REPRODUCTIVE SUCCESS OF NESTING TERNS AND BLACK SKIMMERS ON THE CENTRAL TEXAS COAST

A Thesis

by

RACHEL R. FERN

Submitted to the Office of Graduate and Professional Studies of Texas A&M University
and the Graduate Faculty of The Texas A&M University – Corpus Christi
in partial fulfillment of the requirements for the joint degree of

MASTER OF SCIENCE

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**ABSTRACT**

Reproductive Success of Nesting Terns and Black Skimmers on the

Central Texas Coast (October, 2013)

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Chair of Advisory Committee: Dr. Kim Withers

Seabirds are top predators at sea and are particularly sensitive to changes in the marine environment. This gives them significant potential as bioindicators of the current state of and shifts in marine ecosystems. Nest site selection is important because the demands of reproduction can be substantial and the reproducing pair is often confined to the area selected for the duration of the breeding season. Location of the nest in relation to vegetative cover, colony density and richness can strongly influence reproductive success via exposure to predators or weather events and competition for food resources and optimal nest sites. Additionally, the timing of nesting in the breeding season can influence the outcome of the breeding effort due to storm events and increasing ambient temperatures.

This study defines temporal effects and correlations between reproductive success of nesting terns and skimmers and environmental characteristics of the nest site: area (ha), vegetative coverage, *Spartina* spp. coverage, elevation, nest density, assemblage richness and human disturbance. The four species included in this research (Forster's Tern *Sterna forsteri*, Gull-billed Tern *Gelochelidon nilotica*, Least Tern *Sternula antillarum* and Black Skimmer *Rhynchops niger*) were monitored at various nesting sites during the 2012 and 2013 breeding seasons. Reproductive success of Forster's Terns seemed to be influenced by human disturbance, nest density and species richness of the nest site. Elevation and *Spartina* spp. coverage both positively influenced the success of Least Terns. The nesting success of Gull-billed Terns was positively correlated with elevation and species richness of the nest site, and success of Black Skimmers was negatively correlated with species richness and positively correlated with elevation. All species that nested early in the breeding season suffered nest failure due to storm events; however, Gull-billed Terns were only marginally impacted. Establishing these correlations in environmental nest site characteristics and reproductive success of nesting terns and skimmers provides a baseline understanding of tern and skimmer breeding biology in the central Coastal Bend region of Texas, which may assist future management decisions and restoration efforts.

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# BACKGROUND AND RELEVANCE

Although most seabirds spend the majority of their time in pelagic zones, their influence on the coastal environment can be substantial. Terns (Family Sternidae) in particular, are top marine predators at sea and carry nutrients from the open ocean to terrestrial systems where they can significantly alter plant communities and soil properties (Moller et al. 2000). Considering the integral role they play in linking pelagic and coastal landscapes, discerning the interactions between seabirds and the environment is crucial in establishing any baseline understanding of coastal ecology. Terns show particular sensitivity to biotic changes in the marine environment and these changes often manifest in abnormal reproductive behavior or output (Le Corre and Jaquemet 2004). Thus, terns have significant potential as bioindicators in marine ecosystems (Burger et al. 1994). The importance of this potential is magnified due to threats of climate change and fisheries collapse. Black Skimmers (*Rynchops niger*) are also particularly sensitive to human disturbance (Safina and Burger 1983), which make them valuable in assessing and monitoring current and changing human impacts in the coastal environment. The goal of this research was to elucidate the basic nesting ecology of Forster's Terns (*Sterna forsteri*), Gull-billed Terns (*Gelochelidon nilotica*), Least Terns (*Sternula antillarum*), and Black Skimmers (*Rynchops niger*) using man-made habitats on the central Texas coast.

**Impacts of nest site parameters**. Terns and skimmers, like other seabirds, are relatively long-lived, lay small clutches and have deferred sexual maturity (Langham 1974; Furness and Monaghan 1987). Habitat selection during breeding is important because the demands of reproduction can be substantial and the reproducing pair is often confined to the area selected for the duration of the breeding season (Burger and Gochfeld 1988). Location in relation to cover, nests of conspecifics or other species, and food resources can strongly influence reproductive success via exposure to predators or weather events, availability of optimal nesting sites, and food supply (Monaghan et al. 1989; Burger and Gochfeld 1988; Langham 1974). Manufactured habitat, like dredge material islands, typically provides nesting seabirds with suitable nesting habitat. However, new dredge material islands, while offering minimal disturbance, often lack the vegetative cover and suitable substrate that some birds require for successful reproduction. Vegetative cover can affect reproductive success of nearby ground-nesters by providing cover for chicks from predation and extreme temperatures (Saliva and Burger 1989; Miyazaki 1996; Stauffer and Best 1986). Dredge material islands that have been "naturalized," some over decades, may require some disturbance tolerance and competitive ability on the part of nesting seabirds but offer protection from weather exposure and predators via vegetation cover.

While some studies have suggested a positive correlation between reproductive success and seabird nesting density due to advantages in predator evasion (Mooring and Hart 1992), other studies have suggested a negative correlation due to noise attraction of predators and prevalence of disease (Lariviere and Francois 1998; Brunton 1997). Nesting within a dense colony may provide added protection from predators, the "selfish herd" hypothesis: predators are detected earlier when more individuals are present (Wittenberger and Hunt 1985). However, in some dense Least Tern colonies nests located in the center suffered higher predation rates than those on the fringe or in less dense colonies (Brunton 1997). In the central Coastal Bend region of Texas, it has been suggested that Black Skimmers benefit from nesting alongside Gull-billed, Least, and Forster's terns because of the more violent nest and colony defense strategies of terns (Pius and Leberg 1998). However, reports of direct predation and kleptoparasitic behavior by Gull-billed Terns on Black Skimmer and Least Tern fledglings raises concerns when planning for future management of nesting colonies in which these species nest alongside one another (Landaberde 2007). Kleptoparasitism by Gull-billed Terns within mixed nesting colonies has substantial impacts on the reproductive success of skimmers and other tern species (Newstead and Blacklock 2005; Marschalek 2009)

**Temporal effects**. Once a nest is initiated, the breeding pair is confined to that space for the entire nesting and fledging process. Environmental conditions change as the season progresses; air temperatures typically increase, rainfall patterns change and precipitation may increase or decrease, and food availability may increase or decrease. Extreme temperatures threaten eggs and newly hatched chicks late in the season; however, storm events are much more frequent early in the breeding season allowing for greater nest retention for those pairs nesting in the later months. Breeding success has been linked in other species, e.g. Common *Sterna hirundo* and Roseate terns *Sterna dougallii*, to later nest initiation in the season (Burger and Gochfeld 1988; Spendelow 1982).

**Impacts of disturbance**. Reproductive success of colonial ground-nesters can be affected by human disturbance in a variety of ways. Aside from direct human damage (i.e. egg harvest or nest destruction), the presence of fishermen and other recreationalists can cause indirect damage. Early in the breeding season, frequent or continual presence of recreationalists can cause nesting pairs to shift to sub-optimal nest sites where they may be more susceptible to high tides, storm events, or predation (Burger 1977; Burger and Lesser 2008). Noise can also influence reproductive success (Potter 1992) through alterations of courtship behavior and by disturbing birds foraging near the colony (Parris and Schneider 2008). Additionally, when people are present birds may flush from their nests, exposing eggs to predation. Later in the breeding season, this becomes particularly important as summer temperatures can threaten the viability of the eggs if the adults are flushed and not able to return to shade the nest.

## SPECIES DESCRIPTIONS

The four species included in this study are Forster's Tern (*Sterna forsteri*), Least Tern (*Sternula antillarum*), Gull-billed Tern (*Gelochelidon nilotica*) and Black Skimmer (*Rynchops niger*).

**Forster's Tern.** This is a medium-sized member of the family Sternidae that breeds in freshwater lakes and coastal wetlands and marshes from North America south to the Caribbean and northern South America (BirdLife International 2012). Forster's Terns prefer to nest in floating or emergent vegetation but will also utilize dredge material or gravel islands (del Hoyo et al. 1996). Forster's Terns along the central Texas Gulf coast have historically been sensitive to disturbance, although they typically relocate their nests rather than wholly abandoning the nesting effort (Mueller and Glass 1988). On Mustang Island, Texas, a significant decline in Forster's and Gull-billed Tern abundance occurred from 1979-2007, and appeared to be correlated with a substantial increase in human activity (Foster et al. 2009). Elsewhere in its range, Forster's Terns are more directly threatened by storm events and avian predation than by human disturbance (McNicholl 1982).

**Least Tern**. Least terns are the smallest member of Sternidae; adults are only 22-24 cm long and have a wingspan of 50 cm. The species is divided into three subspecies: *S. a. antillarum* (breeds on the Atlantic coast of North America from Maine to the Carribean and northern Brazil), *S. a. athalassos* (breeds inland on the Arkansas, Mississippi, Brazos, Trinity and Rio Grande River basins) and *S. a. browni* (breeds on the Pacific coast of North America from California to the western coast of Mexico) (Thompson et al. 1997). Nest site selection and habitat preferences have been extensively researched. On the central Texas coast, Least Tern colonies are most often found at the highest available elevations where vegetation is sparse (Thompson and Slack 1982) which is similar to their nesting preferences in North Carolina (Jernigan et al. 1978). Elsewhere in its range, Least Terns have been known to nest on roof-tops in urban areas, where they are marginally more successful due to the inaccessibility of roofs to humans (LeGrand 1989; Cimbaro 1993; Krough and Schweitzer 1999). The roof-tops, however, do not shelter them from other serious threats: storm events and flooding, terrestrial and avian predation, and extreme temperatures (Krough and Schweitzer 1999). This species is especially sensitive to human disturbance (Krough and Schweitzer 1999; Burger 1984; Galli 1978). Birds tend to be more disturbed by foot or vehicular traffic than by boats (Thompson and Slack 1982). Although there has recently been a notable shift of Least Tern nest sites from traditional beach and barrier islands to dredge spoil islands (Mallach and Leberg 1999), nesting success has not changed. Direct comparisons of nesting success between man-made and natural sites are becoming increasingly difficult as more

Least Terns abandon beaches, barrier islands, and more human accessible sites and move their colonies to dredge material islands.

**Gull-billed Tern**. A fairly large species in the family Sternidae, Gull-billed Terns breed in most coastal temperate regions of the world (Parnell et al. 1995). These birds nest on shell hash substrate with sparse vegetation, some oyster shell aggregations in marshlands, and even on roof-tops in Louisiana and Texas (Eyler et al. 1999; Smalley et al. 1991). Despite its wide range, breeding data on this species is deficient (Molina and Erwin 2006). Although their breeding distribution is large, they are not abundant in any particular region in their North American range which makes assessing current population status and trends difficult (Parnell et al. 1995). However, based on local breeding waterbird surveys, they are believed to be declining regionally (Brinker 1996; Erwin et al. 1998; Florida Fish and Wildlife Conservation Commission 2003). Habitat loss threatens this species by forcing colonies to sub-optimal nesting sites at lower elevations, subjecting nests to tidal inundation, and increases the occurrence of human-subsidized species such as gulls and raccoons that prey upon their eggs and young (Blus and Stafford 1980; Erwin et al. 1998).

Despite possible declines, Gull-billed Terns are creative predators. Their diet differs from that of most sternids; this species does not often dive or plunge for their food, but they will eat fish from the surface of the water, insects on the wing, and even small reptiles and amphibians (Parnell et al. 1995). On the central Texas coast, Gull-billed Terns have been documented stealing food from neighboring ground-nesters (often Black Skimmers) as well as directly preying on newly hatched chicks of other species (Landaberde 2007).

**Black Skimmer**. Black Skimmers are large, tern-like seabirds and one of three members of the family Rynchopidae (Gochfield and Burger 1994). Their breeding range in the United States extends from Massachusetts to Florida on the Atlantic Coast, the entirety of the Gulf Coast, and to a small patch of coastal southern California (Gochfield and Burger 1994). This species is strongly colonial and nests in large colonies, commonly with a mixed-species assemblage (Clapp et al. 1983). Although skimmers do not prefer open shell hash nesting substrate to fine silt, they are typically more successful on the shell hash sites (Leberg et al. 1995; Mallach and Leberg 1999). Threats to this species include environmental pollutants (Hays and Risebrough 1972), avian and terrestrial predation (Burger 1981; Gochfield 1981; Quinn 1989), human disturbance (Gochfield 1981), and loss of habitat (Burger 1977; Burger and Lesser 1977; Erwin 1980). On the central Texas coast, the Black Skimmer breeding population has declined over 60% in the past three decades (Texas Colonial Waterbird Database 2005). While not considered a species of concern in Texas, elsewhere in its range it is considered a species of concern by some states due to similar population declines (Schuford and Gardali 2008; New York State Department of Environmental Conservation 2013; Florida Fish and Wildlife Commission 2013).

## OBJECTIVES

This study provides data on reproductive success of Forster's, Gull-billed, and Least terns and Black Skimmers on the central Texas coast. Reproductive success is examined as a function of timing in the breeding season, island area, total vegetative cover, *Spartina* spp. coverage, nest density, richness of the nesting assemblage, and human disturbance. For the purposes of this study, reproductive success is defined by clutch size, hatching success, and colony productivity; hatching or reproductive success describes a nest that produces at least one fledgling. The study began at the start of April and extended into mid-July in the 2012 and 2013 breeding seasons.

The objectives of this study were to answer the following questions:

1. To what extent is reproductive success in nesting terns and skimmers affected by the timing of nest initiation in the breeding season, richness of the nesting assemblage, total vegetative coverage, *Spartina* spp. coverage, human disturbance, nest density, elevation, and island area?
2. Can correlations between these parameters and hatching success be defined in order to better inform future management decisions?

Establishing these relationships in environmental nest site parameters and reproductive success will provide a baseline understanding of tern and skimmer nesting ecology, and should inform management actions or strategies aimed at conserving seabird species and for conserving or restoring nesting habitat on the central Texas coast.

## METHODS

**Study sites.** Sites included in this study were: The Portland Causeway Marsh Restoration Project in Nueces Bay, Texas (Nueces Bay Salt Marsh Restoration – NBSR); a stabilized land spit in Oso Bay located on the north side of the Oso Bay bridge; a small dredge material island just north of the JFK causeway leased by the Texas Department of Transportation (TxDoT); and a sandy beach located adjacent to the Texas A&M University-Corpus Christi campus on Corpus Christi Bay (Figs. 1, 2). These sites provided a diverse selection of vegetation cover, island area, human disturbance, and

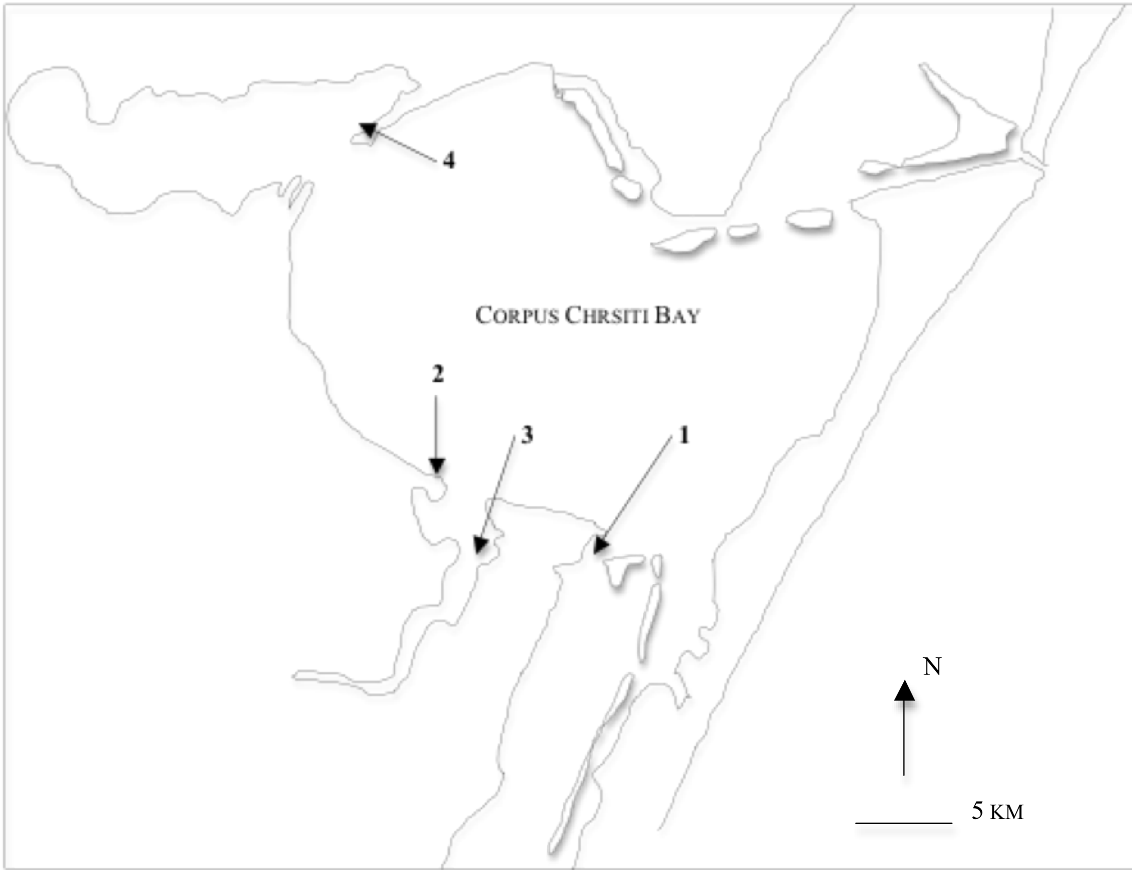


Fig. 1. Map showing study sites in the central Coastal Bend region of Texas. 1 – TxDoT leased island, 2 – Campus Beach site, 3 – Oso Bay site and 4 – Nueces Bay Salt Marsh Restoration site (NBSR).

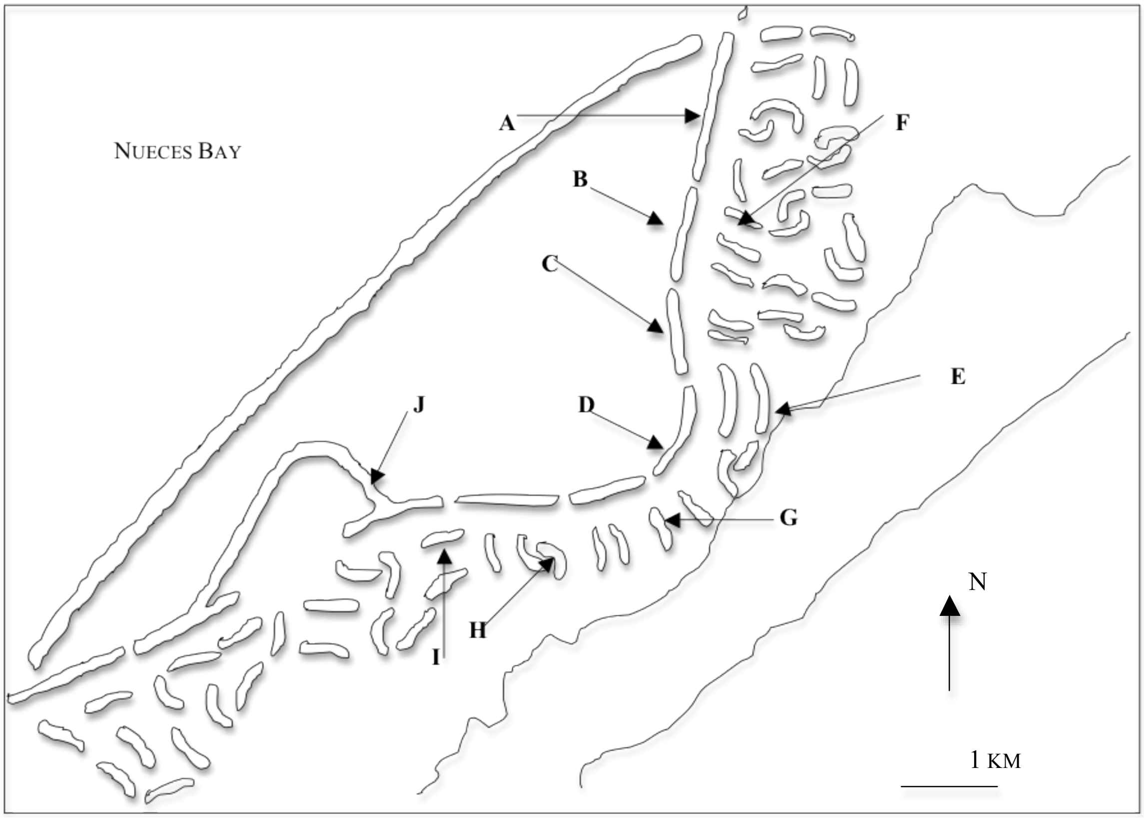


Fig. 2. Map showing the ten islands within site 4, the Nueces Bay Salt Marsh Restoration site that were monitored during the 2012 and 2013 breeding season. Each island was named a letter (A-J) to assign identity.

nesting bird assemblages. These sites were monitored for two consecutive years – the breeding seasons of 2012 and 2013. Without physical marking or manipulation of the birds, it was impossible to determine individual fidelity or monogamy among these colonies. Nonetheless, this study still sheds light on the importance of specific sites to seabird breeding ecology along the Texas coast.

**Reproductive success**. Individual nest success was monitored for all species nesting within colony sites. Nests were marked at initiation using a painted and numbered wooden (~30.5-cm) marker wedged in the ground roughly 0.5 m from the nest. The species of each nest was recorded as well as the number of eggs and fledglings present at the date of survey. Nesting sites were visited every 8-10 days, frequent enough to capture fledglings in the record but seldom enough to minimize disturbance caused by the sampling (Safina and Burger, 1983). With this data, colony productivity (fledglings produced per colony), hatching success (proportion of nests resulting in at least one fledgling), and mean clutch size per colony were calculated and compared against a gradient of potentially influential factors:

Environmental

- Disturbance (index: 1-3)
- Elevation (m)
- Island area (ha)
- % total vegetation cover
- % *Spartina* spp. cover
- Temporal scale

Biotic

- Density (nests/$ha^2$)
- Assemblage composition (richness index: 1-5)

Disturbance was measured categorically. The category represents the degree of disturbance each site was subjected to, primarily based on ease of access. Average number of weekly visits by recreationalists and average visit duration in hours were taken into account when a site was not easily categorized based solely on accessibility. Categories of disturbance were scaled from 1 to 3: low/none (1), low/medium (2), and high (3). Sites that were only accessible by boat were categorized as low/none, sites accessible by wading at least at low tide or a short kayak trip were included in the low/medium disturbance category and sites that were accessible by land at low and high tide were labeled as high disturbance.

Elevation was measured as a relative to the surface of the water and not to absolute elevation at mean sea level. Since ground nesting birds are particularly susceptible to nest loss due to high tides and storm events (Fisk 1975; McNicholl 1982; Erwin et al. 2001), using relative elevation provided a more accurate depiction of nest site suitability. Island area was calculated in square hectares using tools in the online software GoogleEarth™.

At each site, percent total vegetation cover and surrounding *Spartina* spp. coverage were estimated by sight. Date of initiation and ultimate outcome (success/failure) for each nest was recorded. Breeding success has been linked in other studies to time of nest initiation within the breeding season (Burger and Gochfeld 1988).

For each colony, total density (total nests per hectare) was calculated. Richness was measured as an index of assemblage composition: 1 ( only a single species present) to 5 (all 4 species included in this study were present in addition to another nesting seabird species – usually Black-necked Stilt *Himantopus mexicanus* or Laughing Gull *Leucophaeus atricilla*).

**Statistical analyses.** Because two breeding seasons are not sufficient to draw long-term, blanket conclusions, nesting data for the two years was pooled. The Mayfield method of determining nesting success was used to establish probability of success for each species (Mayfield 1961). This method, rather than solely taking into account number of successful nests, estimates the probability of success (a nest resulting in at least one fledgling) using the number of days the nest is exposed to predation, weather elements, and other factors. Data were analyzed using the statistical software R. Pearson's correlation coefficients were calculated for relationships between reproductive success (hatching success) and nest density (nests per ha), island area (in ha), species richness, percent vegetative cover, elevation (from water surface at high tide), and human disturbance.

## RESULTS AND DISCUSSION

Results are presented as species accounts in which environmental descriptors that were correlated to reproductive success are discussed in detail. Here, observations not reflected in the raw data are also reported to support claims and conclusions. Environmental characteristic data for each site are also presented (Table 1). Ten islands within the Nueces Bay Salt Marsh Restoration site (NBSR) that were monitored and are listed within Table 1 as A-J. *Spartina* spp. was only present at islands within this site. The largest nest sites with the highest elevations were also found in the NBSR site, with the exception of Campus Beach. The Oso Bay and Campus Beach sites were the most heavily disturbed and were both accessible by land. The TxDoT island was moderately disturbed as it is accessible via a mid-depth wade and the NBSR islands were least disturbed being only accessible by boat. The islands within the NBSR site were the least vegetated, and the TxDoT island had the highest vegetation cover.

**Forster's Tern *Sterna forsteri*.** Forster's terns nested on a land-accesible island in Oso Bay and multiple islands within the NBSR site. The nest site in Oso Bay is heavily disturbed year round with visitation by fisherman (and their vehicles) becoming more frequent later in the season. Islands in Nueces Bay are only accessible by boat and were seldom visited by fishermen in both seasons. Hatching success was substantially higher at

Table 1. Data measured for all nest site environmental characteristics: area, elevation, *Spartina* coverage, vegetative cover, disturbance and richness. A-J refers to the specific island within the NBSR island complex.

| | Area ($ha^2$) | Elevation (m) | % *Spartina* spp. cover | % total vegetative cover | Disturbance | Richness |
|---|---|---|---|---|---|---|
| **NBSR** *A* | 0.345 | 0.80 | 0.40 | 0.1 | 1 | 5 |
| *B* | 0.138 | 0.90 | 0.25 | 0.30 | 1 | 5 |
| *C* | 0.097 | 0.85 | 0.05 | 0 | 1 | 3 |
| *D* | 0.113 | 1.1 | 0 | 0 | 1 | 3 |
| *E* | 0.107 | 0.70 | 0 | 0.05 | 1 | 5 |
| *F* | 0.062 | 0.78 | 0 | 0.05 | 1 | 4 |
| *G* | 0.044 | 0.85 | 0.30 | 0 | 1 | 2 |
| *H* | 0.052 | 0.68 | 0 | 0 | 1 | 4 |
| *I* | 0.059 | 0.85 | 0 | 0 | 1 | 2 |
| *J* | 0.016 | 1.1 | 0.50 | 0 | 1 | 3 |
| **Oso Bay** | 0.085 | 0.35 | 0 | 0.30 | 3 | 3 |
| **TxDot** | 0.048 | 0.30 | 0 | 0.60 | 2 | 1 |
| **Campus** | 0.592 | 0.38 | 0 | 0.05 | 3 | 1 |

the Nueces Bay site as was colony productivity, re-lay frequency, average clutch size and Mayfield probability (Table 2). Although not statistically significant ($p<0.1$), success seemed to be most strongly correlated with island area, *Spartina* spp. cover, nest density, disturbance, and richness (Table 3).

Total nests, nest initiation and the likelihood of success peaked in the last week of May for both years. Nest loss was greater early in the season and decreased as the season continued. Figures 3 and 4 show a large proportion of total nests were newly initiated in the first four surveys and new initiations only comprised small portions of total nests later in the season. Initiation and nest density dropped sharply in the second week of June at both sites and no active nests existed by the first week of July. Although total nest density was greater at the Oso Bay site, success was higher at the NBSR site (Figs. 3, 4). While nest numbers were still high in early June, likelihood of success dropped to zero after the last week of May. Most nests initiated after the peak in late May ultimately failed. This may indicate sensitivity to increases in rising ambient temperature, shortages of available

Table 2. Nesting success data for Forster's Terns pooled for the 2012 and 2013 breeding seasons. [1] A refers to live chicks and D refers to dead chicks.

| | **NBSR** | **Oso** |
|---|---|---|
| Total nests | 103 | 44 |
| Hatching success | 26.2% | 9.1% |
| Colony productivity (A/D)[1] | 25/9 | 5/3 |
| Re-lay occurrence | 4 | 2 |
| Clutch size | 2.2 | 1.7 |
| Mayfield probability | 0.48 | 0.14 |

Table 3. Pearson's correlation coefficients for relationships between measured environmental nest site charactericters and reproductive success of Forster's (FOTE), Least (LETE), and Gull-billed terns (GBTE) and Black Skimmers (BLSK). * denotes significance (p<0.1)

| | **Area** | **Vegetative cover** | ***Spartina* spp. cover** | **Elevation** | **Density** | **Disturbance** | **Richness** |
|---|---|---|---|---|---|---|---|
| **FOTE** | 0.04 | 0.004 | 0.25 | 0.20 | -0.03 | -0.24 | -0.33 |
| **LETE** | -0.19 | -0.19 | 0.53* | 0.13 | -0.44* | -0.16 | -0.38 |
| **GBTE** | 0.25 | 0.15 | 0.56* | 0.51* | 0.41 | -0.15 | 0.72 |
| **BLSK** | 0.37 | 0.37 | -0.16 | -0.41* | 0.43 | 0.45 | -0.37* |

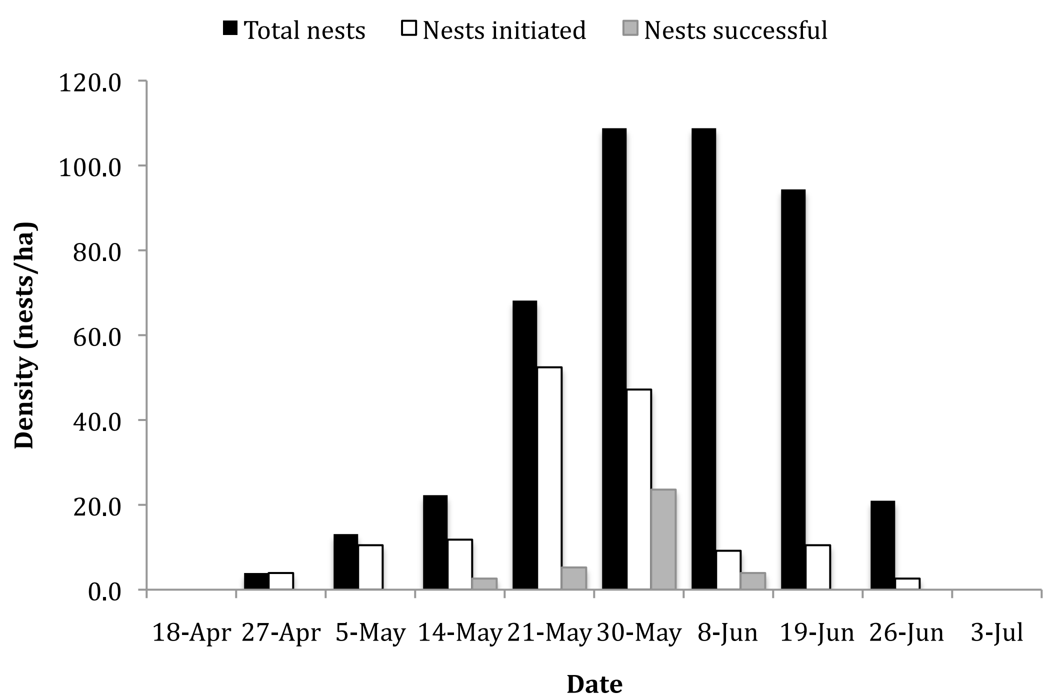


Fig. 3. Temporal distribution of total nest density, initiation, and success of nesting Forster's Terns at the NBSR site pooled from the 2012 and 2013 breeding seasons.

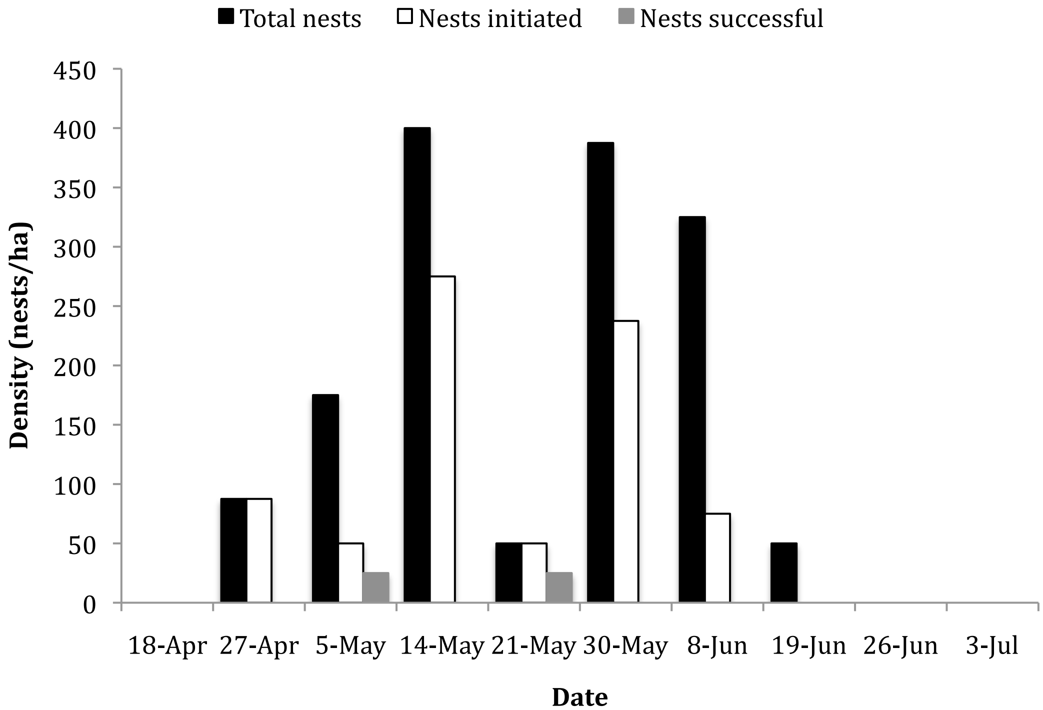


Fig. 4. Temporal distribution of total nest density, initiation, and success of nesting Forster's Terns at the Oso Bay site pooled from the 2012 and 2013 breeding seasons.

food as small fish seek the cool temperatures of deeper water, or the prevalence of fire ants *Solenopsis* spp. late in the summer.

Despite lacking statisitical significance, hatching success seemed to be negatively associated with human disturbance (Table 3). High disturbance caused birds to flush from their nests allowing excessive heat, inundation, fire ant attacks, and predation by other birds. Even disturbance at neighboring islands where they were not nesting caused Forster's Terns to flush and remain aflight until the disturbance either ended (the fishermen or researchers left) or the birds became accustomed to their presence.

Based on observation,  richness of the nesting assemblage also seemed to influence the reproductive success of Forster's Terns at both sites (Table 3). There is a negative relationship between the richness of the nesting group and hatching success, although statistical significance was not possible with this sample size. Forster's Terns are relatively aggressive to humans and other terrestrial potential predators that venture too close to nest sites and will flush quickly to attack the intruder or stay aflight until the perceived danger has passed. As previously mentioned, Forster's Terns will flush even when the disturbance is on a neighboring island, often a good distance (20-50 m) away. On nest sites where Forster's Terns nest alongside other species (particularly those sites that are highly disturbed), spending a long time away from the nest allows for egg stealing and nest predation by other species. While neither was directly observed during the course of this study, Laughing Gulls have been observed in other nearby nest sites stealing and consuming eggs of Forster's Terns, as well as other species (O'Connell and Beck 2003). However, Laughing Gulls were absent the first breeding season at both sites where the Forster's Terns nested. Egg stealing attempts by Gull-billed Terns were observed on nests of other species (Forster's Terns included) in which a Gull-billed Tern would land and stand on a nest of another species while the birds belonging to the nest were flushed. They were often chased off by returning birds before any direct predation or stealing were observed. It is likely the Forster's Terns' sensitivity to assemblage richness is due to the possibility of predation by Gull-billed Tern.

The eggs of Forster's Terns are particularly small (2.5 - 3.8 centimeters in length) and nests, although usually constructed with a thin layer of vegetative matter, are essentially on the ground. This makes Forster's Tern nests especially susceptible to storm events in which strong winds may carry eggs away from the nest and tides or surges submerge them. *Spartina* spp. stabilizes low lying islands and serves as a buffer to storm surges and rough wave action during storm events and high tides (Ranwell 1967; Daehler and Strong 1996). Based on observation and the slight positive relationship in the correlation analysis, nests placed at higher elevations and in areas protected by surrounding *Spartina* spp. were generally more successful.

**Gull-billed Tern *Gelochelidon nilotica.*** Gull-billed Terns nested at both the NBSR site and the land accessible island in Oso Bay. At both sites, this species nested relatively densely and in mixed assemblages only; Gull-billed Terns were not observed nesting exclusively with their species. Hatching success in Nueces Bay was nearly double that in Oso Bay as was Mayfield probability (Table 4). This was the only species of which no dead chicks were observed. Hatching success of this species was significantly correlated with *Spartina* spp. cover and elevation although observations during this study suggest nest density and assemblage richness are also somehow correlated (Table 3).

Gull-billed Tern nest initiation was more consistent throughout the season and total density and success were higher at the NBSR site (Figs. 5, 6). Nest retention, the persistence of the nest week to week, was greater later in the season which might imply impacts from storm events. However, the likelihood of success was higher earlier in the season which might suggest that nest site selection was very important as early nesters were typically more successful. Despite slightly lower nest retention early in the season, nesting Gull-billed Terns did not seem to be heavily impacted by storms. Likelihood of success was higher earlier in the season, despite the higher frequency of storm events, and majority of nests were observed intact on survey dates following storms. At higher elevations on the islands, chicks are closer to clumps of vegetation that provide shelter from heat and predation (Montevecchi 1978).

Table 4. Nesting success data for Gull-billed Terns at the NBSR and Oso Bay sites pooled for the 2012 and 2013 breeding seasons. [1] A refers to live chicks and D refers to dead chicks.

| | NBSR | Oso |
|---|---|---|
| Total nests | 86 | 42 |
| Hatching success | 39.5% | 19% |
| Colony productivity (A/D)[1] | 37/0 | 10/0 |
| Re-lay occurrence | 6 | 1 |
| Clutch size | 2.8 | 2.6 |
| Mayfield | 0.6 | 0.35 |

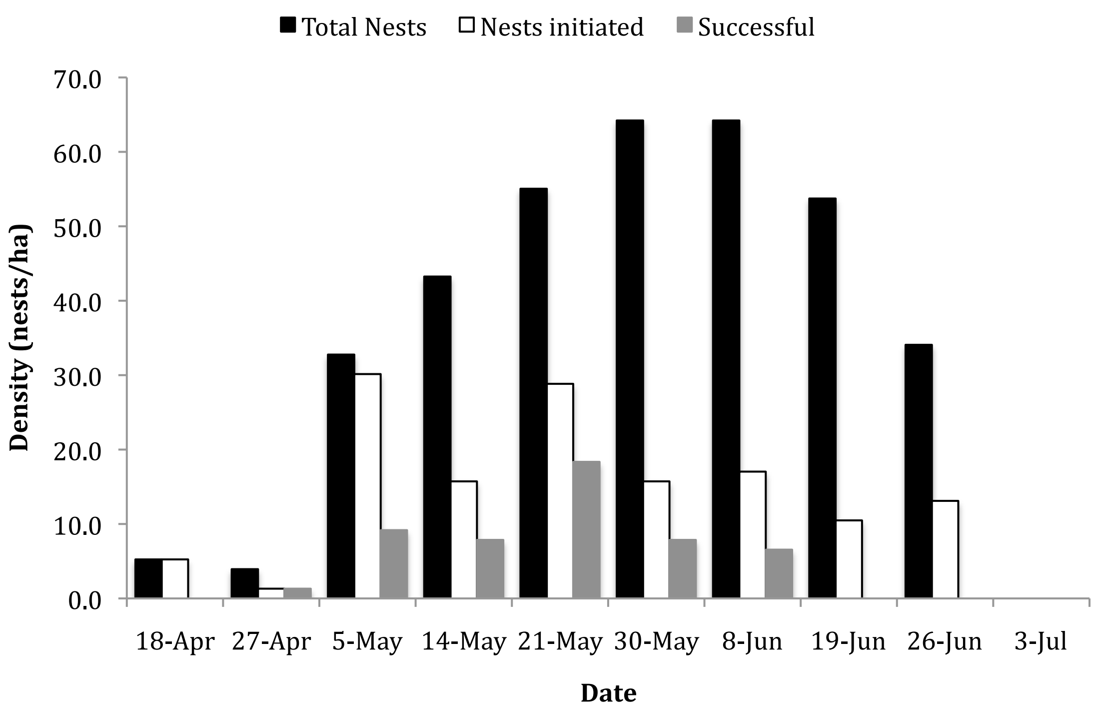


Fig. 5. Temporal distribution of total nest density, initiation, and success of nesting Gull-billed Terns at the NBSR site pooled from the 2012 and 2013 breeding seasons.

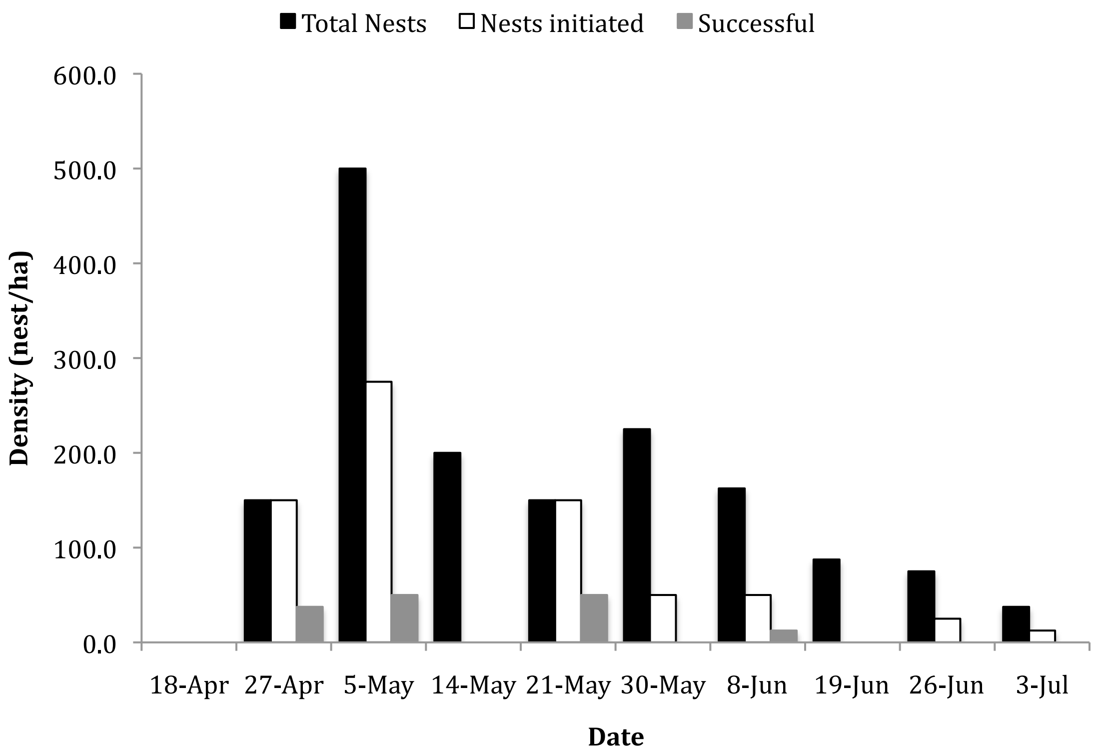


Fig. 6. Temporal distribution of total nest density, initiation, and success of nesting Gull-billed Terns at the Oso Bay site pooled from the 2012 and 2013 breeding seasons.

Despite lacking statistical significance, Gull-billed Terns tended to be more successful on islands with more nesting species and greater density of nesting birds. Locally and elsewhere within its range, Gull-billed Terns are kleptoparasitic (Landaberde 2007; Dies and Dies 2005). On dredge material islands near the Nueces River Delta in Nueces Bay, Gull-billed Terns kleptoparasitized other terns and Black Skimmers returning to nest and roost sites and preyed upon newly hatched Least Tern chicks (Landaberde 2007; D. J. Newstead, Coastal Bend Bays and Estuaries Program, pers. comm.; A. Baxter, Center for Coastal Studies at Texas A&M University–Corpus Christi, pers. comm.). Other evidence such as cracked eggs and missing fledglings, discussed in other species accounts, is consistent with the idea that this species utlizes heterospecific nesting assemblages to provide for offspring. It is the only species included in this study in which reproductive success seemed higher at nest sites with more diverse nesting assemblages.

**Least Tern *Sternula antillarum.*** Least terns nested at the NBSR site and the Texas A&M University-Corpus Christi Campus Beach. The colony at Campus Beach was unusual in that Least Terns do not normally nest in soft sand near the ocean or bay surf, typically preferring bare, hard shell hash (Thompson and Slack 1982). This species was over twice as successful in Nueces Bay than on Campus Beach (Table 5). Clutch size was slightly lower at Campus Beach and Mayfield probability was substantially lower. Reproductive success was most strongly correlated with *Spartina* spp. cover and density although observations during this study suggest assemblage richness and vegetative cover may also influence hatching success (Table 3).

Least Terns initiated nests earlier than the other four species. Nest loss was substantial during the first half of the season and remained relatively high throughout the breeding period (Fig. 7; Fig. 8). Nest loss was greatest at the Campus Beach site (Fig. 8). Likelihood of success is only observable in the last two weeks of May; success was near zero both before and after those two weeks. Nest initiation followed a pattern of "peaks and valleys," rather than the typical bell-shaped curve, owing largely to sensitivity of Least Terns to storm events (Hagar 1937; Loftin and Thompson 1979). Even later in the breeding season, the number of newly initiated nests remained high in the absence of storms, most likely due to their susceptibility to predation and disturbance; this species nested in the most highly disturbed site included in this study.

Table 5. Nesting success data for Least Terns at the NBSR and Campus Beach sites pooled for the 2012 and 2013 breeding seasons. [1] A refers to live chicks and D refers to dead chicks.

| | NBSR | Campus Beach |
|---|---|---|
| Total nests | 171 | 38 |
| Hatching success | 19.2% | 7.9% |
| Colony productivity (A/D)[1] | 32/3 | 3/1 |
| Re-lay occurrence | 42 | 0 |
| Clutch size | 2.3 | 1.9 |
| Mayfield | 0.21 | 0.004 |

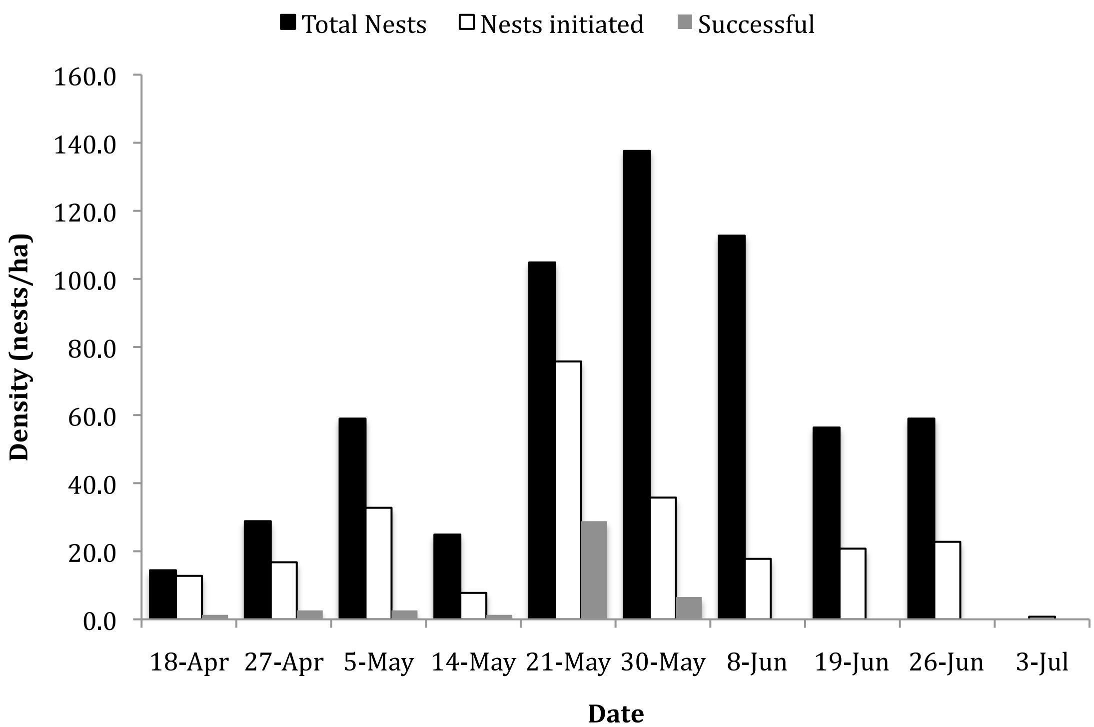


Fig. 7. Temporal distribution of total nest density, initiation and nest success for nesting Least Terns at the NBSR site pooled for the 2012 and 2013 breeding seasons.

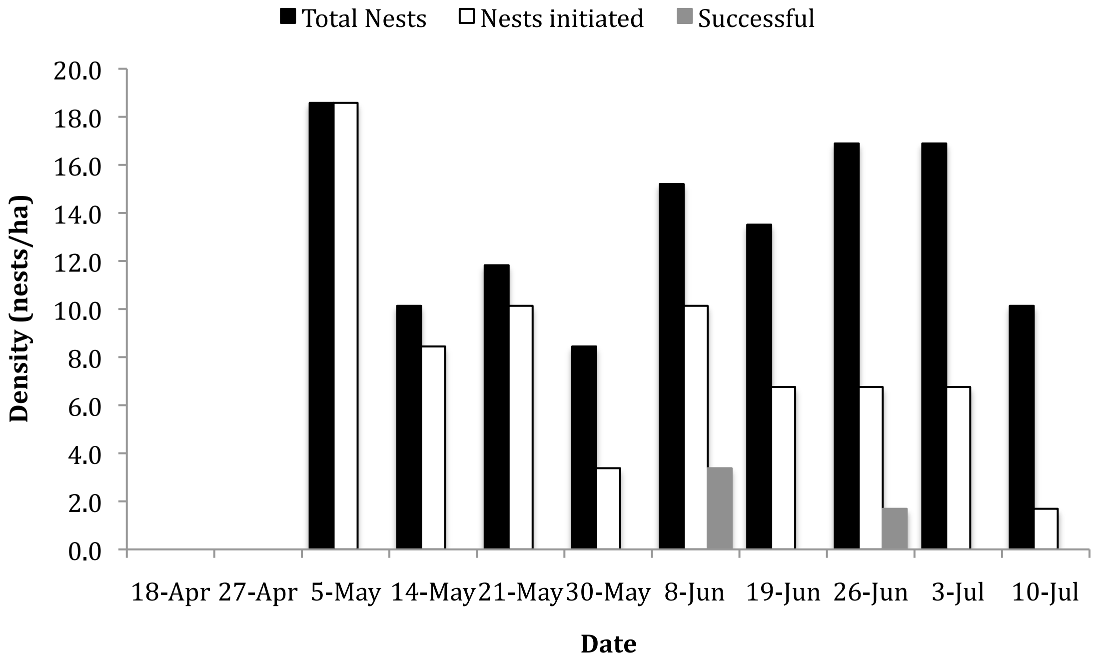


Fig. 8. Temporal distribution of total nest density, initiation, and nest success for nesting Least Terns at the Campus Beach site pooled for the 2012 and 2013 breeding seasons.

Percent total vegetative cover seemed to relate to hatching success of Least Terns, despite lacking statistical significance. While clumps of vegetation offer shelter from predation and harsh weather to chicks, they also attract other ground-nesting species attracted to vegetation that may be better competitors than Least Terns. Elsewhere in its range, Least Terns nest preferentially in areas with sparse vegetation and tend to have higher success nesting in areas with surface materials such as shell hash, dredged material, or even shingled building roofs (Katliar and Burger 1986; Voigts 1999).

Least Terns nesting in this study in colonies with lower densities tended to have higher success. Elsewhere in its breeding range, colony density affected predation rates depending on the predator type. Lower density colonies have lower rates of aerial predation while higher density colonies have lower rates of terrestrial predation (Brunton 1999). Aerial predation may have been a major factor in success of Least Terns in nesting

Nueces Bay based on the observed and statistically significant negative relationship between success and lower nesting density.

Least Terns were more successful on sites with a lower richness of other ground-nesting seabirds. Although showy, Least Terns were not very aggressive during surveys. Compared to the other tern species included in this study, Least Terns exhibited the weakest nest protection in terms of attacking or mobbing. Aerial predation is a serious concern for this species and nesting alongside more aggressive ground nesting species likely makes Least Tern nests more susceptible to failure. However, on islands where Least Terns nested exclusively alongside Forster's Terns, Least Tern nests were more successful. Forster's Terns are aggressive and flush easily when disturbed. Predatory or kleptoparasitic behavior by Forster's Terns has not been documented and was not observed during the course of this study. Least Terns may have benefited from the protective tendencies of Forster's Terns and likely increased their probability of success.

Gull-billed Terns, however, behaved aggressively toward other nesting seabirds, Least Terns and Black Skimmers, in particular. Least Tern adults were often dive-bombed on the wing, while flushed and Gull-billed Terns were frequently observed attempting to steal eggs. Additionally, Least Tern nests would commonly retain their eggs for the proper incubation period (~ 21 days) but would not produce a fledgling. No evidence of terrestrial predation was present and egg shell fragments were removed from the nest, implying that hatching had occurred. This is consistent with personal accounts of Gull-billed Terns consuming newly hatched Least Tern chicks whole (D.J. Newstead, Coastal Bend Bays and Estuaries Program, pers. comm.; A. Baxter, Center for Coastal Studies at Texas A&M University-Corpus Christi, pers. comm).

Hatching success of Least Terns was significantly correlated with *Spartina* spp. coverage. However, based on observations during this study, nests placed at higher elevations also tended to be more successful. Least Terns are especially sensitive to storm events. Their nests are shallow scrapings decorated with shell hash fragments and their eggs are very small (2.0-2.5 cm diameter) compared to the other species in this study. This makes Least Tern eggs extremely susceptible to removal by storm surges and moderately strong winds (Gore and Kinnison 1991). Least Tern nests on islands with more *Spartina* spp. coverage were generally more successful due to the protection the plant offers as a buffer to storm surges and high tides (Ranwell 1967; Daehler and Strong 1996).

**Black Skimmer *Rynchops niger.*** Black Skimmers nested at the NBSR site, the land-accessible island in Oso Bay and the recently disconnected island under lease by the Texas Department of Transportation (TxDoT) in the Laguna Madre. Of the species included in this study, Black Skimmer was the only species to have a lower success rate in Nueces Bay than at other sites where they nested (Table 6). Skimmers were the most successful on the TxDoT island where they nested alone, with 63% hatching success and a 0.58 Mayfield statistic (Table 6). This was the highest rate of success for any species at any site included in this study. Clutch size was slightly smaller in Oso Bay but was similar in Nueces Bay and the TxDoT island. Success was most strongly correlated with elevation and richness (Table 3).

Black Skimmer nest initiation remained relatively consistent throughout the entire month of May (Figs. 9, 10, 11). However, initiation at the NBSR site tapered off quickly

Table 6. Nesting success data for Black Skimmers at the NBSR and TxDoT island sites pooled for the 2012 and 2013 breeding seasons. [1] A refers to live chicks and D refers to dead chicks.

| | NBSR | Oso Bay | TxDot |
|---|---|---|---|
| Total nests | 91 | 121 | 92 |
| Hatching success | 18.7% | 33.9% | 63% |
| Colony productivity (A/D)[1] | 25/0 | 48/3 | 66/0 |
| Re-lay occurrence | 13 | 3 | 0 |
| Clutch size | 3.6 | 3.1 | 3.5 |
| Mayfield | 0.24 | 0.47 | 0.58 |

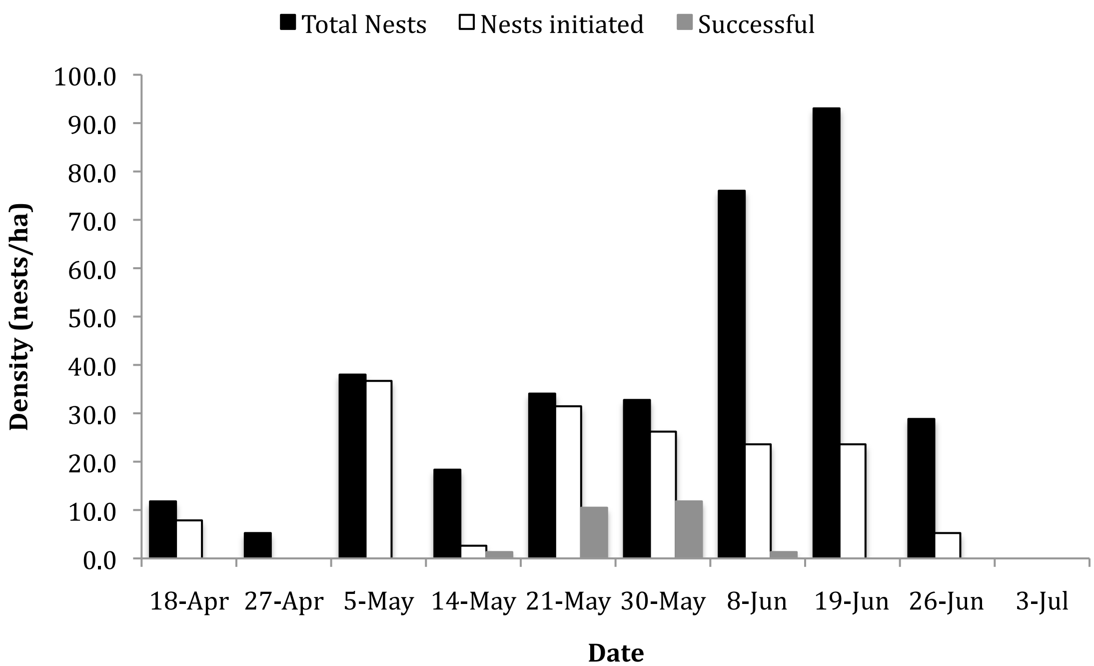


Fig. 9. Temporal distribution of total nest density, initiation and success of nesting Black Skimmers at the NBSR site pooled for the 2012 and 2013 seasons.

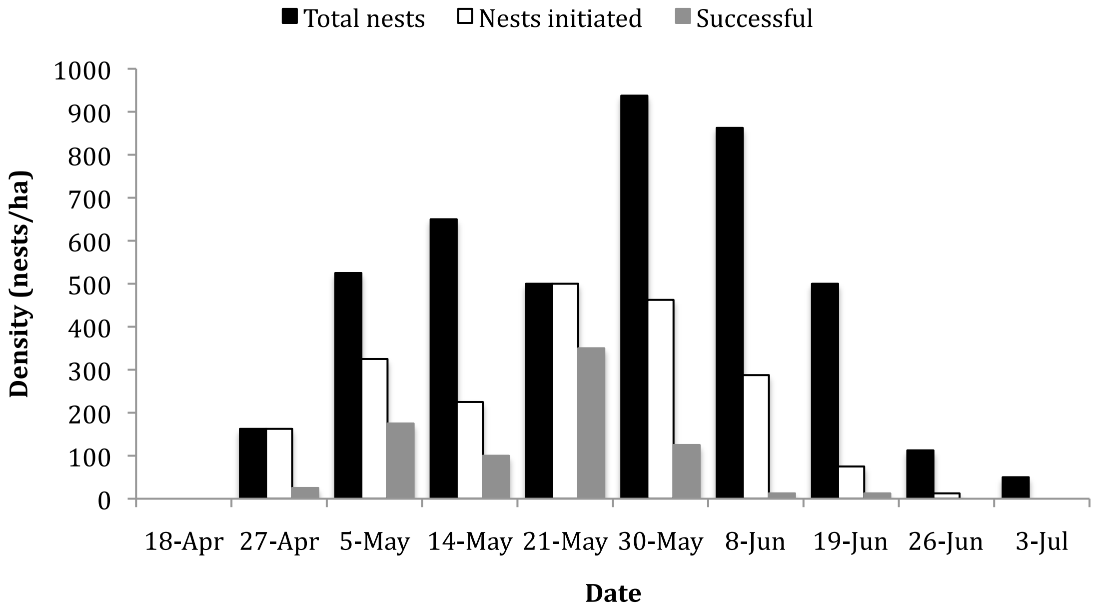


Fig. 10. Temporal distribution of total nest density, initiation and success of nesting Black Skimmers at the Oso Bay site pooled for the 2012 and 2013 seasons.

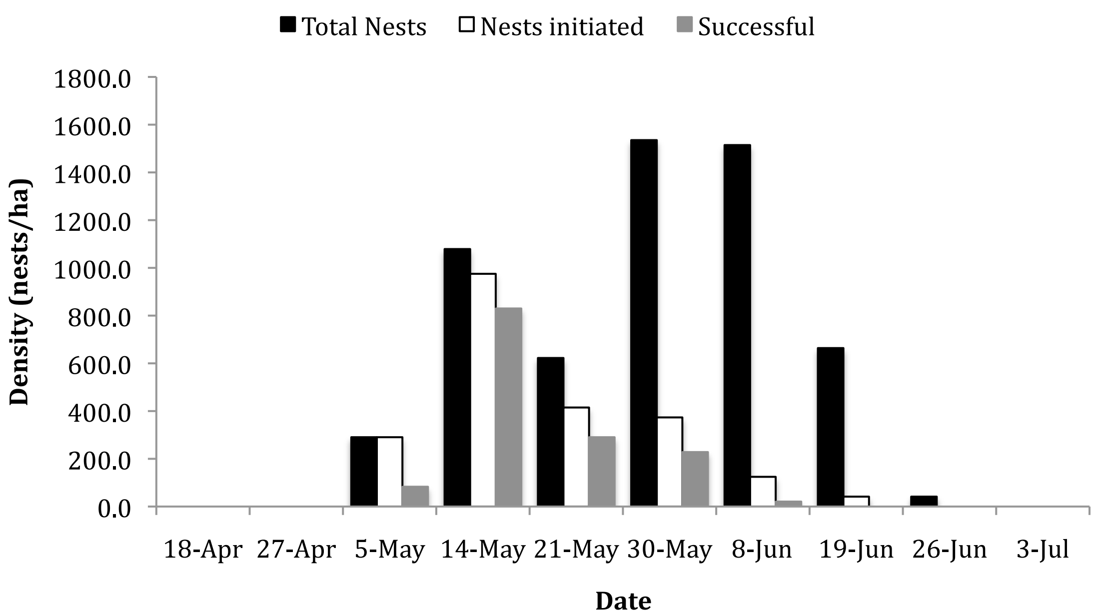


Fig. 11. Temporal distribution of total nest density, initiation and success of nesting Black Skimmers at the TxDoT leased island pooled for the 2012 and 2013 seasons.

after the second week in May (Fig. 9). The initiation period at the TxDoT island was slightly longer in comparison with the tern species included in this study, who usually exhibited a definitive peak in initiation at some point during the season (Fig. 11). Nesting density was substantially higher at the TxDoT island on which the skimmers nested exclusively within the species. Nest retention was highest in the later part of the season, owing to the storm events in the earlier months. However, likelihood of success peaked inmid-May; earlier than the other species in this study. Black Skimmers have a relatively long fledgling period of 4-4.5 weeks (Gochfeld and Burger 1994). Nests initiated earlier most likely had a higher likelihood of success since they avoided the extreme temperatures, shortages of food, and/or prevalence of fire ants characteristic of later in the breeding season (Spendelow 1982). Nests initiated after the last week of May were typically not successful.

Nests of Black Skimmers tended to be more successful at higher elevations (Table 3). Skimmers nested in moderately deep scrapings on bare, compact shell hash and used no vegetation. While the depression might have protected eggs from wind gusts and high ambient temperatures, they commonly collected sediment and water. Many eggs were observed buried or crushed by trapped sediment. Higher elevations made nests less likely to be submerged during surges and more likely to drain if the island was sloped. During surveys, skimmer chicks often sought refuge in clumps of vegetation. For ground-nesters, vegetation provides modest relief from extreme temperatures and shelter from avian predators (Saliva and Burger 1989; Miyazaki 1996; Stauffer and Best 1986). Nests at higher elevations were also closer to larger patches of vegetation which may have provided chicks protection from predation or disturbance.

Richness of the nesting assemblage was negatively correlated with reproductive success of skimmers. Black Skimmers, like Least Terns, are weak competitors with regards to nest protection (Quinn 1989; Pius and Leberg 1998). However, unlike the Least Terns who seemingly benefited from the fiercely protective nature of Forster's Terns, the advantages of "symbiotic protection" were not great enough to outweigh the disadvantages associated with the additional competition. Nest density was not a significant descriptor for the success of skimmer nests implying competition for space or food was not responsible for the decreased success in higher richness colonies.

Kleptoparasitism by Gull-billed Terns which often focuses on Black Skimmers may provide one explanation. Adult skimmers are approached on the wing by Gull-billed Terns, alone or in small groups, harassed and forced to surrender food intended for skimmer fledglings. As a result, many skimmer chicks starve (D.J. Newstead, Coastal Bend Bays and Estuaries Program, pers. comm.; B. Hardagree, United States Fish and Wildlife Service, pers. comm.). During this study, cracked skimmer eggs, consistent with avian predation, were a common sight on all sites, with the exception of the TxDoT leased island. Skimmer fledglings 3-4 weeks old were a common target of harassment by Gull-billed Terns during surveys. On several occasions, small groups (3-5 fledglings) were found killed, though not eaten, in Nueces Bay during the first breeding season. While Laughing Gulls might be an obvious suspect for due to their documented aggression and predatory tendencies (O'Connell and Beck 2003), Laughing Gulls were absent at all sites and were not observed during any survey. This physical evidence, paired with multiple observations by other biologists in this region, suggests that Gull-billed Terns may pose a serious threat to the reproductive success of Black Skimmers.

## TRENDS AND MANAGEMENT IMPLICATIONS

Nesting seabird colonies are complex, often consisting of many species with overlapping ecological niches. In this study, nesting success of Forster's Terns was correlated with storm events (via the proxy of elevation), human disturbance, and assemblage richness. The high occurrence of nest loss and abandonment during the first half of the season, most likely due to storm events, was alarming. Because this species flushes easily, their eggs are more susceptible to aerial predation and high ambient temperatures. Populations of Forster's Terns are thought to be increasing throughout its range (BirdLife International 2012), although in this study reproductive success was very poor. However, in light of a changing environment and developing coastline, their sensitivity to disturbance suggests that Forster's Terns could potentially become a species of concern in coastal Texas. Forster's Terns in this region would benefit from non-land accessible islands of higher elevations from the water surface. This study did not include sites at which Forster's Terns nested alone or sites in more remote areas where disturbance may be very low. More monitoring across a larger portion of its range on the central Texas coast is needed to determine if nesting Forster's Tern colonies are stable in terms of location and size, and if reproductive success is better elsewhere.

The only species that exhibited a positive correlation between reproductive success and colony species richness was Gull-billed Tern. Their aggressive and kleptoparasitic behavior make their presence in a mixed colony a concern for other ground-nesting seabirds. Laughing Gulls have been accused of reducing nesting success due to their aggressive behavior (O'Connell and Beck 2003). However, in this study Laughing Gulls were absent from all colonies that were monitored. However, when Gull-billed Terns were present, they appeared to pose the major avian threat to nesting terns and skimmers. Future management and conservation efforts aimed at Least Terns and/or Black Skimmers should consider environmental manipulation or human intervention to discourage nesting by Gull-billed Terns in mixed colonies. Elsewhere in its range, Gull-billed Terns are believed to be declining largely due to loss of habitat through wetland drainage, agriculture expansion, pesticide use, and beach erosion (del Hoyo et al. 1996; Molina and Erwing 2006).

Least Terns experienced the highest rate of nest loss in this study due to the susceptibility of their nests to storm events and lack of protective aggression. Two of the three populations of Least Terns (Interior and California) are federally listed as Endangered. The Atlantic and Gulf Coast population is not federally listed. However there are no clear morphological or genetic distinctions among subspecies and chicks banded on the Texas coast have been found later breeding in Kansas (Thompson et al. 1997) Because of the lack of distinction between populations and movement between breeding areas, the status of this species in Texas deserves careful monitoring. Exclusionary fencing of nests has been successful in rebuilding population numbers for a subspecies in Massachusetts (Rimmer and Deblinger 1992).

Gull-bill Tern predation has been observed in that region of California and identified as a serious threat, decreasing reproductive success in a colony to less than 10% (Marschalek 2009). Future management should include significantly reducing human disturbance in sensitive nesting areas, decreasing the threat of Gull-billed Tern predation, and providing optimal nesting habitat either by raising elevations in colony areas or by planting *Spartina* spp. to buffer storm surges.

There is a debate regarding the advantages and disadvantages of Black Skimmers nesting in mixed versus single species colonies. Skimmers are relatively non-aggressive when the colony is disturbed by intruders and can benefit from the fiercely protective tendencies of neighboring ground-nesters. Skimmers are commonly found nesting alongside Gull-billed Terns (Pius and Leberg 1998). However, this may not be an optimal situation in the central Texas coast because of documented kleptoparasitic behavior on Black Skimmers by Gull-billed Terns, which may result in starving chicks and colony failure.

In this study, skimmer nesting success was substantially higher at the site where Gull-billed Terns were not present. This species, while not federally endangered, is showing signs of decline across its range in Texas; 38% since 1974 (Texas Colonial Waterbird Database 2005). Attempts to rebuild falling population numbers by relocating colonies occupying heavily disturbed areas have been made in Texas, but it is too early to tell if these efforts will slow, or perhaps halt, skimmer population declines (D. J. Newstead and O. Fitzimmons, Coastal Bend Bays and Estuaries Program, pers. comm.). Future management strategies should consider ways to reduce of Gull-billed Tern predation and kleptoparasitism on nesting skimmers as well as to provide nesting habitat not likely to be submerged during storm events.

These correlations between reproductive success and environmental nest site characteristics, while perhaps not universally applicable, are important and should be regarded in future nesting seabird management decisions and restoration efforts in the central Coastal Bend region of Texas.

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