Daily survival rate for nests of Black Skimmers from a core breeding area of the southeastern USA

Author(s): Gillian L. Brooks, Felicia J. Sanders, Patrick D. Gerard, and Patrick G. R. Jodice

Source: The Wilson Journal of Ornithology, 126(3):443-450. 2014.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/13-136.1
URL: http://www.bioone.org/doi/full/10.1676/13-136.1

The Wilson Journal of Ornithology 126(3):443–450, 2014

DAILY SURVIVAL RATE FOR NESTS OF BLACK SKIMMERS FROM A CORE BREEDING AREA OF THE SOUTHEASTERN USA

GILLIAN L. BROOKS,[1,5] FELICIA J. SANDERS,[2] PATRICK D. GERARD,[3] AND PATRICK G. R. JODICE[4,6]

ABSTRACT.—Little is known about the reproductive success of Black Skimmers (*Rynchops niger*) throughout the southeastern USA where availability of undisturbed beaches for nesting is limited. Daily survival rates (DSR) of nests were examined at three nesting sites in Cape Romain National Wildlife Refuge (CRNWR), South Carolina, USA, 2009–2010. The percent of successful nests ($n = 346$ nests) ranged from 42–69% among colony sites when data were pooled across both years. The DSR of nests was primarily related to colony site, predation risk, height of high tide, and clutch size. Predation and overwash were the principal causes of identifiable nest loss, each accounting for ~33% of nest failures during the two study years. Because of the challenges of resighting skimmer chicks, we were not able to measure chick survival effectively and therefore accurate measures of productivity remain elusive. High variability in nest success among sites within close proximity to each other (<20 km) suggests factors at local scales such as disturbance, predation, and overwash events strongly influenced nest success of Black Skimmers during these 2 years as opposed to more region-wide stressors such as tropical storms or food availability. Although time-intensive techniques to control predators do exist, management options to limit flooding and overwash are far more limited. Conservation of Black Skimmers in the southeastern USA would benefit from coordinated, multi-state efforts to measure nest and chick survival. *Received 26 August 2013. Accepted 26 April 2014.*

Key words: Black Skimmer, nest predation, nest success, nest survival, *Rynchops niger*, South Carolina.

Black Skimmers (*Rynchops niger*) in the eastern USA are exclusively coastal and nest in colonies often with or adjacent to other near shore seabirds such as terns and gulls. The status of Black Skimmers in the eastern USA ranges from state-listed as endangered (New Jersey, Maryland) or imperiled (Alabama) to no listing (Texas, Louisiana, Mississippi, and South Carolina). The most recent estimate of the population for the Atlantic and Gulf states of the USA is 30,000–35,000 pairs (Nisbet et al. 2103). The species appears to be declining south of Virginia (Nisbet et al. 2013) and along the Texas coast (Gawlik et al. 1998, Foster et al. 2009). Within the southeastern Atlantic states, Virginia appears to support the greatest number of nests (~1,500–2,000; Nisbet et al. 2013). In South Carolina, nest counts for Black Skimmers ranged from 483–1,450 between 1988 and 2009, and skimmers nested at as few as two and as many as 11 colonies annually (Snipes and Sanders 2012). Nest counts in North Carolina appeared to be slightly lower than in South Carolina (~700; Nisbet et al. 2013). Nest counts for Georgia and Atlantic Florida combined are estimated to be <200 (Jodice et al. 2013).

Black Skimmers are subject to many of the same management and conservation challenges faced by shorebirds and near shore seabirds in the eastern USA such as loss of and degradation to nesting habitat, sea-level rise, nest predation, oil pollution, and human disturbance (Hunter et al. 2001, Kushlan et al. 2002, Evers et al. 2010). Despite their year-round occurrence and abundance in coastal habitats, their relative high-profile nature, and their prominent role in the Natural Resource Damage Assessment for the *Deepwater Horizon* oil spill, research focusing on Black Skimmers has been limited. In particular, data pertaining to reproductive success are lacking, and as such the development of site-specific and region-wide conservation plans have been challenging (Dinsmore 2008, Snipes and Sanders 2012).

As part of a larger effort to investigate the reproductive ecology of nearshore seabirds and shorebirds in the southeastern USA (e.g., Jodice et al. 2007, Sanders and Snipes 2012, Brooks et al. 2013), we investigated nest success of Black

[1] School of Agriculture, Forest, and Environmental Science and South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, SC 29634, USA.

[2] South Carolina Department of Natural Resources, 220 Santee Gun Club Road, McClellanville, SC 29458, USA.

[3] Department of Mathematical Sciences, Clemson University, Clemson, SC 29634, USA.

[4] U.S. Geological Survey, South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, SC 29634, USA.

[5] Current address: NRCS Sage Grouse Initiative, USDA Service Center, 1837 5th Avenue S., Belle Fourche, SD 57717, USA.

[6] Corresponding author; e-mail: pjodice@clemson.edu

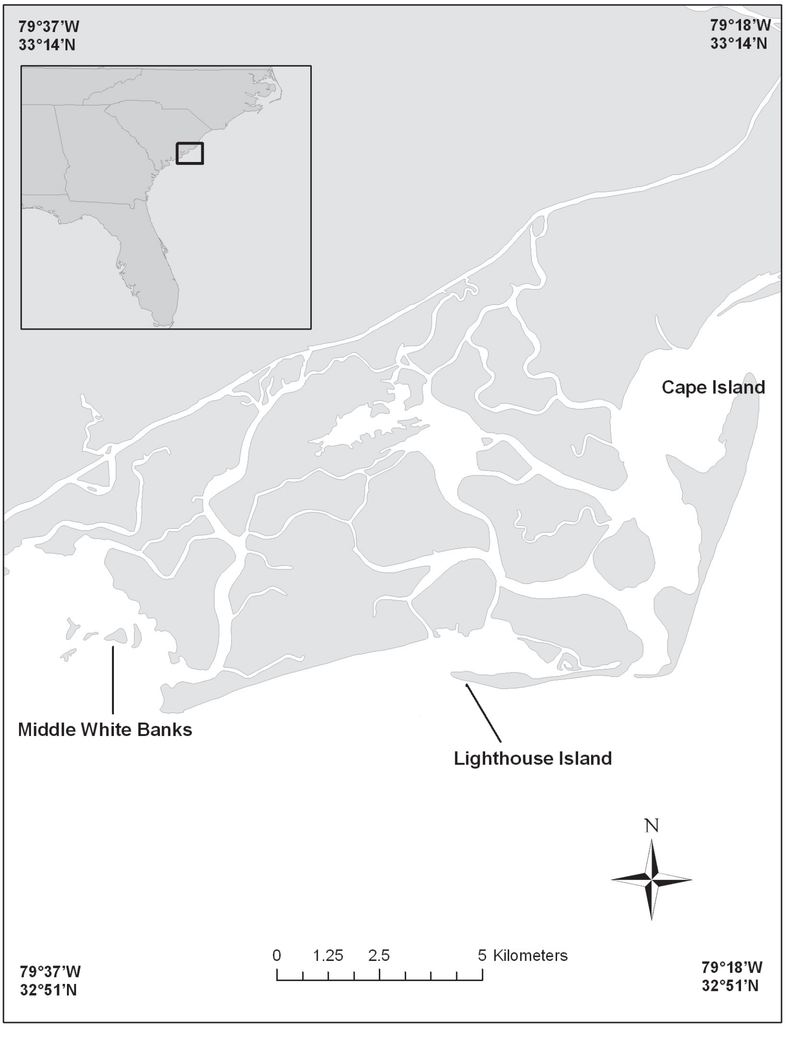

FIG. 1. Location of colony sites of Black Skimmers (*Rynchops niger*) within Cape Romain National Wildlife Refuge, South Carolina, 2009–2010.

Skimmers within a core portion of their breeding range. We sought to determine which stressors contributed to nest loss at three colonies in South Carolina, USA. Our objectives were to measure the daily survival rate (DSR) of nests and to identify factors that influenced DSRs. Identifying these factors is an important first step in prioritizing conservation of high quality nesting sites and determining if management strategies can be designed to minimize nest loss.

METHODS

Study Area.—Cape Romain National Wildlife Refuge (CRNWR) extends along 35 km of coastline in Charleston County, South Carolina, and relevant descriptions of the area can be found in Thibault et al. (2010) and Brooks et al. (2013). We monitored three sites within the refuge for skimmer colonies during the two years of this study (Fig. 1). Middle White Banks, located in Bulls Bay, is an 11-ha island formed from the accretion of Eastern oyster (*Crassostrea virginica*) and clam (*Mercenaria* sp.) shells. Lighthouse Island and Cape Island are each 500-ha barrier islands comprised primarily of salt marshes, maritime forest, and sandy beaches. Each island that we monitored during this study is used regularly for nesting by near shore seabirds and shorebirds. Public access to Middle White Banks is prohibited February–September. Lighthouse Island and Cape Island are open to the public year-round, except for colony areas that are closed to the public April–August.

Nest Monitoring.—We monitored active colonies of skimmers on Cape Island, Lighthouse Island, and Middle White Banks in 2009 and 2010. Numbers of monitored nests within colonies were not constant within a nesting season but increased as new nests were found. We sought to include nests from throughout the colony to avoid location bias (e.g., to avoid any bias associated with edge or center effects) but also constrained the sample size to limit our time in the colony. Each egg within a study nest was marked with permanent nontoxic marker to indicate egg and nest number. We estimated egg age by a combination of factors including observation of nest initiation, addition of new egg to monitored clutch, and floating of eggs. To record flooding or overwash events at colonies, we positioned plastic cups ($\sim$0.5 L) adjacent to nests located along colony edges. We secured cups to the ground by affixing nails to a wooden panel glued onto the base of the cup. Cups had holes set along the upper circumference to allow inflow of water from horizontal movement (e.g., flooding), and had lids which restricted water flow from vertical movement (e.g., rain). Flooding was inferred based on the presence of salt water in cups (Brooks et al. 2013). To document disturbance and identify nest predators within colonies of Black Skimmers, we deployed a video camera system following the methods of Sabine (2005) and Thibault (2008). The system was placed away from the colony edge ($>$6 m) to allow for a large field-of-view, and to minimize any disturbance to skimmers because of its presence.

We monitored nests beginning in late May and continued to do so until nest fate was determined. Nests were checked every 2.9 (SD = 0.8) days. Colony visits were $\leq$45 mins in duration and occurred before 1030 Eastern Daylight Time (EDT) or after 1630 EDT to minimize heat stress. We did not enter colonies during heavy rain, high wind (ca. $\geq$20 km/h), or extreme temperatures (ca. $\geq$32°C). During each visit, we recorded the number and condition of eggs within each nest. We defined the fate of each nest as successful if $\geq$1 egg hatched (i.e., if recently-hatched chicks were observed lying within the monitored scrapes or if we observed a sequential decrease in the number of eggs at nests that contained a pipping egg on the previous visit); failed if the nest was abandoned (eggs were cold and/or moisture was seen on the eggshell), depredated (signs of predation such as broken eggshells and yolk stains and/or evident predator tracks leading to the nest scrape), overwashed (overwash cup next to a study nest contained saltwater, marked eggs found in wrack debris that was recently deposited), or failed to hatch (hatching never occurred although parents continued to incubate through subsequent nest observation intervals); or unknown (empty scrapes were observed before estimated hatch date and no sign of predation or overwash were evident). The cause of nest loss for one nest did not fit any categories. The nest was lost because of a shell slide and we identified cause of nest loss as 'other.' Nest fate was recorded as undetermined for nests where there was no clear evidence of success or failure.

Statistical Analysis.—We used a chi-square analysis to assess the distribution of clutch sizes, and a logistic regression model to assess the relationship between clutch size and the independent variables season, colony site, and year (alpha level of significance = 0.05 for each but consider $P < 0.10$ as marginally significant). A suite of logistic-exposure models (Shaffer 2004) was used (SAS PROC GENMOD, binomial distribution and logit function; SAS Institute, Inc. 2008) to estimate DSR of nests following procedures described in detail in Brooks et al. (2013), although here we present a brief overview. We applied the information-theoretic approach (Burnham and Anderson 2002) to a set of *a priori* models, using the same set of models used to assess nest success in Least Terns (*Sternula antillarum*) in a companion study in CRNWR (see Appendix 1 in Brooks et al. 2013 for complete list of models). Independent variables available to the model included year (2009 or 2010), colony site (Middle White Banks, Lighthouse Island, or Cape Island), nest age (average for observation interval), date (average for observation interval; proxy for seasonal effect), clutch size, rainfall (cumulative rainfall during observation interval), ambient temperature (maximum during observation interval), tide height (maximum during observation interval), and predation risk (during the observation interval if $\geq$1 egg within the colony was preyed upon, if predator tracks were observed, or if a predation event was documented on video camera then predation risk = yes). Independent variables were chosen to allow us to assess effects of site, time within the nesting season, abiotic factors, and biotic factors that have

TABLE 1. Average coefficient estimates, unconditional standard errors, and 85% confidence intervals for the parameter estimates for variables included in 95% confidence set of models predicting survival of Black Skimmers' (*Rynchops niger*) nests in Cape Romain National Wildlife Refuge, South Carolina, 2009–2010.

Variable[a]	Coefficient Estimate (unconditional SE)	85% Confidence Interval
Colony – Lighthouse Island	−0.35 (0.27)	−1.10, 0.40
Colony – Cape Island	0.86 (0.30)	0.07, 1.65
Clutch size	1.01 (0.22)	0.33, 1.68
Predation risk – No	1.16 (0.24)	0.45, 1.86
Tide Height	−4.00 (0.53)	−5.05, −2.95

[a] Reference levels for categorical variables were Middle White Banks for colony (e.g., the estimate reflects the difference between Lighthouse Island and Middle White Banks) and Predation Risk = Yes (e.g., the estimate reflects the difference between the occurrence and lack of occurrence of predation risk during the observation interval).

been shown to affect nest success in other near shore seabirds in the southeastern USA (e.g., Erwin et al. 2001, O'Connell and Beck 2003, Dinsmore 2008, Brooks et al. 2013). For example, predation risk was a nonintrusive method for estimating the potential of eggs to be lost to predators while high tide levels were used as a surrogate for flooding potential. Although tide or storm induced flood events or predation could affect large portions of colonies, we also observed that individual nests could be affected independently (e.g., Brooks et al. 2013) and hence applied these variables to each nest and observation interval.

Daily rainfall and ambient temperature were obtained from records at the Charleston International Airport (69 km from study area) and reflect the general climate of the study area. Tide height was obtained from records at the South Carolina Port Authority, Charleston, South Carolina, and then adjusted with a tide correction factor specific to our study sites. We assessed goodness-of-fit of the global model using c-hat (i.e., residual deviance/residual df) which indicates no overdispersion when the value is ~1.0. We then ranked all models based on their Akaike Information Criteria (AIC) value (Burnham and Anderson 2002), and calculated DSR based on regression coefficients from the most-supported model. Model-averaged coefficients, standard errors, and 85% confidence intervals were used to interpret the effect of specific variables on daily nest survival and to calculate odds ratios. An 85% confidence interval was calculated because it allowed for more congruent model selection and model-evaluation criteria (Arnold 2010, Brooks et al. 2013). Nest success (the probability of a nest surviving from completion of egg-laying to hatch) was calculated as the DSR from the most supported model raised to an exponent equal to 23, the typical number of days for incubation in Black Skimmers (Burger and Gochfeld 1990). Means are presented ± SD and coefficient estimates ± SE throughout.

RESULTS

In 2009 and 2010, Black Skimmers' nests were first found on 21 May (laid ~20 May). The time from nest initiation until the last chick was observed to fail or fledge was 71 days in 2009 and 68 days in 2010. We monitored 346 nests during 1,772 observation intervals (i.e., one interval is the time period between nest visits) at three colonies during 2009 and 2010. Observation intervals ranged from 1–5 days, although 75% of intervals were 2–3 days. The fate of 28 nests was undetermined and these nests were not included in calculations of DSR. Duration of incubation length was significantly higher ($F_{1,77} = 11.1$, $P = 0.001$) in 2009 (25.0 ± 2.8) compared to 2010 (22.7 ± 2.9). There was a significant difference in the distribution of clutch size for Black Skimmers ($\chi^2{}_2 = 355.6$, $P \leq 0.001$). Clutches with three or four eggs (88%) were more frequent than clutches with one or two eggs (6%) or ≥5 eggs (6%). Season, colony site, and year were not significantly related to clutch size for Black Skimmers ($P > 0.07$ for each).

The global model fit the observed values well (c-hat = 1.08) and had a >99% chance of being the best model given the models tested and data collected. Site, clutch size, maximum tide height, and predation risk were strongly related to nest survival (Table 1). Nest age, precipitation amount, date, and year all had 85% CIs that included zero. Nest survival was highest at Cape Island and least at Lighthouse Island where colony failure occurred during 2009. The odds of a nest surviving at Middle White Banks were 0.7 and 2.4 times the odds of a nest surviving at Cape and Lighthouse islands,

TABLE 2. Daily survival rate (SE) and probability of success for Black Skimmer (*Rynchops niger*) nests in Cape Romain National Wildlife Refuge, South Carolina, 2009–2010. Probability of success is the daily survival rate raised to an exponent equal to 23 (incubation days). All estimates were calculated by using coefficients and standard errors from the global model.

Variable	Daily Survival Rate	Probability of Success
Colony site		
Lighthouse Island	0.938 (0.004)	0.421
Cape Island	0.975 (0.002)	0.689
Middle White Banks	0.940 (0.003)	0.457
Clutch Size		
<3	0.897 (0.005)	0.286
≥3	0.972 (0.001)	0.622
Predation risk		
No	0.977 (0.002)	0.720
Yes	0.944 (0.002)	0.471

respectively. Nest survival was negatively related to tide height during observation intervals, although this variable was not collected directly from colony sites. For every 10 cm increase in estimated tide height, the odds of a nest surviving decreased by 33%. Nest survival was positively related to clutch size and predation risk. The odds of a nest surviving when clutch size was large (≥3 eggs) were 2.7 times the odds of a nest surviving when clutch size was small (<3 eggs), and the odds of a nest surviving when a predation event did not occur were 3.2 times the odds of a nest surviving when a predation event did occur. The probability of nest success calculated from the best model ranged from 0.286 (small clutch size) to 0.720 (no predation events) (Table 2). Nest success was higher at Cape Island compared to the other two colonies, higher for larger clutches, and higher when predation events were absent compared to present (Table 2). Complete colony failure occurred at Lighthouse Island in 2009 because of a combination of flooding and predation.

Of the 346 nests of Black Skimmers that we monitored, 44% (n = 152) of nests failed before hatching. Nests failed primarily from overwash and predation although abandonment, failure of eggs to hatch, and deterioration of the nesting substrate (i.e., other) all contributed to nest failures as well (Fig. 2). Physical signs, observations, and/or remote documentation from video cameras documented Black Vulture (*Coragyps atratus*) and American mink (*Neovison vison*) as definitive nest predators. We observed raccoons (*Procyon lotor*), Great Horned Owls (*Bubo virginianus*), Laughing Gulls (*Leucophaeus atricilla*), Atlantic ghost crabs (*Ocepode quadrata*), and people within colonies.

DISCUSSION

We present the first estimates of DSR for nests of Black Skimmers from South Carolina and one of the very few estimates for DSR from the southeastern or Gulf regions. Our model-based estimates of nest survival ranged from 0–78% among colonies and years. The only comparable

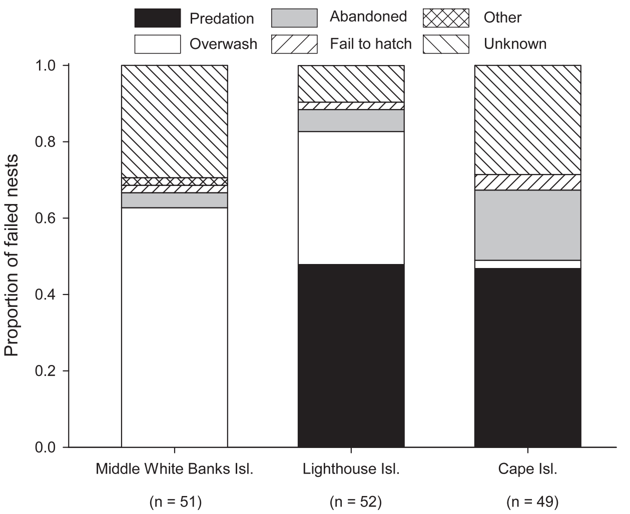

FIG. 2. Cause of nest loss for Black Skimmers (*Rynchops niger*) in Cape Romain National Wildlife Refuge, South Carolina, 2009–2010.

measure of DSR of nests was conducted in Mississippi where Dinsmore (2008) found that model-based predicted nest survival during two years ranged from 0–98% across six colonies. Estimates of apparent nest success are available for several states (Blus and Stafford 1980, Cluster and Mitchell 1987, Mallach and Leberg 1999, Rounds et al. 2004, Roman 2008) although these values should be interpreted cautiously because of the inherent challenges that exist with this technique.

Nest survival of Black Skimmers within CRNWR was related primarily to clutch size, site, predation activity, and tide height. Burger and Gochfeld (1990) and Dinsmore (2008) reported higher rates of nest success with larger clutches for Black Skimmers nesting in New Jersey, New York, and Mississippi. Dinsmore (2008) speculated that the effect of clutch size on nest survival may be related to a combination of female condition or age, location of nest within the colony, and other factors. Experienced breeders appear to have larger clutches than first-time breeders, and tend to nest at the center of colonies where they may be less vulnerable to predation or overwash (Burger and Gochfeld 1990).

DSR of nests was highest at Cape Island, intermediate at Middle White Banks, and lowest at Lighthouse Island. The Black Skimmer colonies at Cape Island were larger and located a greater distance from the high tide line compared to the colony on Middle White Banks. Colony failure occurred at Lighthouse Island in 2009 and appeared to be because of an acute flooding event. Brooks et al. (2013) measured DSR of Least Terns' nests on these same three islands in 2009 and 2010. They found that while terns also had the least success at Lighthouse Island, they had higher success at Middle White Banks compared to Cape Island and attributed this difference to larger colony size, enhanced protection at Middle White Banks where human access is prohibited, and lower incidences of flooding at Middle White Banks. A difference in the ranking of DSR for Black Skimmers and Least Terns at each colony suggests that prioritization for protection of colony sites that support multiple species cannot be based on DSR measured from a single species.

Predation accounted for nearly 50% of nest loss at Cape and Lighthouse islands during our 2-year study and has been identified as a primary source of nest loss for Black Skimmers in the southeastern U.S. (Erwin et al. 2001, O'Connell and Beck 2003, Dinsmore 2008). We documented and trapped American mink at Cape and Lighthouse islands and observed caches of Black Skimmers' eggshells, a finding that suggests regular predation activity. Although pipping eggs were observed at Cape Island in 2010 we never observed any chicks, further suggesting predation pressure may have been substantial during late incubation. Avian predators (e.g., Laughing Gulls) were also observed within Black Skimmers' colonies, but these species often do not leave conspicuous signs from which predation can be definitively ascertained. Our calculation of nest loss attributed to predation (particularly avian) may therefore be underestimated. We also documented predation of eggs and chicks by ghost crabs similar to that observed with Piping Plovers (Loegering et al. 1995, Watts and Bradshaw 1995). Predation rates and home ranges of ghost crabs are lacking and hence their impact on beach-nesting birds is somewhat unknown.

Acute and chronic overwash is a common cause of nest loss for coastal nesting birds in the southeastern USA (Rounds et al. 2004, Dinsmore 2008, Brooks et al. 2013). Each colony during our study experienced high nest loss because of storm-driven tides at some point, although the timing of such tides in relation to nesting activity varies among years. Even though the southeastern U.S. is prone to tropical storms and hurricanes which can result in region-wide nest loss for species such as skimmers (Dinsmore 2008), no such activity occurred in CRNWR during the breeding season in either year. In addition, overwash events may occur more often with increasing sea level along the southeastern U.S. (Daniels et al. 1993).

High variability in nest success among proximal sites suggests factors at local scales influenced nest success of Black Skimmers during these 2 years. Predation and overwash from high tides accounted for a substantial proportion of nest loss. Similar results have been reported for Least Terns (Brooks et al. 2013) and American Oystercatchers (*Haematopus palliatus*) (Thibault 2008; Collins 2011) nesting within the same study area. Differences in causes of nest loss between species but within the same site suggest, however, that management actions directed at enhancing nest survival of coastal birds may need to be fine-tuned by site and species. While techniques (albeit time-intensive) are available to control mammalian predators if such a management action is desired, it appears to be more challenging to control avian predators such as gulls or raptors.

Efforts such as construction of elevated nest platforms designed to alleviate nest loss from flooding appear to achieve limited success and have limitations for colonial species (Rounds et al. 2004). The construction of dredge-spoil islands with higher elevations than surrounding natural islands may alleviate nest loss because of flooding but also are time-intensive and expensive to create and manage. Ultimately, conservation and management actions for Black Skimmers in the southeastern and Gulf states will require regular measures of nest and chick survival to develop useful population models. Coordinated efforts across state borders would benefit this highly-mobile species.

ACKNOWLEDGMENTS

We thank M. Spinks, S. Dawsey, C. Wakefield, L. Eggert, M. Martin, L. Brooks, J. Tavano, and L. Barnhill as well as numerous interns and volunteers for support and assistance in the field. This research was funded by the State Wildlife Grant Program, U.S. Fish and Wildlife Service, South Carolina Department of Natural Resources; School of Agriculture, Forestry, and Environmental Sciences at Clemson University; and the USGS South Carolina Cooperative Fish and Wildlife Research Unit. Logistical support was provided by the U.S. Fish and Wildlife Service, South Carolina Department of Natural Resources, and the USGS South Carolina Cooperative Fish and Wildlife Research Unit. The manuscript benefited from comments by R. Powell and anonymous reviewers. Permits for various phases of this research were provided by The Clemson University Institutional Animal Care and Use Committee (Protocol # 2009-018). The South Carolina Cooperative Fish and Wildlife Research Unit is supported by the South Carolina Department of Natural Resources, Clemson University, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. We thank E. A. Forys and anonymous reviewers for comments that have improved this manuscript.

LITERATURE CITED

ARNOLD, T. W. 2010. Uninformative parameters and model selection using Akaike's information criterion. Journal of Wildlife Management 74:1175–1178.

BLUS, L. J. AND C. J. STAFFORD. 1980. Breeding biology and relation of pollutants to Black Skimmers and Gull-billed Terns in South Carolina. Special Scientific Report – Wildlife, Number 230, U.S. Fish and Wildlife Service, Washington, D.C., USA.

BROOKS, G. L. 2011. Factors influencing reproductive success of near-shore seabirds in Cape Romain National Wildlife Refuge, South Carolina. Thesis. Clemson University, South Carolina, USA.

BROOKS, G. L., F. J. SANDERS, P. D. GERARD, AND P. G. R. JODICE. 2013. Daily survival rate for nests and chicks of Least Terns (*Sternula antillarum*). Waterbirds 36:1–10.

BURGER, J. AND M. GOCHFELD. 1990. The Black Skimmer: social dynamics of a colonial species. Columbia University Press, New York, USA.

BURNHAM, K. P. AND D. R. ANDERSON. 2002. Model Selection and Multi-model Inference: a practical information-theoretic approach, Second Edition. Springer-Verlag, New York, USA.

COLLINS, S. A. 2012. Reproductive ecology of American Oystercatchers in the Cape Romain Region of South Carolina: implications for conservation. Thesis. Clemson University, South Carolina, USA.

CUSTER, T. W. AND C. A. MITCHELL. 1987. Organochlorine contaminants and reproductive success of Black Skimmers in south Texas. Journal of Field Ornithology 58:480–489.

DANIELS, R. C., T. W. WHITE, AND K. K. CHAPMAN. 1993. Sea-level rise: destruction of threatened and endangered species habitat in South Carolina. Environmental Management 17:373–385

DINSMORE, S. J. 2008. Black Skimmer nest survival in Mississippi. Waterbirds 31:24–29.

ERWIN, R. M., B. R. TRUITT, AND J. E. JIMENEZ. 2001. Ground-nesting waterbirds and mammalian carnivores in the Virginia barrier island region: running out of options. Journal of Coastal Research 17:292–296.

EVERS, D., P. JODICE, P. FREDERICK, V. BYRD, W. VERMILLION, J. SCHMERFELD, D. WELSH, V. VARELA, T. MCBRIDE, M. SEYMOUR, AND L. CARVER. 2010. Work plan for estimating oiling and mortality of breeding colonial waterbirds from the Deepwater Horizon (MC 252) oil spill (Bird Study #4). Deepwater Horizon Trustee Council, Fairhope, Alabama, USA.

FOSTER, C. R., A. F. AMOS, AND L. A. FUIMAN. 2009. Trends in abundance of coastal birds and human activity on a Texas barrier island over three decades. Estuaries and Coasts 32:1079–1089.

GAWLICK, D. E., R. D. SLACK, J. A. THOMAS, AND D. N. HARPOLE. 1998. Long-term trends in population and community measures of colonial-nesting waterbirds in Galveston Bay Estuary. Colonial Waterbirds 21:143–151.

HUNTER, W. C., L. PEOPLES, AND J. COLLAZO. 2001. South Atlantic coastal plain Partners in Flight conservation plan. U.S. Fish and Wildlife Service, Atlanta, Georgia, USA.

JODICE, P. G. R., T. M. M. MURPHY, F. J. SANDERS, AND L. M. FERGUSON. 2007. Longterm trends in nest counts of colonial seabirds in South Carolina, USA. Waterbirds 30:40–51.

JODICE, P. G. R, J. TAVANO, AND W. MACKIN. 2013. Chapter 8: marine and coastal birds and bats. Pages 475–587 *in* South Atlantic information resources: data search and literature synthesis (J. Michel, Editor). OCS Study BOEM 2013-01157. U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Gulf of Mexico OCS Region, New Orleans, Louisiana, USA.

KROGH, M. G. AND S. H. SCHWEITZER. 1999. Least Terns nesting on artificial habitats in Georgia, USA. Waterbirds 22:290–296.

KUSHLAN, J. A. AND 22 OTHERS. 2002. Waterbird conservation for the Americas: the North American waterbird conservation plan. Version 1. Waterbird conservation for the Americas, Washington, D.C., USA.

LOEGERING, J. P., J. D. FRASER, AND L. L. LOEGERING. 1995. Ghost crab preys on Piping Plover chick. Wilson Bulletin 107:768–769.

MALLACH, T. J. AND P. L. LEBERG. 1999. Use of dredged material substrates by nesting terns and Black Skimmers. Journal of Wildlife Management 63:137–146.

NISBET, I. C. T., R. R. VEIT, S. A. AUER, AND T. P. WHITE. 2013. Marine birds of the eastern United States and the Bay of Fundy. Nuttall Ornithological Monographs. Number 29, Cambridge, Massachusetts, USA.

O'CONNELL, T. J. AND R. A. BECK. 2003. Gull predation limits nesting success of terns and skimmers on the Virginia barrier islands. Journal of Field Ornithology 74:66–73.

ROMAN, K. M. 2008. Reproductive success of Least Terns and Black Skimmers in southeastern North Carolina. Thesis. University of North Carolina, Wilmington, USA.

ROUNDS, R. A., R. M. ERWIN, AND J. H. PORTER. 2004. Nest-site selection and hatching success of waterbirds in coastal Virginia: some results of habitat manipulation. Journal of Field Ornithology 75:317–424.

SABINE, J. B., J. M. MYERS, AND S. H. SCHWEITZER. 2005. A simple inexpensive video camera setup for the study of avian nest activity. Journal of Field Ornithology 76:293–297.

SAS INSTITUTE, INC. 2008. SAS Statistical Software. Version 9.2. Cary, North Carolina, USA.

SHAFFER, T. L. 2004. A unified approach to analyzing nest success. Auk 121:526–540.

SNIPES, K. C. AND F. J. SANDERS. 2012. Black Skimmer (*Rynchops niger*) breeding trends in South Carolina. Southeastern Naturalist 11:437–446.

THIBAULT, J. M. 2008. Breeding and ecology of American Oystercatchers in the Cape Romain Region, South Carolina. Thesis. Clemson University, South Carolina, USA.

THIBAULT, J., F. SANDERS, AND P. G. R. JODICE. 2010. Parental attendance and brood success in American Oystercatchers. Waterbirds 33:511–517.

WATTS, B. D. AND D. S. BRADSHAW. 1995. Ghost crab preys on Piping Plover eggs. Wilson Bulletin 107:767–768.