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# Nesting Habitat Requirements of the Brown Pelican and Their Management Implications

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**ABSTRACT**

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Because of the severe land loss in coastal Louisiana, many natural nesting areas for the Brown Pelican (*Pelecanus occidentalis*) are disappearing. Based on field measurements, geographical information system analysis, and a review of the relevant literature, we developed design criteria for the optimal artificial breeding habitat for Brown Pelican. Brown Pelican colonized islands had at least 70% open water within 20 km surrounding the island. Persistent pelican colonies occurred at least 7 km from the mainland and 0.3 km from the nearest island. Long-term colonized islands were between 10 and 70 ha in size with the shrub and dune habitat ranging from 2 to 20 ha on these islands. Pelicans preferred nesting in shrubs, and nesting occurred at an average elevation of 30 cm above mean sea level. We recommend that management for pelican nesting habitat includes loafing habitat: a beach that is at least 28 m wide is recommended.

**ADDITIONAL INDEX WORDS:** Pelecanus occidentalis, *Louisiana, breeding habitat, seabird.*

## INTRODUCTION

Louisiana contains the largest area (142,454 ha in 1982) of undeveloped coastal barriers in the United States (WILLIAMS and JOHNSTON, 1995). From 1853 to 1989, the barrier islands of Louisiana have undergone alarming land loss (WILLIAMS, PENLAND, and SALLENGER, 1992). This land loss is the result of a complex interaction among subsidence, sea-level rise, wave processes, tropical and extratropical storms, inadequate sediment supply, and human disturbance (PENLAND and BOYD, 1981; MCBRIDE *et al.,* 1991). Because of this loss, many natural nesting areas for pelicans are disappearing. Recent hurricanes—Andrew in 1992 and Georges in 1998—have led to severe reductions of habitat on the islands used by the Brown Pelican (*Pelecanus occidentalis*). Simultaneously, the numbers of Brown Pelican nesting in Louisiana is rapidly increasing, after the local extirpation and reintroduction in the early 1970s (HOLM *et al.,* 2004; VISSER and PETERSON, 1994, 1998). In the past decade the number of breeding birds in Louisiana has increased exponentially from 2,000 nests in 1990 to 14,000 nests in 2000 (HOLM *et al.,* 2004). However, the population is stabilizing around 15,000 nests (1999–2003; LDWF, unpublished data). The amount of nesting habitat will become the most important limiting factor on Brown Pelican numbers in Louisiana (HOLM *et al.,* 2004).

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LANDIN (1979) reviewed the use of dredged material islands by colonial waterbirds and found that these artificial habitats were extensively used where natural habitats were destroyed. However, where natural sites remained available, the use of artificial habitats decreased. The Brown Pelican habitat suitability index of the US Fish and Wildlife Service (HINGTGEN, MULHOLLAND, and ZALE, 1985) provides the following recommendations for breeding habitat: (i) island area between 2 and 8 ha, (ii) distance from the mainland > 0.4 km, (iii) distance from nearest human activity center > 0.4 km, and (iv) island covered with greater than 50% woody (0.6–10.7 m height) vegetation (for Florida, Alabama, and Louisiana). Since waterbird colonies tend to occur on islands that are too small to support mammalian predators (*e.g.,* raccoons), a small island size was recommended. However, the 2- to 8-ha size recommended by HINGTGEN, MULHOLLAND, and ZALE (1985) seems extremely small when considering existing colonized islands in Louisiana. For example, Raccoon Island—one of the premier colonies containing Brown Pelicans in Louisiana—was approximately 80 ha in 1988 (WILLIAMS, PENLAND, and SALLENGER, 1992). At Queen Bess Island, 180 additional ha of marsh were created on the original footprint of the island (LOUISIANA DEPARTMENT OF NATURAL RESOURCES 1998), and the colony has remained active. Most of the large islands used by Brown Pelicans in Louisiana are located far from the mainland and human activity centers (Figure 1). In addition, these islands may be too low

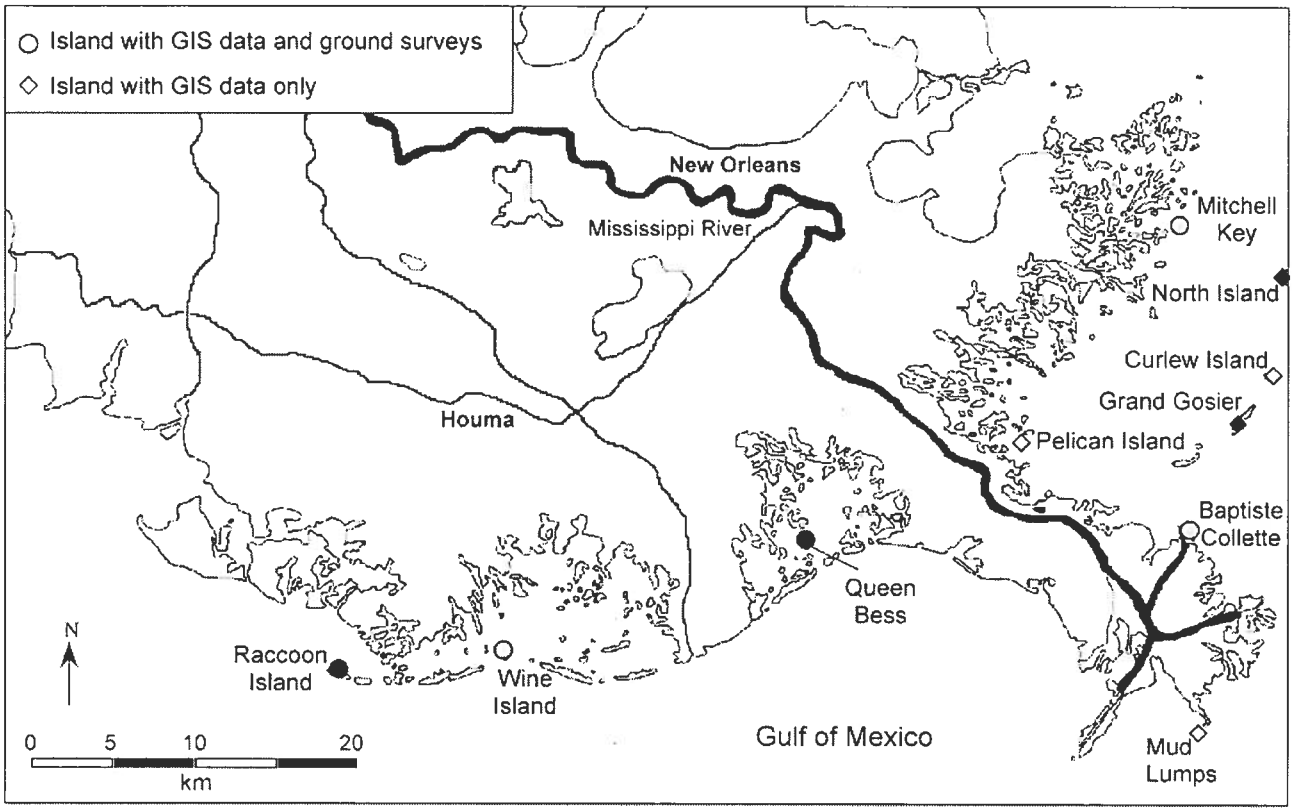


Figure 1. Location of islands used by breeding Brown Pelican in 2000. Persistent colonies are indicated with black symbols, and recent colonies are indicated with gray symbols.

in elevation to support mammalian predators, making small island size less important.

The disappearance of islands used for breeding by colonial waterbirds due to erosion and human disturbance is a nationwide problem (ERWIN, ALLEN, and JENKINS, 2003; ERWIN, HATFIELD, and WILMERS, 1995; PARNELL *et al.*, 1988). The creation of artificial habitats where natural habitats are limited has been advocated by waterbird researchers (PARNELL *et al.*, 1988). The creation of artificial habitats with dredged material has resulted in the establishment of new waterbird breeding colonies (ERWIN, ALLEN, and JENKINS, 2003; LANDIN, 1979 and references therein; VISSER and PETERSON, 1994; WOOD *et al.*, 1995), but there exists little quantification of the criteria that led to this success or how it might have been enhanced through management. The opportunity for artificial habitat creation in coastal Louisiana exists with ongoing coastal restoration activities under the Coastal Wetland Planning Protection and Restoration Act, through mitigation of oil and gas exploration impacts, and through beneficial use of dredged material from navigation channel maintenance. The objective of this study was to re-evaluate design criteria for optimal breeding habitats for Brown Pelicans.

## METHODS

We compiled a list of quantifiable criteria to describe nesting habitat requirements of seabirds to select variables for this study (BUCKLEY and BUCKLEY, 1972; BURGER and LESSER, 1978; BURGER and SHISLER, 1980; GOCHFELD, 1983; LACK, 1968; LANDIN and SOOTS, 1978; MCCRIMMON and PARNELL, 1983; STOREY, 1987). This literature review included seabird species other than Brown Pelican to maximize the number of variables for consideration.

During the breeding season in June 2000, we surveyed from the air all Louisiana barrier and back-barrier islands that were used by Brown Pelicans in the past (Figure 1) except the colonies on the Breton National Wildlife Refuge (*i.e.,* North Island, Grand Gosier Island, Curlew Island, and Baptiste Collette), which were surveyed by refuge personnel. These surveys included three colonies that already received some restoration effort (Wine Island, Queen Bess, and Raccoon Island) and one dredged material island not specifically created for seabird nesting (Baptiste Collette). On most surveyed islands, we marked all areas used for nesting on a map and made photographic records of the location of the birds. These activities were performed in such manner as to mini-

Table 1. *Metrics determined for Brown Pelican colonized islands. Persistent colonies are those islands used regularly for at least the past 10 years and include Queen Bess, North Island, Raccoon Island, and Grand Gosier South (see Table 2).*

| | All Colonies | | Persistent Colonies | | | Recent Colonies | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | Mean ± SE* | *n* | Mean | Range | *n* | Mean | Range |
| Isolation parameters | | | | | | | | |
| Distance to mainland (km) | 10 | 13.2 ± 4.5 | 4 | 18.9 | 7.2–33.4 | 6 | 9.5 | 0.2–39.0 |
| Distance to nearest land (km) | 10 | 2.4 ± 0.7 | 4 | 2.2 | 0.3–4.7 | 6 | 2.4 | 0.1–7.1 |
| Distance to nearest launch (km) | 10 | 32.9 ± 6.1 | 4 | 36.4 | 4.8–70.9 | 6 | 30.6 | 15.0–50.3 |
| Food availability parameters | | | | | | | | |
| Water within 20 km (%) | 10 | 86 ± 4 | 4 | 88 | 70–98 | 6 | 85 | 65–98 |
| Distance to inlet (km) | 10 | 7.1 ± 3.4 | 4 | 5.9 | 0–20.0 | 6 | 7.9 | 0–27.5 |
| Habitat parameters | | | | | | | | |
| Island size (ha) | 10 | 36.0 ± 17.3 | 4 | 36.2 | 11.0–68.4 | 6 | 35.8 | 0.6–178.3 |
| Dune and shrub area (ha) | 10 | 11.7 ± 6.2 | 4 | 9.5 | 2.0–20.1 | 6 | 13.1 | 0.3–65.2 |
| Mean elevation (cm) | 5 | 22 ± 5 | 2 | 23 | 15–30 | 3 | 20 | 8–32 |
| Maximum elevation (cm) | 5 | 62 ± 6 | 2 | 71 | 68–74 | 3 | 55 | 41–72 |
| Beach width (m) | 5 | 33 ± 15 | 2 | 58 | 29–88 | 3 | 15 | 6–33 |

* SE = standard error.

mize impacts to the birds. Two islands surveyed only by air were Pelican Island and the Mud Lumps.

From August 23, 2000, to October 11, 2000 (after the breeding season but before major storms could alter the habitat), we took field measurements on five colonized islands. We attempted to take field measurements at all islands that were used by Brown Pelicans in 2000. However, weather conditions prevented field measurements at five remote islands (North, Curlew, Grand Gosier, Pelican, and Mud Lumps). We were able to take geographical information system (GIS) measurements of all 10 islands with breeding pelican in 2000 (which are described here).

We used digital orthophoto quarter quadrangle (DOQQ) imagery flown in the first months of 1998 (obtained from http://www.atlas.lsu.edu) to determine island parameters for 10 colonized islands (Figure 1). Using a minimum mapping unit of 5 m, we interpreted the land/water interface to establish the island boundaries. We employed Intergraph Corporation's MGE (modular GIS environment) to determine island size, dune and shrub habitat area, and distances to the nearest contiguous landmass (or mainland), nearest island, and Gulf of Mexico. In addition, we measured the percentage of water area within a 20-km radius from each island.

Field surveys used five parallel transects representing a cross section of the island through the areas that had been used by breeding pelican. Measurements were taken at 5-m intervals along each transect. Each transect started at the water's edge and extended up to 100 m inland. On islands that were less than 50 m wide, station intervals were reduced to assure a minimum of 10 stations per transect. At each station relative elevation was measured using a self-leveling Leitz level to the nearest 3 mm. We also measured the elevation and location of the high-water mark along each transect. The elevation relative to mean sea level (MSL) of the high-water mark was estimated using the maximum water level in the 2 weeks prior to the survey from the NOAA gauge at Grand Isle (gauge 8761724 data downloaded from http://co-ops.nos.noaa.gov). This measurement was then used to transform the measured relative elevation data to elevation data relative to MSL. The width of the beach (high-tide width) was estimated by calculating the distance between the high-water line and the first station with greater than 50% vegetation cover along each transect.

At each station a 1-m$^2$ plot was surveyed for vegetation species composition and cover. Ocular cover estimates (5% intervals) were made by the same observer. At the same time, the location of the station was classified as no nesting or pelican nesting habitat. We used two-way indicator species analysis (TWINSPAN; HILL, 1979) to classify these plots into vegetation types.

Habitat selection was determined with the selection ratio (MANLY *et al.*, 2002). Statistical differences in the selection index for different vegetation types/habitats were determined by ranking vegetation types/habitats based on increasing selection index and then testing adjacent habitats using the appropriate chi-square test statistic (see MANLY *et al.*, 2002). We tested the difference in elevation of the plots with analysis of variance, with pelican use, habitat type, and their interaction as sources of variation.

We generated 10 parameters for each island based on the variables measured (Table 1). Three island parameters were used to describe the relative isolation of the island. The first isolation parameter was distance from the mainland. For this measurement mainland was defined as the semicontiguous land (*i.e.*, separated by water bodies less than 0.1 km wide). The second isolation parameter was the distance to the nearest land. This was the smaller of the following two: (i) distance to the nearest island and (ii) distance from the mainland. We estimated the isolation from human disturbance using the surrogate distance to the nearest boat launch. We generated two parameters that are indirectly related to food sources: percentage of the area within 20 km from the colony that can be classified as water and distance of the island to the nearest inlet of the Gulf of Mexico into a coastal bay. The remaining five island parameters describe the habitat. These include the size of the island, the amount of breeding habitat available on the island (for determination of breeding habitat,

Table 2. *Number of adult birds present at active Brown Pelican colonies during the 2000 breeding season and breeding colony history.*

| Island Name | 2000 Pelican Count | Colony History* |
|---|---|---|
| Queen Bess | 1,300 | Point of reintroduction in 1971 |
| North Island† | 1,300 | Historic colony‡, first reuse recorded 1983 |
| Mud Lumps | 35 | Historic colony, intermittently used |
| Raccoon island | 1,550 | Historic colony, first reuse recorded 1989 |
| Grand Gosier South† | 700 | Historic colony, first reuse recorded 1990 |
| Curlew Island† | 2,840 | Historic colony, first reuse recorded in 2000 |
| Wine Island | 70 | New colony, first use recorded in 1997 |
| Baptiste Collette† | 11,280 | New colony, first use recorded in 2000 |
| Pelican island | 120 | New colony, first use recorded in 2000 |
| Mitchell Key | 50 | New colony, first use recorded in 2000 |
| Total | 19,245 | |

* Based on PORTNOY (1977); KELLER, SPENDELOW; and GREER (1984); MARTIN and LESTER (1990); VISSER and PETERSON (1994, 1997); and this study.
† Data provided by James Harris (USFWS).
‡ Historic colony represents sites that were used by breeding Brown Pelican before extirpation in Louisiana.

see the "Results" section), the mean and maximum elevation, and the average width of the beach.

## RESULTS

### Colony Site Histories

In 2000, we found approximately 19,000 adult birds at 10 colonies, with 59% of birds nesting at Baptiste Collette (Table 2). Four colony sites were first used or reused in 2000, reflecting both the dramatic increase in the breeding population (see HOLM *et al.* 2004) and the destruction of breeding habitat at Grand Gosier resulting from Hurricane Georges in the fall of 1998. In 1997, Grand Gosier North had 2,500 adults present, and Grand Gosier South had 3,000 adults present (VISSER and PETERSON, 1998); most of these birds and their offspring were forced to find new breeding sites after Hurricane Georges destroyed all breeding habitat on Grand Gosier North (only a submerged sand bar was present in 1999) and most of the breeding habitat on Grand Gosier South. All new colony sites recorded in 2000 are in the vicinity of Grand Gosier Islands. The mud lumps (or diapers) are unique unstable geological structures (ROBERTS and COLEMAN, 1996) that are historically intermittently used by breeding pelicans. In addition to the colony site at Queen Bess—used to reestablish breeding pelicans after their local extirpation in the early 1960s (PORTNOY, 1977)—three colony sites used by pelicans before extirpation were recolonized in the mid-1980s and early 1990s (Table 2). ERWIN, GALLI, and BURGER (1981) define optimal breeding sites as those that are reused in subsequent years. Therefore, we report results for those colony sites that have been regularly used in the past 10 years (persistent colonies) separate from those that have been used only in recent years (recent colonies).

### Vegetation Classification

Using TWINSPAN we clustered the surveyed plots into eight vegetation types. Of these the bare type was the most common, representing 44% of the plots (Table 3). Bare plots had generally less then 20% vegetation cover, although almost all the plant species occasionally occurred in these plots. Bare plots were present in beach, dune, and overwash areas. The *Spartina alterniflora* (oyster grass)–dominated marsh was the second most common vegetation type, representing 23% of the plots. The plots occasionally were covered by parts of *Avicennia germinans* (black mangrove) shrubs or seedlings. Four different dune vegetation types were distinguished, all with greater than 20% vegetative cover dominated by different grasses (Table 3). Of the dune vegetation types, the *Sporobolus virginicus* (coastal dropseed)–dominated vegetation type was the most common. Two shrub vegetation types, one dominated by *Avicennia germinans* and the other dominated

Table 3. *Vegetation type selection by Brown Pelican for nesting. Standardized selection index and chi-square comparisons follow MANLY* et al. *(2002).*

| | Surveyed Stations | | Nesting Stations | | |
|---|---|---|---|---|---|
| Vegetation Type | Number | Percentage | Number | Percentage | Standardized Selection Index* |
| Marsh | 97 | 22.7 | 7 | 7.2 | 0.02 A |
| Bare | 187 | 43.7 | 16 | 16.7 | 0.03 A |
| *Distichlis*-dune | 7 | 1.6 | 1 | 1.0 | 0.05 A† |
| *Sueda*-dune | 12 | 2.8 | 3 | 3.1 | 0.08 A† |
| *Sesuvium*-dune | 31 | 7.2 | 9 | 9.4 | 0.10 A |
| *Sporobolus*-dune | 47 | 11.0 | 17 | 17.7 | 0.12 A |
| *Avicennia*-shrub | 13 | 3.0 | 11 | 11.5 | 0.28‡ B |
| *Iva*-shrub | 34 | 7.9 | 32 | 33.3 | 0.32‡ B |
| Total | 428 | | 96 | | |

* Letters indicate habitat selection parameters that are not significantly different from each other.
† These two vegetation types had insufficient observations for reliable chi-square test.
‡ Indicates a significant preference.

Table 4. *Habitat selection by Brown Pelican for nesting. Standardized selection index and chi-square comparisons follow* MANLY et al. *(2002).*

| Habitat | Surveyed Stations | Nesting Stations | Standardized Selection Index* |
|---|---|---|---|
| Marsh | 97 | 7 | 0.05 A |
| Bare | 187 | 16 | 0.06 A |
| Dune | 97 | 30 | 0.22 B |
| Shrub | 47 | 43 | 0.66† C |
| Total | 428 | 96 | |

* Letters indicate habitat selection parameters that are not significantly different from each other
† Indicates a significant preference.

by *Iva frutescens* (groundsel bush), together represented 11% of the sampled plots.

### Habitat Selection on Colonized Islands

Pelicans significantly preferred nesting in the two shrub vegetation types over all other vegetation types (Table 3). When vegetation types are combined into habitats, shrub habitat remains the preferred habitat (Table 4). Dune habitats are frequently used, but not more than expected based on the availability of this habitat (Tables 3 and 4). Although ground nesting occurred on dunes, nests were often located in scattered *Iva frutescens* shrubs throughout this habitat. Bare areas and marsh are infrequently used. We observed nesting in the scattered *Avicennia germinans* shrubs that are present in the marsh. The recorded use of bare areas is due mostly to small plot size (1 $m^2$) used during our surveys (with hindsight this plot size was too small). Some pelican nesting areas had small scattered shrubs that did not cover our plots leading to the classification of bare. This was especially evident on Queen Bess and Mitchell Key.

### Isolation of Colony Sites

The average colony site in 2000 was 13.2 km from the mainland, while the persistent colony sites were on the average twice as far from the mainland as the recent colonies (Table 1). Queen Bess was the persistent colony site closest to the mainland (7.2 km), while Baptiste Collette was the recent colony site closest to the mainland (0.2 km). Baptiste Colette was also the colony site closest to the nearest land (0.1 km). The colony site farthest from the nearest land was Curlew Island (7.1 km). Queen Bess was the colony site closest to a boat launch (4.8 km), while the average colony site was 33 km from the nearest boat launch. These results indicate that Baptiste Colette is the least isolated of the recent colonies and that Queen Bess is the least isolated of the persistent colonies.

### Food Availability Parameters

Water within the 20-km foraging radius ranged from 65% to 98% (Table 1), with the persistent colony sites having slightly more water in the foraging range than the recent colonies. The least percentage water in the foraging range occurred at Baptiste Colette, while Queen Bess had the least water (70%) in the foraging range of the persistent colony sites. Since many colonies were located on barrier islands, the distance to the nearest inlet was frequently zero. Recent colonies were on average slightly farther from the nearest inlet than persistent colonies. The longest distance from an inlet for persistent colonies was measured for North Island (20 km), while Pelican Island was the longest distance from an inlet of the new colonies (27.5 km). Both of these colonies are in the Breton Sound—a sound that has large openings connecting it to the Gulf of Mexico.

### Habitat Parameters

The islands colonized by pelicans ranged in size from 0.6 to 178.3 ha (Table 1). The smallest island colonized was the irregularly used Mud Lumps, while the largest island was the recently recolonized Curlew Island. Of the persistent colony sites, the smallest colony site was North Island (11 ha), and the largest colony site was Raccoon Island (68.4 ha). Although the range in size of the recent colonies was larger than the persistent colonies, the recent sites were smaller on average than the persistent sites (Table 1).

Mean elevation of all islands was 22 cm above MSL and differed little between persistent and recent colony sites. However, the maximum elevation of the persistent colony sites was higher than the maximum elevation of the recent colony sites. Of the two persistent colonies, Raccoon Island had the lowest maximum elevation at 68 cm above MSL, while Queen Bess had the highest maximum level (74 cm above MSL). The lowest maximum elevation of 41 cm above MSL was measured at Wine Island, with Mitchell Key having the second lowest maximum elevation (54 cm above MSL).

In general, the elevation of Brown Pelican nesting habitat (29.4 $\pm$ 1.5 cm above MSL; $n$ = 107) was significantly higher (ANOVA, $\alpha$ = 0.05) than the elevation of habitat not used by Brown Pelican (19.5 $\pm$ 0.7 cm above MSL; $n$ = 346). However, there was a significant interaction (ANOVA, $\alpha$ = 0.05) between habitat type and elevation (Figure 2). The areas classified as bare that were used by the pelicans for nesting were significantly higher in elevation than the unused bare areas. The bare areas used by pelicans had similar elevations to the dune areas. Within dune areas, there was no difference in elevation between nesting areas and unused areas. Although marsh areas used by pelicans were slightly higher than the unused marsh areas, the elevation was the lowest of any of the habitats used for nesting. Once more this is an artifact of our small plot size: pelicans were nesting in scattered *Avicennia* shrubs and not on the ground in the marsh.

Beaches were wider on the average at the persistent sites. The smallest beach was measured at Mitchell Key (6 m), while the largest beach was at Queen Bess (88 m). This very wide beach is the result of the fact that this island was restored with dredged material surrounded with a rock dike. Because we defined beach as the distance from the high-water line to the first plot with >50% vegetation cover, the large unvegetated area on Queen Bess was classified as beach.

Average dune and shrub habitat area of all islands was 36 ha and differed little between persistent and recent colony sites. The smallest dune and shrub area was measured on the recently colonized Pelican Island with 0.3 ha. The largest

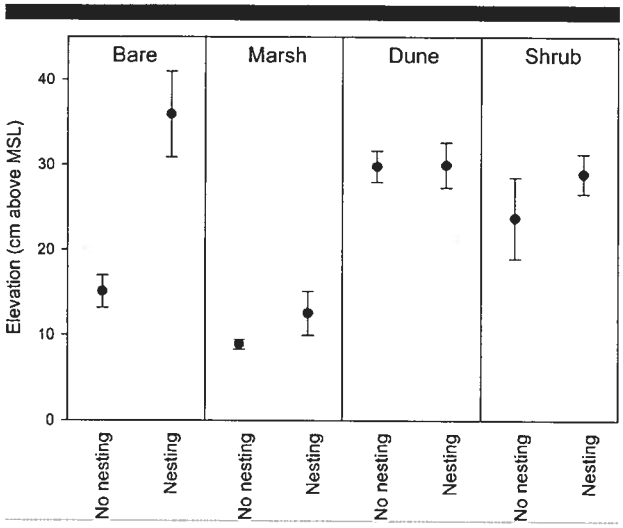


Figure 2. Difference in elevation between areas used by pelican and unused areas for the four habitats on islands colonized by Brown Pelican.

dune and shrub area was measured on the recently colonized Curlew Island (65 ha).

## DISCUSSION

### Colony Persistence

The suitability of a site for breeding depends on the availability of nest sites and food, protection from predators, and human disturbance (ANDERSON and KEITH, 1980; BUCKLEY and BUCKLEY, 1972; BURGER, 1985). In addition, site selection by colonial seabirds is often influenced by site tenacity—birds reusing previously successful breeding sites—and group adherence—birds nesting with the same sets of neighbors (MCNICHOLL, 1975; FAIRWEATHER and COULSON, 1995). Both site tenacity and group adherence tend to increase as birds age (GONZALEZ-SOLLIS, WENDELN, and BECKER, 1999; MCNICHOLL, 1975). ERWIN (1978) noted that high site tenacity is often the result of the lack of suitable colony sites and not the stability of nesting habitats as postulated by MCNICHOLL (1975). VISSER and PETERSON (1994) note that the high site tenacity of Brown Pelicans in coastal Louisiana is probably an indication that suitable breeding sites for these species are rare. Therefore, recent breeding sites selected by this species in Louisiana may be suboptimal. ERWIN, GALLI, and BURGER (1981) showed that suboptimal breeding sites (defined by ERWIN, GALLI, and BURGER as those that were abandoned the next breeding season) generally contained fewer breeding pairs than optimal breeding sites (those that were reused the next breeding season). Therefore, recent colonies with relatively few breeding pelicans such as Mitchell Key and Pelican Island may represent suboptimal habitat for this species. Both these islands had little shrub and dune habitat (<1.2 ha) and were relatively close to the mainland (<3.6 km).

We found that the area of colonized islands averaged 36 ha, with very little difference in average size between persistent and recent islands. From a management perspective, creating or preserving many smaller islands is preferred over fewer larger islands (ERWIN, HATFIELD, and WILMERS, 1995). Based on our observations from persistent colonies, we recommend an island size between 10 and 70 ha for the creation of artificial Brown Pelican nesting habitat.

### Isolation of Colony Sites

Our results show that distance to the mainland averages 13 km (Table 2). Persistent colonies were more isolated than the islands that were only recently colonized. The recently colonized island closest to the land was Baptiste Collette. This island was the largest Brown Pelican colony in Louisiana during our survey, but this site was used only recently and most likely contains birds that were displaced when available habitat on the Grand Gosier Islands was severely reduced by Hurricane Georges. Because of its proximity to the land, this island has potential for discovery by mammalian predators and was the only island where we observed signs of predator presence in the form of a mink burrow. Presence of coyote has also been noted at this site. Predation has been noted as a cause for reduced reproductive success in several colonial waterbirds but seldom leads to abandonment of the breeding site (SOUTHERN *et al.*, 1985; but see BURGER and GOCHFELD, 1991). In general, small mammals (*e.g.*, cats and rats) probably do not have significant effects on Brown Pelican reproductive success (ANDERSON *et al.*, 1989), but the bigger ones (*e.g.*, dogs, coyotes, and bobcats) might (D. ANDERSON, personal communication). Yet it is generally assumed that the significant isolation of colony islands is an adaptation to avoid mammalian predators, and seabird colony stability was associated with colony isolation from other islands and the mainland (GREER, CORDESS, and ANDERSON, 1988). In 2002, Baptiste Colette was abandoned by breeding Brown Pelican (LDWF, unpublished data). Based on our observations we recommend that islands created for Brown Pelican breeding habitat are at least 7 km from the mainland and at least 0.3 km from the nearest island.

### Availability of Food Sources

The Brown Pelican's diet consists of small fish (<25 cm) such as *Brevoortia patronus* (Gulf menhaden), *Mugil* sp. (mullet), *Polydactylus octonemus* (Atlantic threadfin), *Leiostomus xanthurus* (spot), and *Lagodon rhomboids* (pinfish) (HINGTGEN, MULHOLLAND, and ZALE, 1985, and references therein). Adults must supply approximately 57 kg of fish to each young before fledging (SCHREIBER, 1978). The Gulf of Mexico menhaden fishery is the second largest fishery in tonnage in the United States (US DEPARTMENT OF COMMERCE, 1996). Although fishing areas extend from Florida to Texas, more than 86% of the catch occurs off the Louisiana coast (LEARD *et al.*, 1995). Fishing is mostly restricted to offshore waters because of the draft of the vessels and to reduce catch of juveniles (R. CONDREY, personal communication). The only inshore area fished in Louisiana is the Breton Sound area (DE SILVA and CONDREY, 1998). Brown Pelicans forage primarily in estuarine bays and nearshore marine waters (SCHREIBER, 1978; WILLIAMS, 1979). California Brown Pelican foraging occurs

within 20 km of the nest site (BRIGGS *et al.*, 1981). Pelicans were most frequently found feeding on menhaden in water less than 5.5 m deep (DE SILVA, 1998). These observations fit well with our observation that in Louisiana persistent Brown Pelican colonies are located on islands surrounded by at least 70% open water within the 20-km foraging range. Baptiste Colette, an island that may represent suboptimal habitat (see previous discussion), had the lowest percentage (65%) of water within the foraging range. All Brown Pelican colonized islands are near water areas that support large concentrations of prey fish, and distance to the nearest inlet (where prey densities are generally denser) may be less important for Brown Pelican nesting site selection in Louisiana.

### Human Disturbance

In this study, we did not determine human disturbance at the colony sites, which is a potentially important factor in the selection of colony sites. However, all colony sites were much farther from human populations (smallest distance from a boat launch was 4.8 km) than the 0.4-km minimal distance from human population criteria in HINGTGEN, MULHOLLAND, and ZALE (1985). The Louisiana colony sites are disturbed mainly by people fishing in the surf. Anglers are not likely to be aware of the negative impacts their presence may have on the colony (BURGER, 1998). Human disturbance has been shown to affect reproductive success of Brown Pelican (ANDERSON and KEITH, 1980; SCHREIBER and RISEBROUGH, 1972). CARNEY and SYDEMAN's (1999) management advice based on a literature review is to keep at least a 100-m (300-ft) buffer between the nests and human visitors both on land and in the water.

### Habitat Selection

Brown Pelicans nested in a variety of habitats. Shrub habitat was preferred, but dune habitats were frequently used. Our (in hindsight) too small (1 $m^2$) sampling plots lead to the observations of use of bare and marsh habitat, while nesting actually may have occurred in the sparse shrubs found in these habitats. We recommend the use of a 4 × 4-m plot for future studies. Tree or shrub nesting is considered optimal for Eastern Brown Pelican because nests can be constructed above high tide on low-elevation islands, and pelicans are less vulnerable to human disturbance and opportunistic predators (SCHREIBER, 1978). Nesting on the ground occurs when shrubs are not available (BLUS *et al.*, 1979). Elevation of the island becomes very important when pelicans nest on the ground (HINGTGEN, MULHOLLAND, and ZALE, 1985). In our study, ground nesting occurred generally in dune habitats approximately 30 cm above MSL.

Beach width is a habitat selection criteria for several reasons. First, the establishment of a new colony is often preceded by the use of that island for nonnesting activities such as loafing and roosting (SCHREIBER and SCHREIBER, 1982). Beaches, sandbars, and spits are often used for these activities. Beaches are essential drying areas for pelicans that become waterlogged after more than an hour on the water (SCHREIBER and SCHREIBER, 1982). Second, beaches are also important for Brown Pelican fledglings that have not developed the coordination to land on branches (HINGTGEN, MULHOLLAND, and ZALE, 1985) and provide a relatively safe place for young pelicans that often flee into the water as potential land predators approach (J. VISSER, personal observation). We found an average beach width of 33 m at colonized islands.

### Management Implications

Numbers of breeding Brown Pelican have dramatically increased along the Louisiana coast, and the population may currently be restricted by breeding habitat. At the same time, coastal erosion is diminishing the available habitat. Data on breeding habitat requirements could assist future preservation, restoration, and/or creation efforts.

We found that the area of colonized islands averaged 36 ha. From a management perspective, creating or preserving many smaller islands is preferred over fewer larger islands (ERWIN, HATFIELD, and WILMERS, 1995). Based on our observations from persistent colonies, we recommend an island size between 10 and 70 ha for Brown Pelican nesting habitat.

Of the persistent colonies, Queen Bess was the least isolated; therefore, we used this island's relative isolation as a basis for recommending that future management efforts are directed toward islands that are at least 7 km from the mainland, at least 0.3 km from the nearest land, and at least 5 km from the nearest boat launch. To ensure sufficient foraging habitat, at least 70% of the area within a 20-km radius of the island should be open water.

Breeding pelicans prefer shrub habitat, and the establishment of shrubs such as *Avicennia germinans* and *Iva frutescens* is advised for the management of nesting habitat. We recommend augmenting shrub habitat with dune habitat with an average elevation of 30 cm above MSL. A minimum of 2 ha of these habitats should be available, but as much as 20 ha have been observed on persistently colonized islands. Persistent colonies had wider beaches than recent colonies. Therefore, we recommend that the management of pelican nesting habitat includes considerations for loafing habitat. A beach that is at least 28 m wide is recommended.

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