this area, sightings of large, late summer flocks of young-of-the-year birds were frequent. Norris (1963) also documented seeing storks on the Savannah River "Plant" (now the SRS) in the mid-1950s and early 1960s. Research concerning the potential impacts of restarting the L-reactor, which would increase water flow into the Steel Creek delta, included an assessment of restart on Wood Storks, then a candidate species of concern being assessed for federal protection as an endangered species. This research suggested that effluents from the L-reactor would preclude the use of this habitat by feeding Wood Storks and that storks inhabiting the Birdsville Colony (approximately 45 km to the south) likely would be negatively impacted by this habitat loss (Smith et al. 1982). All impacts suggested in this study were based purely on increased water levels, and did not consider possible contaminants in the effluent as a potential threat.

After the Wood Stork was classified as an endangered species in 1984 (Bentzein 1984), the DOE entered into a Section 7 consultation (Endangered Species Act) with U.S. Fish and Wildlife Service (USFWS) concerning potential im-

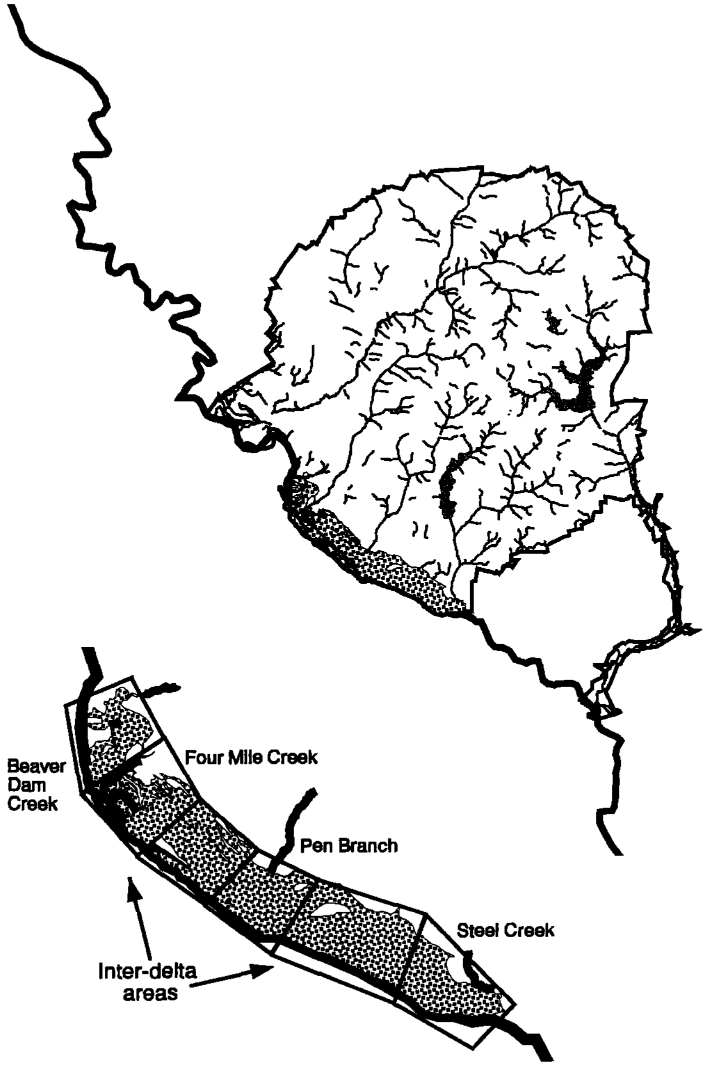

FIGURE 1. The Savannah River Site, including the surveyed areas of the Savannah River Swamp System (SRSS).

pacts on storks resulting from the L-reactor restart. The USFWS agreed with the determination that the restart could impact negatively the endangered Wood Storks breeding at the nearby Birdsville colony. Due to this determination, the DOE entered an Interagency Agreement with USFWS to mitigate the lost foraging habitat by creating impoundments (the Kathwood foraging ponds; see description below) managed as Wood Stork foraging habitat (McCort and Coulter 1991). Also, the DOE initiated a program to monitor the following: the SRSS to determine patterns of stork use; the breeding biology and foraging ecology of the Birdsville Colony; and Wood Stork use of the Kathwood foraging ponds. Since this initial consultation, the research program also has addressed additional potential impacts to this species resulting from SRS operations, including the drawdown of the Par Pond reservoir.

INITIATION OF WOOD STORK RESEARCH ON SRS

Monitoring to document Wood Stork use of the SRS initially focused on the SRSS, since the proposed restart would presumably impact the Steel Creek delta within that system (Fig. 1). The entire SRSS was monitored by aerial surveys of the open wetlands and drainages within the forested-palustrine system from 1983

TABLE 1. WOOD STORK USE OF THE SAVANNAH RIVER SWAMP SYSTEM BY YEAR AND AREA, 1983-1996[a]

Year	N[b]	Steel creek delta	Inter-delta area	Pen branch delta	Inter-delta area	Four mile creek delta	Beaver dam creek	Average number storks observed
1983	35	87	0	6	0	0	170	7.51
1984	89	95	0	21	102	46	106	4.16
1985	120	9	0	9	236	346	0	5.00
1986	115	81	0	0	0	94	15	1.65
1987	123	139	0	0	0	11	0	1.22
1988	143	6	1	0	0	0	0	0.05
1989	99	9	1	5	6	6	2	0.29
1990	12	1	0	0	0	12	0	1.08
1991	34	1	16	1	17	36	7	2.29
1992	41	9	79	70	10	0	4	4.20
1993	40	22	1	16	68	55	6	4.20
1994	29	21	2	1	0	5	1	1.03
1995	26	5	7	0	1	0	0	0.50
1996	16	4	0	0	0	1	0	0.31
Totals	880	480	100	129	439	611	311	33.50
Ave. Storks/ Area/Yr		34.29	7.14	9.21	31.36	43.64	22.21	
Ave. Storks/ Area/Survey		0.55	0.11	0.15	0.50	0.69	0.35	

[a] Numbers represent the total storks counted during that year.
[b] N = number of aerial surveys.

through 1996. Six areas within the SRS were delineated: Beaver Dam Creek, Fourmile Creek delta, Pen Branch delta, Steel Creek delta, and the two inter-delta sections of the SRSS (Fig. 1). Approximately 900 aerial surveys for storks have been flown since 1983, with 89–143 flown per year in 1984–1989 and 12–41 surveys flown per year in 1983 and 1990–1996 (Table 1).

Wood Stork use of the SRSS appeared to vary in relation to year, season, and area (of the SRSS). Annual averages suggest a general decline in stork use since the surveys were initiated (Table 1). These averages probably were influenced by the reduction in surveying effort in the last 5 years (1990–1996) of the project. Peaks of stork occurrence were observed in the SRSS from 1983–1985 and 1992–1993, and these peaks likely were associated with reactor operations. In 1983–84, testing of the L-reactor resulted in fluctuating water levels in the Steel Creek delta, presumably trapping fish in the delta areas and attracting storks in high numbers (Table 1; Fig. 2a). In 1985, C-reactor ceased operations, which resulted in lower water levels in the Four Mile delta and the inter-delta area to the east, also presumably trapping fish and attracting high numbers of storks (Fig. 2b). Finally, in 1992, K-reactor was tested for several weeks, which led to water level fluctuations in the Pen Branch delta. This area had received little stork use previously, but attracted storks during the reactor testing (Fig. 2c). Variation in stork use probably was also affected by (1) varying annual reproductive success rates of the stork colonies (in a "good" year there are more juveniles dispersing), and (2) the influence of rainfall patterns on the availability of "natural" foraging habitats. Also, as reactor operations (and water flows) were reduced, vegetative succession within the open areas of the SRSS probably resulted in a reduced amount of foraging area within this system.

Seasonal patterns were noted in regard to stork occurrence. The majority of stork observations occurred in the late summer months, as breeding activity at the nearby Birdsville colony was coming to a close (Fig. 3). These observations suggested that parent storks foraging for their nestlings rarely made trips to the SRSS to obtain prey, and that this wetland system was more important as a post-breeding/dispersal foraging area.

PAR POND DRAWDOWN

Par Pond is an 1,100 ha reservoir on the SRS that served as a cooling reservoir for thermal effluent from two nuclear reactors from 1960 to 1988. It was maintained at a constant water level from 1960 until July of 1991, when structural anomalies discovered in the reservoir dam resulted in the lowering of its water level by 6 m, reducing its volume and surface area by 50%

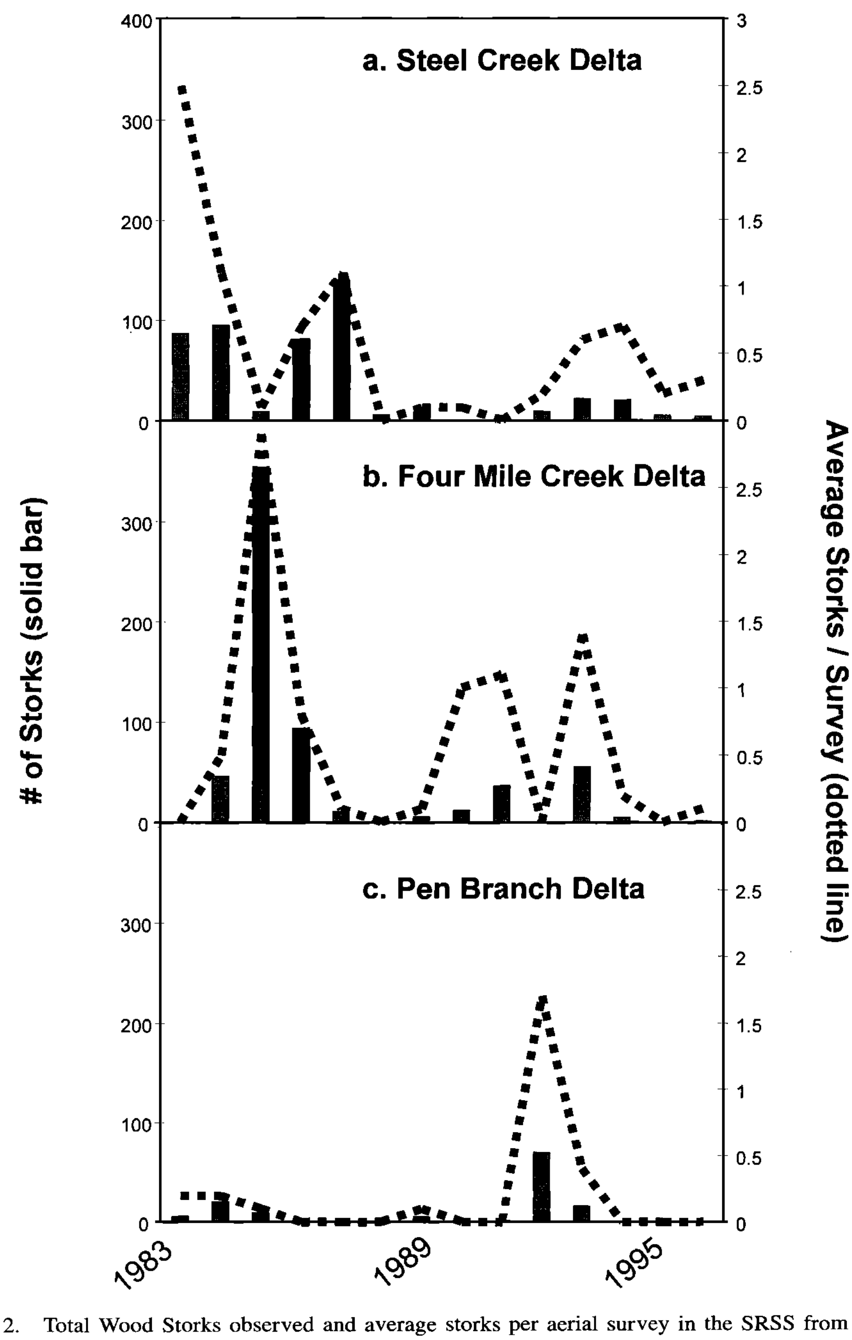

FIGURE 2. Total Wood Storks observed and average storks per aerial survey in the SRSS from 1983–1996. A. Steel Creek delta; B. Four Mile Creek delta; C. Pen Branch Delta.

and 65%, respectively. Wood Storks do not typically forage in lacustrine habitats; however, surveys were initiated to see if this large-scale drawdown would make shallow parts of the reservoir available for foraging storks and thus attract the birds to the site. The concern over stork use of this site was due to the presence and concentration of mercury and several radionuclides, particularly the gamma-emitting cesium 137, within this reservoir. Mercury concentrations in smaller stork prey-sized fish (Bryan et al. 1997) have been documented at levels higher than rec-

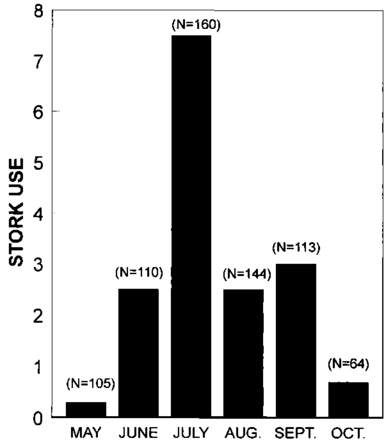

FIGURE 3. Seasonal use of the SRSS by Wood Storks, 1983–1996. Use equals the total number of storks observed during that month divided by the number of surveys (shown in parentheses).

ommended in the diet of sensitive avian species (0.1 μg Hg/g fresh weight; Eisler 1987). Aerial surveys (weekly) of this reservoir for Wood Storks were initiated in July of 1991 and have been maintained from March–October through 1996.

Seventeen aerial surveys were flown over the Par Pond reservoir in 1991. Wood Storks were observed consistently on the reservoir from late July through mid-October. An average of 26.1 ± 29.5 (SD) storks were observed on Par Pond per survey, with a maximum count of 85 storks on a single survey. Ground counts of the birds indicated the storks used the reservoir continuously during this period. Small, stork prey-sized fish, which typically inhabit the protective cover of the reservoir's well-established macrophyte bed, were exposed to stork predation when water levels dropped below the level of the protective macrophytes. Surveys in subsequent years (approximately 30 surveys per year, from March through October) have documented only one additional stork using this reservoir since that time, despite the continued low water level through 1994. Presumably, the lack of use in subsequent years was the result of either (1) the density of prey-sized fish not recovering from predation pressures of storks and other aquatic predators in 1991, or (2) that the reservoir in its second year of drawdown (and beyond) no longer looked conducive visually as a foraging habitat (exposed mudflats perhaps suggesting a recent drawdown and concentrated prey) to attract storks.

Another proposed action on the SRS that could potentially impact Wood Storks is a recent proposal to cease using the DOE's "river water system" to maintain water depths in both the Par Pond and L-Lake reservoirs (DOE 1996a). This cessation could result in the fluctuation of Par Pond water levels and would result in the complete draining of L-Lake, a 405 ha reservoir perched on the Steel Creek drainage, which would then return to its original streambed. Both reservoirs contain fish with high mercury levels and, if their water levels drop substantially, they both potentially could attract Wood Storks seeking foraging areas. We have monitored both sites for stork use since 1991, as well as the mercury concentrations in prey-sized fish, to provide information necessary to assess the potential risk, if any, of this proposed operation to the Wood Stork. Also, we monitor stork use and contaminant levels of prey in natural wetlands on the SRS, typically Carolina bays and other ephemeral wetlands with fish populations (Snodgrass et al. 1996), to provide information to DOE as custodian of the SRS and to allow comparisons to the impacted reservoir sites. Stork use of Carolina bays is linked to rainfall patterns and their effects on wetland hydroperiod, particularly when and if a drawdown in water level occurs.

CONTAMINANT STUDIES

In response to contaminant concerns for the Wood Stork on the SRS, we initiated studies addressing mercury intake by storks in colonies throughout the state of Georgia. First, prey fed to nestlings (and collected as regurgitant) were analyzed for mercury to determine the concentrations present in typical (and non-SRS) food. This study indicated that mercury was present in all prey fed to nestlings, often at levels (0.1 *ug* Hg/g fresh weight; Eisler 1987) which can affect sensitive avian species (Gariboldi et al. 1998). Freshwater prey species fed to stork nestlings throughout Georgia contained levels of mercury equal to or greater than levels in SRS prey-sized fish (Bryan et al. 1997). A study determining mercury concentrations present in nestling tissues (blood and feathers) in the same Georgia colonies is on-going.

BIRDSVILLE COLONY STUDIES

Studies were initiated in 1984 to address many baseline ecological and behavioral unknowns concerning Wood Storks nesting in the Birdsville colony (Jenkins County, GA), the nearest source of storks foraging on the SRS. These baselines were needed in order to judge the impacts of SRS operations and mitigation attempts on this colony. While these studies were initiated in response to and in support of the mitigation efforts, they also provided much-needed information regarding this species in an unstudied (i.e., northern) portion of their expanding range. This information included colony size fluctuation, reproductive success and breeding biology, foraging ecology, and habitat use.

The Birdsville Colony expanded from approximately 100 nests in 1984 to over 300 nests in 1993, then declined to about 250 nests in 1994 (Coulter and Bryan 1995a; A. L. Bryan, unpubl. data). This latter decline probably has resulted from the formation in 1993 of a satellite colony within 5 km of Birdsville in Chew Mill Pond (also Jenkins County, GA) and its subsequent expansion from 45 nests to 100 nests. Therefore, this area has supported a total of approximately 350 stork nests since 1993. Reproductive success for Birdsville storks is typically high (>2 fledged young per nest), although interannual differences suggest catastrophic nest losses related to differences in weather patterns in some years (Coulter and Bryan 1995a). Documented mortality factors included conspecific aggression (Bryan and Coulter 1991), raccoon predation, cold and/or severe weather, as well as the influence of prey availability (Coulter and Bryan 1993).

Observations of parent storks within the colony documented an average foraging trip duration (parent departing nest until it returns with food for young) of 4 hours (Bryan et al. 1995), suggesting a low likelihood of parent storks traveling as far as the SRS (45 km) to forage. Also, this program has placed leg bands on nestling storks since 1984. A number of these banded individuals have been observed back in the Birdsville colony each year, and a Birdsville stork banded as a nestling was observed nesting in the neighboring Chew Mill colony in 1995. Marked Birdsville storks have also been regularly observed in low numbers at the Kathwood mitigation ponds (see below). Banding operations also have allowed for the collection of nestling food habits data, which indicated that the Birdsville storks typically prey on fish, particularly sunfish (Centrarchidae), although other fish species common to ephemeral wetlands also are found in the diet (Depkin et al. 1992).

More than 250 Wood Storks were followed from the Birdsville colony to foraging sites to determine foraging habitats used. The average direct foraging site distance was 12.0 km from the colony (Bryan et al. 1995), and 86% of the foraging sites were within 20 km of the colony (Coulter and Bryan 1993). Although single storks were followed from Birdsville to the SRSS in 1983 (Meyers 1984) and 1984, less than 5% of the total number of sites were in the foraging range associated with the distance to the SRS (≥40 km). Seasonal patterns were observed, with storks tending to travel greater distances to forage in the latter half of the breeding season (Bryan and Coulter 1987). Storks or other wading birds were already present at 55% of the foraging sites visited by storks, but they were typically present in very low numbers. The foraging sites visited were highly variable in regard to habitat type (small farm ponds and ditches to forested wetlands), but typically had little to moderate vegetative cover (Coulter and Bryan 1993). This habitat data was incorporated into a foraging habitat mapping study utilizing satellite imagery, which documented the effects of weather patterns (primarily rainfall) on available foraging cover. Satellite imagery data suggested that the amount of foraging habitat could be reduced by as much as 47% in a dry (lower than average rainfall) year (Hodgson et al. 1998). Fish were present at the majority of these sites in varying densities (0.0 to 249 per m^2). Comparisons of fish abundance at foraging sites with nestling dietary studies indicated that sunfish occurrence in nestlings' regurgitations was disproportionately higher than their occurrence at foraging sites and that other species typically abundant at these sites, such as mosquitofish (*Gambusia holbrookii*), generally were not selected as prey (Depkin et al. 1992).

KATHWOOD LAKE MITIGATION PONDS

In order to "replace" the 16 ha of SRS foraging habitat (Steel Creek delta) presumed to be impacted by the restart of L-reactor, the DOE negotiated with the National Audubon Society for the right to lease and modify the drained Kathwood Lake on their Silverbluff Sanctuary adjacent to the SRS in Aiken County, South Carolina. This was approved and foraging impoundments were constructed in 1985 and 1986. The four resulting impoundments were part of a gravity-flow water system in which each impoundment could be raised or lowered independently (Coulter et al.1987, Coulter and Bryan 1995b). The impoundments were stocked with bluegill sunfish (*Lepomis macrochirus*) and brown bullhead (*Ameiurus natalis*), both documented stork prey (Depkin et al.1992) and thought to be compatible/non-competitive within this type of system. The ponds were maintained at full pool during the majority of the season and were lowered to a suitable depth for stork foraging, typically in July, when stork nestlings were fledging and dispersing from the Birdsville colony. The impoundments were first available for storks in the summer of 1986.

Storks used the impoundments from July through September 1986, and have foraged there every year since through 1996 (Bryan and Coulter 1995; A. L. Bryan, unpubl. data). Most storks using the impoundments were immature birds (<4 yrs old), who made up >70% of the total storks present in most years (Bryan and Coulter 1995). Storks banded as nestlings in the Birdsville colony have been observed foraging at Kathwood in almost every year of its operation, indicating its importance to storks dispersing from that colony. However, in 1988, approximately 35 nestlings fledged from Birdsville and over 150 fledged juveniles (hatching year storks) were observed at Kathwood in a group at one time, thus indicating that fledged juvenile storks from other colonies were using the impoundments as well. And, in 1995 and 1996, nestlings banded in 1995 at the Harris Neck colony on the coast of Georgia also were observed foraging in the Kathwood impoundments. These impoundments also function as a field laboratory in which to study the foraging behavior and interactions of Wood Storks and other wading birds. For example, Walsh (1990) compared foraging success rates of different-aged Wood Storks on these impoundments and nocturnal foraging has been found to be a common behavior of storks in this setting (Bryan 1996).

CONCLUSIONS

In response to a perceived threat to the endangered Wood Stork, an integrated long-term program was initiated to determine the timing and extent of stork use of the SRS site and the habitat requirements of the species. The findings from these studies led to the creation of managed foraging impoundments to replace the impacted habitat on the SRS, based on scientific data from this region rather than data from other studies. This research was initiated in an unstudied part of the species' range, with the majority of the previous research occurring in the south Florida Everglades. The results of monitoring from various components of this project, in contrast to the preliminary findings of the original L-reactor restart EIS research (Smith et al. 1982), suggest that the majority of stork use of the SRS occurs post-breeding, with the SRS probably being more important to dispersing juveniles than to breeding adults. Regardless, the initial mitigation need (foraging habitat replacement) was met very successfully (McCort and Coulter 1991), and the program has adapted to provide data for current and possible future assessment needs (Par Pond, River Water System Shutdown, etc.) of the managers of the SRS.

The studies also have gathered information that was not necessarily required to aid with the mitigation, but which has filled gaps in our understanding of this species and, therefore, may be important to its recovery. Not only has this project met the required needs for DOE mitigation, it also has addressed many of the "tasks" designated in the initial recovery plan for this species: Task 111-locate foraging habitat; Task 1111-develop technique to identify potential feeding area (GIS); and Task 1121-monitor prey response to water management (USFWS 1986). Recent contaminant studies address Task 3.8 in the revised recovery plan for this species (USFWS 1996). In this way, this program has proved to be of benefit to the long-term recovery of the Wood Stork over and beyond the need to understand and mitigate the possible negative effects of nuclear industrial activities at this particular DOE site.

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