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Reproductive Success of Wading Birds Using *Phragmites* Marsh and Upland Nesting Habitats

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ABSTACT: Colonial nesting of long-legged wading birds (Ciconiiformes) in the coastal northeastern U.S. is limited primarily to islands, which provide isolated habitats that are relatively free of ground predators. Estuarine wetlands in this heavily developed region, including foraging wetlands and fringe marshes surrounding nesting islands, are often dominated by *Phragmites australis.* On Pea Patch Island in Delaware Bay, site of one of the largest and most enduring mixed-species heron colonies on the East Coast, wading birds nest in *Phragmites* marsh habitat as well as in adjacent upland shrubs and trees. Because *Phragmites* is aggressively managed in Delaware Bay, we investigated the relative habitat value of marsh and upland nesting sites for the purpose of developing recommendations for marsh and wildlife management. Utilization of marsh habitat by nesting birds ranged from 27–82% during 1993–1998. Two species (great blue heron *Ardea herodias* and great egret *A. alba*) never nested in *Phragmites,* four species (little blue heron *Egretta caerulea,* snowy egret *E. thula,* cattle egret *Bubulcus ibis,* and black-crowned night-heron *Nycticorax nycticorax*) nested in approximately equal proportions in both habitats, and one species (glossy ibis *Plegadis falcinellus*) was largely confined to marsh nesting. Productivity (egg and nestling production) varied between habitats for some species. Cattle egrets produced larger clutches and had higher hatching rates in *Phragmites* compared to upland habitat. Little blue herons were more successful in the uplands. Managers should retain *Phragmites* marsh at colony sites, such as Pea Patch Island, where it provides critical habitat for nesting wading birds both as substrate for nesting and buffer habitat to control human disturbance.

Introduction

Many studies of wading bird (Ciconiiformes) nesting ecology have examined spatial and temporal patterns of colony formation (see review in Burger 1981), but few have assessed the consequences to reproductive performance of nesting habitat choice (Moser 1984). Rarely have researchers reported the occurrence of different habitat types within a single colony (Parsons 1995).

In Delaware Bay, wading birds have nested on Pea Patch Island since the mid-1970s in both marsh and upland habitats. During the last two decades, Pea Patch Island has supported one of the largest mixed species heron colonies on the Atlantic Coast of North America (Erwin and Korschgen 1979; Parnell et al. 1997). Marsh habitat on the island is dominated by monotypic stands of *Phragmites australis,* which are subject, estuary-wide, to a variety of weed control programs carried out by state agencies (Delaware Estuary Program 1996; Pea Patch Island Heronry Region Special Area Management Plan 1998). *Phragmites* control in the heronry portions of Pea Patch Island could cause adverse impacts to nesting birds through the removal of nesting substrate and vegetative buffer, but these potential impacts have not been quantified.

To address this information need, I investigated the nesting ecology of wading birds using both marsh and upland habitats during the 1993–1998 breeding seasons. My objective was to characterize use of *Phragmites* marsh by nesting wading birds and to assess its value to breeding birds relative to upland nesting habitat. I also sought to develop recommendations for state resource managers charged with managing *Phragmites* in upper Delaware Bay.

Study Area

The study took place on Pea Patch Island, New Castle County, Delaware (39°35′N, 75°34′W), located in upper Delaware Bay. The island has been used by breeding wading birds since the mid-1960s when nearby mainland colonies abandoned and relocated on the island (Cutler 1964). Wading birds have nested in both upland treed portions of the island and in surrounding *Phragmites* marsh habitat since at least the mid-1970s (Wiese 1978).

Methods

ABUNDANCE OF NESTING BIRDS

During 1993–1998 and 2000, estimates of total wading bird abundance were obtained by several

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low-impact methods including ground-based nest counts, counts of attending adults, flight line observations, and aerial surveys. I obtained nest counts (± 2.0%) in all upland portions of the colony primarily during the egg-phase of nesting. To minimize investigator disturbance in the marsh, I established transects through the nesting area in March before nesting began. In late May, I obtained nest density measurements and adult counts along all transects. In addition, in late May–early June, I surveyed and photographed marsh areas used by nesting birds from a fixed-wing aircraft. I estimated the areal extent of nesting within the stand and adult density of species discernible from approximately 175 m above ground (small white species) with the use of aerial photographs.

I obtained estimates of number of nests in the *Phragmites* marsh using nest density measurements obtained from transect surveys, and adult density estimates and nesting area estimates obtained from aerial photographs (± 15%). I corrected density estimates for species not visible in the aerial photographs by using adult counts obtained during transect surveys.

The method produced an estimate of adult density for the entire marsh area obtained from the air and corrected by adult counts obtained on the ground. The adult counts were needed to estimate density of species not visible from the air and to discriminate between the two small white species. In addition, the protocol produced an estimate of nest density for each species explicitly from transect surveys that was then extrapolated to the entire marsh area. Both estimates relied on aerial and ground-based data, and were generated to produce an average estimate of number of nests of each species using the marsh. Further details can be found in Parsons (1995).

Wading Bird Productivity

I determined productivity of species using both nesting habitats from 1993–1998 including snowy egret (*Egretta thula*), cattle egret (*Bubulcus ibis*), little blue heron (*E. caerulea*), and black-crowned night-heron (*Nycticorax nycticorax*). I selected for monitoring 20–30 active nests (nests containing at least one egg) of each species in each habitat as available. Marked study nests were distributed throughout nesting habitats (Parsons et al. 2001) and were monitored every 2–3 d from egg-laying through the nestling period (15 d post-hatch). Eggs and young were marked with nontoxic dye. Only study nests in which nesting events were known to have occurred within 3 days were included in analyses of nesting chronology. Further details can be found in Parsons (1995) and Parsons et al. (2001).

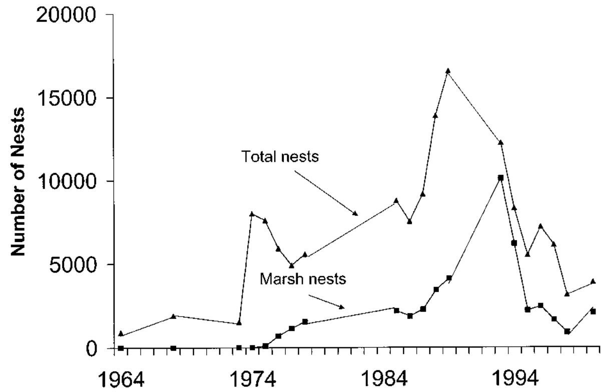

Fig. 1. Abundance of nesting wading birds on Pea Patch Island, Delaware Bay, 1964–2000. Sources of estimates are as follows: 1964–1979 (summarized in Wiese 1979); 1985–1989 (Delaware Department of Natural Resources and Environmental Control unpublished data); 1993–2000 (this study). Quantitative estimates of abundance of marsh-nesting and upland-nesting birds were obtained in the 1970s and 1990s. In the 1980s, estimates of upland-nesting birds only were obtained. Numbers of marsh-nesting birds for 1985–1989 shown are speculative based on 1970s trend.

Data Analysis

Wading bird species were analyzed separately and all analyses were conducted on a per nest basis. I tested productivity data sets for normality (Shapiro-Wilk statistic) and homogeneity of variance (Bartlett's test). Data not complying with the assumptions of parametric analysis were corrected with transformations, or the data were ranked. I used ANOVA and Tukey mean separation procedure and paired *t*-tests to examine relationships between nesting habitat type and chronology and productivity. I used chi-square statistic to compare frequency data. All analyses were performed with SAS (Version 8) software (SAS Inc., Cary, North Carolina).

Results

Abundance of Nesting Birds

Estimates of wading bird abundance on Pea Patch Island have ranged from approximately 1,000 to 17,000 nesting pairs since the mid 1960s (Fig. 1). Nesting in the *Phragmites* marsh was first documented by Wiese (1978) and became the predominant habitat type by the early 1990s. In recent years, the colony has declined in abundance as has the proportion of birds nesting in the marsh.

Of the ten wading bird species documented nesting on Pea Patch Island, four numerically dominant species (snowy egret, cattle egret, little blue heron, and black-crowned night-heron) nested in most years of study in both *Phragmites* marsh and upland habitats (Fig. 2). Great blue heron (*Ardea herodias*) and great egret (*A. alba*) never nested in

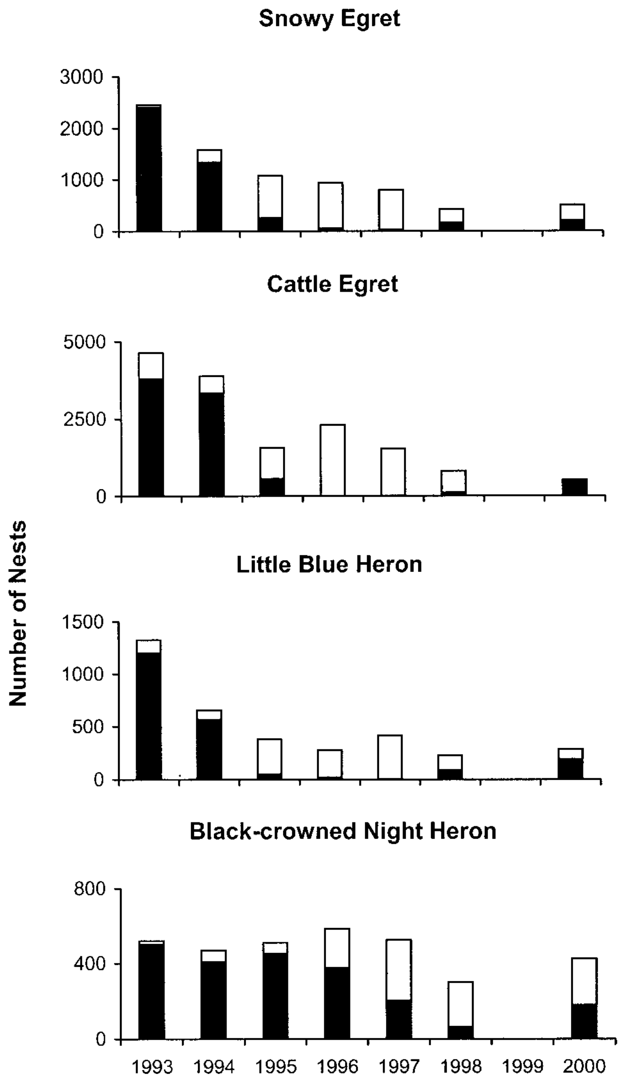

Fig. 2. Abundance of marsh-nesting and upland-nesting wading bird species on Pea Patch Island, Delaware Bay, 1993–2000. Shown are number of nests occurring in *Phragmites* marsh (solid) and upland (open) habitats for snowy egret, cattle egret, little blue heron, and black-crowned night-heron.

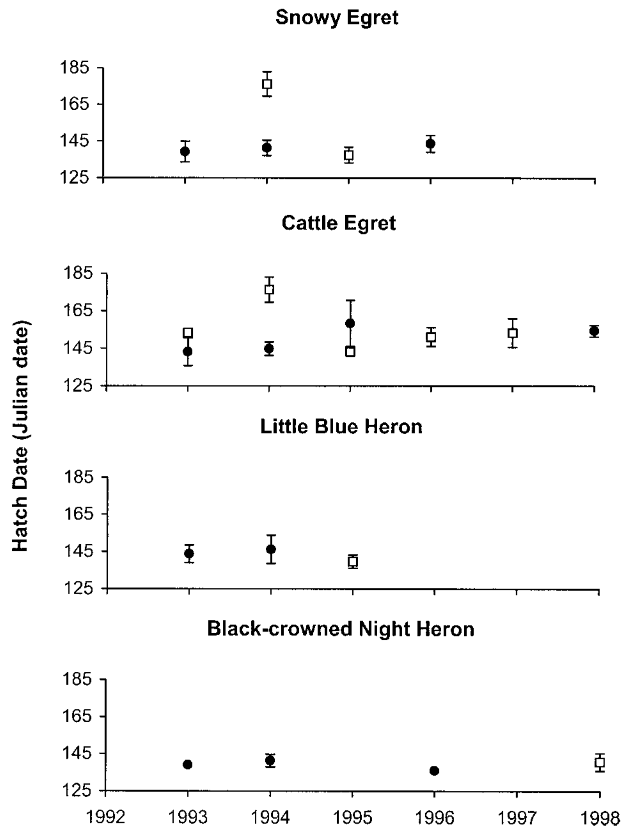

Fig. 3. Chronology of wading bird species using *Phragmites* marsh and upland nesting habitats, Pea Patch Island, Delaware Bay, 1993–1998. Shown are x ± SD hatch date (Julian) for snowy egret, cattle egret, little blue heron, and black-crowned night-heron nesting in *Phragmites* (solid circles) and upland (open squares) habitats.

the marsh during the course of the study. Glossy ibis (*Plegadis falcinellus*) nested predominantly in *Phragmites*. Tricolored heron (*Egretta tricolor*), yellow-crowned night-heron (*Nyctanassa violacea*), and green heron (*Butorides virescens*) nested in both habitats in small numbers.

Wading Bird Productivity

Nesting chronology varied within nesting habitat type over the study period for some but not all species (Fig. 3). Mean hatching date of snowy egrets in the *Phragmites* did not differ over the study period ($F_{2,50} = 2.7$, $p = 0.07$), but snowy egrets in the uplands varied over the study period ($F_{1,31} = 412.2$, $p < 0.0001$). Hatching dates of cattle egrets varied both in the marsh ($F_{3,98} = 26.4$, $p < 0.0001$) and in the uplands ($F_{3,63} = 14.1$, $p < 0.0001$). Hatching dates of little blue herons in the *Phragmites* did not differ over the study period ($F_{1,44} = 1.72$, $p = 0.20$), but chronology of marsh-nesting black-crowned night-herons varied ($F_{2,55} = 4.1$, $p = 0.02$).

Data were available to examine chronology patterns between habitats for snowy egret and cattle egret (Fig. 3). For both species, nesting chronology differed between marsh and uplands in any given year, but these differences were not consistent year to year. For example, cattle egrets nested earlier in the *Phragmites* in 1993 and 1994, but later than upland-nesting birds in 1995 (Fig. 3).

The relative success of wading bird nests in *Phragmites* marsh compared to upland habitat varied between species. Snowy egret nests producing at least one hatchling were more abundant in the marsh than in the upland portion of the island in 1994 and 1997 (Table 1). In 1994, cattle egrets

TABLE 1. Relative success of wading bird nests in *Phragmites* and upland habitat at Pea Patch Island, Delaware Bay, 1994–1997. Given are numbers of successful (hatching ≥ 1 nestling) and unsuccessful nests (hatching = 0) in each nesting habitat. Tests of independence (chi-square) between habitats were performed only when all cells had expected frequency > 5. Cells with highest cell chi-square values are in bold.

Species	Year	Habitat	N Nests: Successful	N Nests: Unsuccessful	
Snowy egret	1994	*Phragmites*	18	**15**	$\chi^2_1 = 4.1$
		Upland	20	**5**	$p < 0.05$
	1997	*Phragmites*	5	**8**	$\chi^2_1 = 5.0$
		Upland	12	**3**	$p < 0.05$
Cattle egret	1993	*Phragmites*	32	10	$\chi^2_1 = 0.1$
		Upland	48	13	ns
	1994	*Phragmites*	28	13	$\chi^2_1 = 8.5$
		Upland	**10**	**20**	$p < 0.01$
	1995	*Phragmites*	28	6	$\chi^2_1 = 0$
		Upland	28	6	ns
Little blue heron	1993	*Phragmites*	36	31	$\chi^2_1 = 8.6$
		Upland	**21**	**3**	$p < 0.01$

were less successful in upland habitat than expected, and in 1993, little blue herons were more successful in uplands than expected.

Egg and nestling production in marsh and upland habitats also varied between species. Snowy egret and cattle egret nests located in the *Phragmites* marsh produced more eggs than nests in the uplands (Table 2), but little blue herons nesting in the uplands produced more eggs than birds nesting in the marsh. Nestling production (15 d post-hatch) did not differ between nesting habitat types for snowy egrets and cattle egrets, however, little blue heron nests in the uplands produced more young than nests in the marsh (Table 2).

Hatching success (% eggs hatched/laid) was greater in upland nests of snowy egrets ($F_{3,180} = 5.0$, $p = 0.008$; year also significant factor in model) and little blue herons ($F_{3,151} = 8.3$, $p < 0.0001$; year significant) than in marsh nests, but the reverse was true for cattle egrets ($F_{6,380} = 3.2$, $p = 0.005$; year significant; Fig. 4). Nestling survival (% nestlings surviving 15 d post-hatch/eggs hatched) was greater in upland nests of little blue

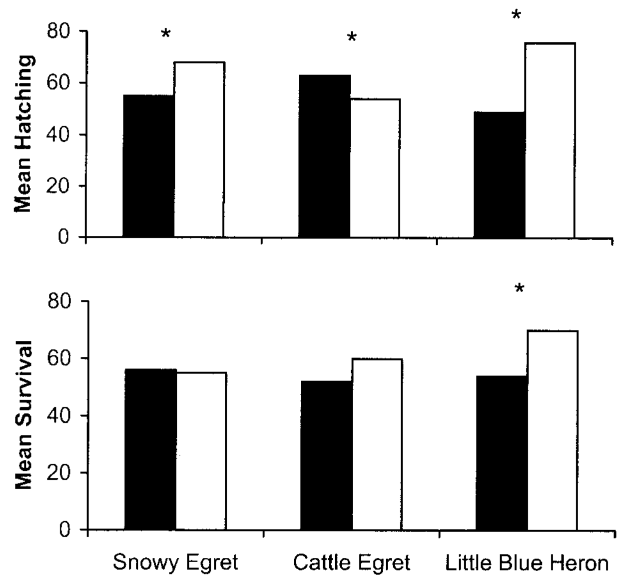

Fig. 4. Reproductive success of marsh-nesting and upland-nesting wading birds on Pea Patch Island, Delaware Bay, 1993–1998. Shown are mean hatching (% eggs hatched/laid) and survival (% nestlings surviving 15 d post-hatch/eggs hatched) of snowy egret, cattle egret, and little blue heron in *Phragmites* (solid) and upland (open) habitats. Asterisks indicate significant differences in reproductive success between habitats (see text).

TABLE 2. Wading bird productivity in *Phragmites* marsh and upland habitats on Pea Patch Island, Delaware Bay, 1993–1998. Given are the number of nests producing eggs and nestlings of snowy egret, cattle egret, and little blue heron. Chi-square tests of independence were performed between habitats for each species. Production category included only if expected cell frequency > 5. Cells with highest cell chi-square are in bold.

Species	Habitat	Number Offspring per Nest: 0	1	2	3	4	5	
Eggs								
Snowy egret	*Phragmites*			9	**26**	66	16	$\chi^2_3 = 21.7$
	Upland			11	**31**	21	**2**	$p < 0.0001$
Cattle egret	*Phragmites*			**16**	85	**48**		$\chi^2_2 = 12.2$
	Upland			44	141	**41**		$p < 0.005$
Little blue heron	*Phragmites*		**12**	8	19	32	19	$\chi^2_4 = 9.6$
	Upland		1	3	10	**32**	11	$p < 0.05$
Nestlings (15 d post-hatch)								
Snowy egret	*Phragmites*	51	14	11				$\chi^2_3 = 2.0$
	Upland	30	14	5				ns
Cattle egret	*Phragmites*	68	29	14				$\chi^2_3 = 2.2$
	Upland	102	29	24				ns
Little blue heron	*Phragmites*	16	**9**	12	**3**			$\chi^2_3 = 8.5$
	Upland	16	**3**	16	**12**			$p < 0.05$

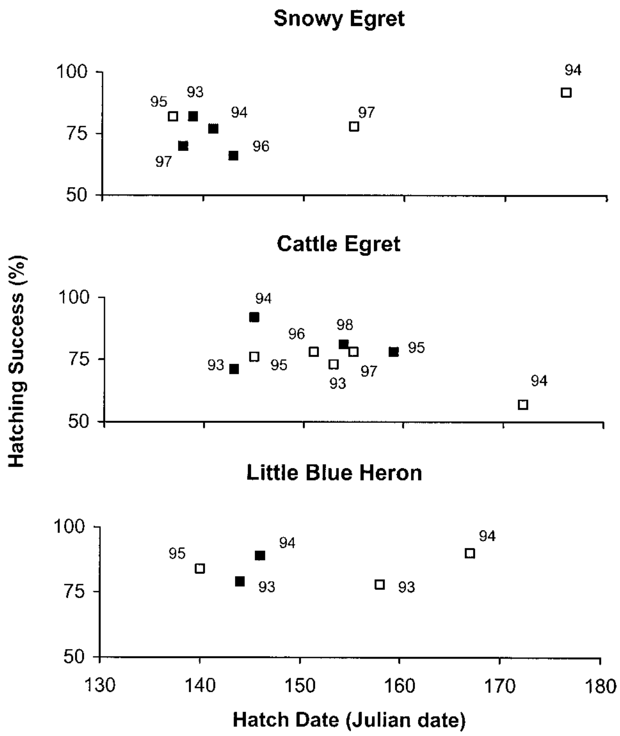

Fig. 5. Hatch date and hatching success of marsh-nesting and upland-nesting wading birds on Pea Patch Island, Delaware Bay, 1993–1998. Shown are mean hatch date (Julian) and hatching success (% eggs hatched/laid) of snowy egret, cattle egret, and little blue heron in *Phragmites* (solid squares) and upland (open squares) habitats.

herons than in marsh nests ($F_{3,56}$ = 4.2, p = 0.01; year not significant). Nestling survival did not differ between habitat types for snowy egrets and cattle egrets (Fig. 4).

Although greater nesting synchrony occurred within habitat type than between species, timing of nesting was not consistently correlated with reproductive success (Fig. 5). Late-nesting snowy egrets in 1994 using marsh habitat were more successful hatching eggs than early-nesting upland birds (t_{34} = 2.3, p = 0.03). Late-nesting cattle egrets in *Phragmites* were less successful hatching eggs than early-nesting upland birds (t_{11} = 11.1, p = 0.004). No other differences were detected between habitat types for other species or years.

Discussion

On Pea Patch Island, site of one of the largest heronries in eastern North America, two distinct habitats, marsh and upland, provided nesting substrate to 10 breeding Ciconiiform species. During the 1970s, marsh-nesting birds comprised 0–38% of the total colony. Since 1993, utilization of the marsh has ranged from 27–82% of nesting birds.

Several species nested exclusively in either upland (great blue heron, great egret) or marsh (glossy ibis) habitats, but four numerically dominant species (snowy egret, cattle egret, little blue heron, and black-crowned night-heron) nested in both habitats in most years of the study. In recent years, a decline in abundance of marsh-nesting species has driven a 70% decline in colony size. Relative proportion of birds using the marsh has also dropped by approximately 50%.

Although nesting chronology of marsh-nesting species varied over the study, timing of nesting was not consistently related to reproductive success as it has been in other studies of colonial species (see review in Burger 1981). At Pea Patch Island, early nesting birds chose marsh habitat in some years (1995, 1998) and upland habitat in other years (1993, 1994, 1997). Within-habitat synchrony among species was greater than within-species synchrony among habitats, which mirrors a similar pattern observed across colonies (Beaver et al. 1980).

Wading bird species also varied in their reproductive performance in different nesting habitat. Marsh-nesting snowy egrets produced more eggs but had lower hatching success than upland nesting egrets. Cattle egrets produced larger clutches in *Phragmites* habitat and experienced greater hatching success there. Conversely, little blue herons produced more eggs and experienced greater hatching success in upland habitat. Little blue herons also produced more nestlings with greater survivability in upland nests than in marsh nests.

Utilization of nesting habitats on Pea Patch Island was characterized by long-term reliance on both marsh and upland substrates by several wading bird species. In the 1990s, years of highest overall abundance were also years of highest marsh utilization. Cattle egret had higher success in marsh nests than in uplands, but little blue heron had greater success in uplands. Snowy egret productivity was mixed.

It is unknown whether declines in abundance since the late 1980s reflect changes in nesting habitat use, although this scenario is conceivable for cattle egret. Cattle egret abundance declined by nearly 90% since 1993; use of the marsh where cattle egret experiences greatest reproductive success, dropped from approximately 85% to 0% from 1993 to 1997. Other studies show that cattle egrets are exposed to insecticides in their foraging habitats in upper Delaware Bay (Parsons et al. 2000) and are consequently subject to high predation rates regardless of nesting habitat (Parsons 1995; Parsons et al. 2001).

Of the diverse Ciconiiform community on Pea Patch Island, glossy ibis and cattle egret appear to benefit most significantly from the provision of nesting habitat by *Phragmites* marsh. The glossy ibis is a marsh-nesting specialist. The cattle egret, as a late-nesting species (relative to other day herons), with potentially large and densely-nesting populations, is most easily accommodated by the extensive stands of *Phragmites* that surround the upland portions of the colony. The reeds also provide nest material for nest-building, which is limiting in some colonies (Telfair 1994).

In addition to providing essential nesting habitat to Pea Patch Island's wading birds, the extensive stands of *Phragmites* around the island conceivably provide a buffer against human disturbance from unauthorized boat landings and visitors to the historic fort on the south end of the island.

Management Recommendations

Recommendations made specifically for Pea Patch Island may be generally applicable to other wading bird nesting situations. It is important to retain *Phragmites* stands around upland portions of colony sites to provide nesting substrate and a source of nest material to small day herons and ibises, as well as retain *Phragmites* stands from the upland interface to the water's edge or to a distance > 100 m to provide a vegetative buffer against human disturbance including foot traffic, unleashed dogs, and noise disturbance.

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