REPRODUCTIVE SUCCESS OF LEAST TERNS AND BLACK SKIMMERS IN SOUTHEASTERN NORTH CAROLINA

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ABSTRACT

One mixed colony of Least Terns and Black Skimmers at Wrightsville Beach, N.C., was monitored to determine the reproductive success of these birds from 2003-2005. Nests were visited, on average, every 3 days from April through July of each year. Mean clutch size differed significantly for both Least Terns and Black Skimmers among years. In 2005, there were significantly more 1-egg clutches for both species. Nest success differed significantly by clutch size for both species in 2005, and total nest success (2003-2005) also differed significantly for both species, with 1-egg clutches having much lower nest success. Hatching success differed significantly by clutch size in Least Terns in 2003 and 2005 and in Black Skimmers in 2005, and total hatching success (2003-2005) also differed significantly for both species among years. In Least Terns, 2-egg clutches had significantly greater hatching success in 2003 and 1-egg clutches had significantly lower hatching success in 2005. Overall (2003-2005), 2-egg clutches had the greatest hatching success and 1-egg clutches had the least. In Black Skimmers, hatching success increased as clutch size increased in 2005 and overall. There was a negative correlation between number of nests and nest success for both Least Terns and Black Skimmers, and number of eggs and hatching success for both Least Terns and Black Skimmers. This research provides important baseline data that may be used for conservation efforts for Least Terns and Black Skimmers in managed coastal habitats.

ACKNOWLEDGMENTS

I would like to thank Dr. Wm. David Webster for asking me to be his graduate student. His belief in me encouraged me to persevere through some of the most trying experiences of my life. His patience and understanding as an advisor is exemplary.

I would like to thank my mother, who reveling in the joys of being a grandmother, lovingly cared for my children while I attended school. If it were not for her, this opportunity would not be possible.

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Special thanks to Dr. D. Ann Pabst for her kindness and sincere concern for my success. Her enthusiasm and positive spirit greatly enhanced my experience at UNCW.

Finally, I thank my Lord for His love which lifts me daily.

DEDICATION

I would like to dedicate this thesis to my two wonderful children, Daniel and Anna, who continually remind me what is most important in life.

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INTRODUCTION

In the last 30 years, both the number and size of colonies of colonial nesting waterbirds, including Least Terns (*Sterna antillarum*) and Black Skimmers (*Rynchops niger*), have declined considerably (Rounds *et al.* 2004). It is believed that human disturbance and the development of beach habitat is responsible for this decline (Safina and Burger 1983, Gochfeld 1983, Burger 1994). Fragmentation of habitat has also concentrated birds into fewer, larger colonies making them more susceptible to catastrophic events (Burger *et al.* 1994).

To determine the productivity and stability of coastal waterbird populations, yearly assessments of reproductive success are crucial (Parnell *et al.* 1988, Burger 1989). Determining the causes of variation in reproductive success among colonies in a metapopulation is an important aspect of biomonitoring and species management (Burger *et al.* 1994).

In the literature, there are typically two estimates of reproductive or breeding success. Hatching success or egg success is calculated by dividing the number of chicks by the number of eggs laid (Murray 2000). Fledging success is generally calculated by dividing the number of chicks fledged by the number of eggs laid or the number of fledged young per pair (Burger 1984, Krogh and Schweitzer 1999). In colonial waterbird studies, the most accurate assessments of fledging success involve banding individual birds. Previous studies of Least Terns and Black Skimmers have focused on calculating hatching success (Britton 1982, Brunton 1999, Dinsmore 2008) and fledging success (Burger 1984, O'Connell and Beck 2003) to estimate reproductive success.

In this investigation, I used two measures to estimate reproductive success for each species, nest success (where a nest hatches ≥ 1 egg) and hatching success (number of chicks divided by the number of eggs), to test the following four null hypotheses:

- There is no significant difference in nest success for nests of Least Terns and Black Skimmers with differing clutch sizes.
- There is no significant difference in hatching success for nests of Least Terns and Black Skimmers with differing clutch sizes.
- There is no significant difference in nest success for Least Terns and Black Skimmers across years (2003-2005).
- There is no significant difference in hatching success for Least Terns and Black Skimmers across years (2003-2005).

Here, I also investigated the effect of colony size on reproductive success of both Least Terns and Black Skimmers. It has been suggested that colonial nesting species have optimal colony sizes (Brunton 1999), which is especially important for management, specifically for determining the size of an area to set aside for nesting habitat.

METHODS

Study Area

I conducted my research on the northern tip of Wrightsville Beach, (34° 14′ 24" N, 77° 46′ 18" W), a natural barrier island off the coast of southeastern North Carolina (Figure 1). The study area is between 300 and 500 m wide and 1000 m long. Wrightsville Beach is a typical barrier island with a landward side bordered by extensive salt marshes and tidal mudflats. The dominant vegetation includes seashore elder (*Iva imbricata*), sea oats (*Uniola paniculata*), bitter panicum (*Panicum amerum*), and

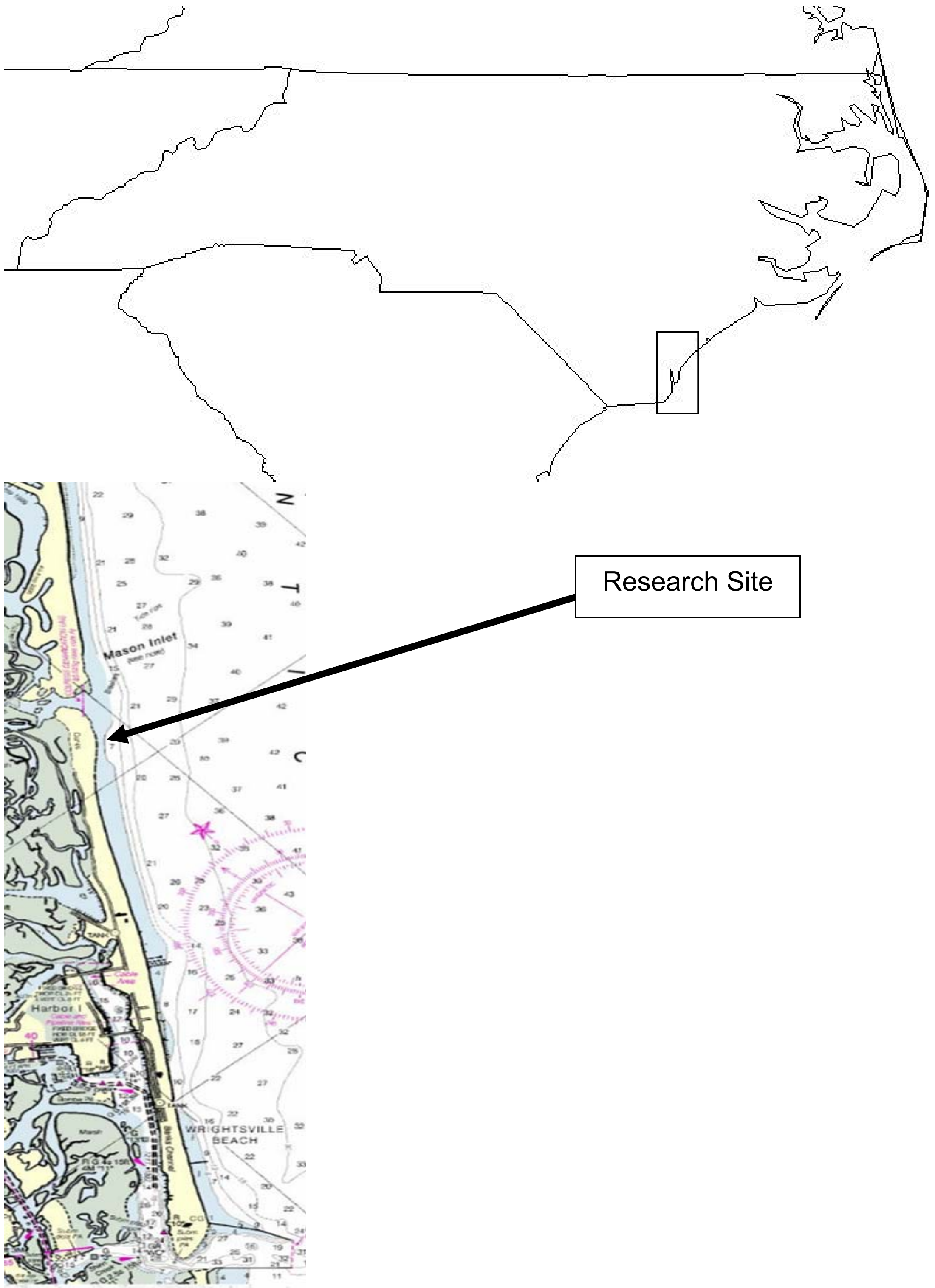

Figure 1. Map of Wrightsville Beach, North Carolina.

saltmeadow cordgrass (*Spartina patens*). This research site is unique because it is newly formed habitat as a result of the Mason Inlet relocation project, which was completed in 2002. The southward migration of the inlet was threatening to destroy both commercial and private properties on the beach, so New Hanover County hired a coastal engineering company to relocate the inlet 1000 m north. Because the work involved altering wildlife habitat, specifically habitat used by the federally endangered Piping Plover, a bird monitoring plan was put in place. In short, this nesting area will be protected and managed for the life of the permit, which is 30 years. As a result, my research site became a sanctuary under the management of the Audubon Society. It is restricted from public use by ropes and signage and patrolled seasonally by an Audubon warden.

Research Design

I started scouting for nests in early April in 2003-2005 when birds began to arrive from their wintering grounds. To find new nests and revisit marked nests, I walked in the same serpentine pattern each time I visited the site. Newly discovered nests were numbered and marked with painted tongue depressors that were placed in the sand approximately 0.5 m from the nests (Figure 2). Information recorded for each nest included species, date found, nest number, and number of eggs. Nests of Least Terns and Black Skimmers were monitored, on average, every 3 days to record the number of eggs and chicks for the duration of incubation, or until nests were lost to predation, tides, or weather events. Upon completion, markers were removed. All monitoring was conducted after 1700 hr so eggs and chicks were not subjected to midday heat. I avoided monitoring nests during periods of heavy rain and wind, and at temperatures

Figure 2. Photograph of Least Tern nest with marker.

exceeding 35 ˚C. Finally, Least Terns and Black Skimmer colonies were surveyed at sunrise at 22- and 24-day intervals, respectively, to determine the total number of nests laid each year.

Statistical Analyses

To examine consistency in research effort, I used ANOVA to compare the mean number of days between visits to the research site for Least Terns and Black Skimmers in each year (2003-2005). Since one of the assumptions of parametric tests (mutually independent data), was violated, I decided to use non-parametric tests to analyze mean clutch size and frequency of clutch sizes for both Least Terns and Black Skimmers. The Kruskal-Wallis test was used to compare mean clutch sizes for each species. The Fisher's Exact test, which is recommended when cells have expected counts of < 5, was used to compare frequencies of clutch sizes. To evaluate nest success (the production of at least one chick), each nest of each species was given a binary value of either 1 for successful or 0 for unsuccessful and analyzed by clutch size and year using logistic regression. Hatching success (the number of chicks divided by the number of eggs) was also evaluated by clutch size and year using regression analyses. Regression analyses were used to determine a correlation between total number of nests and nest success and total number of eggs and hatching success for both species; nest success and hatching success percentages were arc sin transformed prior to these analyses. Clutches with sample sizes of one (df = 0) were omitted from analyses. In all analyses, data were considered to differ significantly at $P < 0.05$.

RESULTS

Least Terns

I monitored 50 Least Tern nests in 2003, with 10 individual visits over a period of 25 days. I monitored 50 Least Tern nests in 2004, with 11 individual visits over a period of 24 days. In 2005, I monitored 204 Least Tern nests, with 30 individual visits over a period of 82 days. Even though total number of visits and length of study was three times greater in 2005, mean number of days between visits did not differ significantly among the three years (ANOVA: F = 0.39, P = 0.68; Figure 3).

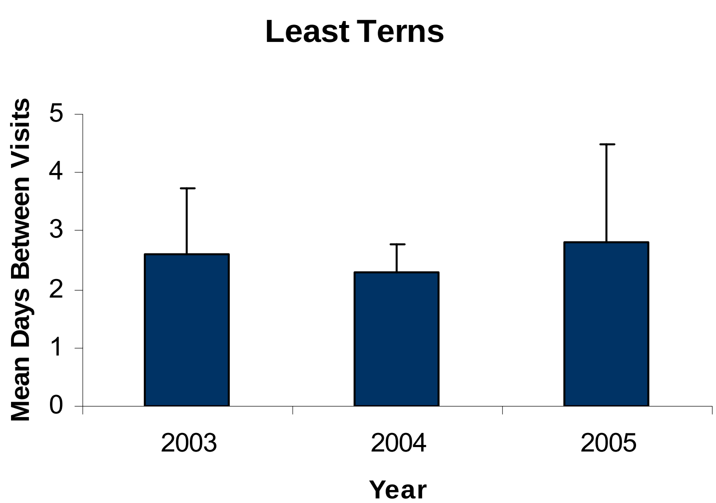

Figure 3. Mean number of days between visits for Least Terns (2003-2005).

In 2003, mean clutch size was 2.05 (94% of the nests had 2 eggs and 6% of the nests had 3 eggs). No 1-egg clutches were observed. In 2004, mean clutch size was 2.06 (4% of the nests had 1 egg, 86% of the nests had 2 eggs, and 10% of the nests had 3 eggs). In 2005, mean clutch size was 1.65 (36% of the nests had 1 egg, 63% of the nests had 2 eggs, and 1% of the nests had 3 eggs). Mean clutch size varied significantly among the three years (Kruskal-Wallis: df = 2, $\chi^2 = 45.75$, $P < 0.0001$; Figure 4), and there was significant variation in the number of 1-, 2-, and 3-egg clutches in Least Terns (Fisher's Exact: $P < 0.0002$; Figure 5). In this study, Least Terns laid 2-egg clutches more frequently (72%) than 1-egg (27%) and 3-egg (4%) clutches. Moreover, there were more 1-egg clutches laid in 2005 than in 2003 and 2004.

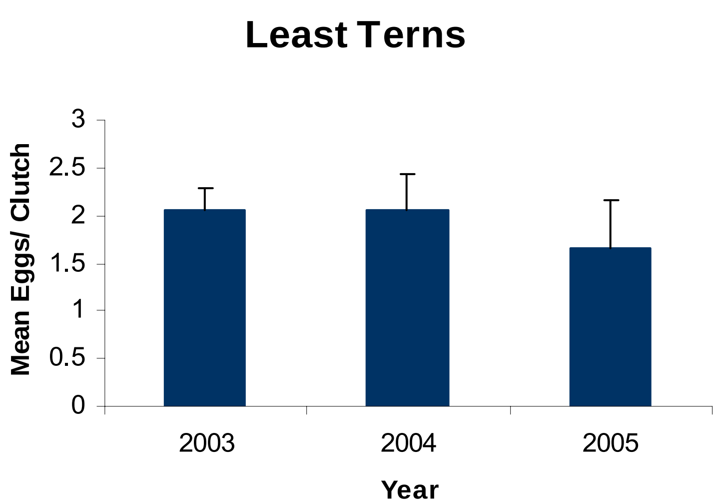

Figure 4. Mean number of eggs per clutch for Least Terns (2003-2005).

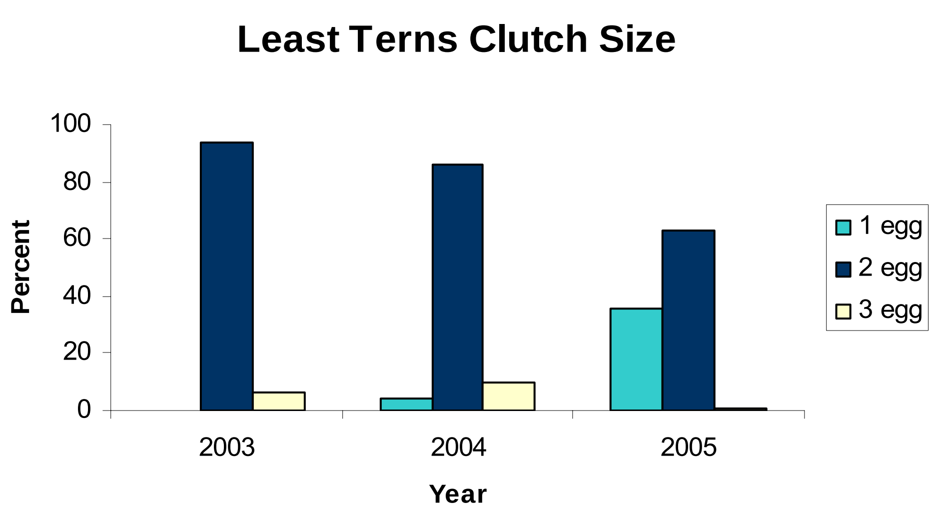

Figure 5. Frequency of clutch sizes for Least Terns (2003-2005).

In 2003, 45 of 50 nests produced one chick yielding a 90% nest success rate. Two-egg nests were 91% successful and 3-egg nests were 67% successful. No 1-egg nests were observed in 2003. In 2004, 33 of 50 nests produced one chick yielding a 66% nest success rate. One-egg nests were completely unsuccessful. Two-egg nests were 70% successful and 3-egg nests were 60% successful. In 2005, 84 of 204 nests produced one chick yielding a 41% nest success rate. One-egg nests were 22% successful, 2-egg nests were 52% successful, and 3-egg nests were 67% successful. From 2003-2005, 162 of 304 nests produced one chick yielding a 53% nest success rate. One-egg nests were 21% successful, 2-egg nests were 64% successful, and 3-egg nests were 64% successful. There was a significant difference in nest success among 1-, 2-, and 3-egg clutches in 2005 ($F = 18.9$, $P < 0.001$, $r^2 = 0.08$; Figure 6) and 2003-2005 ($F = 39.18$, $P < 0.001$, $r^2 = 0.11$; Figure 6). In 2003, a total of 103 eggs produced 81 chicks yielding a 79% hatching success rate. In 2004, a total of 103 eggs produced 58 chicks yielding a 56% hatching success rate. In 2005, a total of 338 eggs produced 118 chicks yielding a 35% hatching success rate. There was a significant difference in hatching success among 1-, 2-, and 3-egg clutches in 2003 ($F = 11.26$, $P < 0.05$, $r^2 = 0.17$; Figure 7) and 2003-2005 ($F = 20.38$, $P < 0.001$, $r^2 = 0.06$; Figure 7).

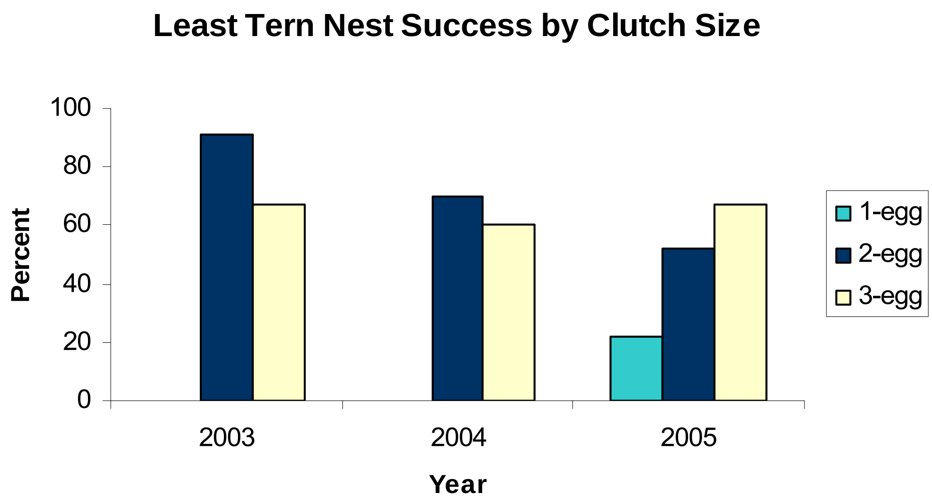

Figure 6. Nest success by clutch size for Least Terns (2003-2005).

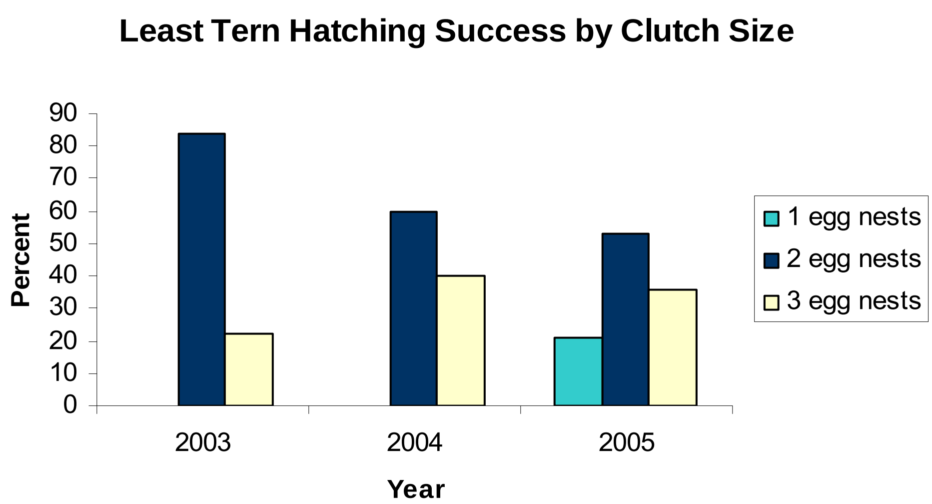

Figure 7. Hatching success by clutch size for Least Terns (2003-2005).

Total number of Least Tern nests at the research site increased each year of the study (202 in 2003, 369 in 2004, and 614 in 2005). There was a negative correlation between total number of nests and nest success (r = -0.995; Figure 8). Total number of Least Tern eggs at the research site increased each year of the study (453 in 2003, 674 in 2004, and 944 in 2005). There was a negative correlation between total number of eggs and hatching success (r = -0.996; Figure 9).

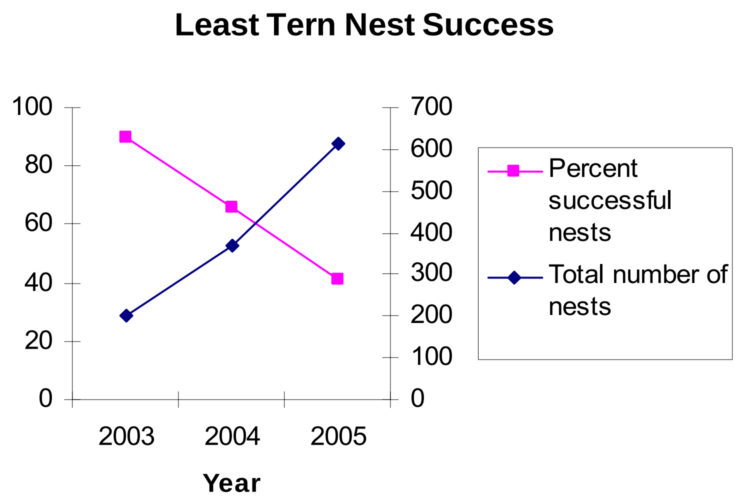

Figure 8. Percent nest success and total number of nests for Least Terns (2003-2005).

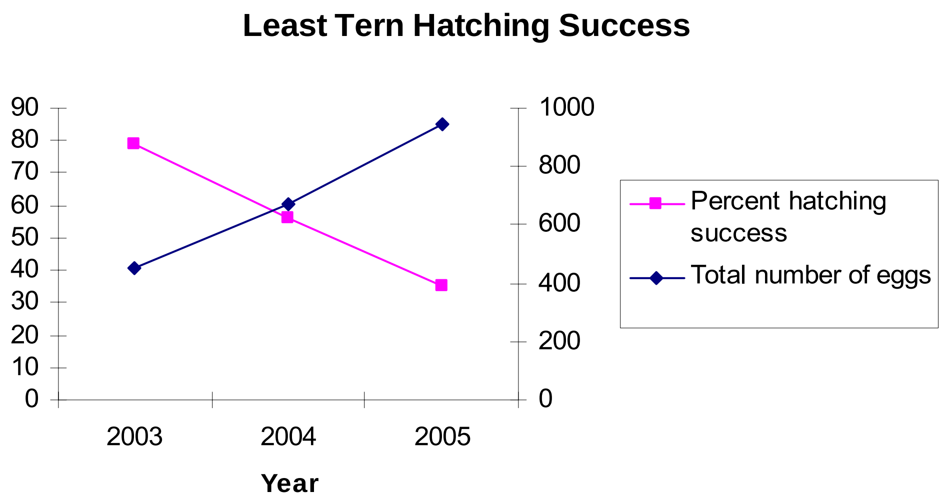

Figure 9. Percent hatching success and total number of eggs for Least Terns (2003-2005).

Black Skimmers

I monitored 50 Black Skimmer nests in 2003, with 13 individual visits over a period of 33 days. I monitored 49 Black Skimmer nests in 2004, with 9 visits over a period of 23 days. In 2005, I monitored 77 Black Skimmer nests, with 22 visits over a period of 73 days. Mean number of days between visits did not differ significantly among the three years (ANOVA: F = 1.22, P = 0.31; Figure 10).

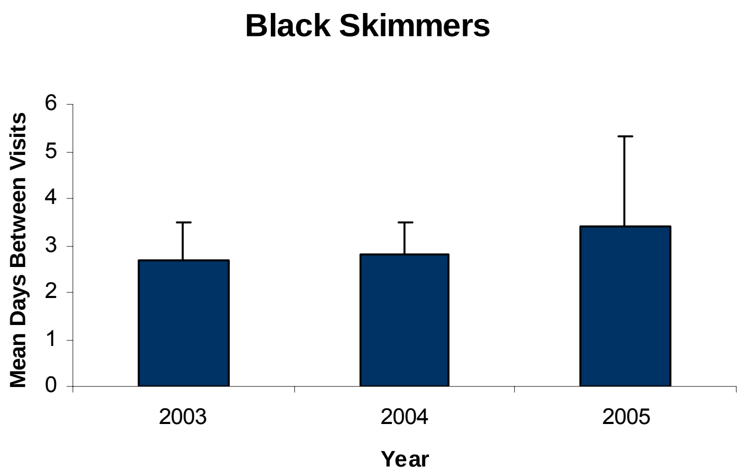

Figure 10. Mean number of days between visits for Black Skimmers (2003-2005).

In 2003, mean clutch size was 3.24 (18% of the nests had 2 eggs, 40% of the nests had 3 eggs, and 42% of the nests had 4 eggs). No 1-egg or 5-egg clutches were observed. In 2004, mean clutch size was 3.47 (2% of the nests had 1 egg, 6% of the nests had 2 eggs, 37% of the nests had 3 eggs, 53% of the nests had 4 eggs, and 2% of the nests had 5 eggs). In 2005, mean clutch size was 2.62 (13% of the nests had 1 egg, 25% of the nests had 2 eggs, 49% of the nests had 3 eggs, and 13% of the nests had 4 eggs). No 5-egg clutches were observed in 2005. Mean clutch size differed significantly among the three years (Kruskal-Wallis: df = 2, χ^2 = 31.81, P<0.0001; Figure 11), and there was significant variation in the number of 1-, 2-, 3-, 4-, and 5-egg nests in Black Skimmers (Fisher's Exact: P < 0.005; Figure 12). Black Skimmers laid 3- and 4-egg clutches more frequently (43% and 32%, respectively) than 1- (6%), 2-(18%), and 5-egg (0.5%) clutches during this investigation. There were more 1- and 2-egg clutches laid in 2005 than in 2003 and 2004.

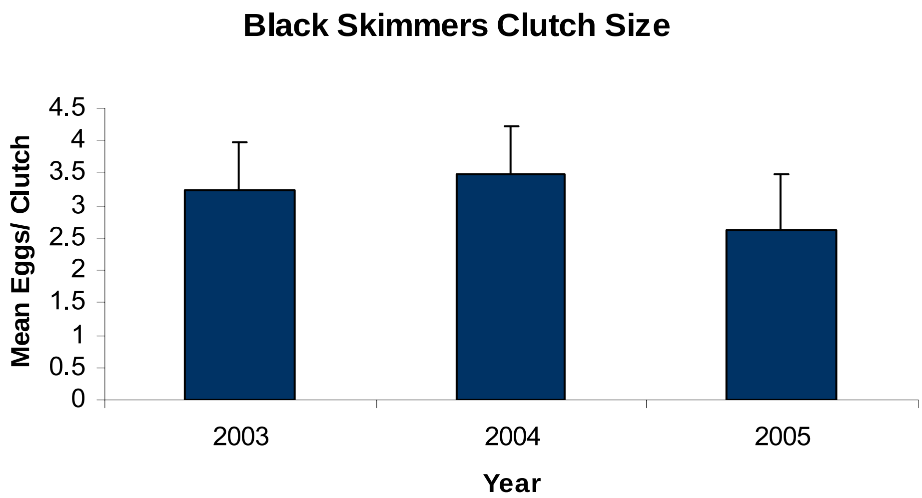

Figure 11. Mean number of eggs per clutch for Black Skimmers (2003-2005).

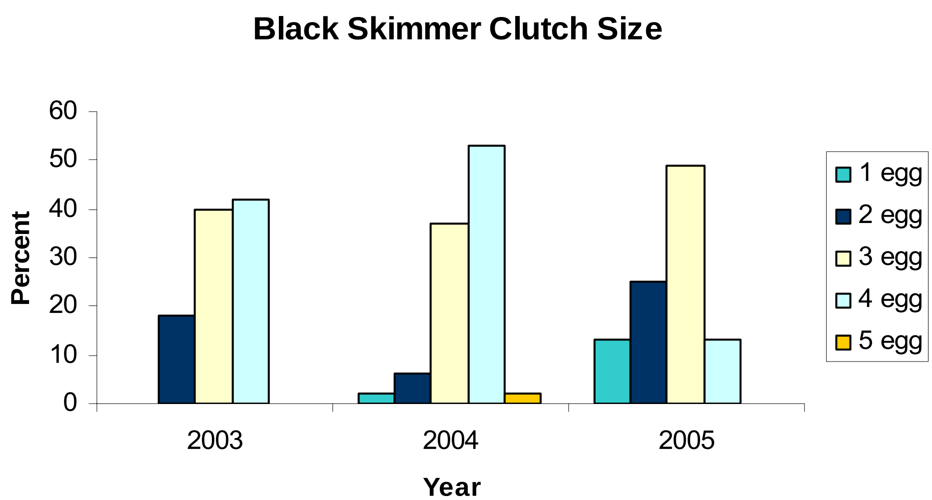

Figure 12. Frequency of clutch sizes for Black Skimmers (2003-2005).

In 2003, 36 of 50 nests produced one chick yielding a 72% nest success rate (2-egg nests were 78% successful, 3-egg nests were 65% successful, and 4-egg nests were 76% successful). No 1- or 5-egg nests were observed in 2003. In 2004, 36 of 49 nests produced one chick yielding a 73% nest success rate (2-egg nests were 33% successful, 3-egg nests were 72% successful, and 4-egg nests were 81% successful. In 2005, 41 of 77 nests produced one chick yielding a 53% nest success rate (1-egg nests were 10% successful, 2-egg nests were 26% successful, 3-egg nests were 68% successful, and 4-egg nests were 90% successful). No 5-egg nests were observed in 2005. From 2003-2005, 113 of 176 nests produced one chick yielding a 64% nest success rate (1-egg nests were 9% successful, 2-egg nests were 42% successful, 3-egg nests were 93% successful, and 4-egg nests were 81% successful. Nest success differed significantly by clutch size in 2005 ($F = 28.2$, $P<0.001$, $r^2 = 0.26$; Figure 13). There was a significant difference in nest success among years ($F = 31.84$, $P < 0.001$, $r^2 = 0.15$; Figure 13).

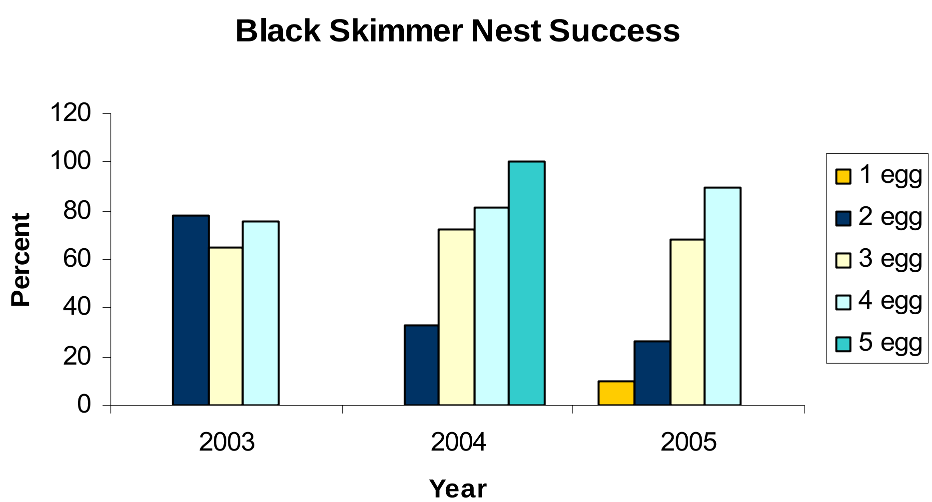

Figure 13. Nest success by clutch size for Black Skimmers (2003-2005).

In 2003, a total of 162 eggs produced 60 chicks yielding a 37% hatching success rate. In 2004, a total of 170 eggs produced 79 chicks yielding a 46% hatching success rate. In 2005, a total of 198 eggs produced 78 chicks yielding a 39% hatching success rate. Hatching success differed significantly among 1-, 2-, 3-, and 4-egg clutches in 2005 ($F = 10.80$, $P = 0.002$, $r^2 = 0.11$; Figure 14), and there was a significant difference in hatching success among 1-, 2-, 3-, and 4-egg clutches in 2003-2005 ($F = 15.11$, $P < 0.001$, $r^2 = 0.07$; Figure 14).

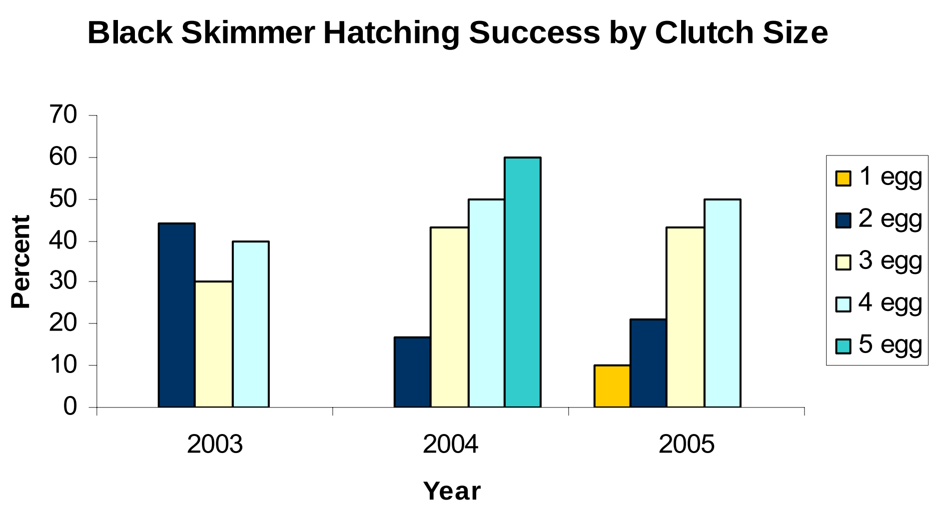

Figure 14. Hatching success by clutch size for Black Skimmers (2003-2005).

Total number of Black Skimmer nests at the research site decreased from 162 in 2003 to 64 in 2004. Total number of Black Skimmer nests then increased to 143 in 2005. There was a negative correlation between total number of nests and nest success (r = -0.344; Figure 15). Total number of Black Skimmer eggs at the research site decreased from 417 in 2003 to 159 in 2004, and then increased to 300 in 2005. There was a negative correlation between total number of eggs and hatching success (r = -0.967; Figure 16).

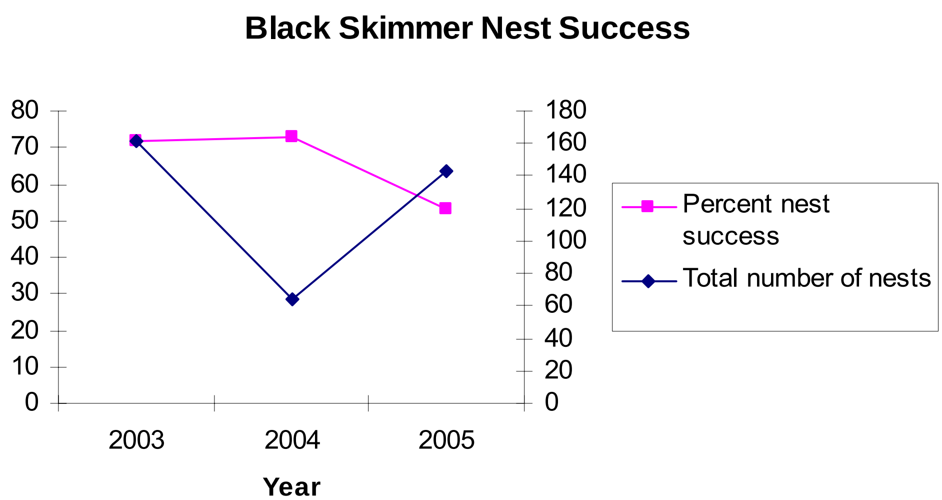

Figure 15. Percent nest success and total number of nests for Black Skimmers (2003-2005).

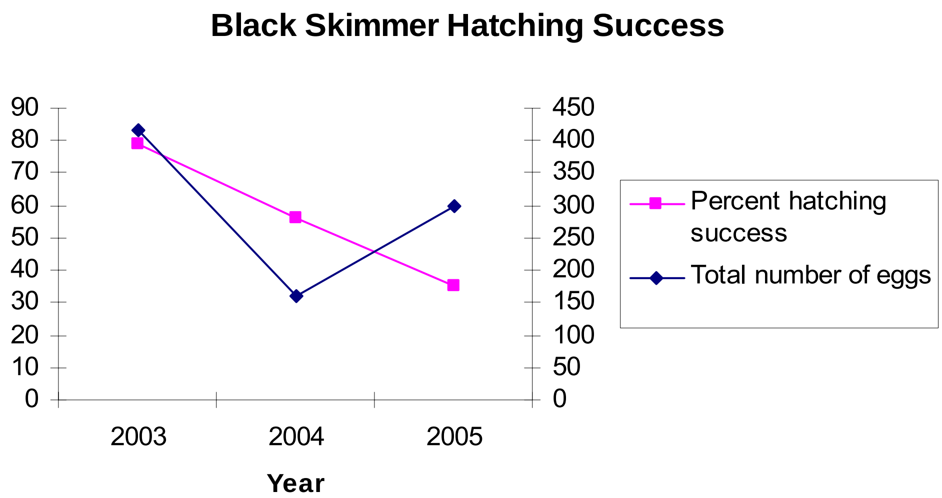

Figure 16. Percent hatching success and total number of eggs for Black Skimmers (2003-2005).

DISCUSSION

Because both Least Tern (Massey 1981, Smith and Renken 1993) and Black Skimmer (Burger and Gochfeld 1990, Gochfeld and Burger 1994) chicks leave the nest 1-2 days after hatching, and I monitored nests on average every 3 days, my nest and hatching success calculations should be considered underestimates. However, I chose this interval to reduce the effect of observer disturbance. Although some would debate that human disturbance does not affect reproductive success (Blanco *et al*. 1999), there are numerous studies of larid breeding biology that suggest otherwise (Hunt 1972, Ollason and Dunnet 1980, Safina and Burger 1983, Burger 1991, Potter 1992, Coburn 1995, Lord *et al*. 2001). Because the mean number of days between visits did not differ significantly among the 3 years for either species, it appears that differences in reproductive success during my study were not influenced by my research effort. Furthermore, reproductive success ostensibly was not influenced by human disturbance from the public because access to the nesting site was minimized by the use of ropes, signage, and an Audubon warden who patrolled the study area daily.

Mean and frequency of clutch size was consistent with other studies of both Least Terns (Smith and Renken 1993, Elliot *et al*. 2007) and Black Skimmers (Erwin 1977, Dinsmore 2008). However, both species experienced a decreasing trend in mean clutch size from 2003-2005. This may be explained by philopatry (returning to the birth place to reproduce), which is common in Least Terns (Burger 1984, Atwood and Massey 1988) and Black Skimmers (Burger 1982). Since both species reach sexual maturity at 2 years of age (Massey *et al*. 1992, Gochfeld and Burger 1994) and because young larids exhibit age specific reproductive success (Coulson and Horobin 1976, Veen 1977, Ryder 1980, Massey and Atwood 1981, Nisbet *et al*. 1984), smaller clutches in 2005 may be explained by the reproductive yield of 2-year-old parents hatched at the same site in 2003. Future studies should include a rigorous banding protocol to test this hypothesis.

In Least Terns, 2-egg clutches had the greatest nest success rates in 2003 and 2004, however, in 2005 and 2003-2005, 3-egg clutch nest success exceeded or equaled, respectively, 2-egg clutch nest success. The results of this research suggest that 2- and 3-egg clutches have an equal chance of producing at least one chick. The large increase in 1-egg nest success in 2005 may simply be due to the increase in number of 1-egg clutches that year. Even though the colony increased in size from 2003-2005, overall nest success did not increase. These results are similar to the results of a study of 11 Least Tern colonies in Connecticut, where there was no significant correlation between nest success and colony size (Brunton 1999).

In Black Skimmers, nest success increased with clutch size, with the exception of 2003, when 2-egg clutches had higher nest success rates than 3- and 4-egg clutches. In Least Terns, 2-egg clutches had the greatest hatching success rates in 2003, 2004, and 2003-2005. In 2005, 3-egg clutches had the greatest hatching success rates. The total hatching success rate for 2003 (79%) is similar to a study by Britton (1982) who recorded an 82% hatching success rate of a Least Tern colony on a managed beach site in Virginia. In Black Skimmers, the average hatching success for 2003-2005 was 41%. This result is consistent with other studies of this species. For example, Burger and Gochfeld (1990) reported a mean hatching success of 43% during a comprehensive survey of 14 Black Skimmer colonies in coastal New Jersey.

From 2003-2005, total nest success and hatching success for both species followed a decreasing trend. These results may be explained by the increase in colony size. In a study of 44 Least Tern colony sites in coastal New Jersey, Burger (1984) noted that larger colonies experienced more reproductive failures than smaller ones. Studies of other colonial seabird populations show that larger colonies experience lower reproductive success (Birkhead and Furness 1985, Hunt *et al*. 1986). Large colonies experience greater competition for resources (Gill 2003) and higher predation rates (Erwin 1977, Burger 1984, Brunton 1997). In a predation study in Least Terns, Brunton (1999) suggests an optimal colony size of 150 nests. Interestingly, the highest rates of nest and hatching success in the Least Tern colony I observed occurred in 2003, when the total number of nests was 202, as opposed to 369 in 2004 and 614 in 2005. The presence of both aerial (gulls) and terrestrial (cats, raccoons, dogs, rats) predators was documented in and around nests.

I do not believe that weather variations had any bearing on the outcome of this research. Although I did not record weather data during visits to the nesting site, data compiled from the state climate office of North Carolina did not show notable differences in average monthly temperatures, average monthly wind speed, and average monthly precipitation during the research period. Also, severe weather events, specifically hurricanes Isabel (2003), Charley (2004), and Ophelia (2005) could not have influenced the results of this research because all occurred after mid-August when monitoring had ended.

In conclusion, the results of this investigation provide baseline nesting data for Least Terns and Black Skimmers in a managed site in southeastern North Carolina. In Least Terns, mean clutch size decreased dramatically in the third year of this study. In addition, as the size of the Least Tern colony increased, nest success and hatching success diminished. These results might be explained by the influx of philopatric first-time 2-year-old nesting individuals in 2005. A long-term banding study would provide critical information necessary to test this hypothesis.

In Black Skimmers, mean clutch size also decreased dramatically in the third year of this study and hatching success was negatively correlated with the total number of eggs. Although there was a negative correlation between the total number of nests and nest success, the relationship was not as strong as observed in Least Terns, suggesting that Black Skimmer nest success may not be as strongly influenced by colony size as Least Tern nest success.

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