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ASSESSING HABITAT SELECTION BY FORAGING EGRETS IN SALT MARSHES AT MULTIPLE SPATIAL SCALES

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Abstract: We assessed salt marsh use by foraging egrets in coastal Rhode Island, USA. Two species [great egret (*Ardea alba*) and snowy egret (*Egretta thula*)] nest in mixed-species colonies on islands in Narragansett Bay and regularly forage in adjacent salt marshes. We surveyed 13 salt marshes approximately twice weekly during the breeding and post-breeding seasons in 2001 and 2002. Based on resource selection functions, foraging great and snowy egrets strongly preferred pools within salt marshes, while mosquito control ditches were rarely used. Foraging egrets were never detected in stands of common reed (*Phragmites australis*). The number of egrets using individual marshes varied considerably, although density estimates were far less variable. Salt marsh area was better at predicting the mean number of foraging egrets using a marsh than landscape-level parameters, such as distance to the nearest nesting colony or the total area of salt marsh within 5 km. Carefully designed salt marsh restoration projects could benefit local egret populations because it appears that foraging habitat availability may be a limiting factor. To ensure use by foraging egrets, salt marsh restoration designs should increase the availability of pool and open water habitat, reduce common reed, and modify deep ditches and channels to make them more accessible for foraging egrets.

Key Words: foraging, great egret, habitat selection, resource selection, salt marsh restoration, snowy egret

INTRODUCTION

Egrets (Ardeidae) nesting in coastal areas often use salt marshes as their primary foraging habitat (Custer and Osborn 1978, Maccarone and Brzorad 1998, Parson and Master 2000). Although current federal and state regulations protect estuarine habitats, over 80% of the salt marshes in New England have been altered or lost due to anthropogenic modification (Bertness et al. 2002). Loss of salt marshes has likely had detrimental impacts on egret populations because foraging habitat availability often limits local populations and productivity (Kushlan 2000). There is increasing interest in salt marsh restoration as a means to enhance wetland structure and function in degraded marshes, with the creation of wildlife habitat frequently listed as a principal goal (Zedler and Weller 1990, Zedler 2001). However, few quantitative studies have assessed habitat selection by egrets in salt marshes to better guide restoration efforts.

Great egrets (*Ardea alba* (L.)) and snowy egrets (*Egretta thula* (Molina)) were first reported nesting in Rhode Island, USA in 1964 (Ferren and Myers 1998). Since the mid-1960s, egrets have nested on five different islands in Narragansett Bay, Rhode Island. Although all five islands are now protected and have suitable vegetation for nesting wading birds, only three are currently used by breeding egrets (C. Raithel, RI Div. of Fish and Wildlife, personal communication). While colony locations have changed over time, the mean number of snowy egret nests ($\bar{x}$ = 173 ± 73 from 1977 to 2002) in Narragansett Bay has decreased after reaching 330 in 1979, while the number of great egret nests ($\bar{x}$ = 114 ± 71 [SD]) had increased slightly to 250 nests by 2002 (Ferren and Myers 1998, C. Raithel, unpublished data). In addition, less than a dozen pair of little blue heron (*Egretta caerulea* (L.)) typically nest in Narragansett Bay each year. If nesting habitat is not a limiting factor, then the availability of foraging habitat may be limiting local egret populations in southern Rhode Island.

The overall objective of this research was to quantify salt marsh habitat use by foraging egrets. Our specific objectives were to (1) survey the abundance (both total number and density estimates) of foraging egrets in salt marshes during the breeding and post-breeding seasons as a function of tidal regime; (2) assess egret habitat selection within salt marshes to determine if egrets showed preferences for pools, open water, mosquito ditches, or salt marsh graminoid habitat; (3) quantify marsh attributes that may affect the numbers of foraging egrets using a marsh (e.g., marsh size, salt marsh graminoid area, open water area, pool area, pool perimeter, or mosquito ditch length); and (4) evaluate landscape-level parameters that may influence egret use of individual marshes (distance to active nesting colonies, amount of salt marsh habitat in the surrounding landscape).

METHODS

Egret Surveys

During 2001 and 2002, we surveyed 13 salt marshes in and near Narragansett Bay, Rhode Island. Potential study marshes were identified using statewide wetlands data available through Rhode Island Geographic Information System (RIGIS), queried for estuarine emergent wetlands (August et al. 1995). Marshes were selected based on their proximity to active colonies (from 3 to 20 km from colony sites), marsh size (ranging from 2 to 60 ha), and access. In Rhode Island, salt marshes average approximately 2 ha, so selected study marshes represent many of the largest marshes available and approximately 16% of total salt marsh habitat within a 20-km radius of active colonies (Trocki 2003).

We conducted visual surveys using binoculars from fixed points that provided visibility of the entire study marsh. We surveyed each marsh approximately two times per week between 0600 and 1100 during the breeding season (6 May–29 June) and the post-breeding season (4 August–20 September) (Ferren and Myers 1998). We recorded the number of foraging egrets (including all great egrets, snowy egrets, and little blue herons) and the habitat being used by each individual. Time spent conducting surveys varied based on the size of the marsh and the number of egrets present but generally ranged from 5 to 15 minutes per marsh. We only considered foraging egrets for these analyses and excluded birds engaged in other behaviors. Foraging egrets were identified as birds engaged in any manner of recognizable foraging behavior but, most generally, peering after or stalking prey.

Major habitats available within each marsh included *Salt marsh graminoids*—including low marsh (cordgrass [*Spartina alterniflora* (Loisel)]) and high marsh species (dominated by salt hay [*S. patens* (Ait.) Muhl.)]); *Open water*—estuarine waters directly adjacent to salt marsh graminoids and present during all or most of the tidal cycle; *Salt marsh pools*—vegetated or non-vegetated pools located within a marsh and exposed to irregular tidal flooding; *Mosquito control ditches*—generally unmaintained grid ditches historically dug for mosquito control; *Common reed stands*–dense monotypic stands of *Phragmites australis* (Cav. Trin. ex Steud.), usually bordering the upland edge of the marsh. In addition to these major habitat types, some marshes also included a small percentage of additional habitats, such as unvegetated intertidal areas, rocks, artificial perches, and upland islands dominated by trees or shrubs.

Surveys consisted of a single visit to each of the 13 marshes, which took 2–3 consecutive days to complete. We conducted a total of 49 surveys over two years, with 14 surveys during the breeding season in both years, 10 surveys during the post-breeding season in 2001, and 11 surveys during the post-breeding season in 2002.

We conducted surveys regardless of tidal stage but recorded the time of observation at each marsh and the time of the closest high or low tide in Newport, Rhode Island. We then assigned each observation to a tide category: low, high, or mid-tide. We classified high and low tides as falling within a window of two hours on either side of the scheduled tide in Newport. Mid-tide was the intervening two hours between high and low tides. All analyses of the effects of tide on the abundance of foraging egrets compared only high ($n = 255$) and low tides ($n = 223$) in order to partition tide categories adequately. Thus we excluded mid-tide surveys from this analysis.

Available Habitat Assessment

We determined the amount of available habitat by digitizing 1997 1:5000 scale aerial orthophotographs (available from RIGIS) using ArcView 3.3 (Environmental Systems Research Institute, Inc. 2002). Because we were limited to panochromatic orthophotographs, we could not distinguish between low and high marsh areas. Using maps, we quantified eight habitat variables including total marsh area (ha; this variable combined all major habitat types at each marsh), salt marsh graminoid area (ha), open water area (ha), pool area (ha), pool perimeter (m), mosquito ditch length (m), salt marsh—open water edge (m), and total edge (m; salt marsh—open water edge + pool edge) for each site. We then converted maps of study marshes into ArcGrids and used FRAGSTATS (McGarigal and Marks 1995) to quantify contagion within salt marshes, which measures both habitat interspersion and habitat dispersion.

We also calculated the distance (km) from each study marsh to each egret nesting colony in Narragansett Bay, weighted by the number of birds nesting in the colony in 2002, and calculated the amount of salt marsh (ha) surrounding (and including) each study marsh within a 5-km radii. The area of salt marsh in the surrounding landscape was determined using statewide wetlands data available through RIGIS, queried for estuarine emergent wetlands (August et al. 1995).

Statistical Analyses

We used t-tests to compare the abundance of egrets between years, seasons, and tides within each marsh. We used one-way ANOVA to compare the mean number of foraging egrets and the density of foraging egrets (birds per ha of salt marsh) among study marshes, with a post-hoc Tukey's Studentized Range Test (SAS Institute Inc. 2002). Density calculations were based on total marsh area, or the combined area estimates of salt marsh graminoids, open water, and pools. We first tested for homogeneity of variance and deviations from normality and found no transformations were necessary.

To assess salt marsh and landscape-level characteristics associated with egret use of salt marshes, we used stepwise multiple linear regression analysis. We regressed the mean number of egrets using a particular marsh against a combination of salt marsh and landscape-level characteristics. Because of multicollinearty issues associated with related habitat variables, we first conducted a correlation analysis among all habitat variables and eliminated one member of a pair when $r > 0.7$. We attempted to retain the most biologically relevant variables; thus, we kept five variables (salt marsh area, open water edge, distance to nest colonies, salt marsh area within 5 km, and contagion within salt marshes).

Habitat Selection Within Salt Marshes

A resource selection function (RSF) is defined as any function that is proportional to the probability of use by an organism (Manly et al. 1993). One simple form of an RSF is a selection ratio of use to availability ($RSFw_i$) where *i* indicates a specific habitat type and *H* indicates the total number of habitat types examined (Boyce and McDonald 1999):

$$RSFw_i = \text{proportion used}_i/\text{proportion available}_i$$

At each site, we calculated selection ratios for each egret species for the three most used habitat types: salt marsh graminoids, open water, and pools. The proportion of habitat used was calculated as the number of egrets observed using a specific habitat type divided by the total number of egrets observed. The proportion of habitat available was calculated as the total area of a specific habitat type divided by the total area surveyed. Observations of foraging egrets using mosquito ditches or rocks accounted for less than 2% of the total observations (Trocki 2003); thus, we excluded them from subsequent analyses. We then standardized selection ratios using the equation.

$$\beta_i = RSFw_i \Big/ \sum_{i=1}^{H} RSFw_i$$

Each standardized ratio (β_i) ranged from 0 to 1 and could be interpreted as the estimated probability of use if all habitat types were made equally available (Arthur et al. 1996). We used standardized selection ratios to compare habitat use within sites (microhabitat scale) by species and tide stage. While the percentage of egrets observed foraging in salt marshes decreased during the post-breeding season (Trocki 2003), we assumed that habitat selection by foraging egrets would not vary within a season and we pooled data by both year and season.

RESULTS

There was no significant difference in the number of foraging egrets observed per survey between years for any marsh; therefore, data from 2001 and 2002 surveys were pooled for all subsequent analyses. At the five largest and most heavily used marshes, the number of foraging egrets observed per survey increased significantly during the post-breeding season, indicating that marsh use needed to be segregated by season. There was no significant difference in the number of foraging egrets observed at low versus high tide at any marsh in either season, indicating that tidal stage did not affect overall site use.

The mean number of foraging egrets observed per survey differed significantly among marshes during the breeding season ($F_{350,12} = 9.87$, $P < 0.0001$) and the post-breeding season ($F_{265,12} = 11.48$, $P < 0.0001$) (Figure 1). The density of foraging egrets per survey showed substantially less variation among marshes, with only one site (a recently restored marsh) having greater densities during the breeding season.

Salt marsh area was the only habitat variable that was significantly associated with the number of foraging egrets using marshes during either the breeding season ($y = 0.106x + 0.484$, $r^2 = 0.81$) or the post-breeding season ($y = 0.318x + 0.311$, $r^2 = 0.87$) (Table 1).

Habitat selection varied among marshes at both high and low tide. Overall, pool habitat was highly preferred in every marsh where it was used during both high and low tide but was not used in all marshes

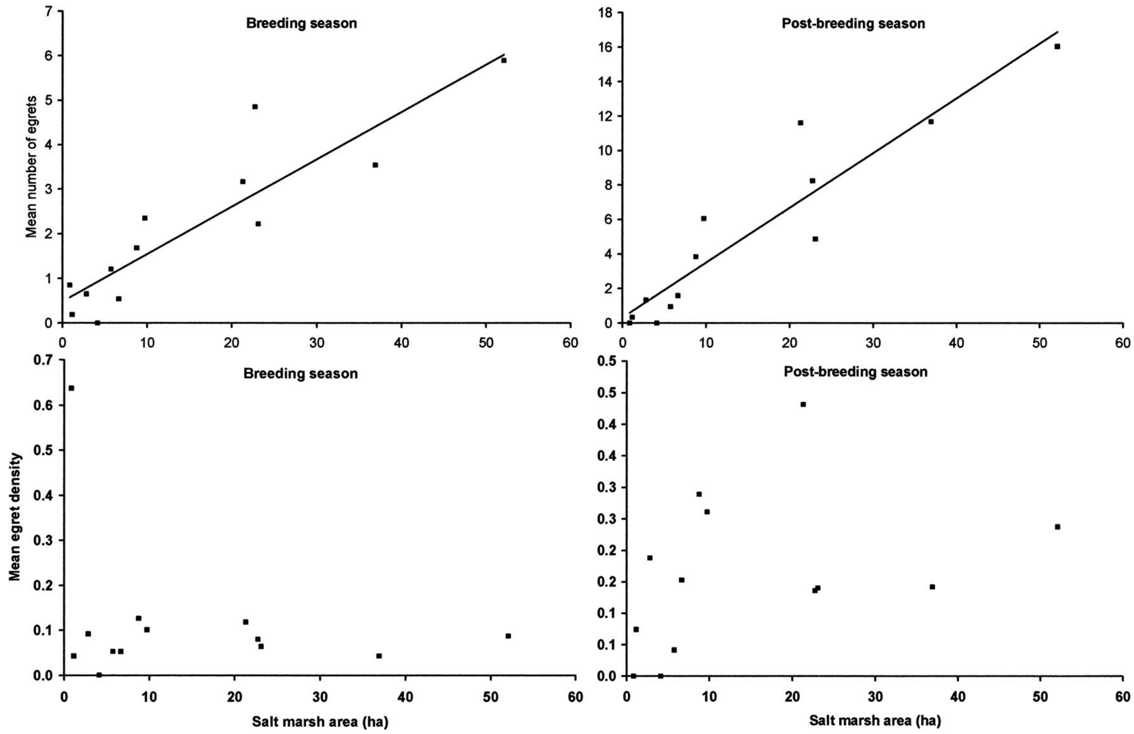

Figure 1. Relationship between salt marsh size (ha) and the (a) mean number of egrets and (b) mean density of egrets detected in 13 salt marshes in Rhode Island during the breeding season and post-breeding season.

where it was available. Open water habitat was selected less frequently than salt marsh graminoids during high tide but 22 times more frequently than salt marsh graminoids during low tide (Table 2). While, overall, salt marsh graminoids were selected for foraging more often at high tide, this was not true for every marsh. Pool habitat accounted for only 0–6% of the total available habitat in any one marsh and only 2% of the total habitat available overall, yet 25% of the foraging egrets observed at high tide were using pools.

At high tide, pools were the most highly preferred habitat type by both great and snowy egrets (Table 2). However, snowy egrets selected both open water and salt marsh habitat more than great egrets. At low tide, both great and snowy egrets used open water more than at high tide, but both species still preferred pools over any other habitat type (Table 2).

Table 1. Relationship between the number of egrets foraging in a salt marshes and habitat characteristics at multiple spatial scales during the breeding season and post-breeding season based on stepwise linear regression. Only significant models are shown.

Model	$F_{1,11}$	*P*	Adjusted r^2
Breeding season			
Salt marsh area	47.5	<0.001	0.81
Post-breeding season			
Salt marsh area	76.5	<0.001	0.87

DISCUSSION

Information presented here can be used to guide salt marsh restoration design to ensure use by foraging egrets. Patterns of habitat use varied substantially among marshes but were generally similar between egret species for any given marsh. Differences in habitat preferences among marshes indicate that habitat selection is occurring and that foraging egrets are selecting specific habitats within each salt marsh. Exten-

Table 2. Standardized selection ratios for habitat selection within salt marshes by great and snowy egrets at both high and low tide. Standardized ratios (β_i) range from 0 to 1, with preferred habitats close to 1.

	β Salt Marsh Graminoids	β Open Water	β Pools
High Tide			
great egret	0.09	0.03	0.88
snowy egret	0.12	0.14	0.74
Low Tide			
great egret	0.02	0.16	0.82
snowy egret	0.01	0.24	0.75

sive salt marsh restoration is ongoing in Rhode Island (Narragansett Bay Estuary Program 2000) and may have positive impacts on local egret populations if designed correctly.

The egrets evaluated in this study feed primarily on nekton, crustaceans, and other aquatic invertebrates (Rogers and Smith 1995, Parsons and Master 2000, McCrimmon et al. 2001), all of which are associated with open water and flooded marsh surfaces. Because within-marsh habitat use varied by tide, but overall salt marsh site use did not, it appears that salt marshes provide a variety of habitat types that accommodate foraging egrets at a range of tidal stages.

Both foraging great and snowy egrets showed strong preferences for pool habitat, which has been well-documented by others (Clarke et al. 1984, Brush et al. 1986, Weller 1994, Benoit and Askins 1999). Exploitation of pool habitat by aggregations of egrets is most common in the early morning when depleted oxygen levels drive fish to the surface (Kersten et al. 1991), and use of pool habitat by aggregations appears to benefit foraging egrets by increasing capture rates and decreasing energy expenditure (Master et al. 1993). Salt marsh pools were available in 11 of 13 study marshes but were not always used where available.

Clarke et al. (1984) found that while mosquito ditches contained abundant prey, they were often inaccessible to foraging birds and negatively impacted salt marsh bird use. Only approximately 2% of foraging egrets observed during this study were using ditches. In New England, pool density is significantly greater in marshes without mosquito ditching (Adamowicz and Roman 2005); thus, mosquito ditches provide little foraging habitat for egrets, and they may reduce the amount of preferred pool habitat available.

Although available in every study marsh, no foraging egrets were ever observed using habitats dominated by *Phragmites australis*. Benoit and Askins (1999) showed that *Phragmites* was negatively related to salt marsh bird use and suggested that prey may be unavailable or inaccessible in dense *Phragmites* stands, especially for relatively large birds. In a recent study of New England salt marshes, Shriver and Vickery (2001) found that *Phragmites* was negatively associated with pool habitat and that wading birds were generally associated with pool habitat and with *Spartina alterniflora*.

Information presented here can be used to assess the importance of existing or potentially restored salt marshes for foraging egrets. The area of salt marsh graminoids was the single greatest factor determining numbers of foraging egrets, regardless of season. The mean number of foraging egrets using each marsh was strongly related to salt marsh graminoid area, but density varied little and showed no relationship to marsh size. This suggests that marsh size does not affect habitat quality for foraging egrets and that even small salt marshes (< 2 ha) have value to wildlife. This is especially important in Rhode Island, where the mean size of salt marshes is approximately 2 ha (Trocki 2003).

Gibbs (1991) found that great blue heron (*Ardea herodias* L.) nesting colonies in Maine were not randomly distributed across the landscape but were situated in locations that minimized flight distance and maximized energetic efficiency in relation to surrounding foraging sites. If one assumes that nesting egrets select foraging sites efficiently and do not fly greater distances than necessary, the lack of relationship between site use and colony distance in this study suggests that foraging habitat in southern Rhode Island may be saturated during the breeding season. This study included foraging sites ranging approximately 3–20 km from active colonies. During the breeding season, colony distance was included as a variable in the selection of models. However, distance to the nearest active nesting colony showed no relationship to the mean number of foraging egrets observed per survey at each marsh. This indicates that 20 km is a reasonable flight distance for foraging egrets in this region. Apparently, distances between nesting colonies and marshes were not limiting marsh use during the breeding season.

Salt marshes are a patchy resource representing less than 1% of the total area within 20 km of active colonies in our study area, reinforcing the concept that egrets seeking foraging habitat are forced to choose among discrete habitat patches. Although foraging efficiency and prey availability were not measured directly in this study, marsh characteristics and habitat configuration, which are assumed to directly affect prey availability (Gawlick 2002) and hence foraging efficiency, varied considerably between marshes. The fact that foraging egret density varied so little among marshes is further indication that foraging habitat may be saturated during the breeding season. If nesting habitat is not limiting, then foraging habitat may be a limiting factor. If this is the case, then salt marsh restoration efforts could enhance the local egret population.

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