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**Keywords**
Black Skimmer, disturbance, Mississippi, nest survival, Rynchops niger

**Disciplines**
Natural Resources Management and Policy | Ornithology | Population Biology | Poultry or Avian Science

**Comments**
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# Black Skimmer Nest Survival in Mississippi

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**Abstract.**—The nest survival of the Black Skimmer (*Rynchops niger*) in coastal Mississippi was modeled to better understand their breeding biology and suggest management strategies for protecting nesting colonies. During the 2004 and 2005 breeding seasons a total of 301 nests was monitored and hatching success was 67% in 2004 and 39% in 2005. Mean clutch size differed between years, although mean incubation length did not differ between years or between colonies on the mainland and barrier islands (P = 0.70). Nest survival was influenced by year, seasonal variation within year, clutch size, and colony. Nest survival was greatest in 2004, and within years nest survival followed a seasonal pattern where it was high from May through late June and then decreased through early August. Large clutches had greater survival than small clutches. There was considerable inter-colony variation in nest survival, and it appeared that low survival was correlated with disturbance risk at many colonies. This study provides the first detailed information on the nest survival of the Black Skimmer in Mississippi, increases the understanding of seasonal variation and other influences on nesting success, and provides a basis for suggesting conservation measures for this species during the nesting season. *Received 28 May 2007, accepted 26 September 2007.*

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The Black Skimmer (*Rynchops niger*) is a colonial-nesting waterbird that reaches the northern edge of its breeding range along the Gulf and southern Atlantic coasts of the U.S. (Gochfeld and Burger 1994). This primarily coastal species nests on barrier and dredge material islands and mainland beaches and its nests are especially susceptible to human disturbance (Safina and Burger 1983) and flooding. In Mississippi, it is a localized breeder on artificial beaches in Harrison County and on barrier and dredge material islands of the Gulf Islands National Seashore (Portnoy 1978a, b). Little is known of the species nesting ecology in Mississippi. Inter-colony hatching success has been estimated elsewhere in the species' breeding range (Erwin 1977; Custer and Mitchell 1987; Burger and Gochfeld 1990) but with little information on the influence of seasonal variation, nest age, or clutch size on nest survival. Typically, more than 50% of all pairs rear less than one chick to fledging, and hatching success is as high as 85% and varies geographically (Gochfeld and Burger 1994).

Conservation efforts have often focused on the Black Skimmer and it is a species of conservation concern in several states (Gochfeld and Burger 1994). This standing is needed because of continued threats to its coastal habitat, primarily the result of human encroachment and disturbance to nesting colonies (Schreiber and Schreiber 1978) and possible long-term impacts of sea-level rise (Reid and Trexler 1992). The susceptibility of nesting colonies to disturbance heightens the need for a better understanding of their patterns of nest survival. The nest survival of Black Skimmers was monitored along the Mississippi coast in 2004-2005. The effects of nest stage, seasonal variation, nest age, clutch size, and nesting colony were incorporated into estimates of nest survival to better understand their breeding ecology and suggest strategies for improving nesting success.

## METHODS

### Study Area and Data Collection

Nesting Black Skimmers were studied along the coast of Mississippi in Jackson and Harrison counties (Fig. 1) during the 2004 (12 May-6 August) and 2005 (2 May-9 August) breeding seasons. In both years, intensive surveys of the Mississippi coastal region were conducted at three to five day intervals to locate active skimmer colonies. Across years, colonies were located on artificial mainland beaches (N = 5), a barrier island, and a dredged material island. Colonies utilized by nesting skimmers had different disturbance regimes. Mainland colonies were subject to daily disturbance by humans, pets, and to a lesser extent by Laughing Gulls (*Larus atricilla*) and Raccoons (*Procyon lotor*), even though they were signed or fenced. Colonies on both

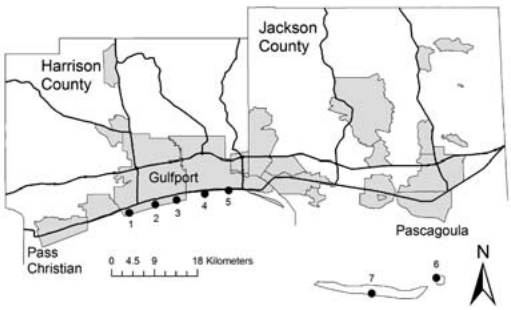


**Figure 1. Map of the Mississippi coast showing the location of colonies used by nesting Black Skimmers (*Rynchops niger*) during the 2004 and 2005 breeding seasons. Numbers denote each colony: Broad Avenue (1), Hewes Avenue (2), West Sanctuary (3), President's Casino (4), Methodist Assembly (5), Sand Island (6), and Middle Horn Island (7).**

islands experienced less frequent disturbance from humans and pets. All nesting skimmers occurred within larger nesting colonies of the Least Tern (*Sterna antillarum*). Nesting skimmers were relatively easy to detect because of their conspicuous plumage, habit of nesting on open, sandy beaches, and distinctive crouching behavior during incubation (Gochfeld and Burger 1994). Once nesting activity was confirmed, a random sample of nests was selected for monitoring at three to seven day intervals to collect information to model nest survival. All nests in a colony were not monitored for two reasons: 1) to keep each colony visit to <30 min to avoid excessive disturbance (Erwin 1980; Burger and Gochfeld 1994), which would have been impossible in all but the smallest colonies, and 2) randomly sub-sampling nests in each colony minimized the possible lack of independence of nest fates for nests in close proximity (Dinsmore and Dinsmore 2007).

At discovery, the location of each nest was recorded with a hand-held global positioning unit and a small numbered wooden stake (driven into the sand so that only two to three cm was above ground) was placed within 0.2 m of each nest. All eggs in a clutch were floated to age the nest (Mabee *et al.* 2006). A nest was age one when the clutch was complete; a separate covariate (see below) was used to distinguish between egg-laying and incubation stages. Thus, age effects only applied to the incubation stage in this analysis. The number of eggs seen on each nest visit was also recorded, and the maximum number of observed eggs across all nest visits was used as a measure of clutch size for a nest.

### Statistical Analyses

The daily survival of Black Skimmer nests was modeled using the nest survival model (Dinsmore *et al.* 2002) in program MARK (White and Burnham 1999). Data for each nest visit were used to construct an encounter history for each nest. When constructing encounter histories, three assumptions were made with nest-check data: 1) that eggs were laid at one-day intervals (Erwin 1977), except in cases where data confirmed some other egg-laying schedule, 2) information from egg floats and the presence of chicks in the nest were used to estimate the timing of hatch, making the assumption that one chick hatched per day (Gochfeld and Burger 1994) unless otherwise confirmed on nest visits, and 3) that incubation lasted 23 days (Gochfeld and Burger 1994) except in cases where it was known to differ. Hatch day was defined as the day on which the first egg hatched. A sample of known-age nests (N = 11 in 2004 and N = 18 in 2005) followed from incubation to hatch was used to develop an egg float schedule to assign ages to nests that were not found during egg-laying.

An information-theoretic modeling approach was used and generally followed the advice of Burnham and Anderson (2002). A list of *a priori* factors believed to influence daily nest survival was generated prior to data collection. From these factors, a hierarchical modeling approach was used to arrive at a set of models for inference, which were ranked by second order Akaike's Information Criterion (AIC*c*) values corrected for small sample size (Akaike 1973; Burnham and Anderson 2002). The slope parameters (betas) were model-averaged across all models in the set and used to predict daily nest survival for combinations of covariates of interest. Model selection results, AIC*c* weights ($w_i$; Burnham and Anderson 2002), and slope parameters (direction of an effect and its 95% CI coverage) were used to make inferences about specific model effects.

Three descriptive measures of nesting ecology were examined to provide baseline information for comparison to other studies. Mean clutch size and incubation period length (±SD) were calculated for each year of the study, and differences between years were tested using a 2-tailed *t*-test ($\alpha = 0.05$). In addition, incubation period length of mainland and barrier island colonies was hypothesized to differ as a result of greater human disturbance to mainland colonies. This was an important issue for skimmer nesting colony conservation in coastal Mississippi, and a significantly longer incubation period length on mainland colonies could potentially result from greater nest disturbance (Carney and Sydeman 1999). This question was also tested using a 2-tailed *t*-test ($\alpha = 0.05$).

A set of 16 candidate models was developed in MARK to address variation in Black Skimmer nest survival. The following six factors were considered important when estimating daily nest survival of Black Skimmers, and a justification for each is provided below.

*Year.* The study encompassed two years, and annual variation in nest survival is common in Black Skimmers (Burger and Gochfeld 1990) and a common finding in studies of birds in general. Differences may result from multiple factors including variation in weather or the predator community, and year effects alone can include factors not considered in the list below.

*Nest Stage.* Possible stage-specific differences (egg-laying and incubation stages) in nest survival were investigated by including a day-specific covariate that coded if eggs were being added to the nest. Because skimmers initiate incubation with laying of the first egg (Gochfeld and Burger 1994), it was hypothesized that there would be no differences in nest survival between the egg-laying and incubation periods.

*Seasonal Variation.* Three models to explain possible seasonal patterns in nest survival were considered: a model with constant nest survival (the Mayfield method; Mayfield 1961), a model where nest survival followed a linear trend (*T*), and a model where nest survival followed a quadratic trend (*TT*). In many studies of nest survival, there is reason to believe that seasonal survival is not constant (Dinsmore *et al.* 2002; Rotella *et al.* 2004) and non-linear patterns may be caused by differential nest initiation and success as a result of adult experience or weather patterns. More complex models (e.g., a cubic trend) were not considered to avoid over-fitting the date due to a relatively small sample of nests.

*Nest Age.* As nests age, their vulnerability to predation can change as a result of nest location or parental activity. In precocial species, older nests are expected to have a positive relationship between nest age and daily survival because nests at risk will be depredated early (Klett and Johnson 1982; Dinsmore *et al.* 2002). Only a linear effect of daily nest age was considered in this study. Nest age can be confounded with seasonal variation in nest survival, although this can be minimized if adequate numbers of nests are monitored throughout the nesting period.

*Clutch Size.* Clutch size may affect nest survival because female condition could be linked to egg quality (Price and Liou 1989), and thus females in poor condition could lay fewer eggs in more vulnerable locations (e.g., the colony edge; see Pasitschniak-Arts *et al.* 1998). In skimmers, larger clutches might be less vulnerable because they are more likely to represent first nesting attempts by experienced adults who tend to nest at the center of the colony (see Burger and Gochfeld 1990).

*Colony.* A colony specific covariate was included and allowed survival to differ between colonies, in addition to any seasonal patterns or variation due to clutch size. Because of their colonial habits, skimmer colonies show considerable annual variation in hatching success with 38% of colonies experiencing total nesting failure (Burger and Gochfeld 1994). This effect was included here because mainland colonies might be more susceptible to disturbance (increased beach use by people and pets, greater risk of predation by raccoons and Laughing Gulls) and less susceptible to storm surge because they were protected by barrier islands. The colony effect was then collapsed to address possible differences in nest survival between mainland and barrier island colonies.

Nest survival models were built hierarchically and model effects were added in this order: 1) models with and without a year effect, 2) three sources of seasonal variation (constant survival and linear and quadratic time trends within year), 3) nest age, clutch size, nest stage, and colony (singly, plus the mainland to barrier island comparison), and 4) combinations of competitive ($\Delta AICc \leq 2$) effects from step 3. The factor(s) in each successive step were added to all competing ($\Delta AICc \leq 2$) models from the previous step, not just the best model. Colony specific best estimate of nest survival (probability of survival from nest initiation to hatch) were calculated for each colony assuming a start date of 5 June (the mean nest initiation date for all nests across both years of the study), an incubation period of 23 days, and the mean clutch size of all nests in the study ($\bar{x}$ = 2.59 eggs).

## RESULTS

A total of 64 nests in 2004 and 237 nests in 2005 was monitored and hatching success varied by colony and year (Table 1). Clutch size of all nests ranged from one to seven eggs; mean clutch size was 2.8 eggs (SD = 0.9) in 2004 and 2.5 eggs (SD = 1.0) in 2005 and differed between years ($t = 2.43$, $P = 0.02$). Mean incubation time was 22.7 days (SD = 2.5) in 2004 and 23.7 days (SD = 3.7) in 2005 and did not between years ($t = 1.73$, $P = 0.09$) or between mainland and barrier island colonies independent of year ($t = 0.39$, $P = 0.70$). Nests failed primarily as a result of predation (62% of failures; most probably by Laughing Gulls), beach over-wash (20% of total), and unknown causes (18% of total).

Nest survival of Black Skimmers in Mississippi was influenced by year, seasonal patterns within year, clutch size, and colony

**Table 1. Number of nests monitored, hatching success, and model-based predicted nest survival for Black Skimmer (*Rynchops niger*) nests along the Mississippi coast, 2004-2005.**

| | Success (%) | | | | | |
|---|---|---|---|---|---|---|
| | 2004 | | | 2005 | | |
| Colony | No. | Hatch[1] | Model[2] | No. | Hatch | Model |
| Broad Avenue | 0 | | | 20 | 30 | 34 (15,54) |
| Hewes Avenue | 11 | 0 | 54 (29,74) | 0 | | |
| West Sanctuary | 22 | 100 | 98 (88,100) | 42 | 40 | 48 (32,62) |
| President's Casino | 31 | 68 | 97 (86,100) | 61 | 48 | 42 (28,55) |
| Methodist Assembly | 0 | | | 2 | 0 | 0 (0,6) |
| Sand Island | 0 | | | 88 | 59 | 59 (44,71) |
| Middle Horn Island | 0 | | | 24 | 0 | 0 (0,10) |
| Total | 64 | 67 | | 237 | 39 | |

[1]This was calculated as the number of successful nests divided by the total number of nests monitored and is a measure of apparent nesting success.

[2]This was calculated using the logistic regression equation from the best model, a start date of 5 June, an incubation length of 23 days, and a clutch size of 2.59 eggs. The 95% CI is given in parentheses.

(Table 2, Fig. 2). Nest survival was substantially greater in 2004 than in 2005. Within years, the pattern of nest survival at each colony was best explained by a quadratic time trend with relatively high daily survival through late June followed by a decline in daily survival towards season's end. Large clutches had substantially greater predicted daily survival than small clutches (Fig. 3), independent of year, seasonal variation, and colony. Colony-specific model-based estimates of nest survival varied in a manner similar to estimates of hatching success (Table 1) and illustrate the spatial variation in this parameter. There was no evidence that nest age or nest stage influenced the survival of skimmer nests; models containing these effects were not well supported (Table 2).

## DISCUSSION

Black Skimmers exhibited annual variation in nest survival in coastal Mississippi, a pattern similar to other areas where the species' breeding biology has been studied (Erwin 1977; Gochfeld and Burger 1994), although this pattern was based on only two years of data. The implications of this short-term pattern are unclear, although this study does provide important baseline data on skimmer nesting ecology in Mississippi.

### Patterns of Nest Survival

Relatively little work has investigated patterns of nest survival in the Black Skimmer, and no comprehensive nesting studies have been conducted on Gulf Coast populations. Estimates of mean clutch size and incubation period length in Mississippi were comparable to those at other sites along the Atlantic (Erwin 1977; Gochfeld and Burger 1994) and Gulf (White *et al.* 1984) coasts. The finding that incubation period length did not differ between mainland and barrier island colonies in Mississippi suggests that skimmers nesting in each area may experience similar disturbance. Had the pattern shown a longer incubation time for mainland nesting skimmers, it might have suggested that they were being disturbed more frequently (Carney and Sydeman 1999) and that protective measures for nesting colonies needed improvement.

Nest survival patterns revealed in this study may have resulted from a combination of factors that include susceptibility to catastrophic weather events and human distur-

**Table 2. Model selection results for the nest survival of Black Skimmers (*Rynchops niger*) along the Mississippi coast, 2004-2005. Factors included the additive effects of year (Year), linear (T) and quadratic (TT) time trends within years, clutch size (Clutch), nest age (Age), nest stage (Stage), and colonies (Colony). Models are ranked by ascending ΔAIC*c* values with the best supported models at the top of the list.**

| Model | ΔAIC*c*[1] | $w_i$ | *K* | Deviance |
|---|---|---|---|---|
| Year+TT+Colony+Clutch | 0.00 | 0.57 | 10 | 620.67 |
| Year+T+Colony+Clutch | 1.12 | 0.32 | 9 | 623.80 |
| Year+TT+Colony | 4.15 | 0.07 | 9 | 626.83 |
| Year+T+Colony | 5.37 | 0.04 | 8 | 630.06 |
| Year+T+Clutch | 45.58 | 0.00 | 4 | 678.30 |
| Year+TT+Clutch | 47.43 | 0.00 | 5 | 678.15 |
| Year+T+Stage | 56.94 | 0.00 | 4 | 689.66 |
| Year+TT+Stage | 58.89 | 0.00 | 5 | 689.61 |
| Year+T | 63.15 | 0.00 | 3 | 697.88 |
| Year+T+Mainland vs. islands | 64.72 | 0.00 | 4 | 697.44 |
| Year+TT | 64.88 | 0.00 | 4 | 697.60 |
| Year+T+Age | 65.07 | 0.00 | 4 | 697.79 |
| Year+TT+Mainland vs. islands | 66.57 | 0.00 | 5 | 697.29 |
| Year+TT+Age | 66.78 | 0.00 | 5 | 697.50 |
| Year | 101.60 | 0.00 | 2 | 738.33 |
| Constant survival | 116.77 | 0.00 | 1 | 755.50 |

[1]AIC*c* for the best model was 640.73.

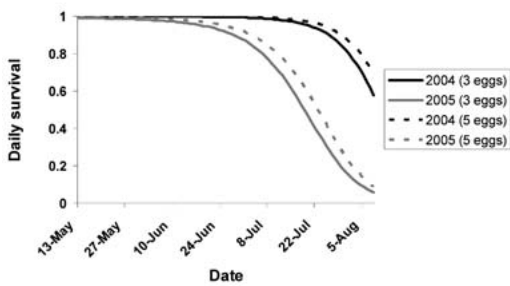


**Figure 2. Predicted daily survival rates of Black Skimmer (*Rynchops niger*) nests at the West Sanctuary colony, Mississippi, 2004-2005. Survival is illustrated for nests containing three eggs (close to the average observed clutch size in this study) and for nests containing five eggs.**

bance. Human disturbance is an important factor influencing the success of colonial-nesting waterbirds (Safina and Burger 1983) and other coastal breeding birds (McGowan and Simons 2006). Disturbance and other factors caused skimmers to occasionally abandon a colony during this study. In both years, skimmers seemed to be prospecting for colonies during late April and early May and courtship and nest scraping were observed at two colonies each in 2004 and 2005 that were abandoned by late May. After nesting began, skimmers were still vulnerable to the negative effects of disturbance. The finding of inter-colony variation in nest survival suggests that differences in disturbance intensity between colonies. Although this study did not directly address the effects of disturbance, it was clear from regular observations that two mainland colonies (Broad Avenue and President's Casino) were subjected to almost daily disturbance and trespassing by humans and pets. Compared to a protected colony (West Sanctuary) and a more remote barrier island colony (Sand Island) these heavily disturbed colonies experienced lower nest survival. This suggests that disturbance may result in reduced nest survival in poorly protected colonies, which is consistent with other studies (Safina and Burger 1983). However, future work should attempt to better document the link between disturbance and nest survival by including disturbance intensity as a covariate in nest survival models. Annual variation in nest survival (Fig. 2) in Mississippi matches patterns seen elsewhere in this species (Burger and Gochfeld 1990), and probably resulted from multiple environmental conditions. The finding of an effect of clutch size is intriguing and could have resulted from a combination of female condition or age, location of the nest within the colony, or other factors.

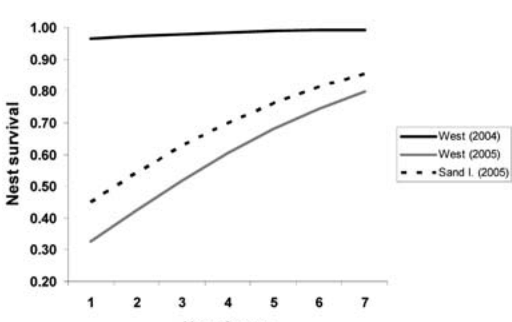


**Figure 3. The influence of clutch size on survival of Black Skimmer (*Rynchops niger*) nests in coastal Mississippi, 2004-2005. Predicted survival to hatch is illustrated for the range of clutch sizes observed in the study and for representative colonies that illustrate the effects of year and colony on nest survival.**

In addition to human disturbance, the effects of tropical cyclones deserve mention. In 2004, no tropical cyclones affected beach nesting areas in Mississippi. However, 2005 was an active storm year and severe beach overwash in the wake of Tropical Storm Arlene (11 June), Hurricane Cindy (6 July), and Hurricane Dennis (10 July) destroyed many nests and was partly responsible for the lower hatching success. Arlene had its greatest impact at Sand Island, where more than half the nests were destroyed; it had minimal impact on mainland nests. Cindy and Dennis were more powerful, and only a few nests survived these successive storms. The lone exception was Sand Island, a dredge material island several meters above sea level; here, many nests survived flooding from the 2005 tropical storms. As noted in other studies, skimmers are vulnerable to catastrophic nest losses as a result of tropical storms (White *et al.* 1984; Gochfeld and Burger 1994), a pattern shared with many colonial-nesting birds in regions prone to such weather.

## Conservation Implications

Black Skimmer nesting colonies face many threats that are enhanced along the Mississippi coast because of the proximity to development and high levels of disturbance from people and pets. In many areas, managed sites such as dredged material islands represent higher quality nesting areas than natural beaches because of their elevation and isolation from predators (Erwin *et al.* 2003). This study provides the first detailed estimates of nest survival for skimmers in Mississippi, illustrates nest-survival patterns resulting from seasonal and annual variation and clutch size, and hints at the negative impact of disturbance to nest survival. Cumulatively, these results may provide a framework for managing disturbance at nesting skimmer colonies in Mississippi, and suggest that additional research should attempt to quantify specific disturbance effects on nest survival.

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