Behavior and Habitat Use of Roseate Terns (Sterna dougallii) Before and After Construction of an Erosion Control Revetment

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BEHAVIOR AND HABITAT USE OF ROSEATE TERNS (*STERNA DOUGALLII*) BEFORE AND AFTER CONSTRUCTION OF AN EROSION CONTROL REVETMENT

A Thesis Presented

By

COREY M. GRINNELL

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements of the degree of MASTER OF SCIENCE

February 2010

Wildlife and Fisheries Conservation
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Approved as to style and content by:

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Peter D. Vickery, Chair

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Curtice R. Griffin, Member

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Ian C.T. Nisbet, Member

Paul Fisette, Department Head
Department of Natural Resources Conservation
DEDICATION

This work is dedicated to my family and friends for their love, support, infinite patience, and tolerance. Let us all go forth to understand and remake the world into a more livable and peaceful home.
I would like to thank my advisor, Peter D. Vickery, for many years of guidance and support. Thanks to my committee members Ian C.T. Nisbet and Curtice R. Griffin for demanding nothing less than perfection through all stages of this endeavor. I also wish to thank Jeffrey A. Spendelow for initial ideas and securing funding for this project.

This research was maintained with funding from the USGS Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service’s Endangered Species Office (Region 5), and the Sounds Conservancy Grants Program of the Quebec-Labrador Foundation’s Atlantic Center for the Environment. The Stewart B. McKinney National Wildlife Refuge (especially William Kolodnicki) and the USGS Patuxent Wildlife Research Center were also instrumental with logistic support and equipment contributions. The Connecticut Department of Environmental Protection (especially Julie Victoria) was also generous with equipment loans for this research. The U.S. Fish and Wildlife Service (especially Rick Schauffler) also provided the initial GIS information.

The Connecticut Audubon Society contributed the staff time of Miley Bull and Marilyn Duda in addition to management of major funding. The Connecticut Chapter of the Nature Conservancy provided volunteer support for placement of modified nest sites each spring. Falkner Island Tern Project staff, the Great Gull Island Project (American Museum of Natural History), Guilford Yacht Club, Little Harbor Laboratory (especially Sarah Richards), and the Massachusetts Audubon Society also contributed with facilities, logistical support, and staff time. I thank you all.
ABSTRACT

BEHAVIOR AND HABITAT USE OF ROSEATE Terns (*Sterna dougallii*) BEFORE AND AFTER CONSTRUCTION OF AN EROSION CONTROL REVETMENT

FEBRUARY 2010

COREY M. GRINNELL

B.S., UNIVERSITY OF MASSACHUSETTS AMHERST

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Directed by: Peter D. Vickery

An erosion control revetment was constructed at the Falkner Island Unit of the Stewart B. McKinney National Wildlife Refuge, Connecticut during the winter of 2000–2001. At the time, Falkner Island was the fifth largest breeding colony site for the federally endangered Roseate Tern. This study measures and describes some baseline information regarding Roseate Tern nesting, behavior, and habitat use at Falkner Island during the three breeding seasons prior to revetment construction (1998–2000). This baseline information is then compared to similar information from the first breeding season following revetment construction (2001).

For Roseate Tern adults, this study examined changes in pre-nesting habitat use, nest site distributions, and pre-nesting behavioral time allocation. Changes in habitat availability and habitat use by Roseate Terns are compared as a result of the revetment construction. Roseate Terns used rocky beach in a greater proportion than other habitats before revetment construction, and used revetment boulders in a greater proportion than all other habitats after revetment construction. Roseate Terns nested more often in
artificial sites (nest boxes and tires) than in natural sites in all years of the study. The mean date for the first eggs in each nest did not differ between years. We observed more Roseate Terns prospecting artificial nest sites (n = 66 times) than natural sites (n = 21 times) for three years of this study. Prospecting behavior occurred later in the season in some subcolonies, but this difference did not appear to be related to the construction.

For Roseate Tern chicks, this study investigated the use of crevices as hiding places from before (1999–2000) and after (2001) the construction of an erosion control revetment. In all years, Roseate Tern chicks used crevices found under artificial nest sites more frequently than expected by chance when compared to crevices found in other microhabitats. Chicks also used crevices formed in various microhabitat types at different stages of development. The erosion control revetment created crevices that had larger openings, steeper floors, and deeper lengths than those previously used by chicks before construction. In the year after revetment construction, the openings of crevices used by chicks that died were wider than crevices used by chicks that survived. We discuss our findings in the context of the potential consequences that the revetment construction had on Roseate Tern chick survival.
PREFACE

This work contains two self contained manuscripts (Chapters I–II) intended for publication in professional, peer refereed journals, along with an inclusive bibliography. The overall format of this thesis adheres to the formatting requirements provided by the Graduate School at the University of Massachusetts Amherst. Specific chapters follow requirements of style and format appropriate for their respective journal submissions (Chapters I for Waterbirds, and Chapter II for the Journal of Wildlife Management). The works, herein, are the results of my research during my interim at the University and I hold all responsibility for these works. Periodically, I use the words "our", and "we" throughout the chapters to meet specific journal requirements and to acknowledge the influence and efforts by my Committee Chair (Dr. Peter D. Vickery), Consulting Committee Member (Dr. Ian C.T. Nisbet), and co-investigator (Dr. Jeffrey A. Spendelow) at the Patuxent Wildlife Research Center.
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CHAPTER I

PRE-NESTING HABITAT USE AND BEHAVIOR OF ADULT ROSEATE TERNs (*STERNA DOUGALLII*) AT FALKNER ISLAND, CONNECTICUT: STUDIES BEFORE AND AFTER AN EROSION CONTROL REVETMENT

Abstract

We examined changes in pre-nesting habitat use, nest site distributions, and pre-nesting behavioral time allocation of adult Roseate Terns before and after the construction of an erosion control revetment at Falkner Island, Connecticut from 1999–2001. We compared changes in habitat availability and habitat use by adult Roseate Terns as a result of the revetment construction. Roseate Terns used rocky beach in a greater proportion than other habitats before revetment construction, and used revetment boulders in a greater proportion than all other habitats after revetment construction. Roseate Terns nested more often in artificial sites (nest boxes and tires) than in natural sites in all years of our study. The mean date for the first eggs in each nest did not differ between years. We observed more Roseate Terns prospecting artificial nest sites (n = 66 times) than natural sites (n = 21 times) for three years of this study. Prospecting behavior occurred later in the season in some subcolonies, but this difference did not appear to be related to the construction.

Introduction

Nest site selection has been studied extensively in many bird species. Among the gulls and terns (Laridae), studies of nest site selection have tended to focus on nest site use at different spatial scales (Burger and Gochfeld 1988, Gochfeld and Burger 1987,
Early work on Common Terns \((Sterna hirundo)\) described their basic breeding biology and behavior (Austin 1929, Marples and Marples 1934, Palmer 1941); and experimented with habitat manipulation (Austin 1934, Floyd 1937). More recent studies on nest site choice in terns (Sterninae) compared the characteristics of sites chosen for nesting (Blokpoel \textit{et al.} 1978, Burger and Gochfeld 1987, 1988, 1990b, 1991, Storey 1987a, b, Goutner 1990) rather than investigating the selection process itself. These studies did not feature the time period during nest site selection. This is crucial to understanding tern behavior and habitat use as they choose where to invest their breeding efforts.

Experimental studies in nest site selection with Common Terns and Black Skimmers \((Rynchops niger)\) (Severinghaus 1982, Richards and Morris 1984, Burger and Gochfeld 1990b, Cook-Haley and Kelly 2002) compared and described habitat selection differences with nesting habitat manipulations. But, they did not explore behavioral patterns during nest site selection. Time-allocation budgets for birds during nest site selection may provide an alternate measure of resource use during a critical period in the breeding cycle. In the case of a major habitat alteration, time-allocation budgets may provide insight into resource use within a given habitat prior to alteration. This allows for a post hoc comparison as a way to assess the effects of the habitat alteration on resource use for a given species.

We had the opportunity to experimentally investigate habitat use, nest site distribution, and behavioral patterns by endangered Roseate Terns \((S. dougallii)\) (U.S. Fish and Wildlife Service 1987) at Falkner Island, Connecticut (FICT). An erosion control revetment was constructed on FICT during the winter of 2000–2001, which
allowed us to document and compare behavior and habitat use before and after a major
habitat manipulation. We sought to describe the behavior and phenology of Roseate
Terns during the pre-nesting period and to describe changes in available habitat and
habitat preference. We compared observations made before and after construction of the
revetment, to evaluate potential effects of habitat modification on nest distribution,
behavior, phenology, time budgets, and habitat use. To place our findings in a wider
context, we compared our results with previous studies of gulls and terns that were
subjected to habitat modification.

Methods

Study Area

The Falkner Island Unit of the Stewart B. McKinney National Wildlife Refuge is
located 5 km off the coast of Guilford, New Haven County, Connecticut, USA (41° 13'
N, 72° 39' W). This crescent-shaped island (2 ha) is the result of glacial deposition, and
is composed of various sized boulders, cobbles, and gravel. A rocky beach forms the
perimeter, surrounds a raised, vegetated plateau, and is flanked by steep bluffs on the
north end and east side of the island (Spendelow 1982, Nisbet 1994, Demos and Paiva

During the 1998–2001 breeding seasons, FICT supported an average of 111
breeding pairs of Roseate Terns and a large Common Tern colony (2,827–3,254 nests
found as of 15 June each year) (Spendelow and Kuter 2001). Roseate Terns nested
within six distinct subcolonies in all four years of this study. The subcolonies were
located on the northern end, eastern side, and southern end of the island (Figure 1.1).
Most Roseate Terns (>95%) nested in specially designed nest boxes and nest tires (Spendelow 1982, 1996).

**Habitat Classification**

We used ten major classifications to characterize habitat at FICT (Table 1.1). We quantified the amount of available habitat within each subcolony with a digital photomosaic of the island created by the U.S. Fish and Wildlife Service (USFWS) with Microimages MIPS software. The photomosaic was composed of photographs taken from a Cessna 172 at an altitude of approximately 570 m in November 1999. In July 2000, USFWS traced the outlines of vegetation features within each subcolony with a Trimble GPS Unit. In April 2001, USFWS traced the outlines of the revetment with the same GPS unit. We overlaid all of the GPS outlines onto the photomosaic and measured the areas of all habitat types within each Roseate Tern subcolony using Arc View 3.2a (Table 1.2).

Since logs, nest boxes, and nest tires are specific features within a habitat, we measured them differently than other habitat types. We counted each linear meter of log as one square meter. We also counted each nest box and each nest tire as one square meter, unless two boxes or tires were adjacent to each other occupying less than one square meter on the ground, which counted as two boxes or tires per square meter. We think this method of measurement accurately accounted for the area around each site that would be defended or occupied by a Roseate Tern in the process of selecting a nest site.
Changes in Subcolony Habitat after Revetment Construction

During the winter of 2000–2001, the U.S. Army Corps of Engineers constructed a rock revetment to stabilize the eroding bluffs by decreasing the slope on the upper portion and adding an anchor or toe at the bottom. This anchor was composed of four to six ton basalt boulders placed in a manner that created gaps of up to two meters, producing a network of crevices (Chapter II). The anchor portion of the revetment now occupies more than half of the original beach on the east side of the island. In addition to the gradual slope and anchor of boulders, a shelf (ranging from one to three meters) was created on a level portion of the revetment boulders in an effort to provide substitute nesting habitat in combination with artificial nest sites (Spendelow 1982, 1996). The shelf was located on top of the revetment, but partway down the original slope of the island. The shelf was covered with a thick layer of gravel (grain size of ~1 cm$^3$) upon which artificial nest sites (boxes and tires) were placed. The revetment affected four of the six Roseate Tern subcolonies. Most of the beach in the affected areas was replaced by revetment boulders, which substantially changed the overall morphology of the island (Figure 1.1 and Table 1.1).

For purposes of this study, we labeled each subcolony A–F starting with the northernmost subcolony and working clockwise around the island. Artificial nest sites (nest boxes and nest tires) were deployed each year in mid-April and removed in early August after all breeding ceased. Artificial nest sites in Subcolony A consisted exclusively of nest tires. In 1998–2000, we placed 100 nest tires on an area of rocky beach from above mean high water (MHW) to the toe of the bluff. In 2001, revetment boulders were added to areas of Subcolony A, which reduced the amount of rocky beach
habitat. The edge of the revetment came close to where the southern-most nest tires had been placed in previous years. We moved some nest tires further north than in previous years; although no revetment boulders were placed directly where we had previously placed nest tires. We placed 100 nest tires on the smaller area of rocky beach between MHW to the bottom of the revetment. We placed no tires on the nesting shelf (Figures 1.1 and 1.2; Tables 1.2 and 1.3).

In Subcolony B, we placed 20 nest boxes adjacent to a large log and boulders located on the rocky beach in 1998–2000. In 2001, we placed 24 nest boxes on the shelf. Rather than placing most boxes along a log and near boulders on the beach as in previous years, we lined the nest boxes up along the edge of the shelf of the revetment adjacent to revetment boulders for 2001. All rocky beach, Black Mustard, and log habitat was removed or buried beneath the revetment in Subcolony B and was replaced with revetment boulders and revetment gravel. A few revetment boulders were also placed on this shelf, but no Roseate Terns were observed using the revetment boulders during the 2001 breeding season. The shelf was the only logical place for nest boxes while minimizing the danger of chicks falling into crevices formed by the revetment boulders (see Chapter II). We increased the total number of nest boxes in this subcolony from 20 in 1998–2000 to 24 in 2001 while taking up less area by placing the boxes closer together (Figures 1.1 and 1.3; Tables 1.2 and 1.3).

In Subcolony C, we placed 24 nest boxes adjacent to boulders and logs in areas where Virginia Creeper had historically grown for 1998–2000. Since the revetment was constructed in only a portion of this subcolony, we decided to place ten nest boxes on the shelf of the revetment in 2001, and the remaining ten nest boxes on the beach as in the
previous breeding seasons. Some rocky beach and Virginia Creeper were removed or buried in this portion of the revetment construction. This habitat was also replaced with revetment boulders and revetment gravel (Figures 1.1 and 1.3; Tables 1.2 and 1.3).

Subcolonies D and E were not modified by revetment construction. We placed 40 nest boxes in Subcolony D. However, the nest boxes occupied slightly more area here in 2001 than in 1999–2000. Nest boxes were placed adjacent to boulders and in areas where Poison Ivy has historically grown into the subcolony each season. In subcolony E, we placed 20 nest boxes adjacent to boulders and on rocky beach (Figures 1.1 and 1.4; Tables 1.1 and 1.3).

Subcolony F was also partially affected by revetment construction. We placed 72 nest boxes on rocky beach in 1998–2000. Most of these nest boxes were placed in the open, about one meter apart, but some were placed near Virginia Creeper, boulders, and logs. In 2001, we placed 12 nest boxes on the beach as before, but the remaining 60 nest boxes were placed on the revetment shelf. We used a similar arrangement of three rows of 20 nest boxes, as in previous breeding seasons. Nest boxes were placed in a slightly more spread out fashion than before revetment construction. Rocky beach, Virginia Creeper, and logs were replaced with revetment boulders and revetment gravel. Only new habitat (revetment boulders and revetment gravel) was measured, after construction in April 2001, and before terns arrived at the study site (Figures 1.1 and 1.5; Tables 1.2 and 1.3). Subsequently, Black Mustard grew on the shelf of the revetment and this new growth was not quantified (Spendelow and Kuter 2001). This new growth could not have influenced nest site selection since it did not appear until after 15 June 2001 (the normal peak of nesting for terns at this breeding colony site).
General Field Protocol

Once Roseate Terns initiated nesting (laying the first egg in each nest) in mid-May, we marked all new nests and monitored them daily in each year 1998–2001.

Roseate Terns nested in artificial nest sites or in natural nest site locations. A natural nest site was defined as occurring outside an artificial nest site. For example, if a nest was discovered under a nest box, it was considered a natural nest site.

We made observations from blinds to confirm Roseate Tern nests and to identify adults that were associated with each nest. Because ~93% of the Roseate Terns nesting on Falkner Island were previously marked with a unique six-band color combination, we were able to individually identify each tern.

Observation Protocol

We conducted behavioral observations on subcolony areas from blinds from mid-May to mid-June 1999–2001. We randomly selected the subcolony (not more than once per day) and time of day for each observation period. We conducted observations under all weather conditions except when viewing was impaired by wind, fog, or rain. In 1999, we used two-hour observation sessions. To sample more subcolonies, we reduced observation sessions to one hour in 2000 and 2001. We used scan sampling and focal animal watches during each observation session (Crockett 1996).

We collected data only on marked adult Roseate Terns that had not yet initiated a nest. We conducted scan samples every ten minutes and recorded the total numbers of non-nesting terns exhibiting each of six pre-defined behaviors during each scan (Table
1.4). We conducted focal animal watches for five-minute periods between each scan. During each focal period, we recorded the colorband combination, behavior, and the first habitat type that the focal tern was using during the period. If a tern was defending or prospecting a potential nest site, we recorded the habitat of the potential nest site. We chose an individual bird by selecting the left-most bird not yet known to have nested in each subcolony, unless that individual had been previously chosen for a focal period during the current observation session. Unmarked birds were only selected if there were no marked birds that had not yet initiated a nest. Focal observations of unmarked birds were not included in these analyses.

**Statistical Procedures**

We used program PREFER 5.1 to investigate habitat preference (an observed disproportionate use of some habitat types over others) (Johnson 1980). The data for this analysis were derived from the spatial data on the quantity of habitat types as a measure of habitat availability and on identification of individuals using these habitat types from the five-minute focal animal periods as a measure of habitat use. We analyzed these data for all six subcolonies combined because Roseate Terns often visit more than one subcolony while selecting a nest site. We examined the years 1999–2001 separately to establish patterns of habitat preference before revetment construction and to compare those patterns to habitat preference after revetment construction. The four vegetated habitats (Black Mustard, Downy Brome, Phragmites, and Poison Ivy) (Table 1.1) were not included in the habitat preference analysis since Roseate Terns did not use these habitats. Once we established that Roseate Terns displayed consistent habitat preference
in 1999 and 2000, we combined the two years for simplification and made the pre-
construction versus post-construction comparison. We assumed that all habitat types in a
subcolony were “available” for use by Roseate Terns during nest site selection.

The sampling units for the procedure outlined by Johnson (1980) are the
individual bird (total numbers of observations within each habitat type) and its assumed
available habitat (total area of each habitat type in all subcolonies). PREFER 5.1 uses a
difference in ranks between the proportion of observations within each habitat type and
the proportion of area for all available habitat types. PREFER 5.1 then averages these
differences across all individuals to obtain a single average for each habitat type. These
averages are then ranked from least to most preferred.

PREFER 5.1 computes an F-statistic (the between-treatments F ratio) that tests the
null hypothesis of equal preference for used and available habitat. A Bayes rule is used
to determine significant differences (Waller and Duncan 1969). Significant differences
between two or more means are defined as $D > WS_d$, where, $D$ is the difference between
two means, $W$ is a function of the number of means, the degrees of freedom, and the F-
statistic. $S_d$ is the standard error of the difference. PREFER 5.1 also allows the user to
choose a value of $k$, the error weight ratio, where values of $k = 50, 100, \text{ or } 500$, are
equivalent to $\alpha = 0.01, 0.05, \text{ or } 0.10$ respectively. We chose $k = 100$, for this
investigation.

We used procedure GLM to test for annual differences in the number of nesting
attempts and median nest initiation date (date of laying the first egg in each nest), with
Tukey’s test to control for multiple comparisons (SAS Institute, Inc. 2000). We also used
this method to test for differences in the timing of peak prospecting behavior between
subcolonies, age groups, and sexes. We used procedure UNIVARIATE to perform Wilcoxon signed-rank tests on the scan sampling data to determine if the mean proportion of birds exhibiting each behavior varied over time of day, seasonal date, or subcolony. We averaged all scans within an observation period to control for independence and avoid pseudoreplication. We used procedure GLM to test for variation in the mean proportions of behaviors observed, both by year and by pre- versus post-revetment conditions (SAS Institute, Inc. 2000). These data fitted a normal distribution without any transformation. We performed all statistical tests at the P = 0.05 significance level (unless otherwise indicated) and we report means as (mean ± standard error).

Results
Changes in Habitat Availability, Use, and Nest Site Distribution

The revetment directly altered habitat in four out of the six Roseate Tern nesting subcolonies. All of Subcolonies B, F, and part of Subcolony C were moved to the revetment shelf. One hundred fifty-one m$^2$ of rocky beach, substrate for the placement of 149 nest boxes, and 94 m$^2$ of Black Mustard and Virginia Creeper were lost and were replaced by 362 square meters of revetment boulder habitat (Table 1.2).

Roseate Terns did not use the four vegetated habitat types during the pre-nesting period before or after construction of the revetment. Therefore, these habitat types are considered to be the least preferred. Of those habitat types that were used by Roseate Terns during the pre-nesting period, terns displayed preferences for discrete habitats in each year ($F = 712.13$, DF = 3, 167, $P < 0.0001$ in 1999; $F = 266.48$, DF = 3, 81, $P < 0.0001$ in 2000; $F = 916.56$, DF = 3, 251, $P < 0.0001$, in 1999 and 2000 combined; and F
In rank order from most to least preferred, Roseate Terns used nest tire, log, nest box, and rocky beach while choosing a nest site before the revetment was constructed. In 2000, the rank order of preferred habitats was log and then nest tire, but the rank difference between these two habitats was not statistically significant ($W = 1.74, |d|/S_d = 0.28, P > 0.05$) (Table 1.5). After the revetment was constructed, nest tires remained the most preferred habitat, followed by revetment gravel, rocky beach, nest boxes and revetment boulders (Tables 1.5 and 1.6).

The total number of Roseate Tern pairs at FICT in each season (1998–2001) was 120, 110, 115, and 100, respectively. There were no between-year differences in the number of nesting attempts ($F = 0.09, DF = 3, 20, P = 0.962$). There were few nesting attempts in natural sites ($n = 27/487 = 5.5\%$). The median nest initiation date did not differ among years ($F = 2.34, DF = 3, 481, P = 0.073$). The median nest initiation date was 29 May in 1998–2000 and 30 May in 2001.

**Trends in Behavior during Nest Site Selection**

We found differences for three out of six behaviors when comparing the mean proportions of birds exhibiting each behavior among years. The mean proportion of birds observed loafing differed between years ($F = 3.39, DF = 2, 149, P = 0.036$, but did not differ between pre- or post-revetment years ($F = 0.02, DF = 1, 150, P = 0.880$).

Specifically, the mean proportion of birds observed preening was smaller in 2000 ($10.6 \pm 1.0\%$) than in 1999 ($28.3 \pm 1.1\%$) and 2001 ($21.3 \pm 2.1\%$) ($F = 15.04, DF = 2, 149, P < 0.0001$). There was no difference between pre-revetment ($19.8 \pm 1.5\%$) and post-revetment ($21.3 \pm 2.1\%$) mean proportions of birds observed preening ($F = 0.18, DF = 1,$
150, P = 0.669).  The proportion of birds observed prospecting was greater in 2000 (10.7 ± 1.7%) than in 1999 (4.0 ± 0.4%) and 2001 (4.7 ± 1.0%) (F = 3.55, DF = 2, 149, P = 0.031).  Again, there was no difference between the pre-revetment (7.2 ± 1.4%) and post-revetment (4.7 ± 1.0%) mean proportions of birds observed exhibiting this behavior (F = 0.87, DF = 1, 150, P = 0.353.).  The proportions of birds observed defending, courting, and copulating did not differ when comparing both year-to-year differences and pre-versus post-revetment years (Table 1.7).

**Prospecting Behavior: Habitat and Temporal Variation**

We obtained 195 five-minute focal animal periods of prospecting behavior by 87 Roseate Terns.  For purposes of these analyses, we randomly chose one observation for each individual.  We observed more prospecting in artificial nest sites (nest boxes and tires) (n = 66) than in natural sites (n = 21).  We investigated the proportion of birds prospecting each type of potential nest site but found no difference between the proportions of birds prospecting modified and unmodified habitats before or after the revetment construction (χ² = 1.74, DF = 1, P = 0.187).

We also tested for differences in the timing of prospecting behavior between years.  We found no differences in the timing of mean prospecting for date (13.08 ± 0.61 days after first observed prospecting Roseate Tern) (F = 0.55, DF = 2, 192, P = 0.578) or time of day (11:59 ± 0.50 hr) (F = 0.05, DF = 2, 192, P = 0.951).  When testing for differences among subcolonies in all years, we found a difference in season date (F = 3.63, DF = 5, 189, P = 0.004).  Mean prospecting in Subcolony E occurred later (16.4 ±
1.4 days after first observed prospecting Roseate Tern) than in Subcolonies A (8.7 ± 0.6 days) and B (9.3 ± 0.5 days).

**Discussion**

**Pre-nesting Habitat Use and Nest Site Distribution**

While the overall number of pairs at FICT appeared to fluctuate slightly between 120 and 100 from 1998–2001, we found no between year differences in the total numbers of nesting attempts in each year. Likewise, the mean date for a tern to lay a first egg (29–30 May) did not differ between all years. This date was consistent with data from Ram Island, Massachusetts (41°37’N, 70°48’W) in 2001 (J.J. Hatch, unpublished data). Data from Bird Island, Massachusetts (41°40’N, 70°43’W) during 1987–1990 suggest that nest initiations peaked from one to six days prior to the FICT peak, while nest initiations at Cedar Beach, New York (40°38’N, 73°20’W) were as much as 1–12 days later for the same years (Burger *et al.* 1996). The construction of the erosion control revetment at the FICT colony site did not influence the peak date for nest initiations (i.e. there was no marked delay in nest initiations after revetment construction).

Roseate Terns used the newly placed revetment habitat after it replaced rocky beach and other habitat types. While terns used the newly created revetment habitats while choosing nest sites in 2001, Roseate Terns still nested predominately in artificial nest sites. This result was consistent with other manipulative experiments of tern nesting habitat. Severinghaus (1982) demonstrated that Common Tern nest site choice was non-random. Richards and Morris (1984) found that late nesting Common Terns chose nesting habitat that was similar to the preferred habitat chosen by early nesting terns.
Burger and Gochfeld (1990) concluded that Common Tern and Black Skimmer habitat partitioning and nest site competition were factors in individual habitat use and nest site choice.

Our findings supported these previous studies on nest site choice. We found that Roseate Terns will use newly introduced revetment boulder habitat during nest site selection, but did not nest on revetment gravel or in revetment boulders without the presence of artificial nest sites. Our experimental results and evidence from studies with similar species suggests that Roseate Tern nest site selection was non-random, and that Roseate Terns selected artificial nest sites despite a major alteration of surrounding habitats.

**Behavioral Time Allocation and Prospecting Behavior**

We found between year differences for birds observed loafing, preening, and prospecting, but no differences between pre- and post-revetment construction years for any behaviors. Further analysis failed to find biologically important differences in the timing (daily or seasonal) of each behavior. Therefore, we conclude that our time allocation budget for pre-nesting Roseate Terns in the subcolonies was consistent throughout the nest site selection process, and revetment construction did not alter the time activity budget of Roseate Terns.

The only previous data on time activity budgets for Roseate Terns was recorded on Bird Island, Massachusetts (BIMA) (Gochfeld et al. 1998). The BIMA information was based on percent time spent per individual and, therefore, was not directly comparable to our scan sampling data. However, frequency of courtship and, hence,
copulation at FICT was much less than at BIMA. This could be an artifact of our inclusion of nest-building behavior as prospecting rather than courting (Collias and Collias 1984), or it could be that a larger proportion of courtship activity occurs at foraging areas rather than at the breeding colony location.

Loafing at FICT was much greater (~65–70%) than observed at BIMA (20%). The time spent defending mates or nest sites at BIMA was slightly greater (~5–8%) than the findings for FICT (~2–3%). Roseate Terns at FICT may have expended more energy foraging and therefore required more rest once they returned compared to BIMA. This could result in adults spending less time prospecting or defending potential nest sites at FICT.

Foraging areas for breeding Roseate Terns at FICT have not been clearly identified. However, it is possible that birds breeding at FICT travel farther to find suitable foraging shoals than birds breeding at other sites (Kilpatrick and Casey 1996). If suitable foraging areas are further from FICT, then both members of a pair may be away from the colony foraging during the courtship period before nest initiation (See Gochfeld et al. 1998). Our data do not provide any evidence of time allocation while away from the colony site.

A greater proportion of birds prospected potential nest sites in 2000 than in 2001 and 1999. We concluded that the revetment did not present a greater number of new nest site choices for Roseate Terns. Nest site choice could have been reduced, exclusive of the nest boxes and nest tires, with introduction of the revetment. Conversely, Roseate Terns at FICT could prefer nest boxes regardless of the type of alteration of the surrounding habitat. Other behaviors remained consistent despite the presence of this
new habitat. Therefore, we concluded that the revetment did not alter the normal time activity-budget for this species at this site.

We observed Roseate Terns prospecting potential artificial and natural nest sites at about a 3:1 ratio. However, only 5.5% of all nesting attempts were in natural sites (outside of a nest tire or nest box). This suggests that Roseate Terns at FICT investigated potential nesting habitats outside of nest boxes and tires, but either: 1) chose to nest in an artificial nest site, or 2) moved to another colony.

**Acknowledgments**

We thank Jan Amendola, Sandy Chan, Ryan Fitzgibbons, Amy Hinshaw, Michele Kuter, Lauren McCubbin, Christie Pescha, Arno Reinhardt, Rachel Smolinsky, Beth Wenzel, and James Zingo for their assistance monitoring Roseate Terns. We also thank the staff of the Stewart B. McKinney National Wildlife Refuge, especially Refuge Manager William Kolodnicki, for logistic support and permission to work on Falkner Island. Rick Schauffler of Great Bay National Wildlife Refuge compiled the spatial data from which we obtained habitat area measurements. USGS Patuxent Wildlife Research Center and the Quebec Labrador Foundation supported this research. Julie Victoria of The Connecticut Department of Environmental Protection provided a spotting telescope. The Connecticut Audubon Society, The Connecticut Chapter of the Nature Conservancy, and the University of Massachusetts Amherst also provided logistic support.

**Literature Cited**


Table 1.1. Description of habitat types in Roseate Tern subcolonies at Falkner Island. All plants grew in homogenous stands with little to no interspecific mixing.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky Beach</td>
<td>Unvegetated areas consisting of coarse gravel, cobbles, and boulders.</td>
</tr>
<tr>
<td>Black Mustard</td>
<td><em>Brassica nigra</em></td>
</tr>
<tr>
<td>Phragmites</td>
<td><em>Phragmites communis</em></td>
</tr>
<tr>
<td>Poison Ivy</td>
<td><em>Rhus radicans</em></td>
</tr>
<tr>
<td>Virginia Creeper</td>
<td><em>Parthenocissus quinquefolia</em></td>
</tr>
<tr>
<td>Log</td>
<td>Dead woody debris with a maximum diameter greater than 10 cm. Dead woody debris with a diameter less than 10 cm were not considered because they were difficult to measure, occurred infrequently above mean high water, and are not generally considered to provide “good” nesting habitat (Gochfeld et al. 1998).</td>
</tr>
<tr>
<td>Nest Box</td>
<td>A &quot;Series 500&quot; (Spendelow 1996), 15-cm tall by 46-cm wide by 18-cm deep, nest box with roof slanting to the floor on one end, closed at the front, with an opening on one side and an extension of the floor to form a stoop. Nest boxes are partially filled with gravel to a depth of 2-3 cm.</td>
</tr>
<tr>
<td>Nest Tire</td>
<td>An automobile tire that was placed on less than a 30° to 45° angle and half-filled with medium to small rocks and gravel.</td>
</tr>
<tr>
<td>Revetment Boulder</td>
<td>A piece of basalt larger than 1 cubic meter placed on FICT as part of the revetment.</td>
</tr>
<tr>
<td>Revetment Gravel</td>
<td>Material less than 1 cubic centimeter brought to FICT and placed as part of the revetment. There was no material left on the surface of the revetment that fit between the categories Revetment Boulder and Revetment Gravel in size.</td>
</tr>
</tbody>
</table>
Table 1.2. Amount of available habitat (m$^2$) within each subcolony at Falkner Island, Connecticut from 1999–2001. Measurements are listed as pre-revetment / post-revetment. The difference is reported as habitat gain (+) or loss (-) for each habitat type.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Rocky Beach</th>
<th>Black Mustard</th>
<th>Phragmites</th>
<th>Poison Ivy</th>
<th>Virginia Creeper</th>
<th>Log</th>
<th>Nest Box</th>
<th>Nest Tire</th>
<th>Revetment Boulder</th>
<th>Revetment Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Figure 1.2)</td>
<td>46/16</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>1/1</td>
<td>0/0</td>
<td>100/100</td>
<td>0/30</td>
<td>0/0</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>+30</td>
<td>0</td>
</tr>
<tr>
<td>B (Figure 1.3)</td>
<td>72/0</td>
<td>46/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>3/0</td>
<td>18/16</td>
<td>0/0</td>
<td>0/168</td>
<td>0/32</td>
</tr>
<tr>
<td></td>
<td>-72</td>
<td>-46</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3</td>
<td>-2</td>
<td>0</td>
<td>+168</td>
<td>+32</td>
</tr>
<tr>
<td>C (Figures 1.3 and 1.4)</td>
<td>52/12</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>46/11</td>
<td>2/2</td>
<td>23/20</td>
<td>0/0</td>
<td>0/126</td>
<td>0/21</td>
</tr>
<tr>
<td></td>
<td>-40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-33</td>
<td></td>
<td>-3</td>
<td>0</td>
<td>+126</td>
<td>+21</td>
</tr>
<tr>
<td>D (Figure 1.4)</td>
<td>43/42</td>
<td>0/0</td>
<td>23/23</td>
<td>15/15</td>
<td>0/0</td>
<td>0/0</td>
<td>33/34</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E (Figure 1.5)</td>
<td>63/63</td>
<td>0/0</td>
<td>33/33</td>
<td>0/0</td>
<td>0/0</td>
<td>1/1</td>
<td>20/20</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F (Figures 1.5 and 1.6)</td>
<td>10/2</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>21/6</td>
<td>1/0</td>
<td>71/72</td>
<td>0/0</td>
<td>0/38</td>
<td>0/17</td>
</tr>
<tr>
<td></td>
<td>-8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-15</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
<td>+38</td>
<td>+17</td>
</tr>
<tr>
<td>Total</td>
<td>286/135</td>
<td>46/0</td>
<td>56/56</td>
<td>15/15</td>
<td>67/19</td>
<td>8/4</td>
<td>165/162</td>
<td>100/100</td>
<td>0/362</td>
<td>0/70</td>
</tr>
<tr>
<td></td>
<td>-151</td>
<td>-46</td>
<td>0</td>
<td>0</td>
<td>-48</td>
<td>-4</td>
<td>-3</td>
<td>0</td>
<td>+362</td>
<td>+70</td>
</tr>
</tbody>
</table>
Table 1.3. Numbers of available modified nest sites, in parentheses, and successful/total Roseate Tern nests for the 1998–2001 breeding seasons at Falkner Island. Locations of subcolonies are given in Figure 1.1.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Nest sites</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Nest Tire (100)</td>
<td>16/41</td>
<td>17/34</td>
<td>25/42</td>
<td>15/39</td>
</tr>
<tr>
<td>B</td>
<td>Nest Box (20)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>07/14</td>
<td>07/09</td>
<td>06/14</td>
<td>04/11</td>
</tr>
<tr>
<td></td>
<td>Natural</td>
<td>00/01</td>
<td>00/00</td>
<td>01/01</td>
<td>00/00</td>
</tr>
<tr>
<td>C</td>
<td>Nest Box (24)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11/13</td>
<td>12/14</td>
<td>09/10</td>
<td>09/10</td>
</tr>
<tr>
<td></td>
<td>Natural</td>
<td>01/02</td>
<td>00/01</td>
<td>00/00</td>
<td>00/00</td>
</tr>
<tr>
<td>D</td>
<td>Nest Box (40)</td>
<td>14/18</td>
<td>06/13</td>
<td>07/09</td>
<td>07/09</td>
</tr>
<tr>
<td></td>
<td>Natural</td>
<td>00/00</td>
<td>00/00</td>
<td>00/02</td>
<td>00/00</td>
</tr>
<tr>
<td>E</td>
<td>Nest Box (20)</td>
<td>03/08</td>
<td>07/17</td>
<td>07/11</td>
<td>07/11</td>
</tr>
<tr>
<td></td>
<td>Natural</td>
<td>00/03</td>
<td>00/02</td>
<td>01/01</td>
<td>01/01</td>
</tr>
<tr>
<td>F</td>
<td>Nest Box (72)</td>
<td>17/24</td>
<td>20/25</td>
<td>16/29</td>
<td>16/29</td>
</tr>
<tr>
<td></td>
<td>Natural</td>
<td>00/00</td>
<td>00/01</td>
<td>04/08</td>
<td>04/08</td>
</tr>
<tr>
<td>Total</td>
<td>All</td>
<td>70/125</td>
<td>70/116</td>
<td>76/132</td>
<td>60/114</td>
</tr>
</tbody>
</table>

<sup>a</sup>Subcolony B contained 24 nest boxes and Subcolony C contained 20 nest boxes in 2001.
Table 1.4. Definitions and time activity budgets for behaviors exhibited by Roseate Terns at Falkner Island, Connecticut for the three-year period, 1999–2001. This summary is from scan sampling data of birds that have not initiated a first nest of each breeding season. The percentages represent the average proportion of Roseate Terns observed exhibiting each behavior in all subcolonies over all years.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Definition</th>
<th>Percentage (±SE) of Pre-nesting Roseate Terns Exhibiting Each Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loafing</td>
<td>A bird at rest. This includes any state of minimal motion from sleeping to standing alert.</td>
<td>69.6 ± 1.8%</td>
</tr>
<tr>
<td>Preening</td>
<td>The self-maintenance action of grooming feathers.</td>
<td>20.2 ± 1.5%</td>
</tr>
<tr>
<td>Prospecting</td>
<td>A bird investigating a potential nest site. This includes nest building behavior, scraping, entering an artificial nest site (box or tire) without a nest, or paying a noticeable amount of attention to one particular area, especially while in the presence of a mate. Also, any behavior that could be considered “house-hunting” (Cullen 1956).</td>
<td>6.5 ± 1.2%</td>
</tr>
<tr>
<td>Defending</td>
<td>Action taken when resisting attack or protecting a potential nest site from another tern. This includes any head bobbing behavior and “gakkering” (Gochfeld et al. 1998).</td>
<td>2.6 ± 0.6%</td>
</tr>
<tr>
<td>Courting</td>
<td>Behavior involved in mate selection and pair bond formation. While this behavior usually occurs in flight above the colony, this behavior is also displayed on the ground in subcolonies. On the ground, courting consists of “parading” and the “Bent” posture described for Common Terns (Palmer 1941, Cramp 1985).</td>
<td>0.6 ± 0.2%</td>
</tr>
<tr>
<td>Copulating</td>
<td>This behavior is when a male successfully mounts a female. Cloacal contact is often attained.</td>
<td>0.5 ± 0.2%</td>
</tr>
</tbody>
</table>
Table 1.5. Comparison of the proportions of available habitats and the proportions that Roseate Terns were observed using those habitats in each year. Percent available habitat was calculated from the spatial data and percent used habitat was calculated from the focal animal data. Preference for each habitat is ranked in ascending order from most to least preferred.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Percent Available</th>
<th>Percent Used</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky Beach</td>
<td>38.5</td>
<td>38.5</td>
<td>14.6</td>
</tr>
<tr>
<td>Black Mustard</td>
<td>6.2</td>
<td>6.2</td>
<td>NA</td>
</tr>
<tr>
<td>Phragmites</td>
<td>7.5</td>
<td>7.5</td>
<td>6.14</td>
</tr>
<tr>
<td>Poison Ivy</td>
<td>2.0</td>
<td>2.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Virginia Creeper</td>
<td>9.0</td>
<td>9.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Log</td>
<td>1.1</td>
<td>1.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Nest Box</td>
<td>22.2</td>
<td>22.2</td>
<td>17.6</td>
</tr>
<tr>
<td>Nest Tire</td>
<td>13.5</td>
<td>13.5</td>
<td>10.8</td>
</tr>
<tr>
<td>Revetment Boulder</td>
<td>NA</td>
<td>NA</td>
<td>39.2</td>
</tr>
<tr>
<td>Revetment Gravel</td>
<td>NA</td>
<td>NA</td>
<td>7.6</td>
</tr>
</tbody>
</table>

\textsuperscript{a} The difference in habitat preference rank order was not statistically significant ($W = 1.74$, $|d|/S_d = 0.28$, $P > 0.05$).
Table 1.6. Comparisons of rank order of habitats on focal animal period and spatial data obtained for Roseate Terns at Falkner Island, Connecticut from 1999–2001. Results of the combined 1999 and 2000 analysis are shown as pre-construction because the results displayed the same rank order for preferred habitats in each of the two years (Table 1.5). Results from the 2001 analysis are shown as post-construction. The absolute standard difference in mean rank (|d|/Sd) is the absolute value of the difference in mean rank (d) divided by the standard error of the difference (S). This value must be larger than W for statistical significance at the P = 0.05 level in each case. Habitat preference is dictated d. If d > 0, then Habitat I is preferred. If d > 0, then Habitat K is preferred.

<table>
<thead>
<tr>
<th>Habitat I</th>
<th>Habitat K</th>
<th>Pre-construction</th>
<th>Post-construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>d</td>
</tr>
<tr>
<td>Nest Box a,b</td>
<td>Rocky Beach c</td>
<td>W = 1.74</td>
<td>-</td>
</tr>
<tr>
<td>Revetment Gravel c</td>
<td>Rocky Beach</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nest Tire a,b</td>
<td>Log</td>
<td>2.81</td>
<td>-</td>
</tr>
<tr>
<td>Revetment Boulder c</td>
<td>Nest Box</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Revetment Gravel</td>
<td>Nest Tire</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

a indicates the preferred habitat in 1999.
b indicates the preferred habitat in 2000.
c indicates the preferred habitat in 2001.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Group</th>
<th>Mean Proportion of Birds Exhibiting Behavior</th>
<th>Group Comparisons</th>
<th>F</th>
<th>Degrees of Freedom</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loafing</td>
<td>All Years</td>
<td>69.6 ± 1.8%</td>
<td>All Years</td>
<td>3.39</td>
<td>2, 149</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Pre-revetment (1999 and 2000)</td>
<td>69.5 ± 1.9%</td>
<td>Pre- vs. Post-revetment</td>
<td>0.02</td>
<td>1, 150</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>1999</td>
<td>64.5 ± 1.2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>74.9 ± 1.9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-revetment (2001)</td>
<td>70.1 ± 2.1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preening</td>
<td>All Years</td>
<td>20.2 ± 1.5%</td>
<td>All Years</td>
<td>15.04</td>
<td>2, 149</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Pre-revetment (1999 and 2000)</td>
<td>19.8 ± 1.5%</td>
<td>Pre- vs. Post-revetment</td>
<td>0.18</td>
<td>1, 150</td>
<td>0.67</td>
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<tr>
<td></td>
<td>1999</td>
<td>28.3 ± 1.1%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2000</td>
<td>10.6 ± 1.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-revetment (2001)</td>
<td>21.3 ± 2.1%</td>
<td></td>
<td></td>
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Table 1.7. Continued.

<table>
<thead>
<tr>
<th>Behavior</th>
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<th>Mean Proportion of Birds Exhibiting Behavior</th>
<th>Group Comparisons</th>
<th>F</th>
<th>Degrees of Freedom</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospecting</td>
<td>All Years</td>
<td>6.5±1.2%</td>
<td>All Years</td>
<td>3.55</td>
<td>2, 149</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Pre-Revetment (1999 and 2000)</td>
<td>7.2±1.4%</td>
<td>Pre- vs. Post-revetment</td>
<td>0.87</td>
<td>1, 150</td>
<td>0.35</td>
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<tr>
<td></td>
<td>1999</td>
<td>4.0±0.4%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2000</td>
<td>10.7±1.7%</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Post-Revetment (2001)</td>
<td>4.7±1.0%</td>
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<tr>
<td>Defending</td>
<td>All Years</td>
<td>2.6±0.6%</td>
<td>All Years</td>
<td>0.03</td>
<td>2, 149</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Pre-Revetment (1999 and 2000)</td>
<td>2.5±0.6%</td>
<td>Pre- vs. Post-revetment</td>
<td>0.03</td>
<td>1, 150</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>1999</td>
<td>2.7±0.4%</td>
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</tr>
<tr>
<td></td>
<td>2000</td>
<td>2.4±0.6%</td>
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<tr>
<td></td>
<td>Post-Revetment (2001)</td>
<td>2.8±0.9%</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Behavior</td>
<td>GROUP</td>
<td>Mean Proportion of Birds Exhibiting Behavior</td>
<td>GROUP COMPARISONS</td>
<td>F</td>
<td>Degrees of Freedom</td>
<td>P-value</td>
</tr>
<tr>
<td>--------------</td>
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<td>---------------------------------------------</td>
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<tr>
<td>Courting</td>
<td>All Years</td>
<td>0.5±0.2%</td>
<td>All Years</td>
<td>0.41</td>
<td>2, 149</td>
<td>0.66</td>
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<td>Pre-Revetment (1999 and 2000)</td>
<td>0.5±0.3%</td>
<td>Pre vs. Post Revetment</td>
<td>0.50</td>
<td>1, 150</td>
<td>0.48</td>
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</tr>
<tr>
<td>1999</td>
<td>0.3±0.3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>0.6±0.3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Revetment (2001)</td>
<td>0.8±0.3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copulating</td>
<td>All Years</td>
<td>0.5±0.2%</td>
<td>All Years</td>
<td>1.04</td>
<td>2, 149</td>
<td>0.36</td>
</tr>
<tr>
<td>Pre-Revetment (1999 and 2000)</td>
<td>0.5±0.2%</td>
<td>Pre vs. Post Revetment</td>
<td>0.30</td>
<td>1, 150</td>
<td>0.59</td>
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</tr>
<tr>
<td>1999</td>
<td>0.2±0.1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>0.8±0.2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Post-Revetment (2001)</td>
<td>0.3±0.1%</td>
<td></td>
<td></td>
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</tbody>
</table>
Figure 1.1. A. The locations of the six Roseate Tern subcolonies at Falkner Island, Connecticut from 1998–2001. The six subcolonies are labeled A–F from north to south. Nest tires were placed in the location of Subcolony A and nest boxes in the locations of Subcolonies B–F before terns arrived for breeding. We also placed observation blinds on the island’s plateau above each subcolony at this time. B. Four out of six Subcolonies were directly impacted by a revetment that was constructed prior to the 2001 breeding season.
Figure 1.2. Cross-section of the revetment construction in Subcolony A at Falkner Island, Connecticut. Elevation is based on the National Geodetic Vertical Datum of 1929. The zero point on the horizontal scale is also in meters and represents the toe of the eroding bluff before revetment construction. The grey line represents the pre-existing bluff and beach. The black line represents the revetment construction. Mean storm water level (MSW; mostly winter storms), mean high water (MHW), and mean low tide (MLT) are also depicted for reference.

Figure 1.3. Cross-section of the revetment construction in Subcolonies B and C at Falkner Island, Connecticut. Elevation is based on the National Geodetic Vertical Datum of 1929. The zero point on the horizontal scale represents the toe of the eroding bluff before revetment construction. The grey line represents the pre-existing bluff and beach. The black line represents the revetment construction. Only a portion of Subcolony C was altered by the revetment construction (Figure 1.1, See Methods).
Figure 1.4. Cross-section of the bluff at Subcolonies D and E at Falkner Island, Connecticut. These two subcolonies were not directly affected by revetment construction. Elevation (vertical scale) is in meters and is based on the National Geodetic Vertical Datum of 1929. The zero point on the horizontal scale is also in meters and represents the toe of the eroding bluff. The grey line represents the existing bluff and beach.

Figure 1.5. Cross-section of the bluff and revetment construction at Subcolony F at Falkner Island, Connecticut. This subcolony was only partially affected by the revetment construction (Figure 1.1). Elevation (vertical scale) is in meters and is based on the National Geodetic Vertical Datum of 1929. The zero point on the horizontal scale is also in meters and represents the toe of the eroding bluff. The grey line represents the pre-existing bluff and beach.
CHAPTER II

CREVICE USE BY ROSEATE TERN (STerna DOUGALLII) CHICKS ON FALKNER ISLAND, CONNECTICUT

Abstract

We studied the use of crevices as hiding places by Roseate Tern chicks at Falkner Island, Connecticut, USA, before (1999–2000) and after (2001) construction of an erosion control revetment. Roseate Tern chicks used crevices under artificial nest sites (slant-roofed boxes and half-buried tires) more frequently than expected by chance when compared to crevices found in other microhabitats. We also found that chicks used crevices in various microhabitat types at different stages in development. The erosion control revetment created crevices that had larger openings, steeper floors, and deeper lengths than those previously used by chicks before construction. In the year after revetment construction, the openings of crevices used by chicks that died were wider than crevices used by chicks that survived.

Introduction

There are extensive studies of predator avoidance tactics by nesting seabirds from the perspective of breeding adults protecting their nest or brood. Some studies focused on nest site choice as a method of predator avoidance (Komar and Rodriguez 1996, Schauer and Murphy 1996), while others have examined predator swamping (Becker 1995) and nest defense behaviors (Jackson et al. 1982, Burger and Gochfeld 1991, Komar and Rodgiquez 1996). Few detailed studies are available on predator avoidance from the perspective of chicks. Creching, when multiple broods congregate
into one group, is often regarded as a form of predator avoidance (Besnard et al. 2002), but most detailed studies on the phenomenon attribute creching to other factors such as protection from adult aggression (Seddon and Vanheezik 1993, Tourenq et al. 1995, Penteriani et al. 2003).

In tern (Sternae) breeding colonies in the temperate zone, chicks are often unattended by adults in open areas that leave them vulnerable to predators. Sometimes, adults lead their chicks away from nest sites in an attempt to avoid predators (Stienen and Brenninkmeijer 1999). During daylight hours, adult terns usually take flight and mob a potential predator until it leaves the colony. During these events, Roseate Tern chicks either: 1) seek shelter in crevices, or under vegetation and other objects, 2) crouch near some feature on the beach, such as a rock or log, or 3) take advantage of their cryptic coloration and remain motionless (Gochfeld et al. 1998). At night, predator activity can cause temporary colony abandonment by adult terns (Shealer and Kress 1991).

Roseate Tern (Sterna dougallii) chicks at Falkner Island, Connecticut (FICT) use crevices formed in rocks, under artificial nest sites, and in other microhabitat types for shelter and concealment when they begin to move beyond their original nest sites. During the winter of 2000–2001, a rock revetment substantially altered prior habitat distributions and created some new habitat types on most of the beach at FICT (Chapter I). In this study, we describe the physical characteristics of crevices available to Roseate Tern chicks. This included investigating the proportions of microhabitats composing crevices from both before, and after, revetment construction. Then, we compared the characteristics of crevices available to chicks to characteristics of crevices
used by Roseate Tern chicks. We also determined the relationships between crevice characteristics and the ages and masses of the chicks using them, as well as differences in chick survival relative to crevice characteristics and use.

**Methods**

**Study Area**

Falkner Island is a unit of the Stewart B. McKinney National Wildlife Refuge located five kilometers off the coast of Guilford, New Haven County, Connecticut, USA (41° 13' N, 72° 39' W). Before revetment construction, a rocky beach formed the perimeter of FICT. This beach surrounded a raised, vegetated plateau (Spendelow 1982, Nisbet 1994, Zingo 1998). The rocky beach was the focal area of study because Roseate Terns nested on the beach in six distinct subcolonies (Spendelow 1982, 1996, Chapter I), and Roseate Tern chicks used the beach almost exclusively. Chicks often moved away from their original nest sites and used crevices formed within different microhabitats on the beach for shelter.

In the first two years of this study (1999 and 2000), the beach consisted of various-sized rocks, and beached items such as logs and various discarded materials (referred to as “artificial debris” for purposes of this study). These rocks and debris formed numerous crevices. During the winter of 2000–2001, construction of a rock revetment consumed two sections of the island. This revetment now occupies more than half of the original beach, and it has changed the habitats at four of six Roseate Tern subcolonies (Figure 2.1). The revetment was constructed mostly of basalt boulders (> 1 m³), and some sections have a shelf that was topped with gravel (large
 grain size < 1 cm$^3$). Chapter I gives a detailed description of the revetment and the shelf.

**General Field Protocol**

At FICT, most Roseate Terns nested in slant-roofed nest boxes or half-buried tires (Grinnell and Spendelow 2000, Spendelow 1982, 1996). The distribution of artificial nest sites was similar in 1999 and 2000. After revetment construction in 2001, we placed artificial nest sites as close to their previous arrangement as possible, given the limitations imposed by the revetment. We attempted to locate and weigh chicks daily from hatching until fledging, death, or disappearance. Most chicks remained at their original nest site until about day 10, after which they were found in various crevices, vegetation, and infrequently on the open beach. We recorded the locations of crevices and the composition of crevices (Table 2.1) used by tern chicks.

**Crevice Sampling**

We defined a “crevice” as any structure or assembly of objects forming a cavity that could completely conceal a 12.0 g chick from overhead and from at least three out of the four cardinal bearings on a compass. The volume of the cavity had to be greater than that of a 12.0 g Roseate Tern chick (~ 9 cm$^3$) and the opening of the cavity had to be large enough to allow a 12.0 g chick to enter (~ 2 cm high by ~ 3 cm wide). We did not consider nest boxes and tires as crevices for two reasons: 1) they were temporary shelters, placed at the beginning and removed at the end of each breeding season, and 2) their dimensions were standard and could have biased our analysis of crevice
dimensions. We did include cavities formed directly under or adjacent to these structures to form the cavity. Chicks were located by observation from a blind, observing adults, or by searching likely areas near nest sites or the last known locations of chicks. Once we found a chick inside a crevice, the crevice was marked with a small spot of Krylon® marking paint (a unique color for each year of the study) and the location was noted for future measurement.

We randomly selected points on the beach (48 points in 1999 and 45 points in 2000), and randomly selected points on the beach and revetment (37 points in 2001) using a one m² grid-system. At each point, we randomly selected a compass bearing and created a 25 m transect line away from the point in the direction of the bearing with a measuring tape. We sampled all crevices where any part of the crevice (the crevice cavity or crevice opening) situated itself directly below the measuring tape (Elzinga et al. 1998). If the 25 m transect intersected the intertidal zone, we waited until the tide was low enough to get a full transect of unsubmerged beach, since chicks also used crevices within the intertidal zone. We measured these randomly selected crevices and all used crevices in late July and early August after nearly all nesting activity ceased.

We measured six physical characteristics (height, width, negative slope, positive slope, absolute value of slope, and length; Table 2.2) to describe both randomly selected crevices and crevices used by Roseate Tern chicks. The height and width variables relate to the entrance of each crevice and could be important for predator avoidance by chicks. We chose slope because it might influence or limit crevice choice if chicks preferred flat or steep crevice floors. We chose crevice length as a measure of predator
accessibility based on the assumption that a potential predator would have easier access to chicks hiding in shallow crevices.

**Statistical Procedures**

To investigate differences in the variety of crevice microhabitat types, we used Chi-squared goodness-of-fit analysis to test for proportional differences across microhabitat categories. We did this for both used and randomly selected crevices for each year of the study. Since multiple chicks often used the same crevices, and individual chicks often used multiple crevices during development, we faced several possible confounding factors. These factors included pseudoreplication, social behavior (i.e. chicks or their parents cuing into certain crevices after observing other chicks and their parents using them), and differential survival of chicks (see Nisbet et. al. 1995 and 1998 for discussion on differential survival of chicks in relation to growth rates). We avoided such complications by randomly selecting only one use of each crevice by any chick. In cases where duplicate crevices were selected (the same crevice used by more than one chick), we re-selected crevices for all but one (chosen randomly) of the chicks, until as many chicks as possible were assigned a unique used crevice. Of all 398 chicks that hatched on the island during our study, only 43% (n = 171) actually used crevices (Appendix A, Tables A.3 and A.4). The remaining chicks died before using a crevice (n = 94, 24%), simply did not use a crevice before fledging (n = 101, 25%), or went missing (n = 32, 8%). We also randomly selected non-used crevices no more than once for each analysis because we sampled some more than once in rare cases where transect lines overlapped in the field.
We used analysis of variance (ANOVA) to test for differences in: 1) the ages and/or masses that chicks used each crevice microhabitat type, 2) the physical characteristics of used and randomly selected non-used crevices and, 3) the physical characteristics of crevices used by chicks that died and by those that fledged. We used Tukey’s test to control for multiple comparisons. We log transformed the height, width, and length variables to fit normal distributions (Sokal and Rohlf 1995). We performed all statistical tests described above at the P = 0.05 significance level and reported all means as (mean ± standard error).

Our data contained both positive and negative values for slope since the floors of crevices usually sloped upwards (positive slope; n = 554) or downwards (negative slope; n = 483) (Table 2.2). As a cursory analysis, we grouped these slopes together by taking the absolute value. However, since the slopes of crevice floors have the potential for different survival implications for developing tern chicks (i.e. steep, >45°, downward sloping crevice floors could trap a chick), we also treated positive and negative slopes as separate variables. We did not use cases where there was no slope to the crevice floor (n = 23).

We wanted to know if revetment construction affected the crevice characteristics that were both available to, and were used by, Roseate Tern chicks. To do this, we compared the characteristics of randomly selected crevices found in the revetment with all other randomly selected crevices. The small sample size of chicks that used revetment crevices did not allow us to compare characteristics of revetment crevices with crevices used by chicks outside the revetment (2001), or during the two breeding seasons prior to revetment construction.
We assigned each chick that hatched on the island a survival outcome code that followed Nisbet et al. 1990 and Zingo 1998. We based outcome codes on growth rate, age and mass at last observation, parental behaviors, and observations of dead chicks or those that fledged with sustained flight. At the end of each breeding season, we classified all Roseate Tern chicks that used crevices (n = 171) as having died (n = 17), fledged (n = 129), or of unknown outcome (n = 25). In cases where we lost track of a chick and both parents re-nested, we classified the chick as dead. We suspect in some cases, Black-crowned Night-Herons (Nycticorax nycticorax) depredated some Roseate Tern chicks during this study at FICT. In cases where we had good evidence that a chick was depredated (i.e. a chick was growing normally, but was missing on the day after Black-crowned Night-Heron activity in a particular subcolony, and parental behavior suggested that the chick was missing from where it was last observed), we classified the chick as dead (n = 3, all in 2000). In cases where we did not have good evidence, we classified the chicks as unknown. Chicks with unknown outcomes (15.2% in 1999, 9.7% in 2000, and 16.5% in 2001) were chicks that we lost track of during early growth, or a reasonable assessment of outcome could not be determined for other reasons. It is likely that Black-crowned Night-Herons depredated these chicks during nocturnal activity in the colony (Spendelow et. al. 2002), or in 2001, they could also have become lost in the deep crevices of the new revetment.
Results

Crevice Use by Roseate Tern Chicks

Crevices found within different microhabitats were in unequal proportions within each year for our random samples (1999: \( \chi^2 = 31.22, \) DF = 5, \( P < 0.0001; \) 2000: \( \chi^2 = 73.45, \) DF = 6, \( P < 0.0001; \) 2001: \( \chi^2 = 443.87, \) DF = 5, \( P < 0.0001 \)). Roseate Tern chicks occupied crevices under nest boxes and nest tires more frequently than expected by chance (1999: \( \chi^2 = 45.28, \) DF = 5, \( P < 0.0001; \) 2000: \( \chi^2 = 101.67, \) DF = 6, \( P < 0.0001; \) 2001: \( \chi^2 = 174.01, \) DF = 5, \( P < 0.0001 \)) (Table 2.3). Chicks used crevices in revetment boulders less frequently than expected in 2001. Chicks used naturally occurring crevices (boulder, large rock, medium rock, small rock, artificial debris, and log) less frequently than expected prior to revetment construction (Table 2.3).

Therefore, we lumped these microhabitats into one category, ‘natural’, to eliminate any unknown confounding factors. We found that Roseate Tern chicks used crevices under nest boxes and nest tires more frequently than expected by chance. They used crevices within naturally occurring microhabitats (boulder, large rock, medium rock, small rock, artificial debris, and log) less frequently than expected in 1999 (\( \chi^2 = 42.84, \) DF = 2, \( P < 0.0001 \)), 2000 (\( \chi^2 = 94.84, \) DF = 2, \( P < 0.0001 \)) and 2001 (\( \chi^2 = 150.13, \) F = 2, \( P < 0.0001 \)) (Table 2.4). Since the revetment boulder microhabitat was included in the ‘natural’ category, we also tested for differences among these habitats separately from the nest box and nest tire microhabitats. Among the naturally occurring microhabitats, Roseate Tern chicks used crevices in equal proportions to the distribution of microhabitats in randomly selected samples in 1999 (\( \chi^2 = 4.03, \) DF = 3, \( P = 0.259 \)).
but not in 2000 ($\chi^2 = 11.19$, DF = 3, P = 0.011). In 2000, Roseate Tern chicks used crevices formed by boulders and logs more frequently, and they used crevices formed by medium and large sized rocks less frequently (Table 2.5). We found similar results when we combined data for 1999 and 2000 ($\chi^2 = 9.11$, DF = 3, P = 0.028). In 2001, chicks used crevices in revetment boulders less frequently when compared to other naturally occurring microhabitats ($\chi^2 = 39.97$, DF = 2, P < 0.0001) (Table 2.5).

We found that chicks used crevices formed in different microhabitats at different ages and masses. Young chicks mainly used crevices under nest boxes (range of ages 3–20 d, mean 10.0 d, SD 4.4 d; range of body-masses 11.9–102.5 g, mean 63.2 g, SD 19.2 g) and nest tires (range of ages 5–19 d, mean 12.0 d, SD 3.5 d; range of masses 18.9–94.5 g, mean 64.8 g, SD 18.4 g). Older chicks used crevices formed by medium (range of ages 7–26 d, mean 14.9 d, SD 6.1 d; range of body-masses 17.0–100.1 g, mean 67.6 g, SD 30.0 g) and large sized rocks (range of ages 5–28 d, mean 16.8 d, SD 7.3 d; range of masses 38.4–103.3 g, mean 76.2 g, SD 22.9 g), boulders (range of ages 5–36 d, mean 14.6 d, SD 7.1 d; range of masses 29.3–114.7 g, mean 75.2 g, SD 19.1 g), revetment boulders (range of ages 5–18 d, mean 14.3 d SD 8.4 d; range of masses 41.8–110.4 g, mean 77.2 g, SD 25.9 g), and logs (range of ages 7–24 d, mean 16.0 d, SD 5.9 d; range of body-masses 54.8–99.5 g, mean 85.3 g, SD 17.7 g). The oldest chicks used crevices formed by artificial debris (range of ages 14–31 d, mean 20.7 d, SD 9.1 d; range of masses 74.1–98.6 g, mean 83.8 g, SD 12.9 g). A Tukey’s test for multiple comparisons revealed differences between the mean ages of chicks that used nest boxes with those of chicks that used boulders, large rocks, and artificial debris ($F = 5.11$, DF = 7, 149, P < 0.0001). While we found good evidence for differences in the masses of
those chicks using the various microhabitats (F = 2.47, DF = 7, 148, P = 0.020),
Tukey’s test for multiple comparisons failed to reveal a pattern (Table 2.6).

**Crevice Characteristics and Changes with the Revetment**

The heights of crevice openings were larger after revetment construction than prior to construction (random crevices: F = 76.67, DF = 2, 565, P < 0.0001, used crevices: F = 3.24, DF = 2, 168, P = 0.042, all crevices: F = 77.56, DF = 2, 736, P < 0.0001). Likewise, the heights of crevice openings were larger after revetment construction than prior to revetment construction (random crevices: F = 151.13, DF = 1, 566, P < 0.0001, used crevices: F = 6.29, DF = 1, 169, P = 0.013, all crevices: F = 154.24, DF = 1, 737, P < 0.0001). While there were no differences between the heights of random crevice openings and used crevice openings prior to revetment construction (F = 0.24, DF = 1, 454, P = 0.625), the heights of crevice openings of random crevices (21.3 ± 1.0 cm) were larger than those of used crevices (13.9 ± 1.1 cm; F = 9.16, DF = 1, 281, P = 0.003) after revetment construction (Table 2.7).

The widths of crevice openings were also larger after revetment construction than prior to construction (random crevices: F = 17.23, DF = 2, 559, P < 0.0001, used crevices: F = 8.14, DF = 2, 168, P < 0.0001, all crevices: F = 20.94, DF = 2, 730, P < 0.0001). In addition, the widths of crevice openings were larger after revetment construction than prior to construction (random crevices: F = 34.83, DF = 1, 563, P < 0.001, used crevices: F = 5.35, DF = 1, 169, P = 0.022, all crevices: F = 40.69, DF = 1, 731, P < 0.0001). There were no differences in the widths of crevice openings, when
comparing random versus used crevices. This was true after revetment construction \((F = 0.40, \text{DF} = 1, 287, P = 0.529)\), prior to revetment construction combined \((F = 0.27, \text{DF} = 1, 454, P = 0.606)\), and during all years of this study \((F = 0.59, \text{DF} = 1, 731, P = 0.442)\) (Table 2.7).

The values of negatively sloping floors were greater after revetment construction than they were prior to construction (random crevices: \(F = 28.68, \text{DF} = 2, 267, P < 0.0001\), used crevices: \(F = 4.35, \text{DF} = 2, 67, P = 0.017\), all crevices: \(F = 34.89, \text{DF} = 2, 337, P < 0.0001\)). The values of positively sloping floors were greater after revetment construction than they were prior to construction for randomly selected crevices \((F = 7.46, \text{DF} = 2, 279, P = 0.001)\), but not for used crevices \((F = 0.91, \text{DF} = 2, 92, P = 0.405)\). The absolute values of the slopes of crevice floors were greater after revetment construction than prior to construction \((\text{random crevices: } F = 55.71, \text{DF} = 2, 555, P < 0.0001, \text{used crevices: } F = 3.54, \text{DF} = 2, 168, P = 0.031, \text{all crevices: } F = 61.56, \text{DF} = 2, 726, P < 0.0001)\).

The values of negatively sloping crevice floors were greater after revetment construction than prior to construction \((\text{random crevices: } F = 56.45, \text{DF} = 1, 268, P < 0.0001, \text{used crevices: } F = 5.52, \text{DF} = 1, 68, P = 0.22, \text{all crevices: } F = 67.45, \text{DF} = 1, 338, P < 0.0001)\). The values of positively sloping crevice floors were greater after revetment construction than prior to construction for randomly selected crevices \((F = 13.80, \text{DF} = 1, 280, P < 0.0001)\), but not for used crevices \((F = 1.83, \text{DF} = 1, 93, P = 0.180)\) (Table 2.7). Likewise, the absolute values of the slopes of crevice floors were greater after revetment construction than prior to construction \((\text{random crevices: } F = 16.75, \text{DF} = 1, 266, P < 0.0001, \text{used crevices: } F = 3.00, \text{DF} = 1, 67, P = 0.087, \text{all crevices: } F = 19.07, \text{DF} = 1, 338, P < 0.0001)\).
While there were no differences in the absolute values of the slopes of the floors of random crevices and with those of used crevice openings prior to revetment construction (F = 0.07, DF = 1, 454, P = 0.790), the absolute values of the slopes of crevice floors of random crevices (31.9 ± 1.8°) were larger than those of used crevices (20.2 ± 2.5°; F = 8.37, DF = 1, 275, P = 0.004) after revetment construction. We found a similar pattern in the values of slope for crevices with negatively sloping floors, with the values for random crevices being larger (41.9 ± 2.4°) than those of used crevices (28.3 ± 3.4°; F = 5.38, DF = 1, 167, P = 0.022) after revetment construction. We found no differences between randomly selected and used crevices in the values of slope for crevices with positively sloping floors prior to revetment construction (F = 3.48, DF = 1, 268, P = 0.063), or after revetment construction (F = 3.75, DF = 1, 105, P = 0.122) (Table 2.7).

The internal lengths of crevices were larger after revetment construction than prior to construction (random crevices: F = 65.63, DF 2, 559, P < 0.0001, used crevices: F = 3.80, DF = 2, 168, P = 0.024, all crevices: F = 63.49, DF = 2, 730, P < 0.0001). Likewise, the internal lengths of crevices were larger after revetment construction than prior to construction combined (random crevices: F = 129.13, DF = 1, 563, P < 0.0001, used crevices: F = 6.80, DF = 1, 169, P = 0.010, all crevices: F = 126.63, DF = 1, 731, P < 0.0001). Interestingly, lengths of used crevices were longer (29.4 ± 1.8 cm) than they were for random crevices (25.8 ± 2.2 cm) prior to revetment construction (F = 8.43, DF
However, there were no differences in the lengths of random versus used crevices after revetment construction ($F = 2.20, DF = 1, 276, P = 0.122$) (Table 2.7).

Random crevices within the revetment were characterized with openings that were taller ($F = 262.66, DF = 1, 563, P < 0.0001$) and wider ($F = 31.19, DF = 1, 561, P < 0.0001$) than all other random crevice openings. The absolute values of the floors of random crevices within the revetment were also steeper ($F = 172.69, DF = 1, 561, P < 0.0001$) than other random crevices. Likewise, the slopes of crevices floors were steeper for random crevices within the revetment, than they were for non-revetment crevices. This was true whether they were negatively sloping ($F = 58.58, DF = 1, 266, P < 0.0001$) or positively sloping ($F = 41.27, DF = 1, 281, P < 0.0001$). The lengths of the crevices were also longer for random crevices within the revetment than non-revetment crevices ($F = 190.07, DF = 1, 560, P < 0.0001$) (Table 2.8).

**Differential Survival in Relation to Crevice Characteristics**

We examined crevice characteristics on both a seasonal and a pre- and post-construction basis, and found few differences in the characteristics of crevices that were used by surviving chicks compared to those of chicks that died, and with those of unknown outcome. The openings of crevices used by chicks that died prior to revetment construction (1999 and 2000 combined) were wider than those that fledged ($24.3 \pm 0.1 \text{ cm versus } 19.5 \pm 0.0 \text{ cm}; F = 3.75, DF = 2, 122, P = 0.026$). Crevice floors were also steeper for those used by chicks that died than for those used by chicks that fledged ($23.9 \pm 5.9^\circ \text{ versus } 14.6 \pm 1.1^\circ; F = 3.18, DF = 2, 122, P = 0.045$). This was
also true when testing the negative slopes of crevice floors that were used by chicks that died (35.6 ± 8.2°) versus the negative slopes of crevice floors that were used by chicks that fledged (18.3 ± 1.8°) (F = 5.51, DF = 2, 42, P = 0.007).

Surprisingly, in 2001, the slopes of crevice floors that were used by chicks that fledged were just as steep as those that were used by chicks that died (14.1 ± 4.3° versus 22.2 ± 3.2°; F = 0.78, DF = 2, 43, P = 0.464). This was also true when examining both negative slopes (27.5 ± 5.5° versus 30.4 ± 4.4°; F = 0.57, DF = 2, 22, P = 0.574) and positive slopes (8.8 ± 3.2° versus 11.8 ± 2.1°; F = 0.45, DF = 2, 17, P = 0.643). We found similar results for all of the above when 1) removing chicks with unknown outcomes from the analysis, 2) considering chicks with unknown outcomes as dead, and 3) considering chicks with unknown outcomes as fledged.

**Discussion**

**Crevice Use by Roseate Tern Chicks in Different Microhabitats**

Roseate Tern chicks used crevices found under artificial nest sites, (slant-roofed boxes or half-buried tires) more than expected compared to all other crevice microhabitat types on FICT during the 1999–2001 breeding seasons. Chicks also used other types of crevices, such as those formed by boulders, rocks, artificial debris, logs; and in 2001, revetment boulders. In 2001, revetment boulders were the fourth most used crevice microhabitat type, and this microhabitat was used less than expected when compared to other crevice types (Table 2.3). This demonstrated that revetment construction has changed the overall microhabitat composition of crevices on the island, but chicks did not use the new types of crevices as often as they used the pre-existing
types. Revetment boulders comprised 68.1% (156 of 229) of crevice microhabitat available to chicks in 2001 and unaltered crevices in the boulder microhabitat comprised 7.0% (16 of 229) of those available (Table 2.3). Nevertheless, chicks used these two crevice types almost evenly.

Roseate Tern chicks used crevices in different microhabitat types at different ages, and correspondingly, at different masses. Younger chicks that used crevices used those found under nest boxes and nest tires. This was not surprising, since most (95.7%) of the chicks in our sample hatched from nests that were placed in nest boxes or in nest tires and crevices beneath these nest sites were usually the closest available. Older chicks (range of means 14.3–16.8 d) used crevices formed by medium and large sized rocks, boulders, revetment boulders, and logs. The oldest chicks in our sample used crevices formed by artificial debris (20.7 d) (Table 2.6).

Lighter chicks used crevices formed under nest boxes and nest tires, and heavier chicks used crevices formed by boulders, large and medium rocks, artificial debris, logs, and revetment boulders (Table 2.6). Therefore, as Roseate Tern chicks developed, they moved away from their natal nest sites to seek shelter on other parts of the beach; and in 2001, within the revetment construction.

**Crevice Characteristics and Changes with the Revetment**

Prior to revetment construction at FICT, Roseate Tern chicks used crevices with openings that averaged 11.2 ± 0.9 cm tall and 22.0 ± 1.2 cm wide. These crevices exhibited both negatively and positively sloping floors and averaged 29.4 ± 1.8 cm in length. After revetment construction, the mean dimensions of crevices used by chicks
increased in every case except for the mean of positively sloping floors. Therefore, it appears that revetment construction at FICT provided chicks larger crevices than they had used in the past. Construction of the rock revetment on FICT created crevices with larger openings than were originally found prior to revetment construction. It was clear that the revetment provided new crevices that were larger and steeper than crevices that were originally available to and preferentially selected by Roseate Tern chicks.

There were two reasons for these larger mean crevice openings in the revetment. First, the revetment was formed with boulders that were much larger and much more numerous than the original composition of boulders the beach; and they were placed in a fashion that created large gaps between them. Second, the revetment contained a level shelf, built with the intention of mitigating for lost nesting habitat as a result of revetment construction. A coarse uniform gravel of pea-sized stones covered this shelf. This substrate was unlike the natural substrate, which was composed of various-sized rocks. The size of the new gravel eliminated the possibility of new crevices with smaller openings. With no options to use crevices under artificial nest sites on the shelf, the only option for those chicks was to stay inside nest boxes or move into the revetment boulder habitat with larger crevice openings. Moving through or over the revetment was the only option for chicks to access the beach prior to fledging.

Construction of the revetment has reduced the number of crevices previously used by chicks by replacing them with crevices with larger openings and steeper floors. Crevices of this type have the potential to endanger chicks in two ways, 1) larger openings allow predators such and Black-crowned Night-Herons better access to chicks within crevices, and 2) steeper floors could prevent chicks from climbing to the crevice
entrance. Therefore, it does not appear that the revetment added high quality crevice sites for chicks at FICT.

**Changes in the Survival of Roseate Tern Chicks with the Revetment**

Our examination of crevice characteristics revealed few differences in the characteristics of crevices used by surviving chicks, compared with those used by chicks that died and with those whose outcome was unknown. Prior to revetment construction, crevices used by chicks that died were wider (24.3 ± 0.1 cm versus 19.5 ± 0.0 cm) than crevices used by chicks that survived. The slopes of crevices that were used by chicks that died were steeper (23.9 ± 5.9° versus 14.6 ± 1.1°) than crevices used by chicks that survived. This was not the case in 2001, where we found no differences in the characteristics of crevices used by chicks according to their survival outcomes. The reason for this is unclear at this point. Our sampling method was not confounded by pseudoreplication, social behavior, and differential survival. But it did not allow us a significantly large sample to adequately compare the survival outcomes of the chicks using the crevices. This could be why we found so few differences in crevices characteristics according to survival outcome in 2001.

In summary, we were able to detect changes in the composition of microhabitat types for crevices that were available to Roseate Tern chicks, and for those crevices that used by Roseate Tern chicks after construction of the revetment at Falkner Island. We were also able to detect differences in the microhabitat types of crevices used by Roseate Tern chicks at different stages of development. Additionally, we were able to detect changes in some physical characteristics of crevices on the island after revetment
construction as well as changes in crevices used by chicks after construction. We recommend that if a future study addresses Roseate Tern crevice use, that the study uses a larger colony that would provide a large sample allowing for the statistical power required detecting such differences, or that the study uses a sufficient number of breeding seasons to account for this factor.

**Acknowledgments**

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**Literature Cited**


Table 2.1. Descriptions of microhabitat types used to classify crevices on Falkner Island Connecticut, 1999–2001.

<table>
<thead>
<tr>
<th>Microhabitat</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>Cobbles larger than one cubic meter.</td>
</tr>
<tr>
<td>Large Rock</td>
<td>Cobbles ranging from 0.125 m$^3$ to one cubic meter in volume (or roughly between 0.5 and 1.0 m in their longest dimension).</td>
</tr>
<tr>
<td>Medium Rock</td>
<td>Cobbles ranging from 0.008 to 0.125 m$^3$ in volume (or roughly between 0.2 to 0.5 m in their longest dimension).</td>
</tr>
<tr>
<td>Artificial Debris</td>
<td>Objects produced and/or discarded by humans, excluding items categorized as &quot;Log&quot; below.</td>
</tr>
<tr>
<td>Log</td>
<td>Dead, woody, vegetation with a minimum diameter greater than 10 cm.</td>
</tr>
<tr>
<td>Nest Tire</td>
<td>An automobile tire punctured on the bottom rim for drainage, placed on less than a 45° angle and half-filled with medium/small rocks and topped with gravel for a nesting substrate. We included crevices that formed directly under or adjacent to and including part of these structures to form a crevice.</td>
</tr>
<tr>
<td>Nest Box</td>
<td>A &quot;Series 500&quot; (Spendelow 1996) 15-cm tall by 46-cm wide by 18-cm long nest box with roof slanting to the floor on one end, closed at the front with an opening on one side and an extension of the floor to form a stoop, partially filled with gravel to a depth of two to three centimeters for a nesting substrate. We included crevices formed directly under or adjacent to and including part of these structures to form a crevice.</td>
</tr>
<tr>
<td>Revetment Boulder</td>
<td>Sections of basalt that are larger than one cubic meter and placed as part of the revetment.</td>
</tr>
</tbody>
</table>
Table 2.2. Descriptions of variables used to describe the physical characteristics of crevices that were both available to, and used by, Roseate Tern chicks at Falkner Island, Connecticut from 1999–2001.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>The maximum distance, measured in centimeters and perpendicular to the ground, from the bottom to the top of the crevice opening.</td>
</tr>
<tr>
<td>Width</td>
<td>The maximum distance, measured in centimeters and parallel to the ground, from one side of the crevice opening to the other.</td>
</tr>
<tr>
<td>Negative Slope</td>
<td>The predominant slope declining below horizontal, measured to the nearest whole degree with a clinometer, of the floor of the inside a crevice.</td>
</tr>
<tr>
<td>Positive Slope</td>
<td>The predominant slope inclining above horizontal, measured to the nearest whole degree with a clinometer, of the floor of the inside a crevice.</td>
</tr>
<tr>
<td>Absolute Value of Slope</td>
<td>The absolute value of the predominant slope, measured to the nearest whole degree with a clinometer, of the floor of the inside a crevice. This variable is the absolute value of all values of both negative slopes and positive slopes.</td>
</tr>
<tr>
<td>Length</td>
<td>The maximum distance along the floor of a crevice, measured in centimeters, from the crevice opening to the farthest point opposite the opening inside a crevice.</td>
</tr>
</tbody>
</table>
Table 2.3. Results of Chi-squared goodness-of-fit tests of crevice microhabitat types for both randomly selected non-used crevices and crevices used by Roseate Tern chicks at Falkner Island, Connecticut from 1999–2001. Chi-squared analysis first tested for differences in the proportions of randomly selected crevices within each year of the study. We based expected counts on equal proportions for each crevice microhabitat type within a year. Next, Chi-squared analysis tested for differences in the proportions of used crevices within each year. Here, we based expected counts on the observed values from the random samples.

<table>
<thead>
<tr>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
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<tbody>
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<td>1999</td>
<td>Boulder</td>
<td>29</td>
<td>26.2</td>
<td>0.31</td>
<td>1999</td>
<td>Boulder</td>
<td>11</td>
<td>12.2</td>
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<tr>
<td></td>
<td>Large Rock</td>
<td>33</td>
<td>26.2</td>
<td>1.78</td>
<td></td>
<td>Large Rock</td>
<td>9</td>
<td>13.9</td>
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<td>26.2</td>
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<td>Medium Rock</td>
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<td>19.8</td>
<td>8.24</td>
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<tr>
<td></td>
<td>Log</td>
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<td>26.2</td>
<td>6.63</td>
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<tr>
<td></td>
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<td></td>
<td>Nest Tire</td>
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<td>2000</td>
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<td>22.60</td>
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<td>Boulder</td>
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<td>Large Rock</td>
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<td>Artificial Debris</td>
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Table 2.3. Continued.

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<th>Year</th>
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<th>Contribution to $\chi^2$</th>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
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<th>Contribution to $\chi^2$</th>
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<td>2001</td>
<td>Boulder</td>
<td>16</td>
<td>38.2</td>
<td>12.87</td>
<td>2001</td>
<td>Boulder</td>
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<tr>
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<td>27.11</td>
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<td>144.74</td>
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</table>

$\chi^2 = 443.87$  
$DF = 5$  
P < 0.0001

$\chi^2 = 174.01$  
$DF = 5$  
P < 0.0001

$\chi^2 = 134.74$  
$DF = 5$  
P < 0.0001
Table 2.4. Results of Chi-squared goodness-of-fit tests of crevice microhabitat types for both randomly selected non-used crevices and crevices used by Roseate Tern chicks at Falkner Island, Connecticut from 1999–2001. The microhabitat types: boulder, large rock, medium rock, small rock, artificial debris, log, and revetment boulder from Table 2.3 were lumped into the ‘natural’ microhabitat category. Chi-squared analysis first tested for differences in the proportions of randomly selected crevices within each year of the study. We based expected counts on equal proportions for each crevice microhabitat type within a year. Next, Chi-squared analysis tested for differences in the proportions of used crevices within each year. Here, we based expected counts on the observed values from the random samples.

<table>
<thead>
<tr>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
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<td>1999</td>
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<td>122</td>
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<td>21.23</td>
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<td>24</td>
<td>8.0</td>
<td>32.10</td>
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<td>Nest Tire</td>
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<td>25.23</td>
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<td>Nest Tire</td>
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<td>2.72</td>
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<td></td>
<td>$\chi^2 = 139.20$</td>
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<td>$\chi^2 = 42.84$</td>
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<td>101.23</td>
<td>2000</td>
<td>Natural</td>
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<td>49.3</td>
<td>23.89</td>
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<td>5.5</td>
<td>3.74</td>
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<td>$\chi^2 = 94.84$</td>
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<td>P &lt; 0.0001</td>
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<tr>
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<td>Natural</td>
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<td>76.3</td>
<td>197.12</td>
<td>2001</td>
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<td>64.81</td>
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<td>1.0</td>
<td>144.74</td>
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<tr>
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<td>Nest Tire</td>
<td>24</td>
<td>76.3</td>
<td>35.88</td>
<td></td>
<td>Nest Tire</td>
<td>5</td>
<td>4.0</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2 = 297.81$</td>
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<td></td>
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<td>$\chi^2 = 150.13$</td>
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<td></td>
</tr>
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<td></td>
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<td>P &lt; 0.0001</td>
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</table>
Table 2.5. Results of Chi-squared goodness-of-fit tests of crevice microhabitat types for both randomly selected non-used crevices and crevices used by Roseate Tern chicks at Falkner Island, Connecticut from 1999–2001. We removed the microhabitat types nest box and nest tire from Table 2.3. Chi-squared analysis first tested for differences in the proportions of randomly selected crevices within each year of the study. We based expected counts on equal proportions for each crevice microhabitat type within a year. Next, Chi-squared analysis tested for differences in the proportions of used crevices within each year. Here, we based expected counts on the observed values from the random samples.

<table>
<thead>
<tr>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
<th>Year</th>
<th>Microhabitat</th>
<th>N</th>
<th>Expected N</th>
<th>Contribution to $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Boulder</td>
<td>29</td>
<td>30.5</td>
<td>0.07</td>
<td>1999</td>
<td>Boulder</td>
<td>11</td>
<td>7.4</td>
<td>1.79</td>
</tr>
<tr>
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<td>DF = 3 Large Rock</td>
<td>33</td>
<td>30.5</td>
<td>0.20</td>
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<td>DF = 3 Large Rock</td>
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<td>8.4</td>
<td>0.05</td>
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<td>47</td>
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<td>8.93</td>
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<td>11.9</td>
<td>2.05</td>
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<tr>
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<td>30.5</td>
<td>10.04</td>
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<td>Log</td>
<td>4</td>
<td>3.3</td>
<td>0.15</td>
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<td>Boulder</td>
<td>43</td>
<td>29.3</td>
<td>6.46</td>
<td>2000</td>
<td>Boulder</td>
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<td>6.6</td>
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<td>5.8</td>
<td>1.39</td>
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<td>29.3</td>
<td>0.10</td>
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<td>4.8</td>
<td>1.61</td>
</tr>
<tr>
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<td>29.3</td>
<td>20.10</td>
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<td>Log</td>
<td>3</td>
<td>0.8</td>
<td>6.47</td>
</tr>
<tr>
<td>2001</td>
<td>Boulder</td>
<td>16</td>
<td>64.3</td>
<td>36.31</td>
<td>2001</td>
<td>Boulder</td>
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<td>1.6</td>
<td>35.00</td>
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<tr>
<td></td>
<td>DF = 2 Large Rock</td>
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<td>64.3</td>
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<td>DF = 2 Large Rock</td>
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<tr>
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<td>Revetment Boulder</td>
<td>156</td>
<td>64.3</td>
<td>130.61</td>
<td></td>
<td>Revetment Boulder</td>
<td>7</td>
<td>15.4</td>
<td>4.55</td>
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</tbody>
</table>
Table 2.6. Ages (days) and masses (grams) that Roseate Tern chicks used crevices of different microhabitats at Falkner Island, Connecticut, 1999–2001. Here are the ranges of values for chicks within our sample for each microhabitat. Means and standard deviations, in parenthesis, are below the ranges. Chicks used crevices within different microhabitats at different ages ($F = 5.11, DF = 7, 149, P < 0.0001$) and masses ($F = 2.47, DF = 7, 148, P = 0.020$).

<table>
<thead>
<tr>
<th>Microhabitat</th>
<th>N</th>
<th>Ages at Which Chicks Used Crevices of Different Microhabitat Types</th>
<th>N</th>
<th>Masses at Which Chicks Used Crevices of Different Microhabitat Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>30</td>
<td>5–36 d</td>
<td>30</td>
<td>29.3–114.7 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.6 d (7.1 d) *a</td>
<td></td>
<td>75.2 g (19.1 g)</td>
</tr>
<tr>
<td>Large Rock</td>
<td>15</td>
<td>5–28 d</td>
<td>15</td>
<td>38.4–103.3 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.8 d (7.3 d) *a</td>
<td></td>
<td>76.2 g (22.9 g)</td>
</tr>
<tr>
<td>Medium Rock</td>
<td>9</td>
<td>7–26 d</td>
<td>9</td>
<td>17.0–100.1 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.9 d (6.1 d)</td>
<td></td>
<td>67.6 g (30.0 g)</td>
</tr>
<tr>
<td>Artificial Debris</td>
<td>3</td>
<td>14–31 d</td>
<td>3</td>
<td>74.1–98.6 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.7 d (9.1 d) *a</td>
<td></td>
<td>83.8 g (12.9 g)</td>
</tr>
<tr>
<td>Log</td>
<td>7</td>
<td>7–24 d</td>
<td>6</td>
<td>54.8–99.5 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.0 d (5.9 d)</td>
<td></td>
<td>85.3 g (17.7 g)</td>
</tr>
<tr>
<td>Nest Tire</td>
<td>26</td>
<td>5–19 d</td>
<td>26</td>
<td>18.9–94.5 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.0 d (3.5 d)</td>
<td></td>
<td>64.8 g (18.4 g)</td>
</tr>
<tr>
<td>Nest Box</td>
<td>60</td>
<td>3–20 d</td>
<td>60</td>
<td>11.9–102.5 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.0 d (4.4 d) *b</td>
<td></td>
<td>63.2 g (19.2 g)</td>
</tr>
<tr>
<td>Revetment Boulder</td>
<td>7</td>
<td>5–18 d</td>
<td>7</td>
<td>41.8–110.4 g</td>
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<tr>
<td></td>
<td></td>
<td>14.3 d (8.4 d)</td>
<td></td>
<td>77.2 g (25.9 g)</td>
</tr>
</tbody>
</table>

* Tukey’s tests for multiple comparisons revealed differences between the mean ages of chicks that used boulders, large rocks, and artificial debris (a) with those that used nest boxes (b).
Table 2.7. Mean values for characteristics of crevices available to Roseate Tern chicks on Falkner Island, Connecticut, recorded during the two breeding seasons prior to (1999, 2000; and both years combined, labeled as pre-construction), and during the breeding season after construction of a rock revetment in 2001. Sample sizes are in parentheses below means.

<table>
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<tr>
<th></th>
<th>Height (cm)</th>
<th>Width (cm)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1999</td>
<td>2000</td>
</tr>
<tr>
<td>Random</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random</td>
<td>10.4 ± 0.3 a</td>
<td>10.5 ± 0.9 a</td>
</tr>
<tr>
<td></td>
<td>(180)</td>
<td>(151)</td>
</tr>
<tr>
<td>Used</td>
<td>10.3 ± 0.6 b</td>
<td>12.3 ± 1.7 b</td>
</tr>
<tr>
<td></td>
<td>(66)</td>
<td>(59)</td>
</tr>
<tr>
<td>All</td>
<td>10.3 ± 0.3 c</td>
<td>11.0 ± 0.8 c</td>
</tr>
<tr>
<td></td>
<td>(246)</td>
<td>(210)</td>
</tr>
</tbody>
</table>

|                 |             |            |                 |      |           |
| Random          | 22.2 ± 1.0 a| 23.5 ± 3.6 a| 22.8 ± 1.8 d    | 33.4 ± 1.9 a, d | 27.2 ± 1.3 |
|                 | (180)       | (151)      | (331)           | (233) | (564)      |
| Used            | 18.8 ± 1.5 b| 25.5 ± 1.7 b| 22.0 ± 1.2 e    | 29.8 ± 3.7 b, e | 24.1 ± 1.3 |
|                 | (66)        | (59)       | (125)           | (46)  | (171)      |
| All             | 21.3 ± 0.9 c| 24.1 ± 2.7 c| 22.6 ± 1.3 f    | 32.9 ± 1.7 c, f | 26.5 ± 1.1 |
|                 | (246)       | (210)      | (456)           | (279) | (735)      |
Table 2.7. Continued.

### Negative Slope

<table>
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<tr>
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<th>2000</th>
<th>Pre-construction</th>
<th>2001</th>
<th>All</th>
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</thead>
<tbody>
<tr>
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<td>19.6 ± 1.3º a (59)</td>
<td>23.4 ± 1.4º a (67)</td>
<td>21.6 ± 1.0º d (126)</td>
<td>41.9 ± 2.4º a, d, g (144)</td>
<td>32.4 ± 1.5º i (270)</td>
</tr>
<tr>
<td>Used</td>
<td>15.9 ± 1.4º b (20)</td>
<td>23.2 ± 2.2º b (25)</td>
<td>20.0 ± 1.8º e (45)</td>
<td>28.3 ± 3.4º b, e, g (25)</td>
<td>22.9 ± 1.8º i (70)</td>
</tr>
<tr>
<td>All</td>
<td>18.7 ± 1.2º c (79)</td>
<td>23.3 ± 1.2º c (92)</td>
<td>21.2 ± 0.9º f (171)</td>
<td>39.9 ± 2.1º c, f (169)</td>
<td>30.5 ± 1.3º (340)</td>
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</tbody>
</table>

### Positive Slope

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<th>2000</th>
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<th>2001</th>
<th>All</th>
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</thead>
<tbody>
<tr>
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<td>11.2 ± 0.6º a (119)</td>
<td>12.6 ± 0.9º a (76)</td>
<td>11.8 ± 0.5º d (195)</td>
<td>15.9 ± 1.3º a, d (88)</td>
<td>13.0 ± 0.5º (283)</td>
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<tr>
<td>Used</td>
<td>13.7 ± 1.6º (43)</td>
<td>13.9 ± 1.5º (32)</td>
<td>13.8 ± 1.1º (75)</td>
<td>10.7 ± 1.6º (20)</td>
<td>13.1 ± 1.0º (95)</td>
</tr>
<tr>
<td>All</td>
<td>11.9 ± 0.6º c (162)</td>
<td>13.0 ± 0.8º c (108)</td>
<td>12.3 ± 0.5º f (270)</td>
<td>14.9 ± 1.1º c, f (108)</td>
<td>13.1 ± 0.5º (378)</td>
</tr>
</tbody>
</table>

### Absolute Value of Slope

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<th>2000</th>
<th>Pre-construction</th>
<th>2001</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random</td>
<td>13.8 ± 0.7º a (180)</td>
<td>16.7 ± 0.9º a (151)</td>
<td>15.2 ± 0.6º d (331)</td>
<td>31.9 ± 1.8º a, g, d (233)</td>
<td>22.1 ± 0.9º i (564)</td>
</tr>
<tr>
<td>Used</td>
<td>13.7 ± 1.4º b (66)</td>
<td>17.4 ± 1.4º b (59)</td>
<td>15.5 ± 1.0º e (125)</td>
<td>20.2 ± 2.5º b, e, g (46)</td>
<td>16.7 ± 1.0º i (171)</td>
</tr>
<tr>
<td>All</td>
<td>13.8 ± 0.6º c (246)</td>
<td>16.9 ± 0.8º c (210)</td>
<td>15.2 ± 0.5º f (465)</td>
<td>30.0 ± 1.5º c, f (279)</td>
<td>20.8 ± 0.7º (735)</td>
</tr>
</tbody>
</table>
Table 2.7. Continued.

<table>
<thead>
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<th>Length (cm)</th>
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<th>2000</th>
<th>Pre-construction</th>
<th>2001</th>
<th>All</th>
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</thead>
<tbody>
<tr>
<td>Random</td>
<td>27.2 ± 3.3 a</td>
<td>24.1 ± 2.6 a</td>
<td>25.8 ± 2.2 d, h</td>
<td>48.9 ± 2.4 a, d</td>
<td>35.3 ± 1.7</td>
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<tr>
<td></td>
<td>(180)</td>
<td>(151)</td>
<td>(331)</td>
<td>(233)</td>
<td>(564)</td>
</tr>
<tr>
<td>Used</td>
<td>26.8 ± 2.0 b</td>
<td>32.3 ± 3.1 b</td>
<td>29.4 ± 1.8 e, h</td>
<td>38.2 ± 3.8 b, e</td>
<td>31.7 ± 1.7</td>
</tr>
<tr>
<td></td>
<td>(66)</td>
<td>(59)</td>
<td>(125)</td>
<td>(46)</td>
<td>(171)</td>
</tr>
<tr>
<td>All</td>
<td>27.1 ± 2.5 c</td>
<td>26.4 ± 2.1 c</td>
<td>26.8 ± 1.6 f</td>
<td>47.1 ± 2.1 c, f</td>
<td>34.5 ± 1.4</td>
</tr>
<tr>
<td></td>
<td>(246)</td>
<td>(210)</td>
<td>(456)</td>
<td>(279)</td>
<td>(735)</td>
</tr>
</tbody>
</table>

a mean values for characteristics of randomly selected crevices differed among breeding seasons.
b mean values for characteristics of crevices used by Roseate Tern chicks differed among breeding seasons.
c mean values for characteristics of both randomly selected crevices and crevices used by Roseate Tern chicks differed among breeding seasons.
d mean values for characteristics of randomly selected crevices differed during the two breeding seasons prior to revetment construction than in the year after revetment construction.
e mean values for characteristics of crevices used by Roseate Tern chicks differed before and after revetment construction.
f mean values for characteristics of both randomly selected crevices and crevices used by Roseate Tern chicks differed before and after revetment construction.
g mean values for characteristics of crevices differed between randomly selected crevices and those use by Roseate Tern chicks during the breeding season after revetment construction.
h mean values for characteristics of crevices differed between randomly selected crevices and those use by Roseate Tern chicks during the combined two breeding seasons before revetment construction.
i mean values for characteristics of crevices differed between randomly selected crevices and those use by Roseate Tern chicks during all three breeding seasons of this study.
Table 2.8. Mean values for characteristics of randomly selected non-revetment (found both outside the revetment area in 2001 and found in 1999 and 2000, prior to revetment construction) and revetment crevices (found within the revetment area in 2001 only) at Falkner Island, Connecticut. Sample sizes, in parenthesis, are below mean values.

<table>
<thead>
<tr>
<th>Crevice Characteristic</th>
<th>Revetment</th>
<th>Non-revetment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>25.5 ± 1.3 cm a</td>
<td>10.8 ± 0.4 cm a</td>
</tr>
<tr>
<td></td>
<td>(156)</td>
<td>(409)</td>
</tr>
<tr>
<td>Width</td>
<td>36.5 ± 2.7 cm b</td>
<td>23.6 ± 1.5 cm b</td>
</tr>
<tr>
<td></td>
<td>(153)</td>
<td>(409)</td>
</tr>
<tr>
<td>Negative Slope</td>
<td>44.3 ± 2.7° c</td>
<td>23.6 ± 1.2° c</td>
</tr>
<tr>
<td></td>
<td>(113)</td>
<td>(155)</td>
</tr>
<tr>
<td>Positive Slope</td>
<td>21.1 ± 2.1° d</td>
<td>11.7 ± 0.5° d</td>
</tr>
<tr>
<td></td>
<td>(40)</td>
<td>(243)</td>
</tr>
<tr>
<td>Absolute Value of Slope</td>
<td>38.2 ± 2.2° e</td>
<td>15.9 ± 0.6° e</td>
</tr>
<tr>
<td></td>
<td>(153)</td>
<td>(409)</td>
</tr>
<tr>
<td>Length</td>
<td>59.4 ± 3.2 cm f</td>
<td>26.3 ± 1.8 cm f</td>
</tr>
<tr>
<td></td>
<td>(153)</td>
<td>(409)</td>
</tr>
</tbody>
</table>

a mean values for the height of randomly selected crevices differed between non-revetment and revetment crevices.
b mean values for the width of randomly selected crevices differed between non-revetment and revetment crevices.
c mean values for the absolute value of slope of randomly selected crevices differed between non-revetment and revetment crevices.
d mean values for negatively sloping floors of randomly selected crevices differed between non-revetment and revetment crevices.
e mean values for positively sloping floors of randomly selected crevices differed between non-revetment and revetment crevices.
f mean values for the internal length of randomly selected crevices differed between non-revetment and revetment crevices.
Figure 2.1. A. Locations of the six Roseate Tern subcolonies at Falkner Island, Connecticut before revetment construction. B. The extent of the revetment showing the effected subcolonies.
APPENDIX

SUMMARY OF SURVIVAL OUTCOMES FOR ROSEATE TERN CHICKS ACCORDING TO NESTING SUBCOLONY LOCATION DURING THE TWO BREEDING SEASONS PRIOR TO CONSTRUCTION OF A ROCK REVETMENT (1999 AND 2000), AND THE FIRST BREEDING SEASON FOLLOWING CONSTRUCTION (2001) AT FALKNER ISLAND, CONNECTICUT.
Table A.1. Survival outcomes for Roseate Tern chicks in 1999 at Falkner Island, Connecticut according to nesting subcolony location. This was two breeding seasons before revetment construction, which occurred during winter 2000–2001.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Died</td>
<td>2 (12.5%)</td>
<td>13 (29.5%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>7 (43.8%)</td>
<td>18 (40.9%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>7 (43.8%)</td>
<td>13 (29.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16 (100.0%)</td>
<td>44 (100.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>2 (18.2%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>7 (100.0%)</td>
<td>8 (72.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>1 (9.1%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7 (100.0%)</td>
<td>11 (100.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>5 (26.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>11 (84.6%)</td>
<td>12 (63.2%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (15.4%)</td>
<td>2 (10.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>13 (100.0%)</td>
<td>19 (100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>1 (25.0%)</td>
<td>5 (41.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>3 (75.0%)</td>
<td>6 (50.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>1 (8.3%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4 (100.0%)</td>
<td>12 (100.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>2 (20.0%)</td>
<td>6 (37.5%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>7 (70.0%)</td>
<td>8 (50.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (10.0%)</td>
<td>2 (12.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>10 (100.0%)</td>
<td>16 (100.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>9 (25.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>15 (93.8%)</td>
<td>25 (69.4%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (6.3%)</td>
<td>2 (5.6%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>15 (100.0%)</td>
<td>36 (100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>5 (7.6%)</td>
<td>40 (29.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>50 (75.8%)</td>
<td>77 (55.8%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>11 (16.7%)</td>
<td>21 (15.2%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>66 (100.0%)</td>
<td>138 (100.0%)</td>
</tr>
</tbody>
</table>

*a See Figure 2.1 in Chapter II for subcolony locations.*
Table A.2. Survival outcomes for Roseate Tern chicks in 2000 at Falkner Island, Connecticut according to nesting subcolony location. This was the final breeding season before revetment construction, which occurred during winter 2000–2001.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Died</td>
<td>1 (6.7%)</td>
<td>11 (23.4%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (60.0%)</td>
<td>27 (57.4%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>5 (33.3%)</td>
<td>9 (19.1%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>15 (100.0%)</td>
<td>47 (100.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>2 (40.0%)</td>
<td>7 (46.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>2 (40.0%)</td>
<td>6 (40.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (20.0%)</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5 (100.0%)</td>
<td>15 (100.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>5 (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (100.0%)</td>
<td>11 (68.8%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>9 (100.0%)</td>
<td>16 (100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>1 (9.1%)</td>
<td>5 (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>10 (90.0%)</td>
<td>11 (68.8%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11 (100.0%)</td>
<td>16 (100.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>6 (66.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>2 (100.0%)</td>
<td>3 (33.3%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2 (100.0%)</td>
<td>9 (100.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>1 (5.9%)</td>
<td>12 (29.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>15 (88.2%)</td>
<td>26 (63.4%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (5.9%)</td>
<td>3 (7.3%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17 (100.0%)</td>
<td>41 (100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>5 (8.5%)</td>
<td>46 (31.9%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>47 (79.7%)</td>
<td>84 (58.3%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>7 (11.9%)</td>
<td>14 (9.7%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td><strong>59</strong> b (100.0%)</td>
<td><strong>144</strong> b (100.0%)</td>
</tr>
</tbody>
</table>

---

a See Figure 2.1 in Chapter II for subcolony locations.
b Five chicks used crevices in microhabitat types that were not recorded. Therefore, this total does not equal the total presented in Table 2.3 of Chapter II.
Table A.3. Survival outcomes for Roseate Tern chicks in 1999 and 2000 at Falkner Island, Connecticut according to nesting subcolony location. This summary combines the results of survival outcomes for chicks during the two breeding seasons prior to revetment construction.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Died</td>
<td>3 (9.7%)</td>
<td>24 (26.4%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>16 (51.6%)</td>
<td>45 (49.5%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>12 (38.7%)</td>
<td>22 (24.2%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>31 (100.0%)</td>
<td>91 (100.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>2 (16.7%)</td>
<td>9 (34.6%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (75.0%)</td>
<td>14 (53.8%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (8.3%)</td>
<td>3 (11.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12 (100.0%)</td>
<td>26 (100.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>10 (28.6%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>20 (90.9%)</td>
<td>23 (65.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (9.1%)</td>
<td>2 (5.7%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>22 (100.0%)</td>
<td>35 (100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>2 (13.3%)</td>
<td>10 (35.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>13 (86.7%)</td>
<td>17 (60.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>1 (3.6%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>15 (100.0%)</td>
<td>28 (100.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>2 (16.7%)</td>
<td>12 (48.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (75.0%)</td>
<td>11 (44.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (8.3%)</td>
<td>2 (8.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12 (100.0%)</td>
<td>25 (100.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>1 (3.0%)</td>
<td>21 (27.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>30 (90.9%)</td>
<td>51 (66.2%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (6.1%)</td>
<td>5 (6.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>33 (100.0%)</td>
<td>77 (100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>10 (8.0%)</td>
<td>86 (30.5%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>97 (77.6%)</td>
<td>161 (57.1%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>18 (14.4%)</td>
<td>35 (12.4%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>125 (100.0%)</td>
<td>282 (100.0%)</td>
</tr>
</tbody>
</table>

*a See Figure 2.1 in Chapter II for subcolony locations.*
Table A.4. Survival outcomes for Roseate Tern chicks in 2001 at Falkner Island, Connecticut according to nesting subcolony location. This was the first breeding season after revetment construction.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Died</td>
<td>1 (16.7%)</td>
<td>6 (19.4%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>5 (83.3%)</td>
<td>18 (58.1%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>7 (22.6%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6 (100.0%)</td>
<td>31 (100.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>1 (50.0%)</td>
<td>6 (60.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (50.0%)</td>
<td>4 (40.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2 (100.0%)</td>
<td>10 (100.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>4 (26.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>3 (75.0%)</td>
<td>10 (66.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1 (25.0%)</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4 (100.0%)</td>
<td>15 (100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>1 (11.1%)</td>
<td>2 (16.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>6 (66.7%)</td>
<td>8 (66.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (22.2%)</td>
<td>2 (16.7%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>9 (100.0%)</td>
<td>12 (100.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>2 (18.2%)</td>
<td>5 (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (81.8%)</td>
<td>9 (56.3%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>2 (12.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11 (100.0%)</td>
<td>16 (100.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>3 (21.4%)</td>
<td>9 (29.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>8 (57.1%)</td>
<td>19 (61.3%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>3 (21.4%)</td>
<td>3 (9.7%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>14 (100.0%)</td>
<td>31 (100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>7 (15.2%)</td>
<td>26 (22.6%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>32 (69.6%)</td>
<td>70 (60.9%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>7 (15.2%)</td>
<td>19 (16.5%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>46 b (100.0%)</td>
<td>115 c (100.0%)</td>
</tr>
</tbody>
</table>

a See Figure 2.1 in Chapter II for subcolony locations.
b Five chicks used crevices in microhabitat types that were not recorded. Therefore, this total does not equal the total presented in Table 2.3 of Chapter II.
c One chick that hatched in 2001 outside of the six main subcolony areas is not included in this summary. This chick survived to fledge.
Table A.5. Survival outcomes for Roseate Tern chicks which were hatched from nests located inside the revetment project area at Falkner Island, Connecticut in 2001.

<table>
<thead>
<tr>
<th>Subcolony&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Died</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td>A</td>
<td>Survived</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(100.0%)</td>
<td>(60.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0.0%)</td>
<td>(40.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(100.0%)</td>
<td>(100.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>(0.0%)</td>
<td>(25.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(100.0%)</td>
<td>(62.5%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0.0%)</td>
<td>(12.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(100.0%)</td>
<td>(100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>(16.7%)</td>
<td>(31.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(58.3%)</td>
<td>(58.6%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(25.0%)</td>
<td>(10.3%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>(100.0%)</td>
<td>(100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>(13.3%)</td>
<td>(23.4%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>(66.7%)</td>
<td>(59.6%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(20.0%)</td>
<td>(17.0%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>(100.0%)</td>
<td>47&lt;sup&gt;b&lt;/sup&gt; (100.0%)</td>
</tr>
</tbody>
</table>

<sup>a</sup> See Figure 2.1 in Chapter II for subcolony locations.

<sup>b</sup> One chick that hatched in 2001 outside of the six main subcolony areas is not included in this summary. This chick survived to fledge.
Table A.6. Survival outcomes for Roseate Tern chicks which were hatched from nests located outside the revetment project area at Falkner Island, Connecticut in 2001.

<table>
<thead>
<tr>
<th>Subcolony</th>
<th>Survival Outcome</th>
<th>Chicks That Used Crevices</th>
<th>All Chicks That Hatched</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Died</td>
<td>1 (16.7%)</td>
<td>6 (19.4%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>5 (83.3%)</td>
<td>18 (58.1%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>7 (22.6%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6 (100.0%)</td>
<td>31 (100.0%)</td>
</tr>
<tr>
<td>B</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>C</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>2 (28.6%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>3 (100.0%)</td>
<td>5 (71.4%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3 (100.0%)</td>
<td>7 (100.0%)</td>
</tr>
<tr>
<td>D</td>
<td>Died</td>
<td>1 (11.1%)</td>
<td>2 (16.7%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>6 (66.7%)</td>
<td>8 (66.7%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (22.2%)</td>
<td>2 (16.7%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>9 (100.0%)</td>
<td>12 (100.0%)</td>
</tr>
<tr>
<td>E</td>
<td>Died</td>
<td>2 (18.2%)</td>
<td>5 (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>9 (81.8%)</td>
<td>9 (56.3%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>2 (12.5%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11 (100.0%)</td>
<td>16 (100.0%)</td>
</tr>
<tr>
<td>F</td>
<td>Died</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>2 (100.0%)</td>
<td>2 (100.0%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2 (100.0%)</td>
<td>2 (100.0%)</td>
</tr>
<tr>
<td>All</td>
<td>Died</td>
<td>4 (12.9%)</td>
<td>15 (22.1%)</td>
</tr>
<tr>
<td></td>
<td>Survived</td>
<td>25 (80.6%)</td>
<td>42 (61.8%)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>2 (6.5%)</td>
<td>11 (16.2%)</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>31 (100.0%)</td>
<td>68 (100.0%)</td>
</tr>
</tbody>
</table>

*See Figure 2.1 in Chapter II for subcolony locations.
BIBLIOGRAPHY


Harris, J.T., and S.W. Matteson. 1975. Gulls and terns as indicators of man’s impact upon Lake Superior. Wisconsin Sea Grant College Program, Madison, Wisconsin.


