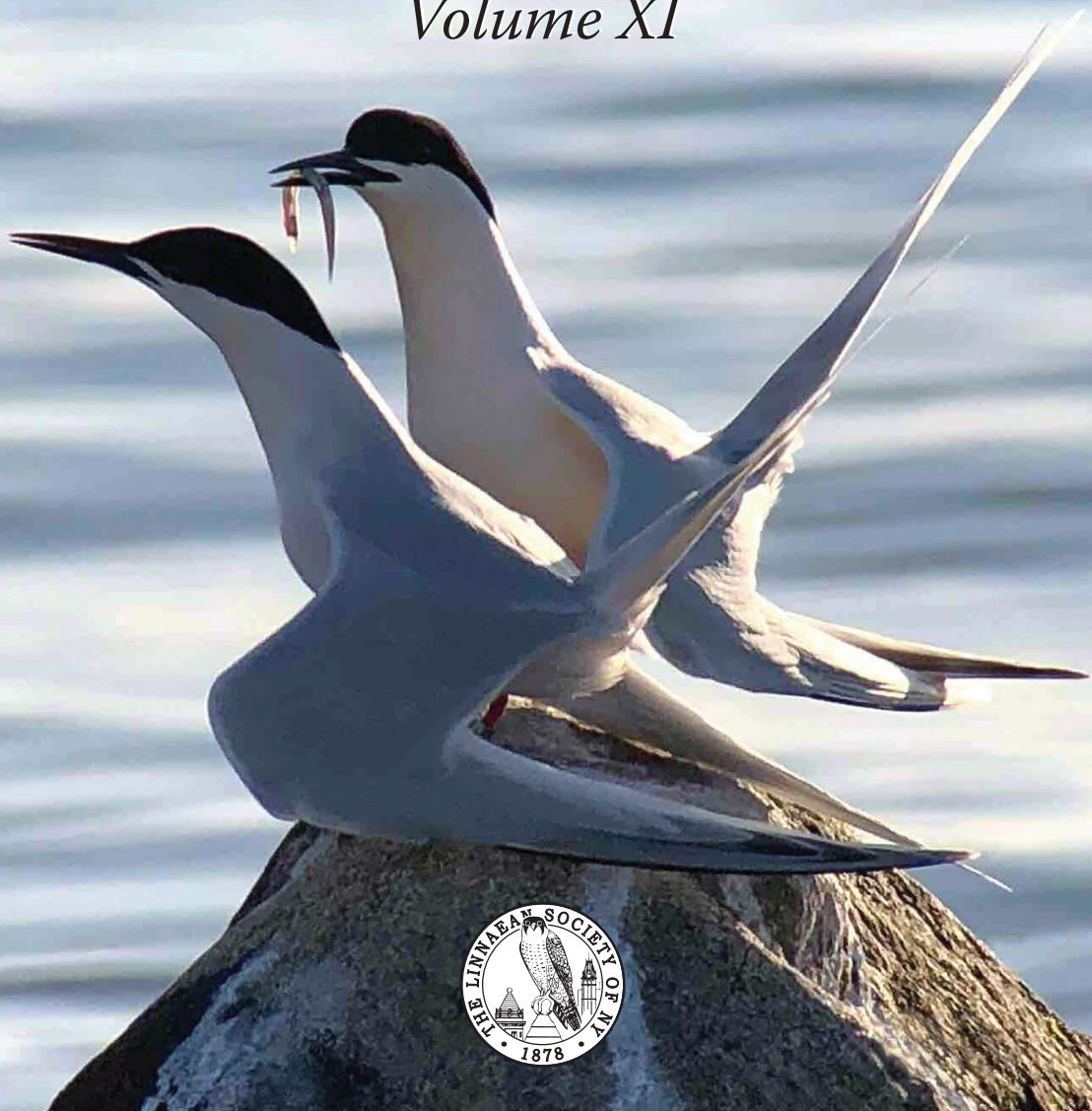


Great Gull Island and the New York Bight

Transactions of the
Linnaean Society of New York
Volume XI



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Great Gull Island and the New York Bight *Transactions Vol. XI*

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Contents

- vi* *Dedication*
- viii* *Introduction*
- 1 Plumage Variation in Known-Age Common Terns
Joseph DiCostanzo, Helen Hays
- 9 Effects Of Nanotags on the Behavior of Roseate Terns Nesting on Great Gull Island
Peter W. C. Paton, Pamela H. Loring, Andrea Nyamekye, Grace Donaldson Cormons
- 21 Using GPS and UAV to Map Common Tern Nesting Habitat on Great Gull Island
Kevin Rogers, Peter August, Peter W.C. Paton, Helen Hays
- 33 Assessing the Movement Ecology of Roseate and Common Terns During the Breeding Season: A Case Study from Great Gull Island
Pamela H. Loring, Peter W.C. Paton, Grace Donaldson Cormons
- 45 Using Nest Cameras and Automated Telemetry to Monitor Chick Provisioning by Common and Roseate Terns
Michael D. Abemayor, Pamela H. Loring, Peter W.C. Paton, Indiana Reid-Shaw, Kalaina Thorne
- 55 PVC Elbow Fittings Provide Protection in Nest Boxes of Roseate Tern Chicks
Catherine J. Neal
- 61 Life Histories of Roseate Terns Nesting in a New Area
Grace Donaldson Cormons
- 71 Observations of Chick-Rearing Success by Single-parent Roseate Terns
Grace Donaldson Cormons, Jeffrey A. Spindelow
- 81 Great Gull Island Roseate Tern Data Summary 1988-2021
Grace Donaldson Cormons
- 99 Oceanic Birds of the New York Bight
Angus Wilson



Helen Hays

This volume of the *Transactions of the Linnaean Society of New York* is dedicated to Helen Hays in recognition of her long service to the Society and her years of work on Great Gull Island.

Helen joined the Society in 1958. Her first officer's position was as secretary of the Society from 1960–1962. She continued to serve on the Council after her term as secretary was finished and served as vice president in 1971–1973. In 1973 Helen was the first woman to serve as president of the Society, serving until 1975. From 2003–2005 Helen was again president of the Society.

After her graduation from Wellesley College and before her work with Common and Roseate Terns on Great Gull Island, Helen attended graduate school at Cornell University, where she did pioneering work on Ruddy Ducks at the Delta Waterfowl Research Station in Manitoba. She has always said that after years of watching lone individuals of Ruddy Ducks sitting on nests, the noise and frantic activity of the tern colony on Great Gull Island immediately attracted her. In 1969, several years after first visiting the island, she started the Great Gull Island Project in 1969 and directed it for fifty years.

Proceedings of the Linnaean Society of New York No. 71, published in December 1971, included some of Helen's first reports on the nesting birds of Great Gull Island. Over one hundred publications by Helen and others followed. Helen has received numerous awards and citations for her work on Great Gull. They include the President's Volunteer Action Award from President Ronald Reagan to the Great Gull Island Project in 1985. Helen personally received the U.S. Department of the Interior's Conservation Service Award in 2002. In 2016 the U.S. Environmental Protection Agency awarded

Helen an Environmental Champion Award. In May 2015, the University of Connecticut (Storrs) awarded Helen an Honorary Doctor of Science degree in recognition of her work. Recently, Helen was the subject of the award-winning documentary *Full Circle* (2021). Beyond her work with the terns, one of Helen's greatest contributions has been her inspiration of several generations of students on Great Gull Island. Many of these students have themselves gone on to distinguished careers in such varied fields as biology, environmental science, medicine, education, law, and literature.

Helen's work on Great Gull has produced a unique and massive amount of data on the Common and Roseate Terns nesting on the island. The main data file for the Common Terns contains over three quarters of a million records covering fifty years. Starting in 1995 Helen led multiple trips to South America, helping to discover the previously unknown wintering areas of the Roseate Tern and forging partnerships with South American tern researchers. Most of the papers in this issue of *Transactions* report on recent work on the island. None of the work on Great Gull Island would have been possible without Helen's tireless energy and dedication.

Joseph DiCostanzo

Introduction

The Linnaean Society of New York is pleased to publish Volume XI of its research journal, *Transactions*. This volume focuses on the Common and Roseate Terns of Great Gull Island, with, in addition, a broad look at oceanic birds in the waters around New York.

Great Gull Island, currently the site of the Northern Hemisphere's largest concentration of nesting Roseate Terns, lies at the eastern end of Long Island Sound. The location previously of Fort Michie, it was purchased by the American Museum of Natural History in 1949 and its environment restored by volunteers to a condition suitable for nesting terns. Beginning in 1963 and continuing to the present day, Helen Hays, working under the auspices of the Museum and on behalf of The Linnaean Society of New York, has directed large teams of undergraduate and graduate students, professional ornithologists, and volunteer researchers each summer as well as on spring and fall work weekends.

This volume collects some of the most recent findings of that research program.

It starts with some new knowledge produced by an old and well-established method: careful observation. Using data from the project's years of banding terns, Joseph DiCotanzo and Helen Hays show that plumage variation in Common Terns, often thought to be an indicator of a bird's age, is not so reliable.

This is followed by four articles reporting on the use of cutting-edge electronic technology. Peter Paton and his co-authors describe the use of VHF transmitters, sutured to terns' backs, to track the birds. They find that the transmitters had minimal effects on the birds' behavior and chick provisioning, thus paving the way for a much broader use of this technology. Kevin Rogers and his co-authors used two other kinds of contemporary technology—handheld GPS units and small drones—to map more fully and accurately the locations and habitats where the terns nest. Pamela Loring and her co-authors took advantage of the digital VHF transmitters attached to the terns to learn about their movement patterns before and after chicks fledged; they find that some parent terns traveled surprisingly long distances for foraging, even before the chicks fledged. Finally, in the “technology” group, Michael Abemayor and his co-authors report on the successful use of high-resolution nest cameras and VHF telemetry to substitute for personal observation from blinds to gather data on the birds' activities.

From there, the volume turns to some slightly older technology: PVC piping. Catherine Neal describes how placing simple PVC elbow fittings in tern nests allows chicks to remain hidden, rather than trying to move to escape predators.

The next two Great Gull Island articles report on successful breeding in the face of disruption. Grace Cormons demonstrates that newly built nest boxes were successful in attracting Roseate Terns to reestablish their nests in an area that had been heavily damaged by Hurricane Sandy. Terns that had previously nested elsewhere on the island also

used the newly built nest boxes. And Cormons and Jeffrey Spendelow, using tracking devices, find that single Roseate Tern parents can successfully raise chicks even after one of a breeding pair has died or gone missing.

Coverage of Great Gull Island concludes with an expansive compilation of data collected about Roseate Terns on the island over more than three decades.

This volume concludes by moving beyond Great Gull Island to a survey of the oceanic birds of the New York Bight, the coastal waters extending along the Atlantic Ocean from Cape May, New Jersey, to Montauk on Long Island. Angus Wilson compiles descriptions of the numerous species that inhabit or visit the Bight, providing a thorough guide for both amateur and professional ornithologists, as well as a summary of key findings about these birds and questions for future research.

Plumage Variation in Known-Age Common Terns

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ABSTRACT

This paper presents photographs of banded known-age Common Terns between one and twenty-five years old taken on Great Gull Island. All birds were originally banded as chicks. The plumage variation shown in the photographs demonstrates that adult Common Terns cannot be safely aged by plumage characters alone.

INTRODUCTION

Common Terns (*Sterna hirundo*) are not sexually dimorphic, so males and females cannot be distinguished by plumage either in the field or the hand. However, this species does show differences in plumage between the breeding season in the Northern Hemisphere and the non-breeding season, which is primarily spent in the Southern Hemisphere. These differences are illustrated in many field guides (e.g., Dunn and Alderfer, 2017; Olsen and Larrison, 1995). Common Terns do not usually breed when they are one year old; some breed when they are two but most start at three or four years old (Nisbet, 2002). Field guides often present an apparently neat sequence of plumages for Common Terns in their first few years of life, frequently labeling these plumages with specific chronological ages such as “first summer” and “second summer” (Dunn and Alderfer, 2017; Olsen and Larrison, 1995). However, the assignment of ages to these plumage variations seems for the most part to be based on assumptions rather than birds of actual known ages. Figure 1 is a photograph of a Common Tern taken on 21 July 2019 on Great Gull Island. Based on criteria presented in various field guides the white forehead and carpal bar on the wing and the dark bill of this bird would lead it to be considered a first-summer individual, However, since the bird is unbanded this age determination cannot be proven. In this paper we present photographs of Common Terns whose ages are known because they were banded as chicks.

Keywords: Common Tern, Plumage, Plumage by age

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Figure 1. Unknown age Common Tern photographed on dock on Great Gull Island.

METHODS

Researchers with the Great Gull Island Project have been studying and banding Common Terns on Great Gull Island, Suffolk County, New York, since 1966 (Cooper et al., 1970; Hays, 2007; DiCostanzo, 2007). Each year, as part of the ongoing research on the island Common Tern young are banded as chicks in the nest or as young who have left the nest but have not yet flown. This yearly banding of young birds provides a population of banded birds of known age that can be observed and/or trapped on Great Gull Island. The island has a number of blinds that provide excellent sites for observing and photographing the terns. A recently constructed blind on the north side of the island overlooking a large nesting area provides an excellent location to photograph terns and to read the band numbers of banded individuals to determine ages of the birds observed. The free-flying birds photographed in Figures 2, 3, 8, and 9 were all observed and their band numbers read using a Swarovski 95 mm spotting scope with a 30–70 power zoom eyepiece. The birds in Figures 4, 5, 6, and 7 were trapped on nests and the bands read

Table 1: Banding dates, observation dates, ages of photographed Common Terns. All birds banded as chicks

Band	Band number	Date banded	Date photographed	Age
Fig. 2	1402-02798	20 June 2018	16 July 2019	1 year
Fig. 3	1332-87680	07 June 2016	06 July 2018	2 years
Fig. 4	1402-17440	21 June 2016	20 July 2018	2 years
Fig. 5	"	"	"	"
Fig. 6	1402-17418	23 June 2016	17 July 2018	2 years
Fig. 7	1362-57194	20 June 2015	19 July 2018	3 years
Fig. 8	1242-69009	25 June 2008	30 July 2018	10 years
Fig. 9	9802-77420	27 June 1993	25 June 2018	25 years

in the hand. Hays first spotted the bird in Figure 9 and read its band number. Recognizing that it was an unusual plumage for its age, Hays had the band number read and confirmed by DiCostanzo and Joan Walsh.

RESULTS

The ages of the birds studied range from just over one year old to just short of twenty-five years old (Table 1). Since all the birds shown, except for that in Figure 1, were banded as chicks the ages of the individuals shown are known.

DISCUSSION

The seven banded Common Terns whose photographs are presented in this paper show the considerable range in variation of plumage present in the field among both young and even quite old individuals. Only a single one-year-old bird is presented. We very rarely encounter one-year-old birds in the colony on Great Gull Island. We believe most one-year-olds remain on the wintering grounds in South America. The one-year-old bird shown here (Figure 2) looks very much like the illustrations of “first summer” birds pictured in the standard field guides. However, it has an adult-like red and black bill instead of the all black bill often represented. The three different two-year-old birds (Figures 3, 4,



Figure 2. Banded one-year-old Common Tern (1402-02798) photographed on Great Gull Island.



Figure 3. Banded two-year-old Common Tern (1332-87680) photographed on Great Gull Island.



Figure 4. Banded two-year-old Common Tern (1402-17440) photographed on Great Gull Island.



Figure 5. Banded two-year-old Common Tern (1402-17440) photographed on Great Gull Island.

5, and 6) show that there is considerable variation in plumage characters of birds of this age. They can look very much like a one-year-old (Figure 3) or be indistinguishable from an adult Common Tern (Figure 6). By three years old most Common Terns are in what would be considered an adult plumage, but a few can show some traces of the plumage of younger birds, such as a few dark carpal bar feathers (Figure 7). What might account for this considerable variation with age? Molt in birds is hormonally controlled (Gill 1990). Thus, the differences in plumage might well be a result of variation in the hormone levels of individual birds. Additionally, Common Terns have a nonbreeding plumage they exhibit primarily on their wintering grounds in the Southern Hemisphere. This plumage is not often illustrated in Northern Hemisphere field guides, although Olsen and Larrison (1995) and newer guides such as Sibley (2014) show it. In nonbreeding plumage adults have extensive white foreheads, dark carpal bars, dark bills, and darker legs than in the breeding season. Thus, even an older bird, such as the ten-year-old bird with a white forehead shown in Figure 8, might exhibit what would be considered aberrant plumage characters for its age if it retained some of its nonbreeding plumage characteristics during the breeding season, perhaps due to a hormonal imbalance. On Great Gull Island we routinely trap birds well into their twenties and they are usually indistinguishable from other adult birds.



There does not appear to be an “old-age” plumage. In extreme cases an old bird, such as the 25-year-old bird shown in Figure 9, might retain all its nonbreeding plumage characters into the breeding season and perhaps be mistaken for a one-year-old bird.

Figure 6. Banded two-year-old Common Tern (1402-17418) photographed on Great Gull Island.



Figure 7. Banded three-year-old Common Tern (1362-57194) photographed on Great Gull Island.

Finally, returning to the unbanded bird in Figure 1, we see that it cannot be safely aged based on plumage characteristics. Many breeding season birds with white foreheads, carpal bars, and even dark bills may be young birds, but the possibility exists that they are older birds, that have retained aspects of their nonbreeding plumage. Conversely, not all birds that look like a full plumaged adult can be assumed to be older birds, as shown by the two-year-old bird in Figure 6.



Figure 8. Banded ten-year-old Common Tern (1242-69009) photographed on Great Gull Island.



Figure 9. Banded twenty-five-year-old Common Tern (9802-77420) photographed on Great Gull Island.

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The authors thank all the many students and volunteers who have banded the thousands of terns banded on Great Gull Island over the years. The photographs reproduced in this paper were taken by Zena Casteel (Figure 3), Karis Daniel (Figure 8), Joseph DiCostanzo (Figures 1, 4, 5, 6, 7, and 9), and Joan Walsh (Figure 2), and we thank them for permission to use them. The blind from which nearly all the birds were photographed was designed and built by Matthew Male. Great Gull Island is owned by the American Museum of Natural History and work on the island is done under the auspices of the Museum. We thank the Chester W. Kitchings Foundation, the Quebec Labrador Foundation, the Black Dog Foundation, members of The Linnaean Society of New York, and private individuals for their support, which enabled the work on Great Gull Island, some of which we report in this paper.

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Effects of Nanotags on the Behavior of Roseate Terns Nesting on Great Gull Island

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ABSTRACT

We used miniature digital VHF transmitters to track the local and regional movements of 30 adult Roseate Terns (*Sterna dougallii*) on Great Gull Island, NY, in 2015. This was the first attempt to track Roseate Terns with small transmitters sutured to their backs; therefore, we monitored the behavior of tagged and non-tagged (control) birds to assess potential adverse impact of transmitters on terns. We documented no difference in preening rates, nest attendance rates, or prey delivery rates between terns with and those without a transmitter. This suggests that small transmitters, attached with sutures to remain on adult Roseate Terns for only several months, will not affect their behavior or chick-provisioning rates on Great Gull Island or at other sites.

INTRODUCTION

Tracking the movements of seabirds provides unique insights to their behavior, physiology, and ecology (Burger and Shaffer, 2008). Overall, seabird populations are declining at a faster rate than many other groups of birds, thus understanding factors affecting populations is important (Croxall et al., 2012). Information learned from tracking studies is critical to conservation efforts, including marine spatial planning and public outreach

(Burger and Shaffer, 2008). The development of telemetry and other remote sensing techniques over the past two decades has allowed scientists to gain new insights into the behavior of seabirds. These studies are imperative because they also allow us to understand the role of seabird populations in marine ecosystems (Monaghan, 1996). However, it is also important that tracking studies monitor and quantify the risks of tracking devices to maximize bird safety and quality of the movement data (Murray and Fuller, 2000).

The effects of tracking devices, including radio transmitters, on birds have been known for several decades (see reviews by Calvo and Furness, 1992, Murray and Fuller, 2000, Barron et al., 2010). Almost 80% of the papers that Barron et al. (2010) reviewed were concerned about the potential negative effects of transmitters on the birds they were investigating. In some species, tracking devices can affect locomotion, food consumption, and courtship displays (Barron et al., 2010). Most studies tend to find minimal adverse impacts (Kenward, 2001), although Barron et al. (2010) found significant negative effects on eight of twelve specific aspects they investigated. One aspect that many biologists investigate is device-induced behavior, with 83% of studies showing some increase in preening and stretching rates, and 6% of studies documenting preening at the device (Barron et al., 2010). After attachment of the device, these behaviors can last from several minutes to a few weeks (reviewed by Calvo and Furness, 1992). To minimize adverse impacts, biologists typically recommend that the transmitter weigh less than 5% of the bird's body mass (Kenward, 2001).

Prior to our research in 2015 with adult Roseate Terns (*Sterna dougallii*) on Great Gull Island, researchers assessed the potential impacts of nanotags on breeding Common Terns (*Sterna hirundo*) at several colonies in New England (Loring, 2016; Loring et al., 2017). Because Roseate Terns are federally listed as endangered, it was essential that researchers critically evaluate the potential impacts of nanotags on a similar species. Biologists evaluated productivity (chicks produced per pair) of 50 Common Tern pairs in which one member had a nanotag compared to 50 control pairs (i.e., neither mate had a nanotag) in the same productivity plots at Monomoy NWR, MA, in 2013 and found no differences in chick fledging rates between groups (Loring, unpubl. data). This suggested that nanotags had no detrimental impacts on tern foraging behavior or nest attendance rates, thus we felt that the use of nanotags could be attempted on Roseate Terns.

During the 2015 field season we attached nanotags to adult Roseate Terns to investigate their local and regional movements. Nanotags are digitally coded VHF transmitters that allow thousands of individuals to be monitored on the same frequency. For studies with large sample sizes of tagged individuals, nanotags provide a major advantage over conventional VHF tags because they permit multiple individuals to be tracked continuously and simultaneously from a receiving station. For this study, we programmed nanotags to continuously transmit signals at 4–6-second burst intervals from activation through the end of battery life. VHF transmitters have been used successfully to assess movement ecology of other species of terns in the UK (Perrow et al., 2006). In the Unit-

ed States, Loring et al. (2019) used nanotags to assess the movements of more than 350 Common Terns (*Sterna hirundo*) in the western North Atlantic.

Due to the sensitive nature of capturing, handling, and tagging a listed species, we initiated a monitoring study to assess possible direct or indirect effects of nanotags on the movement, behavior, and nesting success of tagged individuals. For this study, we were interested in the short-term behavioral impacts of nanotags on adult Roseate Terns including 1) return times to their nest following attachment; 2) increased preening rates or evidence of pulling directly at the nanotag; 3) changes in nest attendance rates; and 4) decreased prey-delivery rates.

METHODS

All fieldwork was conducted on Great Gull Island, at the eastern entrance to Long Island Sound, where Helen Hays and colleagues have monitored Common and Roseate Terns since 1963 (Hays, 2007). Adult Roseate Terns ($N=30$) were captured by the Great Gull Island Roseate Tern crew between 19 and 25 June 2015. Adults were captured at their nests by members of the Roseate team using a variety of Potter-style treadle traps. Birds were trapped when their chicks were 0 to 2 days old (Cooper et al., 1970; Cormons, personal commun.). After capture, birds were transported to a central banding station, where they were processed: if unbanded, they were banded with a USGS band on one leg and a plastic field-readable band (Figure 1) on the other leg. Every bird was weighed, and the wing chord and bill length were measured. Field-readable bands have a unique alphanumeric code to facilitate monitoring. We attached a Lotek NTQB-4-2 nanotag (1.5 g; 12 x 8 x 8 mm; 163 days expected life; Figure 1) to one member of each targeted pair of adult Roseate Terns. The mean mass of adult Roseate Terns fitted



Figure 1. Adult Roseate Tern with a back-mounted, 1.5-g nanotag; note the antenna. This bird is banded with a USGS band on the left leg and a plastic field-readable color band on the right.

with a nanotag was 113.2 ± 5.6 (SD) g (range = 105.0 to 122.4 g). Therefore, nanotags accounted for a mean of 1.3% of body mass (range 1.2 to 1.4%). Each nanotag was back-mounted using epoxy (Warnock and Takekawa, 2003), and held in place with a suture at the proximal and distal ends of the nanotag. Tag attachment added approximately 10 to 20 minutes to the handling time of each bird captured for routine banding. We monitored movements of nanotagged adults using an automated receiving station at the colony site. The receiving station consisting of an SRX-600 receiver equipped with an array of four 5-element Yagi antennas (facing east, west, south, and north) mounted on a 12-m-tall observation tower located on south-central Great Gull Island within the nesting colony (Figure 2). The receiving unit was programmed to automatically log several types of data from each antenna including: transmitter ID number, time stamp (synchronized among all receivers in network using GPS clocks), antenna (defined by receiving station and bearing), and signal strength (nonlinear scale: 0 to 255). We were able to detect birds with nanotags up to 10 km from the receiving stations depending on the flight altitude of terns.

In 2015 there were nine blinds in various locations on Great Gull Island. Whenever possible, adults given nanotags were trapped on nests that could be observed from a blind. For behavioral observations, we monitored nests from blinds during 2-hour stints from 19 June to 3 July (i.e., when chicks were 12 to 14 days old by the end of observations). Blind stints occurred in the morning (06:00–12:00) and late afternoon (17:30–19:30). We monitored nanotag nests where one member of the pair had a nanotag ($N = 13$) and nearby control nests where neither adult had a nanotag (control pairs, $N = 9$).



Figure 2. Observation tower on Great Gull Island where four 5-element yagi antennas (two are shown—see red arrows) were mounted as part of the automated recording station to monitor movements of Roseate Terns during the 2015 breeding season.

To assess return rates (defined as the time in minutes from when a bird was released from the processing station until it returned to its nest), we estimated settlement near the nest site based on bearing and signal strength data. We did not attempt to assess return rates of nanotagged or control birds during blind stints as we did not have enough observers to monitor birds from blinds during banding operations. Using signal strength and bearing to assess the exact timing of return rates was not always feasible, particularly when terns entered their nests underneath rocks or when the bird was behind a large solid object, because we were not always able to continuously track all birds. Therefore, estimates of return rates might be longer than actual return rates. After initial banding operations were completed, we did have enough observers to monitor the behavior of nanotagged and control birds from blinds. The parameters we investigated during blind stints for nanotag and control pairs included: preening rates (proportion of time spent preening, which also included the number of times pulling on the nanotag or antenna), nest attendance (proportion of time spent at or near the nest), and chick provisioning (prey deliveries per hour). To compare behavior between nanotagged and control pairs, we compared the proportion of time that nanotagged and control adults preened and were detected at or near the nest based on visual detections and tag signal detections using a chi-square test. To assess differences between prey delivery rates of nanotagged and control adults, we used a non-parametric Mann-Whitney U-test because prey delivery rates were not normally distributed (Shapiro-Wilk Normality Test, $P < 0.05$). All descriptive statistics present mean \pm 1 standard error (SE), unless stated otherwise.

RESULTS

Of the 30 tagged Roseate Terns nests in our study, a total of 26 nests were within range of the central tracking tower to accurately determine return time of tagged birds to the vicinity of their nest sites. Based on signals detected from nanotags, the return times of Roseate Terns to the vicinity of their nest site following tagging was highly variable, averaging 2.12 hours (\pm 0.67 hrs; range = <0.01–14.70 hrs; Figure 3).

We were able to conduct 48 2-hour stints in blinds (5,778 total minutes of observations) to quantify the behavior of nanotagged ($N = 13$) and control ($N = 9$) adults. Each nest was studied on average for 276 minutes (range 106–602 minutes). There was no evidence of major differences in the behavior of adult Roseate Terns with nanotags compared to control terns. There was no difference in the average amount of time that nanotagged adults spent preening (mean = 2.4 ± 0.48 minutes per 2-hour stint) compared to control adults (2.7 ± 0.72 minutes per 2-hour stint; Mann-Whitney Rank Sum Test, $U = 606$, $df = 48$, 26 , $P = 0.61$), and we did not observe any device-induced behaviors such as adult terns pulling directly on the nanotag. There was no difference in the proportion of time that nanotagged adults attended their nest (0.77 ± 0.04) compared to control adults (0.82 ± 0.03 ; $\chi^2 = 0.78$, $df = 1$, $P = 0.38$). Prey delivery rates were

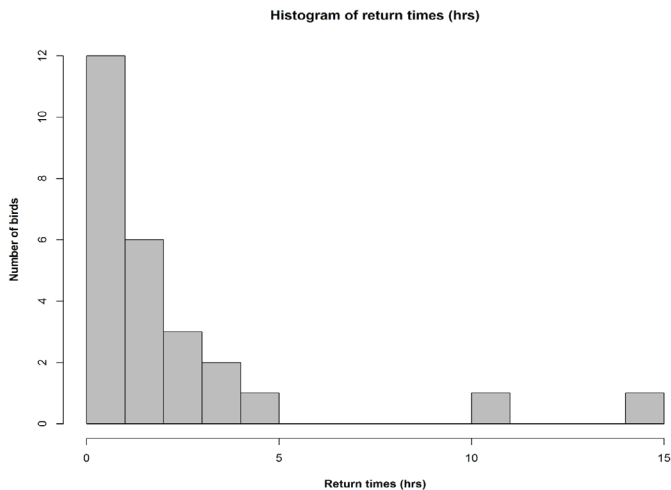


Figure 3. Return time (hours) of adult Roseate Terns ($N = 26$) to the vicinity of nest based on signal strength and direction following the attachment of a nanotag on Great Gull Island in 2015.

similar between nanotagged adults (1.60 ± 0.17 prey per 2-hour stint) compared to control adults (2.04 ± 0.34 prey per 2-hour stint; Mann-Whitney Rank Sum Test, $U = 571$, $df = 48,26$, $P = 0.38$; Figure 4).

DISCUSSION

We found no evidence that nanotags affected the behavior (e.g., preening rates, nest attendance rates) or foraging rates of adult Roseate Terns on Great Gull Island during the 2015 breeding season. This suggests that nanotags will not affect the productivity or survival rates of adult Roseate Terns on Great Gull Island or other sites. This result was not unexpected as Loring et al. (2017) found no effects of nanotags on the productivity or behavior of Common Terns nesting in four colonies from the Gulf of Maine to Massachusetts. In addition, during fieldwork and routine monitoring of Common Terns on Great Gull Island during the 2014 breeding season, there was no evidence to suggest adverse impacts on the behavior or productivity of Common Terns with nanotags (Loring, 2016). After adult Roseate Terns were released from tagging, we documented wide variation in the return times (mean = 2.1 hours, range = <0.01 to 14.70 hours) to their nest sites. Our estimate was similar to research conducted by Nisbet (1981), who trapped incubating adult Roseate Terns (i.e., eggs had been incubated for 17–22 days) and documented substantial variation in return times of adult Roseate Terns following trapping (median = 2 hours, range <1 to 18 hours), with no significant difference between birds that were banded and marked with patagial tags, and birds that were only banded. Peter Cormons (unpubl. data) found return times of adult Roseate Terns ($N = 9$) caring for 1–2-day-old chicks following trapping on Great Gull Island from 2 to 5 July 1995 aver-

aged 1 hour 14 minutes (range = 16 minutes to 2 hours 23 minutes) and adults left the nest unattended for an average of 32 minutes (range 3–55 min). Reasons for slight differences between Peter Cormons' results and our study are unclear, but could be due to differences in methodology (i.e., direct observation from blinds versus using signal strength of nanotags to assess return rates to nests). Eggs and chicks from unattended nests are vulnerable to predation, disturbance, and exposure (Carney and Sydeman, 1999; Nisbet and Weldon, 1984), thus it is important to insure that trapping efforts did not affect survival rates of eggs or chicks. We did observe the adult from an adjacent nest carry off one unattended Roseate Tern chick during trapping efforts, but this was the only evidence of a mortality event during our study. Nisbet (1981) found no significant difference in the productivity of Roseate Terns that were: 1) not trapped; 2) trapped and banded; and 3) trapped, banded, and marked with patagial tags, respectively, suggesting that initial effects of delayed return to nests observed for some of the birds following trapping did not adversely affect their ability to fledge chicks. Although our results suggest that nanotags have minimal impact on the nesting behaviors of Roseate Terns, tracking devices can have adverse impacts on other species of terns. Thus researchers need to be cautious when implementing new technology. For example, Massey et al. (1988) found that adult Least Terns (*Sternula antillarum*) abandoned nests, left nests unattended, and exhibited abnormal foraging behavior, but returned to "normal" adult behavior once the radio tags had fallen off. Other studies have found detrimental influences of transmitters on the foraging behavior of birds, particularly diving species (Wilson et al., 1986). Fortunately,

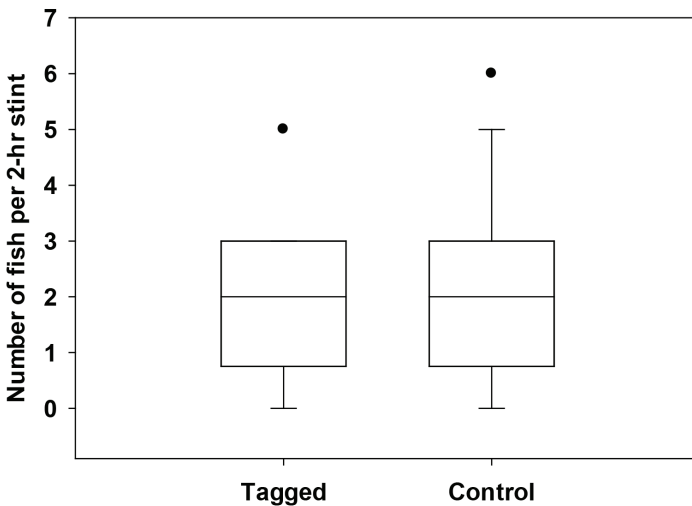


Figure 4. Prey delivery rates (number of fish per 2-hour stint in a blind) to Roseate Tern chicks on Great Gull Island, NY, in 2015; either one parent had a digital VHF transmitter (tagged) or neither adult had a transmitter (control). There was no difference between groups. Boxes represent median and 25–75th percentiles, whiskers are 5–95th percentiles, and black dots are outliers.

we never documented any evidence of the adverse impacts documented in those studies. Our findings agreed with Perrow et al. (2006) who found no apparent adverse effects of back-mounted transmitters on the behavior and nesting success of Little Terns (*Sternula albifrons*), and transmitters glued to the backs of Least Tern chicks did not influence their growth rate or movement, despite being 5–8% of a chick's weight (Whittier and Leslie, 2005). Nanotags are now being used on a wide variety of birds and bats to track local and regional movements (McGuire et al., 2012; Woodworth et al., 2015; Loring et al., 2018). The use of this tracking technology is increasing, as a coordinated network of receiving stations expands throughout North and South America and the Caribbean. This expanding tracking network has been formalized under the Motus Wildlife Tracking System and is coordinated by Bird Studies Canada (www.Motus-Wts.org). As of 2016, thousands of individuals representing a variety of different taxa (including shorebirds, songbirds, raptors, and bats) have been tracked with nanotags on the Motus network, and this number is expected to increase in future years (Motus, 2016). Thus it is imperative to understand the potential detrimental impacts that nanotags might have on target species, particularly for listed species and for studies that plan to tag large numbers of individuals. Our current assessment of the effects of nanotags on Roseate Terns suggests no detrimental impacts to nesting behavior and foraging rates. However, if Roseate Terns are tracked with different models of nanotags or other monitoring devices in the future, we suggest that the behavior of birds be monitored to insure there are no adverse impacts.

ACKNOWLEDGMENTS

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Using GPS and UAV to Map Common Tern Nesting Habitat on Great Gull Island

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ABSTRACT

In coastal New England, most Common Terns (*Sterna hirundo*) nest on offshore islands where sea level rise and invasive plants threaten habitat availability. Great Gull Island (seven ha) provides critical nesting habitat for approximately 10,000 pairs of Common Terns annually, making it one of the largest Common Tern colonies in North America. Accurately monitoring annual changes in habitat availability in relationship to the spatial distribution and abundance of terns nesting on Great Gull is challenging. Our method was to use two technologies, global positioning systems (GPS) and unmanned aerial vehicles (UAV), to rapidly quantify the spatial distribution of Common Terns nesting on Great Gull Island and develop a habitat map of the island, and then combine this information to model Common Tern nest-site habitat preferences. In 2015, biologists used handheld GPS units to map all Common Tern nest attempts ($N=8,867$) on Great Gull. We also collected digital images from a small UAV quadcopter for use in digitizing habitats on the island. Our models suggested that Common Terns on Great Gull Island nested most frequently in herbaceous vegetation (61.6% of nests) and on concrete platforms (16.5%), barren cobble or soil (10.7%), and asphalt paths (5.9%). These four preferred habitat types covered 4.1 ha (56.8% of the island), with an average nest density of

0.185 tern nests per m^2 in 2015. This approach to mapping the distribution of nest sites at a colony-wide scale, coupled with UAV imagery to assess habitat use patterns, adds another tool to aid biologists in making better management decisions.

INTRODUCTION

In the northwest Atlantic, most of the Common Tern (*Sterna hirundo*) population nests in large breeding colonies on offshore islands (1,000 to 10,000 pairs), in part to bolster anti-predator defenses of the colony (Nisbet et al., 2017). Adult Common Terns spend about two months of their annual cycle either incubating eggs or caring for young; thus, finding a suitable nest site is an important task (Nisbet et al., 2017). Intra- and inter-specific competition for space for nest sites can be high in these large colonies (Szostek et al., 2014). This is particularly true when invasive plants dominate the landscape, so maintaining suitable nesting habitat for Common Terns is a challenge for land managers (Lamb et al., 2014). In addition, in the northwest Atlantic, federally endangered Roseate Terns (*Sterna dougallii*) only nest in sympatry within these relatively large, established Common Tern colonies (Nisbet et al., 2014), which adds to the importance of maintaining and monitoring Common Tern colonies in the region. Although Common Tern nesting colonies have been studied for decades in the northwest Atlantic, there are few published studies that have quantified the spatial distribution and abundance of nests, particularly on offshore islands (see Nisbet et al., 2017).

Austin (1932) provided one of the first detailed maps of Common Tern nests in a study of 100 m^2 quadrats on a barrier island in Massachusetts, finding nest densities ranging from 0.25 nests per m^2 in a heavily vegetated quadrat to 0.71 nests per m^2 in a mixed open/grassy quadrat. Past research has shown that Common Terns will nest on the ground in a variety of open habitats (Houde, 1983; Richards and Morris, 1984; Burger and Gochfeld, 1988). On offshore islands, Common Terns generally select nest-site microhabitats that are in open areas with scattered vegetation, on substrates made of either rocks, open sand, or gravel (Blokpoel et al., 1978; Burger and Gochfeld, 1991). At Cedar Beach in New York, Burger and Gochfeld (1988) documented that Common Terns nested in areas with 10–25% cover of American beach grass (*Ammophila breviligulata*).

Accurately monitoring annual changes in the spatial distribution and abundance of Common Terns within large, offshore colonies is challenging. Sites such as Great Gull Island, NY, that can have more than 11,000 nesting pairs, require large crews to monitor the nesting population (Hays, 2007). Prior to 2015, crews on Great Gull would map each nest within a 25 x 25 m grid system staked out over the island. This approach is sufficient to understand broad-scale distribution patterns over a nesting island; however, it limits the ability to model fine-scale nest-site selection. The goals of the 2015 project were to use a new technological approach to develop a fine-scale, spatially explicit model of the distribution of Common Terns on Great Gull Island, construct an accurate

habitat map of the island using digital imagery collected from an unmanned aerial vehicle (UAV), and combine these two data sets to model nest-site preferences. Currently, consumer-grade global positioning system (GPS) units are accurate from 3–5 m (Wing et al., 2005) and are capable of rapidly and accurately mapping nest locations in a tern colony (e.g., Underhill et al., 2003). Recent advances in relatively low-cost UAV with digital cameras provide an opportunity to rapidly quantify vegetation composition on an offshore island (see Chabot and Bird, 2015). We were able to combine location data of nest sites with a vegetation map we developed from digital imagery to estimate habitat preferences of Common Terns on Great Gull. Rogers (2016) previously performed a sensitivity analysis and found that the 3–5 m spatial error in GPS locations did not affect the estimate of Common Tern nest-site habitat preferences.

METHODS

We conducted fieldwork on Great Gull Island, NY, at the eastern end of Long Island Sound. Great Gull Island (seven ha) is about 750 m long and 60–175 m wide. It has one of the largest Common Tern colonies in the world, with approximately 9,000–11,000 pairs nesting annually on the island (Hays, 2007) and also the largest Roseate Tern colony in North America, with about 1,100–2,000 nesting pairs. It holds the remains of a large, concrete fort from the Spanish-American War era (Fort Mitchie) (Duffy and LaFarge, 1972; Coulter, 1981) and is bordered by a large boulder revetment. The interior of the island has several steep berms associated with the fort that are mostly covered by woody vegetation, while the flatter areas are mostly covered in herbaceous vegetation. In addition, asphalt paths, concrete platforms, and dense cobble cover provide unvegetated nesting habitat throughout the island (Duffy and LaFarge, 1972; Coulter, 1981).

During the 2015 breeding season, teams of up to 24 volunteers carefully walked through the tern colony to map the spatial distribution of Common Tern nests on Great Gull. Nest-searching occurred on 30 of 48 days between May 23 and July 9, with most nests (more than 5,000) found on May 30 and June 6. Nests were marked with numbered, wooden tongue depressors to avoid double-counting nests on subsequent days. The crew used handheld GPS units (Garmin GPSMap 62sc), with the Wide Area Augmentation System (WAAS, Shellito, 2013) enabled to record the latitude and longitude of all nests found as GPS waypoints on the units' internal storage.

We downloaded location data from the GPS units using DNRGPS software and imported coordinates into ArcGIS (Environmental Systems Research Institute, v10.3 software, Redlands, CA) at the end of the breeding season. Several points had to be excluded from the analysis because they were located in the headquarters building or not located on the island. This is likely the result of volunteers not allowing time for the GPS units to acquire enough satellites for an accurate fix. We also generated a dataset of random points in ArcGIS to assess habitat preferences by comparing the nest locations.

To assess habitat availability on the island in 2015, we acquired high-resolution (5 cm pixel size) digital orthophotographs using a DJI Phantom 2 Vision+—a small (290 x 290 x 180 mm, 1160 g), quadcopter-style, unmanned aerial vehicle (UAV). The vehicle was GPS-stabilized and equipped with a three-axis gimbal that actively stabilized the proprietary camera and allowed for nadir photography. The camera had a f2.8 lens and a 14-megapixel 6.17 x 4.55 mm complementary metal-oxide-semiconductor (CMOS) sensor. Each flight was limited to approximately 20 minutes due to battery capacity. Six batteries (5200 mAh, 11.1 V lithium-polymer) were used and recharged on the island using a gas-powered generator. Flights occurred on August 22–23, 2014, prior to the 2015 nesting season. Complete coverage of the island required ten flights at an altitude of approximately 60 m with 75% frontal and 60% side overlap of individual photos. This overlap facilitated stitching individual photos into one orthometrically corrected mosaic using Pix4Dmapper software to conduct photogrammetry.

By interpreting the UAV orthophotography, we classified the island into nine habitat classes based on a minimum mapping unit size of 5 m². These included: 1) asphalt—approximately 3 m wide asphalt-covered pathways that traversed the island; 2) barren patches—non-vegetated areas covered by sand, cobbles (greater than 20-cm grain size), or firmly packed soil; 3) buildings—human-constructed brick structures that were remnants of the fort, with some used by researchers as living and working quarters; 4) concrete—cannon batteries and platforms that remained from Fort Michie and were unvegetated; 5) herbaceous—areas dominated by herbaceous vegetation species such as wild radish (*Raphanus raphanistrum*), seaside goldenrod (*Solidago sempervirens*), common lambsquarters (*Chenopodium album*), American pokeweed (*Phytolacca americana*), bindweed (*Convolvulus* sp.), Virginia creeper (*Parthenocissus quinquefolia*), prickly lettuce (*Lactuca serriola*), and other plant species that were generally sparse and short when the terns arrived for nesting in mid-May, but grew dense and taller as the growing season progressed; 6) phragmites—habitat patches where common reed (*Phragmites australis*) dominated; 7) rock—the artificial boulder rip-rap revetment that surrounds the island; 8) terrace habitat—man-made steps dug into steep berms with wooden shelters on each terrace for nesting Roseate Terns; and 9) woody vegetation—dense patches of woody shrubs or trees, mainly comprised of northern bayberry (*Morella pensylvanica*), Asiatic bittersweet (*Celastrus orbiculatus*), poison ivy (*Toxicodendron radicans*), and Japanese black pine (*Pinus thunbergii*).

We converted vector habitat polygons to raster format using a 10 cm pixel size because this was the size of a two-by-two patch of pixels in the orthoimagery and was the smallest discernible area that we could recognize in the photos. Each raster cell was assigned a value of either one if the habitat type was present or zero if absent.

To assess nest-site selection by Common Terns on Great Gull, we generated 8,867 random points (i.e., the same number as tern nest locations) using ArcGIS software. We quantified habitat characteristics at the random sites using protocols similar to those

for the tern nesting sites. We used chi-square analyses to compare random versus nest-site habitat profiles for categorical variables. Based on the habitat preference analyses, the nine habitat types were classified as either preferred or avoided. We then generated a dataset of 100 random points, stratified by preference (50 points in preferred habitats, 50 points in avoided habitats). We calculated the kernel density of Common Tern nests using a 10-m search radius in ArcGIS and extracted the kernel density values at the locations of those 100 random points. We then compared the mean kernel density of preferred habitat to that of avoided habitat using ANOVA.

We also assessed the influence of slope on the density of Common Tern nests. We created a slope raster from a digital elevation model with 1 m resolution that had been derived from aerial light detection and ranging (LiDAR) data acquired in 2014 by the New York State Department of Environmental Conservation and downloaded from the New York State GIS Clearinghouse website. In this way, we extracted slope and nest density at the 100 random locations on the island. All statistical analyses were conducted using Microsoft Excel and R software (R Core Team 2013).

RESULTS

Based on our interpretation of digital imagery, the three dominant habitat types on Great Gull Island in 2015 were herbaceous (2.7 ha, 38.6% of the island), rocks (1.8 ha, 25.5%), and woody vegetation (1.0 ha, 14.3%) (Table 1, Figure 1). During the 2015 breeding season, we recorded the locations of 8,867 Common Tern nest sites (Figure 2), which primarily occurred in either herbaceous areas (62%), on concrete (16%), or in barren areas (11%). Our analysis showed that Common Terns preferred to nest in four

Table 1. Summary statistics for nine habitats on Great Gull Island in 2015, including the total number of Common Tern and random nests estimated in each habitat type. Habitats that were avoided or preferred, based on significant chi-square tests $P < 0.001$, are also shown.

Habitat type	Hectares	% of Island	Number of Nests	% of Nests	% of Random Points	Avoided or Preferred
Asphalt	0.24	3.4%	521	5.9%	3.6%	Preferred
Barren	0.37	5.3%	949	10.7%	5.2%	Preferred
Building	0.09	1.3%	1	0.1%	1.3%	Avoided
Concrete	0.74	10.6%	1459	16.5%	10.9%	Preferred
Herbaceous	2.70	38.6%	5458	61.6%	37.7%	Preferred
Phragmites	0.04	0.6%	29	0.3%	0.7%	Avoided
Rock	1.78	25.5%	196	2.2%	26.3%	Avoided
Terrace	0.03	0.4%	14	0.2%	0.4%	Avoided
Woody	1.00	14.3%	240	2.7%	13.9%	Avoided
Total	6.99		8867			

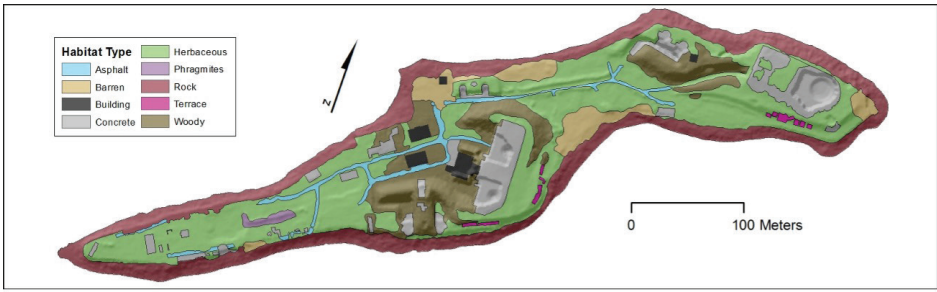


Figure 1. Estimated distribution of nine habitat types on Great Gull Island in 2015 based on our interpretation of digital imagery collected from a UAV. The shaded relief data that serves as the basemap for this and subsequent maps of the island was derived from the 1 m digital elevation model created from the 2014 LiDAR data.

habitat types—asphalt, barren, concrete, and herbaceous—while avoiding five habitat types: on buildings, in phragmites, on rocks or terraces, and in woody areas (Chi-square tests, $P < 0.001$, Table 1).

The density of nests on the island ranged from 0.0 to 0.67 nests per m^2 , with an average of 0.12 nests per m^2 (Figure 3). Mean nest density in preferred habitats (average = 0.185, SD = 0.107 nests per m^2) was significantly greater than nest density in avoided habitats (average = 0.042, SD = 0.066 nests per m^2 (ANOVA, $F = 65.2$, $P < 0.001$, Figure 4). Common Terns preferred to nest in areas that were relatively flat, with an average slope of 7.9 degrees in preferred habitats and a slope of 15.2 degrees in habitats they tended to avoid (Figure 5). In flatter areas (with slopes less than 15 degrees), nest density ranged from an average of 0.0–0.51 nests per m^2 , while ranging from 0.0–0.14 nests per m^2 in areas with steeper slopes (greater than 15 degrees).

DISCUSSION

To our knowledge, this study represents the first attempt to develop a fine-scale map of the distribution of Common Tern nests within an entire large colony in the United States. This fine-scale baseline map will be useful to track changes in the spatial distri-

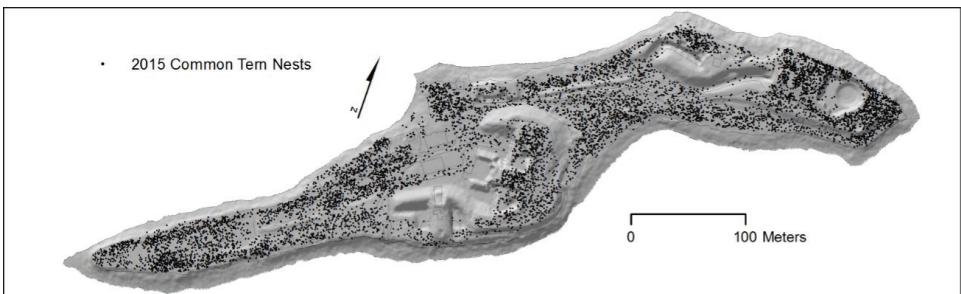


Figure 2. Spatial distribution of 8,867 Common Tern nests (•) detected on Great Gull Island, NY, in 2015, based on data collected from handheld GPS units (accuracy = 3–5 m).

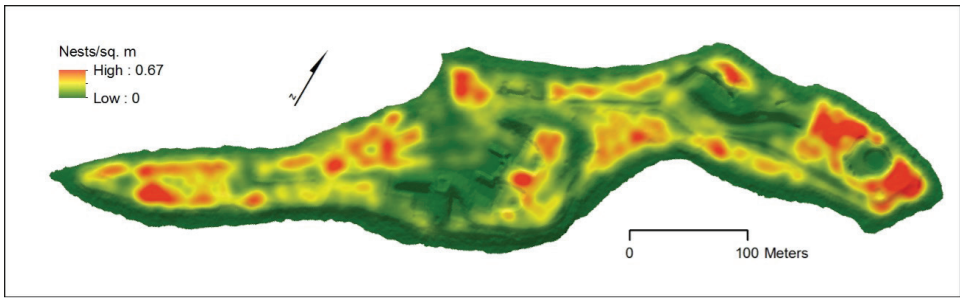


Figure 3. Estimated kernel density (nests per m^2) of Common Tern nests on Great Gull Island, NY, during the 2015 breeding season. Nest density was calculated using a 10 m search radius around each nest (see Fig. 1).

bution of terns nesting on Great Gull Island. Historically, tern nests on the island and in adjacent colonies have been mapped using grid systems of various resolutions, which is fine for most management purposes. However, recent advances in technology such as GPS and UAV permit managers to develop more accurate, fine-scale maps of colonies (e.g., Sardà-Palomer et al., 2014).

Great Gull Island ranks among the most important tern colonies in eastern North America. Thus, tracking changes in the spatial distribution and abundance of both Common and Roseate Terns is vital. There were approximately 3,941 breeding pairs of Roseate Terns in North America in 2015, with 89% of the population nesting on two islands in Massachusetts (Bird and Ram) and one island in New York (Great Gull) (Mostello, 2016). Great Gull Island has consistently been the largest Roseate Tern colony in the United States and Canada, accounting for 33–51% of the total Roseate Tern population from 1988 to 2015. There are approximately 150,000 breeding pairs of Common Terns in North America (Nisbet, 2017). The Common Tern colony on Great Gull Island,

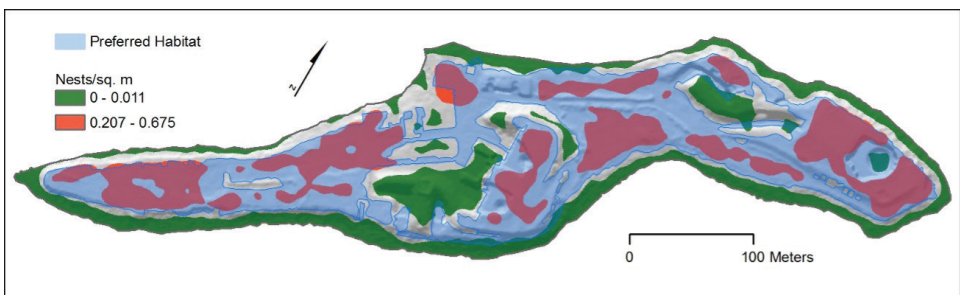


Figure 4. Estimated spatial distribution of Common Tern nest sites in preferred habitats on Great Gull Island in 2015. (Preferred habitats—*asphalt, barren, concrete, herbaceous*—shown in light blue.) Areas with relatively low density of Common Tern nests shown in green (lowest quartile of nest density) and high nest density shown in red (highest quartile). High-density areas are almost completely with the preferred habitat classes, while low-density areas are almost completely excluded. Mid-density areas (second and third quartiles) are excluded for clarity.

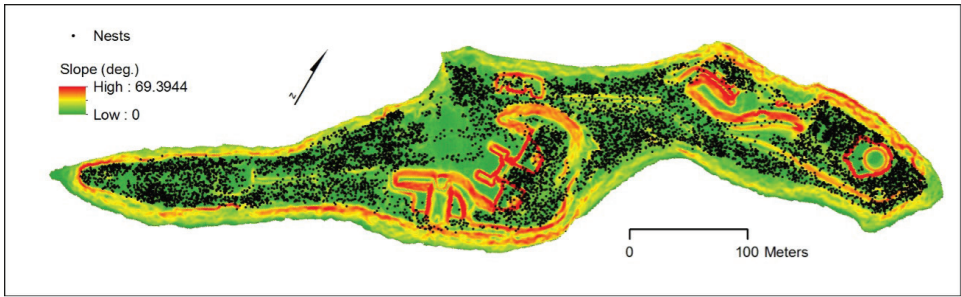


Figure 5. Spatial distribution of Common Tern nests on Great Gull in 2015 in relationship to slope (degrees). Common Terns prefer to nest in relatively flat areas with slopes of less than 15 degrees.

which has from 9,000 to 11,000 pairs annually (Hays, 2007), ranks among the largest Common Tern colonies in North America (Nisbet et al., 2017).

Much still needs to be learned about how to properly manage Common Tern nesting habitat in the northwest Atlantic (Lamb et al., 2014). Using GPS and UAV technology to map tern nests provides several advantages over traditional quadrat-based methods, particularly for large colonies such as the one on Great Gull Island as compared to smaller colonies (e.g., Severinghaus, 1982). The most obvious advantage is the increase in spatial accuracy of maps. Rogers (2016), using data collected on Great Gull, found that if GPS units are accurate to within a 5 m radius (Wing et al., 2005), there will be no significant error in habitat classification. Furthermore, using GPS to determine nest locations and UAV imagery to delineate habitat results in greatly increased mapping resolution. These data can be analyzed to look for patterns in distribution and density that cannot be detected without this spatial resolution.

Having individual biologists collect locations with a GPS unit also increased the efficiency of data collection. It takes less than ten minutes to teach field crews how to collect waypoints on GPS units; they can therefore begin collecting data on their own very quickly. Previously, crew members recording grid coordinates had to ask their leaders repeatedly which grid cell they were currently in, as it was often challenging to see grid stakes. In addition, over time, the stakes marking and labeling the corners of each grid were lost or destroyed. Therefore, nest densities were reported using the distance to the nearest neighbor from a sample of nests (Burger and Lesser, 1978; Burger and Gochfield, 1988; Richards and Morris, 1984) or by counting the number of nests in plots (Houde, 1983). The current approach allows biologists to map changes in nest density (with multiple years of data) for the entire colony, minimize disturbance to nesting terns by spending less time in the colony, and better assess whether management is appropriate.

There are several threats to tern nesting habitat on Great Gull Island, including sea level rise (Sallenger, 2012), an increased number of storm events (Bender et al., 2010),

and invasion by exotic plant species (Lamb et al., 2014). Sea level rise and an increased number of storm events will result in severe erosion and directly reduce the size of the island and the area available for terns to nest. Invasive plants are currently a major management concern on Great Gull Island, exacerbated by terns fertilizing plants with guano (Lamb et al., 2014). Some herbaceous vegetation, in particular wild radish, becomes too dense and too tall for adult terns to access and efficiently feed their chicks. Thus, having detailed vegetation maps will help land managers decide where to target vegetation control measures. These problems are prime examples of how using recent technological advances to map terns and their habitat will aid biologists in monitoring the effects of their management treatments.

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Assessing the Movement Ecology of Roseate and Common Terns During the Breeding Season: A Case Study from Great Gull Island

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Abstract

This case study presents preliminary movement data for two terns, one adult Common Tern (*Sterna hirundo*) and one adult Roseate Tern (*Sterna dougallii*), tagged with digital VHF transmitters on Great Gull Island in 2015 as part of a larger assessment of regional movements of terns in southern New England and Long Island. Signals from the tagged terns were tracked using an array of 15 automated radio telemetry stations extending from Cape Cod, Massachusetts, to Long Island, New York. Colony attendance decreased over time from the tag deployment (within three days of chick hatching) through their chicks' post-fledging period, and overall was higher during night versus day. During their chicks' pre-fledging period, both tagged adults regularly commuted to sites up to 50 km from the nesting colony. Both adults were last detected at the nesting colony in early August and departed from the study area on a northwest trajectory into Long Island Sound.

Introduction

Information on the movement ecology of seabirds in nearshore and offshore ocean habitats is important to their conservation (Burger and Shaffer, 2008). However, technologies for tracking the movements of small-bodied birds (<150 g) are limited due to weight limitations of tracking devices—generally <3–5% of body weight (Fair et al., 2010; Hawkins et al., 2004). For small-bodied species, radio telemetry remains one of the sole options

for collecting frequent, high-accuracy (optimally <10 m) location data over extended durations (Ponchon et al., 2013). Advances in digital VHF tracking technology now make it possible to track thousands of individuals on a single VHF frequency using a coordinated network of automated radio telemetry stations (Taylor et al., 2017).

We used digital VHF technology to track the regional movements of two small-bodied seabirds that are classified as being of conservation concern in the western North Atlantic: Common Tern (*Sterna hirundo*), state-listed in New York as threatened; and Roseate Tern (*Sterna dougallii*), federally listed as endangered. We conducted our research on Great Gull Island, the largest breeding colony of both species in North America (Hays, 2007). Our specific objectives were: 1) examine colony attendance patterns during the chick-rearing (pre-fledging) versus post-breeding (after fledging) periods; 2) quantify distance, duration, and timing of foraging trips; and 3) determine the dates and time of day of departure from the nesting colony during the post-breeding period. For this case study, we present preliminary movement data for two adults, one Common Tern and one Roseate Tern. A more detailed summary of all individuals monitored during the 2014 and 2015 field seasons will be presented elsewhere once more detailed analyses are completed.

METHODS

All fieldwork in 2015 was conducted on Great Gull Island (GGI), a 17-acre site in eastern Long Island Sound, NY, that supports one of the largest concentrations of nesting Common Terns (approximately 9,500 pairs) and Roseate Terns (approximately 1,800 pairs) in the Western Hemisphere (H. Hays and G. Cormons, unpubl. data). GGI is managed by the Great Gull Island Project with the American Museum of Natural History. In 2015, we monitored the movements of 31 Common Terns and 30 Roseate Terns. We randomly selected the movements of one adult female Common Tern and one adult female Roseate Tern to summarize for this paper. The Common Tern with USGS band number 1242-70450 (hereafter Common Tern #450) was first banded on 29 June 2007 as an adult and estimated to be at least ten years old in 2015. The Roseate Tern with USGS band number 1242-79784 (hereafter Roseate Tern #784) was first banded on 19 June 2009 as a chick; she was also given a metal field-readable (MFR) band (84/8N). She was six years old in 2015.

Biologists on Great Gull Island used walk-in treadle traps to capture adult Common Terns at their nest site (Burger et al., 1995) and modified treadle traps to capture Roseate Terns (Cormons, 2022). Common Tern #450 was captured on 21 June 2015 on a nest with two chicks, with one chick banded with a USGS band on 24 June 2015. Roseate Tern #784 was captured on 22 June 2015 on a nest with a single newly hatched chick banded earlier on 22 June, with a USGS band as well as a dark blue plastic field-readable (PFR) band with three white alphanumeric digits (L46). The adult birds were brought back to a central processing station where biologists recorded band information, wing chord (mm), weight (g), and culmen (mm) measurements and collected three to five contour

feathers for molecular-based gender determination by Avian Biotech, Gainesville, FL. The mate of Roseate Tern #784 was banded with a USGS band as well as a dark blue PFR band (V71).

We fitted each bird with a digital VHF transmitter made by Avian NanoTag, Lotek Wireless, Inc., Newmarket, Ontario, Canada. Each transmitter body measured 11 mm x 8 mm x 7 mm, and had custom-fitted tubes (inner diameter 1 mm) at the anterior and posterior ends for attachment sutures, and a 15-cm whip antenna. Transmitters were programmed to transmit signals on 166.380 MHz every five to six seconds over an expected operational life of 163 days. We attached the transmitters to the inter-scapular region using epoxy and two subcutaneous sutures (Warnock and Takekawa, 2003). Total weight of each transmitter was 1.5 g, which was < 2% of the body mass of the birds in our study. Total handling time, from capture to release, for each individual ranged from 20 to 40 minutes per individual.

To assess tern movements on and away from Great Gull Island during the 2015 chick-rearing and pre-migratory staging periods, we strategically deployed an array of 15 automated telemetry stations at coastal and island sites throughout southern New England and Long Island (Figure 1). Each telemetry station consisted of six nine-element Yagi antennas (60° apart) mounted radially atop a 12.2-m mast. In addition, on Great Gull Island we mounted four five-element Yagi antennas to the 12-m observation tower near the center of the island within the tern colony to monitor nest attendance and local movement patterns.

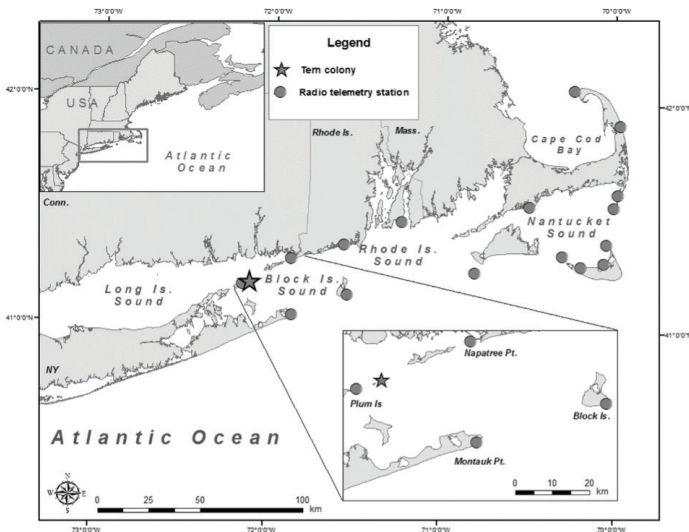


Figure 1. Map of study area in the western North Atlantic Ocean, showing the locations of the tern colony on Great Gull Island, NY (star) and of 15 automated radio telemetry towers (points) distributed from Long Island, NY, to Cape Cod, MA. Callout box shows the locations and names of major foraging areas for terns within the vicinity of Great Gull Island.

We attempted to obtain nearly continuous data from tagged birds when they were within range of a receiving station. At each automated radio telemetry station, a Lotek Wireless SRX600 receiver automatically logged several types of data from each antenna, including: tag ID number, date, time stamp, antenna (defined by monitoring station and bearing), and signal strength (non-linear scale: 0–255). Each receiving station was operated 24 hours per day using a 100-watt solar panel and two 12 v deep-cycle batteries. The digital VHF transmitters had sufficient battery power to transmit signals every 5–6 seconds from deployment until post-breeding dispersal from the study area.

Data Analysis

We used the program R (v. 3.2.3; R Core Team 2015) and associated packages to generate all summary statistics and plots. To estimate colony attendance rates, we calculated the proportion of time each day that tagged birds were within range of the colony receiving station on Great Gull Island. We classified long-distance flights as any time a tern was detected at a station farther than 5 km from Great Gull (i.e., not detected from the Great Gull or Plum Island stations). We estimated the kilometers traveled during long-distance flights based on the straight line (Euclidean) distances between tracking stations, so all distance estimates should be considered a minimum. We estimated the duration of long-distance flights as the difference between the times of departure from and return to Great Gull and the times when terns were detected by stations away from Great Gull. For comparisons between the chick-rearing and post-breeding periods, we assumed that the fledge date of each bird was 25 days after the hatch date (Nisbet, 2002; Nisbet et al., 2014). When birds were no longer detected by the Great Gull tower and were detected by stations away from Great Gull, we assumed they had departed for post-breeding staging areas prior to fall migration. Throughout this paper, we present mean \pm SE unless stated otherwise.

RESULTS

Colony Attendance

During the chick-rearing period (hatch to fledging), Roseate Tern #784 occurred within the vicinity of the nesting colony an average of 65% (\pm 3%; range 41–90%) of the time each day, while Common Tern #450 occurred within the nesting colony an average of 50% (\pm 3%; range 21–74%) of the time each day (Figure 2). During the post-breeding period (chick fledging to adult dispersal), the average time spent in the colony per day decreased to 28% (\pm 4%; range 2–65%) for Roseate Tern #784 and 38% (\pm 4%; range 1–67%) for Common Tern #450. Throughout the breeding and post-breeding periods, both individuals consistently stayed on Great Gull Island during nighttime hours, with little evidence of nocturnal movements away from the island (Figure 3). However, Common Tern #450 spent less time in the colony during daytime hours compared to Roseate Tern #784 (Figure 3).

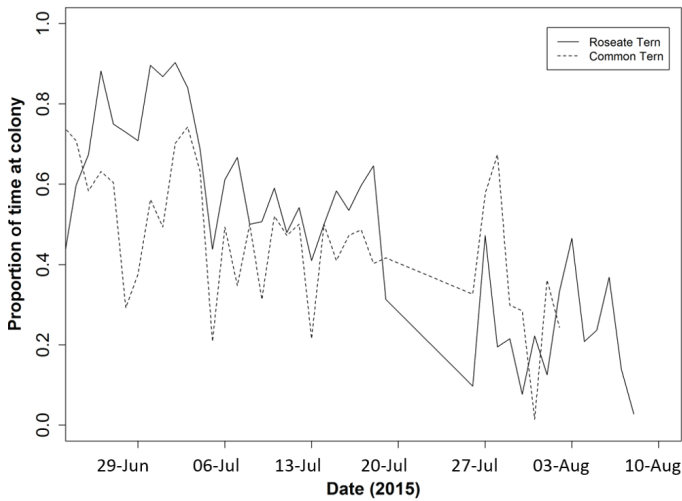


Figure 2. Daily proportion of occurrence within the nesting colony of a VHF-tagged adult female Roseate Tern #784 (solid line) and a VHF-tagged adult female Common Tern #450 (dashed line) on Great Gull Island in 2015.

Long-distance Flights

For Roseate Tern #784, we tracked a total of 25 long-distance flights over the course of 14 days, ranging from one to three flights per day (Figure 4). All long-distance flights occurred during the chick-rearing period. The long-distance flights had a mean (\pm SE) distance of 60 km (\pm 4 km, range 45–105 km), and a mean duration of 206 min (\pm 21 min; range 95–560 min). Roseate Tern #784 tended to fly to Napatree Point, RI, in late June and early July, whereas flights to Montauk Point, NY, occurred throughout July. There were four trips over two different days to Block Island, RI, which is approximately

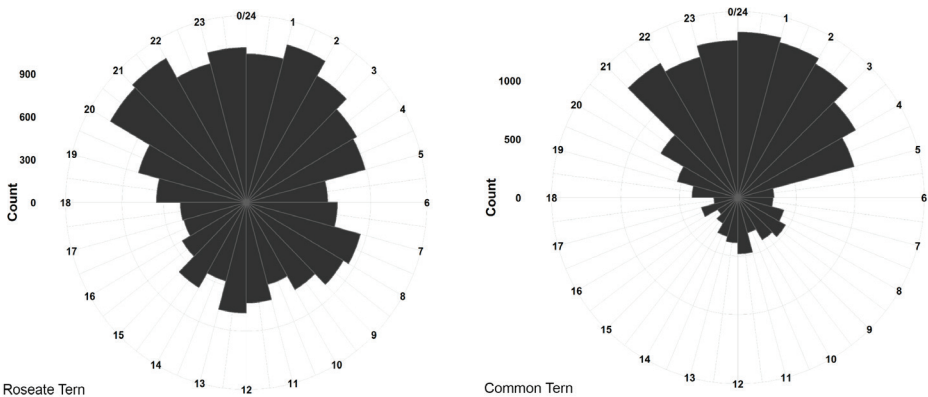


Figure 3. Temporal distribution of occurrence within the nesting colony of VHF-tagged adult female Roseate Tern #784 (left) and VHF-tagged adult female Common Tern #450 (right) on Great Gull Island in 2015. Count values show total number of minutes that each tern was detected within each hourly segment.

47 km from the nesting colony. Two of these trips to Block Island also included a stop at Montauk, resulting in a total trip distance of more than 100 km.

For Common Tern #450, we tracked a total of 22 long-distance flights over the course of 18 days, ranging between one and two flights per day (Figure 4). The flights had a mean (\pm SE) distance of 61 km (\pm 4 km, range 29–103 km), and a mean (\pm SE) duration of 298 min (\pm 35 min; range 146–937 min). Flights to Montauk Point, NY, occurred from late June through late July (Figure 4). Similar to Roseate Tern #784, Common Tern #450 flew to Block Island five times in mid-July, with each flight occurring on a different date. The majority (83%) of long-distance flights that we recorded for Common Tern #450 occurred during the chick-rearing period, with the remaining 17% occurring during the post-breeding period. For both species, all long-distance flights were primarily detected during daylight hours, from dawn (0413 hrs) to late in the evening (2152 hrs) (Figure 4), with the exception of Common Tern #450, which left the colony at 1830 hrs on 19 July, headed toward Montauk, and did not return to Great Gull until 0950 hrs the next morning.

Tracking Duration and Colony Departure

We tracked Roseate Tern #784 for 46 days, and Common Tern #450 for 41 days. Assuming that their chicks fledged 25 days after the hatch date, we tracked Roseate Tern #784 for a total of 21 days into the post-fledging period, and Common Tern #450 for a total of 17 days during the post-fledging period. For post-fledging dispersal, Roseate

Tern #784 departed from Great Gull Island on the evening of 7 August at 1945 hrs. Interestingly, there were no documented long-distance move-

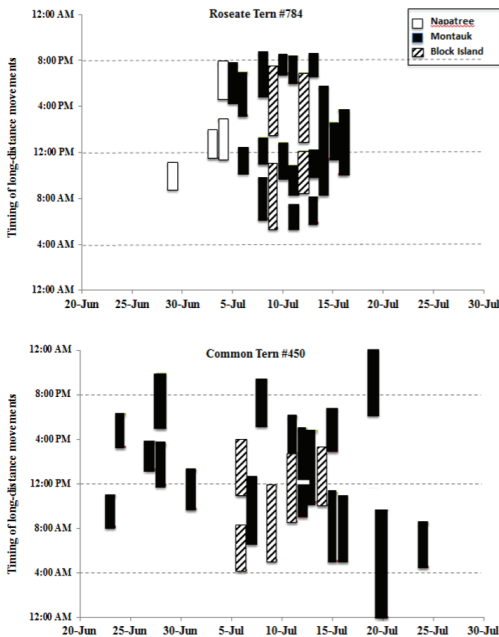


Figure 4. Daily variation in the long-distance movements of a VHF-tagged adult female Roseate Tern #784 (top panel) and a VHF-tagged adult female Common Tern #450 (bottom panel) from their nesting colony on Great Gull Island to probable foraging sites, based on detections from telemetry towers at Napatree (open bars), Montauk (black bars), and Block Island (striped bars) (see Figure 1). Bars represent the length of time (min) from departure to arrival for a specific flight from Great Gull Island. VHF-tags were placed on Common Tern #450 on 21 June and Roseate Tern #784 on 22 June. Roseate Tern #784 had one chick that fledged on approximately 16 July.

ments of Roseate Tern #784 from 16 July (the estimated fledging date of her chick) to 7 August, when she departed from the colony (Figure 4). Common Tern #450 departed from Great Gull Island on 2 August at 0306 hrs. Both terns, on different dates, passed by the telemetry station on Plum Island (3.6 km southwest of Great Gull Island) and continued along a northwest trajectory toward coastal Connecticut and western Long Island Sound until vanishing from detection range.

DISCUSSION

Colony Attendance and Foraging Movements

We found that during the chick-rearing period, both Common Tern #450 and Roseate Tern #784 were regularly away from Great Gull Island for three to five hours daily. Birds often traveled a cumulative distance of over 60 km from Great Gull, with some flights as far as 103 km. The purpose of these long-distance trips is uncertain, although they might have been foraging trips. These trips occurred in July when chicks were growing rapidly and in need of lots of food. We documented multiple trips by both Common Tern #450 and Roseate Tern #784 to Block Island, RI, which is over 45 km from Great Gull. These flights were up to three times farther than previously published estimates of flight distances or flight duration for either species. In 1976, Duffy (1986) conducted detailed observations from a six-meter boat of the foraging ecology of Common and Roseate Terns nesting on Great Gull Island and 11 adjacent colonies in eastern Long Island. He estimated that the majority of Common and Roseate Terns foraged within 4–12 km (maximum of 22 km) from Great Gull Island, and Common Terns in particular preferred to forage at a site 5.5 km from the nesting colony.

Other studies investigating tern movements found much shorter travel distances than those we documented in Long Island Sound. In the German North Sea, Becker et al. (1993) tracked Common Terns with conventional VHF transmitters and estimated cumulative flight distances of 30 km that took 115 min (maximum = 563 min), with terns typically foraging within a six km radius of their nesting colony. Perrow et al. (2011) tracked foraging flights of Common Terns off the English coast by following them in a rigid-hulled boat and estimated cumulative flight distances of 29 km that were up to 9 km from the nesting colony. Rock and Leonard (2007) radio-tracked Roseate Terns from a plane and found birds foraging up to 7 km from their nesting colony in Nova Scotia. Differences between the flight distances and durations observed in our study and those found in previous research are probably due in part to technological differences. The tower network established for this study was much more effective at detecting long-distance movements than conventional VHF transmitters or following birds in a boat (Perrow et al., 2011), although the spatial distribution of prey near other colonies presumably also affects foraging movements (Duffy, 1986; Nisbet, 2002; Nisbet et al., 2014).

During this study, long-distance trips for both terns occurred primarily during the daylight hours, and signals from the transmitters of both individuals suggested that

colony attendance was highest during the nocturnal period. The diel timing of long-distance flights seemed to vary as their chicks became older. For about two weeks after the chicks hatched, neither adult female initiated long-distance flights. It was only during the second half of the chick-rearing period that either adult embarked on early morning flights or was away from the colony for extended periods on long-distance flights. These temporal patterns are somewhat consistent with previous findings that Common and Roseate Terns primarily foraged diurnally during the chick-rearing period, with peak long-distance movements during the early morning and late afternoon (Nisbet, 2002; Nisbet et al., 2014). Working with a congener, Forster's Terns (*Sterna forsteri*) in California with an automated data-logger, Bluso-Demers et al. (2010) also documented high colony attendance rates at night by both adult parents. In addition, the decrease in daytime attendance (20–60%) of pre-fledged chicks as they reach fledgling age is consistent with past studies (Wiggins, 1989; Nisbet et al., 2014).

Departure from the Colony

The individuals in our case study departed from the colony in early August, between 17 and 21 days following the estimated fledge dates of their chicks, which is similar to departure timing documented by other studies (Nisbet, 1976; Nisbet et al., 2014). Both birds departed from the study area on a northwest trajectory over Long Island Sound and were not detected at sites elsewhere in the telemetry array, including Cape Cod, MA, where large numbers of Common and Roseate Terns are known to stage prior to their southward migration (Trull et al., 1999). The chick of Roseate Tern #784 (PFR L46) was detected with the male parent (PFR V71) at North Beach, Chatham, on Cape Cod, between 13–16 August 2016 and near Provincetown on the Cape on 20 September 2016, with one begging observation between the chick and PFR V71, whereas Roseate Tern #784, the female parent, was never detected staging at Cape Cod during 2015 (Cape Cod Roseate Tern Resighting Project, personal commun.). Although MFR bands are harder to detect than PFR bands, this suggests that the nanotagged Roseate Tern #784 never staged at Cape Cod and the adult male took prime responsibility for caring for the chick. It is possible that both Roseate Tern #784 and Common Tern #450 used staging areas on Long Island (Nisbet, 2002; Nisbet et al., 2014) prior to their migratory departure from the region; however, we did not have any additional telemetry stations west of Plum Island. With an expanding network of coordinated radio telemetry stations along the Atlantic shoreline (www.motus.org), however, it may be possible to track movements of terns to additional staging and migratory destinations using VHF technology in the near future.

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Using Nest Cameras and Automated Telemetry to Monitor Chick Provisioning by Common and Roseate Terns

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ABSTRACT

Biologists routinely collect observational data of tern chick provisioning during the breeding period but relying on observations alone can make it challenging to identify individual birds and prey items during feeding events that often happen very quickly. In this study, we used standard visual observation techniques from blinds in conjunction with digitally coded very high frequency (VHF) telemetry and high-resolution nest cameras to assess chick provisioning by nesting adult Common and Roseate Terns on Great Gull Island, New York, in Long Island Sound. Sand lance comprised nearly all of the prey items delivered by Roseate Terns to their chicks and the majority of prey items delivered by Common Terns to their chicks. For both species, the length of sand lance prey items delivered increased as the age of the chicks increased, but nest attendance by adults decreased. Combining high-resolution camera technology with digital VHF telemetry and observational stints was effective for individual-based monitoring of prey selection, delivery rates, and nest attendance patterns. We recommend that future

Keywords: Common Tern, Roseate Tern, chick provisioning, Great Gull Island, nest cameras, VHF telemetry, sand lance, GoPro Hero 4

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studies use cameras in conjunction with standardized blind observation techniques to maximize the quality and quantity of information collected during provisioning studies.

INTRODUCTION

In the western North Atlantic region, Roseate Terns (*Sterna dougallii*) only nest on offshore islands sympatrically with Common Terns (*Sterna hirundo*) (Safina et al., 1990; Nisbet et al., 2014). Previous research has documented habitat segregation between these two species at nest sites (Burger and Gochfeld, 1988), as well as interspecific differences in foraging sites and prey selection (Safina, 1990a, 1990b; Safina et al., 1990), although they often forage together in mixed species flocks for the same prey species (Safina, 1990b). Available evidence suggests that Roseate Terns primarily forage for sand lance (*Ammodytes* spp.) in shallow, warmer waters near shoals and rip currents close to shore (Safina, 1990b; Safina et al., 1990; Heinemann, 1992; Rock et al., 2007). In contrast, Common Terns tend to feed on a broader array of fish species in deeper, colder waters, often for forage fish driven to the surface by bluefish (*Pomatomus saltatrix*) (Safina, 1990b; Safina et al., 1990). Studies monitoring chick provisioning of nesting seabirds provides critical information on their prey, a key influence on fledging success.

Tern biologists have historically quantified chick provisioning rates using binoculars or spotting scopes from observation blinds to monitor one or more selected nests for a standardized period of time (Kress and Hall, 2004). This sometimes requires uniquely marking adult terns with colored leg bands such as plastic field-readable bands or temporary dyes to differentiate among adults at study nests (Safina et al., 1990). However, these unique visual identifiers may be obscured or missed altogether during chick provisioning stints, and temporary markers may fade before the end of the study period (Wagner and Safina, 1989). In addition, identifying and estimating the size of prey items can be challenging because prey exchanges often only take a few seconds and are often obscured by vegetation or nesting substrates (e.g., with nest boxes or cavities in rocks). These challenges can introduce bias due to observer experience levels, missed delivery events, and misidentification of prey items, negatively impacting the quality and quantity of data collected (Cezilly and Wallace, 1988; Gaglio et al., 2016).

In this study, we used standard visual observation techniques from blinds, in conjunction with digitally coded very high frequency (VHF) telemetry and high-resolution nest cameras, to assess chick provisioning rates by nesting adult Common and Roseate Terns on Great Gull Island, New York, in Long Island Sound. Digitally coded VHF transmitters allow large numbers of individuals to be uniquely and simultaneously identified on a single VHF frequency (Taylor et al., 2017). This technology allowed us to accurately identify uniquely tagged terns during chick provisioning events with a high detection probability (continuous monitoring by automated receivers) and temporal resolution (transmitters emit signals every ~5 seconds). Using

nest cameras in conjunction with observations from blinds allowed observers to verify identification of prey species and length estimates post-hoc using time referenced high resolution imagery.

Our primary objectives were to investigate the efficacy of these new technologies to quantify for nesting adult Common and Roseate Terns the following parameters: 1) the species of fish and length of prey items delivered to chicks; 2) prey delivery rate (prey items per hour) to chicks; 3) interspecific and gender differences in prey selection and provisioning flight duration; and 4) variation in nest attendance by members of a pair.

METHODS

All fieldwork was conducted on Great Gull Island, NY, which is a field station operated by the Great Gull Island Project of the American Museum of Natural History located in the Long Island Sound, New York (Hays, 2007). In 2016, approximately 8,500 pairs of Common Terns and 1,800 pairs of Roseate Terns nested on Great Gull Island (H. Hays and G. Cormons, unpubl. data).

From 17–18 June 2016, staff and volunteers with the Great Gull Island Project used walk-in traps to capture adult terns at their nest sites. We attached digitally coded VHF transmitters to adult Common Terns (N=30) and Roseate Terns (N=30) as part of a larger study investigating offshore movements of terns throughout the Atlantic Coast of the United States (Loring et al., 2016). Digitally coded VHF transmitters weighing approximately 1.5 g (12 x 8 x 8 mm; 163 days expected life) were attached to the interscapular region using cyanoacrylate adhesive and two subcutaneous sutures. All transmitters were programmed to continuously transmit signals at 4–6 second burst intervals from activation through the end of battery life.

We assessed chick provisioning for a subset of tagged individuals (10 Common Tern nests and 18 Roseate Tern nests). Selected nests were all visible from existing observation blinds. We marked each nest or the entrance to a nest with a pink garden stake, labeled with the VHF transmitter number of the tagged individual. We conducted observations at each study nest during the pre-fledging period, from their hatch date until the chicks became too mobile to observe continuously (up to 14 days following hatch for Roseate Terns and up to 20 days following hatch for Common Terns).

Weather permitting, two-hour blind stints were conducted between dawn and dusk, within time bins categorized as: morning (0600 to 1000 hrs), midday (1000 to 1600 hrs), and evening (1600 to 1900 hrs). During each stint, observers used handheld VHF antennas connected to an automated receiving unit to differentiate tagged adults from their non-tagged mates. This also allowed us to collect continuous presence-absence data on nest attendance during each stint. Observers monitored one to three nests simultaneously during each stint. Observers conducted a total of 330 nest-observation hours during the 20-day period, with a mean of 11.79 hours per nest (SD = 6.3 hrs, range = 2–22 hrs).

During chick provisioning stints, observers visually identified each prey item to the lowest possible taxonomic level and estimated length of prey relative to bill length of the adult tern that delivered the item, in increments of 0.25 bill lengths (Kress and Hall, 2004). For Common Terns, we assumed a mean bill length of 36 mm based on Coulter (1986), who measured female bill length (mean = 35 mm, range = 31–38 mm), which was shorter than male bill length (mean = 37 mm, range 34–41 mm). We assumed Roseate Terns had a mean bill length of 38 mm based on measurements conducted by Safina et al. (1990). In addition to collecting morphometric data (Coulter, 1986), we confirmed gender of each captured adult tern by plucking 3–5 contour feathers, then sent these feathers to a lab in Gainesville, FL, to determine sex based on a PCR analysis of genomic DNA. To confirm prey identification and size estimates by visual observation, we used high resolution cameras (GoPro Hero 4) mounted on small tripods placed within 0.6 m of selected nests during blind stints. The cameras were set in time-lapse mode to take a photo at two-second intervals. We reviewed the videos post hoc to identify feeding events. As we did so, we identified adults (as either tagged or non-tagged) by: 1) referring to time-stamped detection data of tagged birds at the nest collected from the hand-held VHF antennas; and 2) visual observations of the presence or absence of the nanotag antenna on tagged birds as seen on the video footage.

DATA ANALYSIS

We used the package ‘lme4’ (Bates et al., 2015) in the Program R (R Development Core Team, 2017) to fit a series of linear and generalized linear mixed effects models specific to each response variable. For all models, we used species, sex, and chick age (measured in days since hatch) as fixed effects and bird ID as a random effect. We evaluated candidate models using maximum likelihood and used Wald tests to obtain parameter-specific p-values. We used three linear mixed effects models (function lmer) to assess the effects of these covariates on the following response variables: 1) prey delivery rates to chicks (prey items/hour); 2) length of sand lance prey (in mm, estimated relative to bill length); and 3) duration of chick provisioning flights, calculated as the amount of time (in minutes) between departure of an individual from the study nest and return with a prey item that was delivered to a chick. Feeding events that occurred when individual terns were not present at the nest during the start of the stint were excluded from the analysis of duration of chick provisioning flights.

We used a generalized linear mixed effects model (function glmer) with the binomial distribution to model nest attendance, calculated as the sum of the minutes, per observation stint and individual tern, that each member of the pair was present at the nest, over the total number of minutes in the observation stint. Thus, time spent away from the nest included both known chick provisioning flights (where individuals returned to the nest with a prey item), and all time away from the nest that was not associated with a known provisioning event.

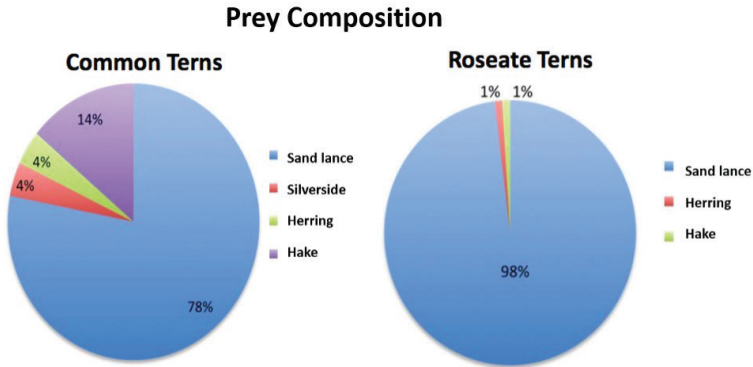


Figure 1. Prey composition of fish delivered to chicks by adult Common Terns (left; $N = 87$) and Roseate Terns (right; $N = 88$) at Great Gull Island, NY, in 2016. Prey are grouped by taxa, with sand lance (*Ammodytes* spp.) in blue, Atlantic silverside (*Menidia menidia*) in red, unidentified herring (either *Alosa* or *Clupea*) in green, and unidentified hake (either *Merluccius* or *Urophycis*) in purple.

RESULTS

Species composition of prey items delivered to chicks was predominantly sand lance (*Ammodytes* spp.), comprising 98% of Roseate and 78% of Common Tern prey deliveries, respectively (Figure 1). Both Common and Roseate Terns delivered lesser proportions of unidentified herring (either *Alosa* or *Clupea*) as well as unidentified hake (either *Merluccius* or *Urophycis*). Common Terns were also observed delivering Atlantic silverside (*Menidia menidia*).

Mean (\pm SE) prey delivery rates (fish/hour) were slightly higher for Common Terns (0.85 ± 0.06 ; range 0.34–2.5) compared to Roseate Terns (0.75 ± 0.05 ; range 0.33–2.0) and decreased with chick

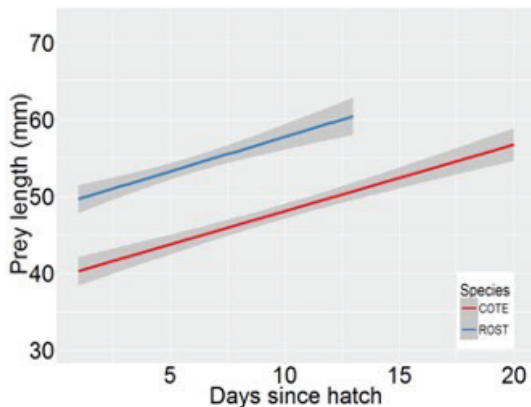


Figure 2. Estimated length of sand lance (*Ammodytes* spp.) (solid line = mean, gray shading in 95% CI) delivered to chicks by adult Common (red) and Roseate (blue) Terns in relationship to chick age (in days following hatch) at Great Gull Island, NY, in 2016.

age ($p = 0.002$). However, for both species, as the age of chicks increased, length of sand lance prey items delivered also increased ($p < 0.001$). Length of sand lance delivered to chicks was significantly greater for Roseate Terns than Common Terns ($p < 0.001$) (Figure 2). Across species, adult male terns delivered slightly longer sand lance (mean length) than did females ($p = 0.064$; Figure 3). We found no significant effects of species, sex, or chick age on duration of chick provisioning flights. However, nest

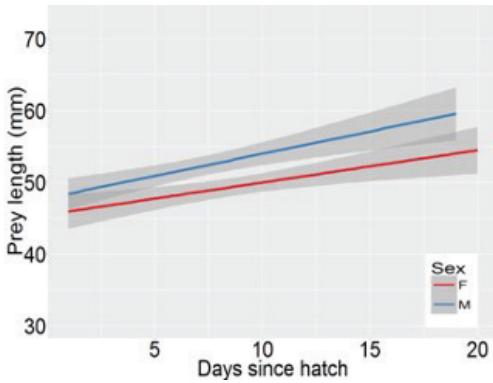


Figure 3. Mean estimated length of sand lance (*Ammodytes* spp.) (solid line, gray shading in 95% CI) delivered to chicks by female (red) and male (blue) Common and Roseate Terns in relationship to chick age (in days following hatch) at Great Gull Island, NY, in 2016.

attendance decreased with chick age ($p < 0.001$), but did not differ between species or sexes (Figure 4).

DISCUSSION

Chick Provisioning

Our results provide additional evidence supporting the importance of sand lance and other small forage fish in the diet of both Common and Roseate Terns chicks in the western North Atlantic Ocean (Kirkham, 1986; Safina et al., 1990; Heinemann, 1992; Tims et al., 2004; Goyert, 2013). In this study, sand lance comprised nearly all of the prey items delivered by Roseate Terns to their chicks and the majority of prey items delivered by Common Terns to their chicks. These results are consistent with other studies of Roseate and Common Tern foraging ecology that have shown Roseate Terns specializing on sand lance and Common Terns consuming sand lance as part of a more varied diet that includes other taxa of fish such as herring, hake, and silverside (Duffy, 1986; Safina et al., 1990; Heinemann, 1992; Tims, 2004; Kress and Hall, 2004; Rock et al., 2007; Goyert, 2014; Nisbet et al., 2014).

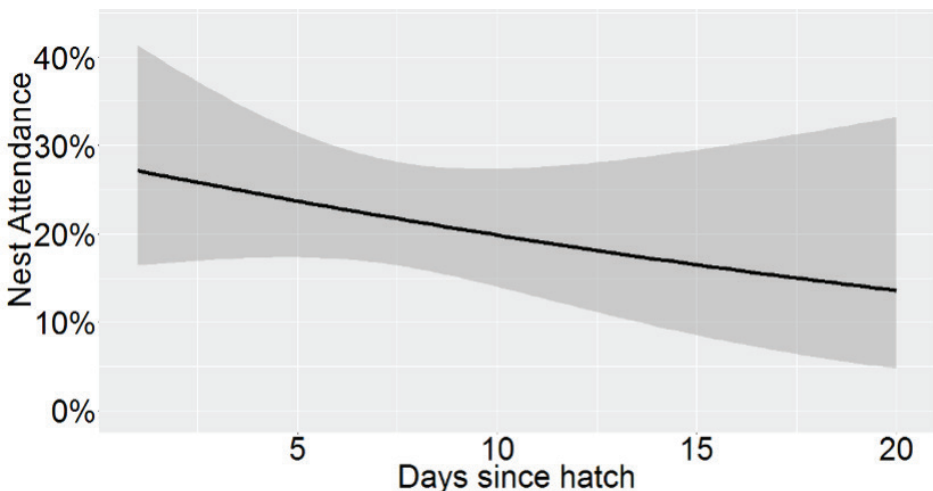


Figure 4. Percent of time (black line = mean, gray shading = 95% CI) that radio-tagged terns attended their nest sites in relationship to chick age (in days following hatch).

We found that, relative to Common Terns, Roseate Terns delivered longer sand lance at slightly lower rates of deliveries per hour, which is consistent with results from provisioning studies conducted in a large tern colony in nearby Buzzards Bay, Massachusetts (Goyert et al., 2013). In addition, our results showed that males, which tend to be larger (Safina et al., 1990; Nisbet et al., 2014), delivered longer sand lance compared to females. These results were consistent with previous work conducted on Roseate Terns in nearby Cedar Beach, New York (Wagner and Safina, 1989).

In this study, we found that the length of sand lance prey items delivered to chicks increased significantly with the age of chicks, which has also been shown in other studies (Wiggins and Morris, 1987; Moore, 1993). We also observed that nest attendance by adults decreased significantly with chick age, which is consistent with results from previous studies on Bird Island in Buzzards Bay, MA (Oswald et al., 2005).

Automated Telemetry and Nest Cameras

In this study, we demonstrated that combining high-resolution camera technology with digitally coded VHF telemetry and observational stints was effective for monitoring individual terns' prey selection, delivery rates, and nest attendance patterns. The automated radio telemetry equipment was highly effective for identifying each member of the pair and accurately measuring their nest attendance. The video footage provides a permanent record for post-hoc identification of prey taxa and length estimates, reducing observer bias that can result from identification conducted during real time in the field (Safina et al., 1990). However, the high-resolution cameras used in this study needed to be programmed to a time-lapse mode (photo every two seconds) to have sufficient battery life to last during the two-hour stint window. While the two-second temporal resolution was sufficient for verifying most prey deliveries that we documented, there is the possibility that we occasionally missed a prey delivery and feeding bout. In addition, the chicks grew increasingly mobile with age and by the end of the two-week study period were moving outside the field of view of the camera. An alternative non-invasive approach would be to photograph returning adults from the blind with a high-resolution digital camera (Gaglio et al., 2016). Therefore, we recommend using cameras in conjunction with standardized blind observation techniques to maximize the quality and quantity of information collected during provisioning studies.

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PVC Elbow Fittings Provide Protection in Nest Boxes of Roseate Tern Chicks

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ABSTRACT

Raised terraces on Great Gull Island provide additional nesting habitat for a large population of Roseate Terns (*Sterna dougallii*). In April 2015, 17 new terraces were built, and rows of wooden nest boxes were placed in them on bare soil. When alarmed by a human or potential predator, incubating adults typically fly off their nests leaving eggs or young chicks exposed. At that time, chicks will seek out small, dark places to hide among rocks, wooden boards, and dense vegetation. This concealment provides protection for chicks and is prevalent in most areas on the island but lacking in these newly excavated areas. If adequate concealment close to the nest is unavailable, chicks may search farther afield, becoming lost or facing a higher risk of predation. To deter the need for chicks to run out of their nest boxes to seek cover when alarmed, a two-inch PVC plumbing elbow was placed inside ten nest boxes on these terraces. Inspection of the boxes on alternating days revealed chicks hiding within, or directly wedged behind the elbow. These findings indicated that as we approached the area and adults flew off their nests, the elbows were being used by chicks as an adequate form of protection. The addition of PVC elbows to nest boxes produced encouraging results, and continued utilization may assist in increasing survival rates of pre-fledged Roseate Tern chicks in nest boxes.

INTRODUCTION

Nest boxes have been used worldwide for the monitoring and conservation of numerous avian species, and some studies have observed population growth following the increase of habitat these boxes provide (Bolton et al., 2003; Corrigan et al., 2011; Libois et al., 2012; Sutherland et al., 2014; Bourgeois et al., 2015). Furthermore, productivity in some seabird species using nest boxes has equaled or surpassed that of nesting in traditional settings (Priddel and Carlile, 1995; Bourgeois et al., 2015). A study conducted from 1993 to 2010 at Benidorm Island, Spain, found that despite breeding experience, productivity of Mediterranean Storm Petrels (*Hydrobates pelagicus*) in nest boxes has exceeded that of birds nesting in natural habitat (Libois et al., 2012). Success was attributed largely to

protection from predators, intraspecific aggression, and reduced egg damage from trampling. Likewise, on Praia Islet, Graciosa, the breeding success of Madeiran Storm Petrels (*Oceanodroma castro*) nesting in boxes was 2.9 times greater than that of birds using natural sites (Bolton et al., 2003).

Great Gull Island (GGI), New York, has employed nest boxes since 1984; they have been well utilized by Roseate Terns, an endangered seabird. One study found that Roseate Terns, despite nesting in areas with ample natural habitat, will readily take to artificial nest sites like nest boxes (Spindelov, 1996).

The largest single colony of breeding Roseate Terns in the Western Hemisphere is found on GGI. In addition to wooden boxes, the island offers significant high-quality habitat in which to nest. Large concentrations of their nests are found among large boulders encircling the island, and considerable numbers are found within dense vegetation and other wooden debris along the upper edges throughout the island. Concern that some natural habitat may be lost to sea level rise in the future prompted the decision to locate the new terraces on highly elevated slopes (Hays, personal commun.). This use of nest boxes placed above areas of potential inundation warrants continued investigation. However, nest boxes in open, newly excavated areas lack the concealment opportunities of nests built in natural areas among rocks or thick vegetation where chicks can seek safety when alarmed, and in the absence of an adult. Concerns regarding nest boxes in these areas include the potential for chicks to run out of the boxes into open areas when panicked, exposing themselves to excessive heat, hypothermia, and predation. In addition, these terraces were constructed on steep slopes at a higher elevation (7 m), adding the additional risk of a chick falling to a lower row where it may become lost or unable to reenter its own nest box. To alleviate these concerns, options for alternative protective cover inside these nest boxes were examined the following season. We found that during periods of stress, when chicks may evacuate the nest box to hide, they utilized the PVC pipe inside the box.

MATERIALS AND METHODS

Ten two-inch 90°-angle PVC (Lasco) plumbing elbows were placed in ten active nest boxes on terraces during the 2016 breeding season on Great Gull Island. The two-inch elbow with a 90° angle was chosen, as opposed to a straight fitting with a similar diameter, due to the tendency for Roseate Tern chicks to seek small, tight spaces. In addition, should the nest contain two chicks, the angled elbow offers an opportunity to share the space, where each chick has its own private area. The angled elbow also fits into a corner and does not interfere with the primary nest site where a parent may brood and feed chicks.

Before installation, the elbows were first placed atop the boxes so adult Roseate Terns had the opportunity to become habituated to the fixtures before being placed inside their nest box. When pipping eggs or newly hatched chicks were observed, a single elbow was placed inside each of the boxes and positioned in a corner opposite the actual nest site.

The elbow was partially filled with existing soil substrate and positioned at a slight downward angle allowing chicks to enter the elbow at a level even with the soil line. Roseate Tern chicks are usually found wedged in small spaces, and partial filling of the elbows upon placement allows for a reduction in the diameter of the elbow, creating a more compact space (Figure 1).



Figure 1. Roseate Tern chick in partially filled PVC elbow inside sampled nest box on Great Gull Island.

Checks were made beginning June 9 on alternating days to avoid excessive disturbance and continued for about two weeks or until chicks were no longer found within the nest boxes. Roseate Terns on GGI tend to relocate chicks out of the original nest area as they continue to grow and begin fledging.

RESULTS

Inspections of all ten experimental nests revealed a chick hiding directly inside or wedged behind the elbow (Figure 2). Additional inspections were made when adults from those boxes were trapped for research purposes. During these times, all elbows were being used by chicks (Figure 3).

DISCUSSION

The addition of PVC elbows to nest boxes in areas devoid of cover was found to be a useful method for protecting vulnerable, unfledged chicks. PVC is durable, inexpensive,



Figure 2. Roseate Tern chick found in PVC elbow during check on newly constructed terrace in nest box on Great Gull Island.



Figure 3. Roseate Tern chick found in PVC elbow during check on newly constructed terrace in nest box on Great Gull Island.

lightweight, and waterproof, and can be easily retrieved at the end of the season for future use. We continue to use PVC elbows in nest boxes where terraces are built on steep slopes, and in areas lacking protective cover. These nests are closely monitored and resighting of chicks is done later in the season to assess fledging rates compared to nests in areas where no elbows were used. These protocols will help evaluate the overall contribution of PVC elbows to the productivity of this endangered seabird. Additionally, this technique may offer a useful strategy in other seabird colonies with similar concerns.

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Life Histories of Roseate Terns Nesting in a New Area

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ABSTRACT

This study examines which Roseate Terns (*Sterna dougallii*) would use nest boxes in a newly terraced section on Great Gull Island, NY, and what the life histories of those nesting birds might be. A sample of previously banded birds trapped in 2015 on nests in this new area showed that the nesting birds varied in age, origin, and previous habitat choice. The hatching peak for these birds coincided with that for the other Roseate Terns nesting on GGI, showing that they had begun nesting as early as birds returning to established sites.

INTRODUCTION

Historically, Roseate Terns on GGI nested primarily among the large rip-rap boulders placed around the perimeter of Great Gull Island by the U.S. government to stabilize the shoreline (Cooper et al., 1970). In the 1980s, Helen Hays hoped to find a way to increase the number of nesting Roseate Terns and provide a place for them to nest where they could be easily observed (personal commun.). Therefore, terraces with nest boxes were built below the south edge of the big gun emplacement, not far from the rocky edge where many Roseate Terns nested. The birds used these boxes and were easily observed. The Roseate Tern population did increase (because of the nests in boxes as well as an increase in other areas) from an estimated total of 1,200 nests in 1988 to an estimated 2,200 in 2019.

When funding from the U.S. Fish and Wildlife Service became available in 2014, Hays suggested terraces with boxes be built on the the island shore area known as the Backline. She chose this site for new terraces because Matthew Male had found 100 Roseate pairs nesting on a 50 m section just above the rocks on the south side of a gun emplacement (the Backline) in the 1980s (Hays, personal commun.). As this area had become overgrown with bittersweet (*Celastrus scandens*) in the intervening years, the numbers of nesting Roseate Terns had decreased until, in 2014, only one Roseate Tern pair nested there. Hays hoped the new terraces might encourage the birds to nest along the Backline

Keywords: ages, Great Gull Island, hatching peak, nest habitat, nest site repopulation, new nest boxes, origins, Roseate Terns, *Sterna dougallii*

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Figure 1. Nest boxes constructed on the Backline of Great Gull Island.

again, this time higher up and in boxes. Assuming they nested, I planned to trap there, hoping to capture banded birds; their records would give us information about these birds that had chosen to nest on the Backline terraces.

Roseate adults and chicks have for decades been banded in their major northeastern colonies: Bird and Ram Islands, MA, and Great Gull Island, NY, as well as in smaller colonies such as Falkner Island, CT. They provide a large sample of banded birds available for studies (Spendelow et al., 2016).

According to annual surveys I have conducted on GGI since 1997, approximately two thirds of the Roseates on GGI are banded; some were originally banded in other colonies. Given the large number of banded birds, I hoped to be able to answer the following questions about the birds nesting in the new Backline terrace boxes.

- Were they birds nesting for the first time?
- Were they birds from other colonies?
- Had they previously nested in the rocks or along the rocky edge below where the new terraces now stood?
- Were they birds displaced by Hurricane Sandy, which, in October 2012, washed away nesting sites on other parts of the island?
- Had they nested in boxes before?

In sum, were there commonalities of age, colony of origin and/or previous nest habitat shared by these birds? This paper addresses those questions.

Methods

Prior to the 2015 breeding season 14 new terraces with a total of 487 nest boxes had been built along selected sloping sections of gun emplacements along the Backline. The Backline terrace section discussed here is not contiguous with other areas on the perimeter of the island where Roseate Terns nest (Figure 2). It is approximately 12 m away from a separate Roseate Tern nesting area to the east and about 90 m away from a Roseate Tern nesting area to the west.

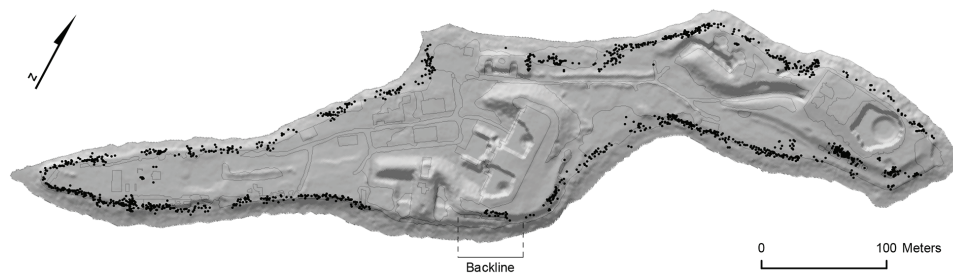


Figure 2. Roseate Tern nests on Great Gull Island in 2015 (black dots) with Backline shown.

From 9 June to 4 July 2015, a team monitored the Roseate Tern colony daily to mark nests and band chicks. When a chick hatched on the Backline, one member of the team marked the nest box with red duct tape and returned later to set a modified treadle trap across the front of the box. Trapping was done when chicks were 0–2 days old. In order to minimize disturbance on successive days, the team tried to trap both members of a pair during the same trapping session by resetting the trap after removing the first bird. If the second bird was not captured, the trap was removed and not set again on that nest. The adult terns discussed in this paper were trapped on the Backline terraces between 26 June and 1 July 2015.

Results

In 2015 the team marked a total of 1,500 Roseate Tern nests on GGI, of which 223 (14.9%) were in nest boxes. Twenty-eight (12.6%) of those were in the new boxes on the Backline. These were the nests trapped for this study.

The team trapped 20 of the 28 nests on the Backline and captured 26 birds; both members of the pair were trapped on six of the nests. Of the 26 trapped birds, 20 (77%) had been previously banded. Fourteen of these were of known age: 11 had been banded as chicks on GGI and three had been banded as chicks in other colonies (Table 1), one on Falkner Is., CT (45 km from GGI), and two on Bird Is., MA (130 km from GGI).

The ages of the known-age birds ranged from five to fourteen years (Figure 3). There were four 5-year-olds, six 6-year-olds, two 7-year-olds, one 11-year-old, and one 14-year-old. There is no way of knowing the exact ages of the six birds banded as adults. Although Roseate Terns usually do not breed until they are three or more years of age, Donaldson (1971) reported trapping a two-year-old breeding on GGI and Spendelow (1991) reported four cases of breeding by 2-year-olds on Falkner Island. Therefore, the birds reported here are assumed to have been two or more years old when they were first banded. In that case, in 2015, those birds would have been at least the following ages: two 3-year-olds, one 6-year-old, one 8-year-old, one 9-year-old, and one 17-year-old.

The six birds first banded on GGI as breeding adults had a known nesting history. They had previously nested in diverse habitats: deep rocks, vegetation, small rocks with

Table 1

Bird trapped in 2015 (A-T)	Year Banded	Banded as adult	Banded as chick	Banding location	Previous nest habitat
A	2000	X		Great Gull Island, NY (GGI)	Small rocks and vegetation
B	2001		X	Falkner Island, CT	
C	2004		X	Bird Island, MA	
D	2008	X		GGI	Small rocks and vegetation
E	2008		X	GGI	
F	2008		X	GGI	
G	2009	X		GGI	Box on original terrace
H	2009		X	GGI	
I	2009		X	GGI	
J	2009		X	GGI	
K	2009		X	GGI	
L	2009		X	GGI	
M	2009		X	Bird Island, MA	
N	2010		X	GGI	
O	2010		X	GGI	
P	2010		X	GGI	
Q	2010		X	GGI	
R	2011	X		GGI	Backline rocks
S	2014	X		GGI	Small rocks and vegetation
T	2014	X		GGI	Rocks

vegetation, or boxes (Table 1). Furthermore, they had nested on different parts of the island (Figure 4). One had been trapped on the Backline along the rocky edge not far from where the new terraces were built, another had nested in an area on the northwest side of the island that was destroyed by Hurricane Sandy, and another, in a box on the original terraces. The three others had nested in other locations around GGI.

The 11 birds originally banded as chicks on GGI had hatched in different sections of the island, and in diverse habitats (Figure 4). Three hatched in nest boxes: one on the western wall, one on the eastern wall, one on the original terraces, and one under an old blind on the eastern end. Four others hatched in areas with small rocks and vegeta-

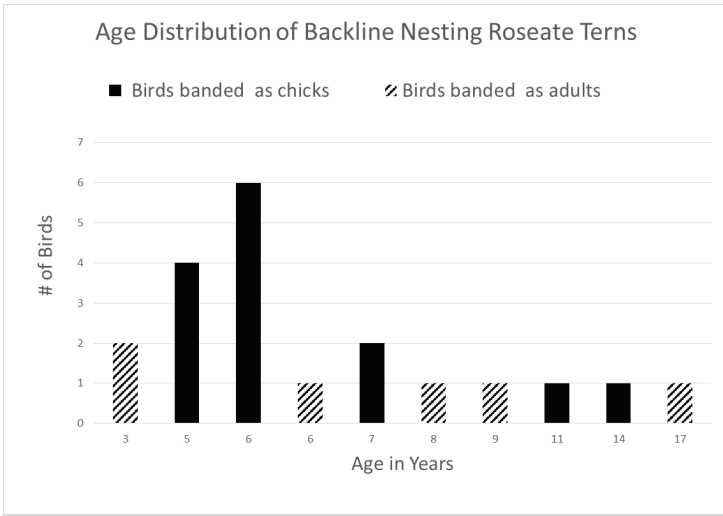


Figure 3. Age distribution of Roseate Terns nesting on the Backline at Great Gull Island in 2015.

tion. Two of these hatched along the north side and the other two on the south. Three hatched in the deep rocks, two on the north and one on the south.

The hatching peak for the chicks in the new Backline area was 26–27 June. This is identical to the hatching peak for the GGI Roseate colony as a whole.

Discussion

The team targeted its trapping to the Backline. We were interested in learning what birds nested there because of its history and because it was a distinct section, separate from other Roseate Tern nesting areas (Figure 2). Other sections of new terraces are adjacent to existing terraces with nesting Roseates, or to areas where Roseates nest nearby, so are less distinctly separate areas. Although we were reluctant to do extensive trapping in newly established areas, it seemed worthwhile to do enough trapping on the Backline to get a sample of the birds nesting there in order to answer questions about age, origin, and previous nest habitat.

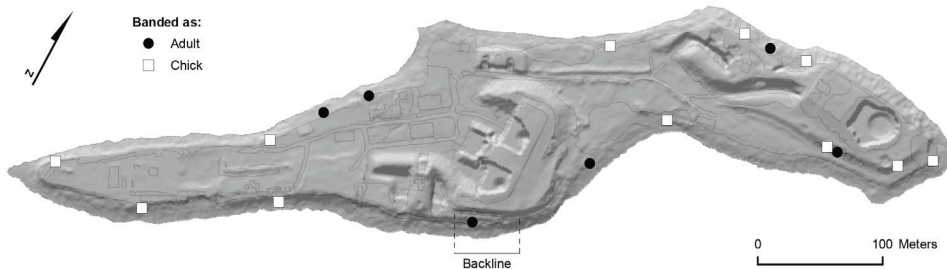


Figure 4. Previous Great Gull Island nest locations of Roseate Terns nesting on the Backline in 2015.

The birds that moved into the new Backline area varied in age from at least three years to at least 17 (Figure 3), with a mean age of at least 7.1 years. This age pattern is similar to that described by Spendelov et al. (2003) for previously banded Roseate Terns on Penikese Island, MA, a recolonized site where tern ages ranged from 6 to 20 years.

Were any of the Backline birds first-time breeders? Although we can't tell anything about the unbanded birds, we do know that among the banded birds few, if any, would have been first-time breeders. Lebreton et al. (2003), in a multi-site mark-recapture study of Roseate Terns, yielded estimates of ages at first breeding as follows: about 2% at age 2 years, 50% at age 3 years, 40% at age 4 years; virtually all were breeding by age 5 years. Therefore, it's possible that of the four 5-year-olds there might have been one or two first-time breeders.

Three of the birds on the Backline were from other colonies: two from Bird Is., MA, and one from Falkner Is., CT. This was not unexpected. In a study of breeding dispersal rates of adults between nesting colonies within the northeastern U.S. metapopulation of Roseate Terns, Spendelov et al. (2016) found that the average annual transition rate of birds moving from Bird Is. to GGI over the 21-year period was 0.014, and the average annual transition rate from Falkner Is. to GGI was 0.068.

Jones (1906) reported that northeastern Roseates select dense vegetation, rocks, or other shelter, usually concealing their nests under cover. Gochfeld and Burger (2020) report that at most sites in the Northeast Roseates now nest in a mix of natural and artificial sites. While in the past on GGI Roseates nested primarily under the large rip-rap boulders stabilizing the shoreline or under small retaining walls, at present about half nest in those locations while others now also nest along the inner edge of the boulders among smaller rocks or vegetation, under wood, or in nest boxes.

I was interested in whether the Backline birds, now nesting in boxes, had previously nested in boxes or had nested under the rip-rap boulders, in vegetation, or other areas. Of the six with nesting histories, only one had nested in a box; the others had nested under the boulders, among smaller rocks, or in vegetation (Table 1). They had moved from a variety of nest-habitat types to the Backline boxes. I was also curious about whether the habitat in which a chick hatched might influence its choice of nesting habitat. The 11 banded as chicks had hatched in every habitat type on GGI. All sections of GGI are represented as well (Figure 4). Most of the Roseate Terns nesting in the Backline boxes had previously nested, or hatched, in the rocks or in vegetation; this suggests that specific habitat type, within the parameters of what Roseates usually accept, is not a predominant factor determining nest site choice.

Despite the variation in age, origin, previous nest habitat, and the adoption of new nest boxes, there was synchrony with the rest of the colony in nest initiation. The chicks' hatching dates on the Backline matched those of the colony as a whole, indicating that their parents, despite having moved into a new area, started nesting at the same time as most of the other Roseate Terns in the colony. This meant they had settled into these

new nest sites as quickly as other birds in the colony started their nests; most in the latter group would have been returning to sites they used in previous years. My observation has been that birds returning to an established site usually nest earlier than those finding a new site. This was not the case with the Backline nesters. Hays points out that Roseates are very vocal; their calls during the breeding season are heard all over the island and likely serve to stimulate them to coordinate their laying (personal commun.). Perhaps the Backline offered the right balance between some proximity to noisy Roseate Tern neighbors, yet enough distance from them to permit the new Backline settlers to claim nest sites (i.e. nest boxes) without prolonged interactions with other terns (Figure 2).

It is hoped that the number of nests on the Backline will keep increasing. Continuing to monitor them should provide more data on the histories of the birds that use this area and insight into factors determining nest site selection.

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Observations of Chick-rearing Success by Single-parent Roseate Terns

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ABSTRACT

This paper records the high fledging success rates of chicks from seven single-parent nests. Satellite tags (sat-tags) had been put on ten Roseate Terns attending chicks on Great Gull Island (GGI), from 23–26 June 2018. Of the nine that returned to their nests, seven disappeared within a few days. This provided an opportunity to follow seven nests where only one parent was left to raise the young. These young, banded with both USGS Bird Banding Laboratory and plastic field-readable bands, were resighted on GGI and/or Cape Cod, MA. In this year with an abundant food supply, these single-parent chicks did as well as those from two-parent nests.

INTRODUCTION

Normally both members of a Roseate Tern (*Sterna dougallii*) pair participate in raising the young (Teets, 1998; Watson et al., 2012). During 50 years of work with the colony on Great Gull Island, NY (GGI), neither Helen Hays nor Cormons ever noticed a nest where only one parent attended the chicks. This pattern of biparental care is common in seabirds and is usually necessary to successfully raise young (Lack, 1968). Nisbet et al. (1978) reported two cases in which single Common Terns (*Sterna hirundo*) whose mates died when the chicks were still young were able to raise chicks (one of two and two of three) to fledging. Spendelow et al. (1997) documented a female Roseate Tern that fledged a chick following the death of her mate during the incubation period. On Coquet Island, England, there appeared to be two instances in 2018 of single Roseate Tern parents raising young (David Kitchen-Smith, personal commun.).

We had the unusual opportunity during the 2018 nesting season on GGI to observe seven nests where one parent was left to care for the young after the disappearance

Keywords: Chick-rearing, food supply, Great Gull Island, parental care, Roseate Tern, single parent, *Sterna dougallii*

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of its mate. To learn more about the post-breeding dispersal patterns and migratory routes of Roseate Terns, satellite tags had been attached to ten breeding adults using shoulder harnesses (Paton et al., 2021). Most of these tagged birds did not attend their nests for more than a few days, leaving all nest and chick-rearing duties to the remaining parent.

Although their provisioning rates may differ (Shealer, 1995, 1998, 1999), typically both parents feed young chicks up until the first-hatched “A” chick is about ready to fledge. At that time each parent may care for just one of the chicks (Teets, 1998; Watson et al., 2012).

In some cases confirmation of fledging at the colony site can be difficult because young often move away from their nest sites to new hiding places when just a few days old. However, if chicks are individually marked before they disappear from the nest site (as were the chicks in this study), then the colony data can be augmented by identifying the missing marked young later as Hatch Year (HY) birds when they move to staging sites and congregate before migrating to South America (Trull et al., 1999; Jedrey et al., 2010; Davis et al., 2019).

METHODS

The first author (Cormons) oversaw and participated in the GGI part of this study. The second author (Spendelow) did the resighting on Cape Cod, Massachusetts.

Observations made at Great Gull Island

As part of the GGI Roseate Team’s routine nest/chick check, chicks zero to two days old were banded with a U.S. Geological Survey Bird Banding Laboratory (BBL) band on one leg and a 3-character plastic field-readable (PFR) band (blue with white characters), on the other leg. Single chicks in a nest were designated “S,” first chicks in two-egg clutches “A,” and second chicks “B.” The chicks described in this paper, i.e., those from nests with a tagged parent, were part of this routine banding procedure.

Ten adult Roseate Terns, captured using Potter-style walk-in traps on nests with a chick, were fitted with satellite transmitters (sat-tags) on 23–26 June 2018 as described by Paton et al. (2021). The sat-tag parents all had, or were given, a BBL band on one leg and, on the other leg, either an alphanumeric metal field-readable (MFR) band or a blue or yellow plastic field-readable (PFR) band. The sat-tag birds were sexed by DNA analysis of 3–4 contour feathers (Animal Genetics, Tallahassee, FL, US). We did not attempt to trap the mates of the sat-tagged parents because we wanted to minimize disturbance at the nest. To facilitate nest observations, wherever possible we selected nests for trapping where both members of the pair were already banded. Every effort was made to trap the birds on nests that would be as easy as possible to observe from one of the many blinds on GGI (Figure 1). On average, sat-tag nests were 10m (range: 3m to 30m) from blinds. Observers used 20–60X spotting scopes to read bands. Nests

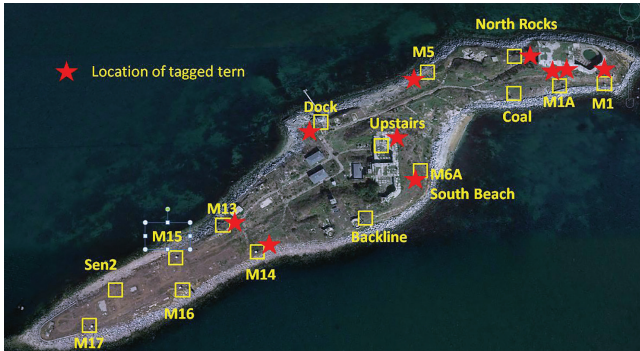


Figure 1. Blind locations on Great Gull Island. Red stars indicate the location of the nests of sat-tagged birds.

were in a variety of habitats: five in boxes on terraces, two on the rocky edge with vegetation, two among medium-sized rocks, and one on concrete with a little vegetation. None were under boulders; they would have been too difficult to observe. In this paper individual sat-tag birds are identified by the blind near their nest.

Observations from blinds were done in 2- to 4-hour shifts from dawn to dusk. Initiated by Peter Paton as part of the sat-tag study, the watch at each nest started with the release of the sat-tagged bird. Observers documented activities at the nest: how long the sat-tag bird took to return to the nest, the reaction of the bird to its tag, how long it took to resume normal brooding/feeding activity (Burger et al., 1995; Zingo, 1998), the mate's behavior, and the brooding and feeding of the chicks. Watches by Cormons and many others continued through 2 July, gradually decreasing in length and frequency after 2 July as it became difficult to see the hiding chicks and fewer people were available to observe.

As Roseate Tern chicks mature and approach fledging, they often move away from their nest site and stand atop the boulders on the perimeter of GGI. This provides an excellent opportunity for reading their bands. Catherine Neal and Ian Putnam of the GGI Roseate Team continued watching sat-tag nests and reading PFR bands of young and adults daily (8–10am and 6–8pm) through 27 July.

While Spendelow et al. (1997) noted that “A” chicks typically fledged at 25–28 days of age, and surviving “B” chicks typically take a day or two longer than their older siblings, for the purposes of this paper we considered a chick as fledged at 21 days or older.

Observations made at Cape Cod, Massachusetts

A history of the Roseate Tern staging site work done on Cape Cod (CC), MA, is given in Spendelow (2018). The general methods for using spotting scopes to observe and identify individuals with PFR bands are given in Althouse et al. (2016) and Davis et al. (2019). Some summary details on the numbers of chicks banded and the numbers later seen as HYs on CC in 2018 are given in Spendelow (2019). Identifications usually began

when the observer was 40–50m from the closest birds in a flock. As the terns habituated to us, we sometimes approached as close as 5m to more tolerant individuals. As shown in Figure 40 of Spendelow (2019), the choice of which staging sites to visit on any given day was determined in part by trying to balance the somewhat opposing goals of (1) going to sites where one could identify a large number of terns with PFRs, and (2) trying to visit at least once each month each area where Roseate Terns might concentrate during the staging period. In 2018, most observation sessions were conducted at Hatches Harbor and Race Point North (two sites to the southeast and northeast, respectively, of the Race Pt. Lighthouse), with a few trips made to North Beach, Chatham, to Powder Hole, South Monomoy Island, and to Jeremy Point, Wellfleet. Most identifications were made while the observer was sitting on a packseat on the beach or in shallow water, and talking into a voice recorder. These notes were transcribed later into notebooks.

RESULTS

In one of the ten sat-tag nests the single chick was lost less than a day after its parent was tagged; neither parent was observed or detected by satellite (Paton et al., 2021) after that. This paper discusses the nine remaining nests. Two of the nests, M5 and M13, had a chick and an egg at the time of trapping. At M5 the “B” chick hatched five days after the “A” chick. The second egg in the M13 nest did not hatch.

Only two of the tagged birds, North Rocks and M5, attended their nests for more than four days. These tagged birds had not resumed feeding and brooding at the nest site until approximately 22 and 66 hours, respectively, after being tagged. Subsequently, however, they were observed brooding and feeding normally, along with their mates, through 2 July. After that, observations were less frequent, but presumably these two tagged birds continued to participate in chick rearing until at least 9 July and 25 July respectively, the last dates they were observed. At that time the North Rocks chick was 33 days old and the M5 chicks were 17 and 12 days old.

At the other seven nests, the tagged parent was only present 0–4 days (mean = 1.9). After that, the tagged bird was no longer seen; these became single-parent nests. At the M1 nest we knew that the sat-tag adult had died (Paton et al., 2021) when the chicks were two and three days old. At the other nests, the sat-tag parent simply disappeared. We continued observations on all sat-tag nests and found that, although the tagged parent was no longer present, the mate, now a single-parent, continued to care for the chick(s).

Observers watching sat-tag nests, as well as those watching Common Tern nests at GGI, noted the apparent abundance of readily available fish (Cormons, 2019). Joe DiCostanzo, GGI Project, photographed flocks of thousands of Roseate and Common Terns fishing 1/4 mile or less from the island on a daily basis throughout the chick-rearing season. Pamela Loring, lead investigator for the sat-tag study, recorded an average rate of seven fish per hour delivered to the two chicks in the M1 nest (Figure 2).

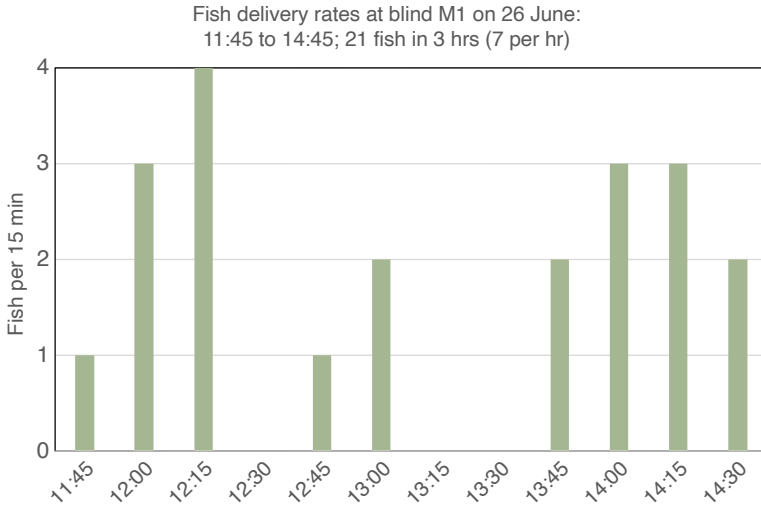


Figure 2. Fish delivery by a single parent to two chicks in the same nest at GGI in 2018.

For comparison, Abemayor et al. (2022), following 20 Roseate Tern nests on GGI in 2016, found that prey delivery rates (fish/hour) had averaged 0.75 ± 0.05 (range 0.33–2.0).

Observers on GGI and CC read the bands of the chicks/fledged young from the sat-tag nests. Table 1 summarizes these sightings of chicks from each of the nine sat-tag nests.

All five "S" chicks, all four "A" chicks, and two of three "B" chicks were resighted. Both "A" and "B" chicks from the M1 and the M5 nests were resighted.

The ages of the young on the dates of observation varied from 21 to 78 days. Of nine A/S chicks, the five observed only on GGI were 21–35 (mean = 28) days old, and four observed on CC, were 75–78 (mean = 77) days old. Of the three "B" chicks, one was never resighted, and two were on CC at 63 and 69 (mean = 66) days old. The 12 banded chicks

Table 1. Resightings at GGI and CC of fledged Roseate Terns from sat-tag nests

AREA	A/S CHICK	OBS. GGI	OBS. CC	AGE	B CHICK	OBS. GGI	OBS. CC
M5	TP3 (A)	27 July		35 days	UA1	24 July	4 Sept
N. Rocks	TP1 (S)	13 July		21 days			
M1	HK9 (A)	24 July	8-9 Sept.	77 days	NY1		27 Aug
S. Beach	TS9 (A)		5 Sept.	75 days	RT1		
M1A "Q"	RT4 (S)*		10 Sept.	77 days			
M1A "R"	US9 (S)	27 July	10 Sept.	78 days			
Dock	UR4 (S)	23 July		31 days			
M13	TJ2 (A)	17 July		24 days			
M14	RT6 (S)	24 July		28 days			

*RT4 was mist-netted by Pedro Lima at the end of January 2020 at Mangue Seco, Bahia, Brazil at 19 months of age. A = first chick in a two-egg clutch, B = second chick, S = single chick. The "area" column is the blind used for observing the nest (Figure 1). In one case, two nests were observed from the same blind (M1A).

Table 2. Sex, age, and origin of banded mates of tagged birds

AREA	MATE #	SEX	AGE	ORIGIN
M5	yellow M94	MALE	4 yrs.	GGI
N. Rocks	1242-18561	MALE	12 yrs.	GGI
M1	yellow R21	MALE	4 yrs.	GGI
S. Beach	blue CB9	FEMALE	5 yrs.	GGI
M1A "Q"	27M6	MALE	15 yrs.	Bird Is., MA
M1A "R"	367U	FEMALE	9 yrs.	GGI
M14	blue F24	MALE	3 yrs.	Monomoy, MA
mean = 7.4 yrs.				

came from nine nests. Of these 12, 11 (91.5%) were resighted. Eight (66.7%) of them were resighted on GGI and 6 (50%) were resighted on CC. Three of the total (25%) were resighted on both GGI and CC, and three (25%) were resighted only on CC.

On GGI, 777 of the 1,171 banded chicks were resighted when 21 days or older, giving a fledging success of 66.4% for the general population. This is almost identical to the 66.6% of sat-tag chicks resighted on GGI. Of the 1,171 banded GGI Roseate chicks, 598 (51.1%) were seen as HYs on CC. This compares with six of 12 (50%) of sat-tag HYs seen on CC.

Table 2 summarizes what is known about the banded mates of the sat-tag adults (two were unbanded). One had only a BBL band, and six had BBL and FR bands. Of these seven birds, ages ranged from 3 to 15 years (mean = 7.4); one originally hatched at Monomoy, MA, one at Bird Island, MA, and five at GGI.

DISCUSSION

The disappearance of sat-tag parents offered a unique opportunity to observe single parents raising young. The fact that the resight rates of the chicks from single-parent nests were nearly identical to those of chicks from "normal" nests, shows that single parents had succeeded at fledging young as well as had normal pairs.

The mates of the sat-tag birds are of special interest as they were left with the care of the chick(s) after the sat-tag birds failed to return. Neither age nor colony of origin seemed to influence their ability to provide for their chicks as single parents in this year when prey fish appeared to be abundant.

We have assumed that the single parent left is the opposite sex from the sat-tag parent. Although Nisbet and Hatch (1999) found that 7% of "normal" (one- or two-egg) clutches were attended by multifemale associations, in our case it seems unlikely any were female-female pairs. All of the nests in this study were initiated within the peak nesting period, not later, as is usually the case with female-female pairs (Nisbet and Hatch, 1999). According to this premise, five of our single parents were male and two

were female. Males usually do more feeding of young than females (Hays, 1993; Shealer, 1995, 1998, 1999; Teets, 1998; Watson et al., 2012). Nevertheless, the two single-parent females each raised a chick that fledged and flew to CC.

Also of note, at M5 the “B” chick didn’t hatch until five days after “A” hatched (rather than the usual two or three days). Blind stint observations documented that the sat-tag parent did not spend much time attending the nest for several days; its mate, a male, had needed to incubate the egg and also feed the chick. Nevertheless, both “A” and “B” chicks fledged.

On GGI, Hays has often noted that when there is frequent human activity near a nest, the parents will move the chicks to another location (personal commun.). Two and three days after the sat-tag parent disappeared, the single parent and chicks at the M1 and South Beach nests could not be found. There had been a lot of traffic to and from the nearby blinds to watch these nests. Apparently the single parent had moved the chicks to a good hiding place; both chicks from the M1 nest and the “A” chick from the South Beach nest survived and were resighted as HYs on CC.

Nest location did not appear to influence fledging success. The sat-tag nests were distributed in different areas of the island (Figure 1), and in a variety of habitats.

As the nests of the single-parent chicks were distributed in different habitats and different parts of the island, and the parents left with the care of the young varied in age and sex, weather and food supply appeared to be the only variables they had in common. This was a season with good weather and an apparently excellent food supply; these may have been the major reasons for the chick-rearing success of the seven single parents described here.

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Great Gull Island Roseate Tern Data Summary 1988–2021

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ABSTRACT

This paper reports numbers of nests, clutch sizes, productivity estimates, and numbers of adults and chicks banded for Roseate Terns (*Sterna dougallii*) nesting on Great Gull Island (GGI) from 1988 through 2021. The use of nest boxes, the effects of erosion and predation, various methods to estimate productivity, and the importance of resighting PFR-banded fledglings are discussed. Notes on the occurrence of hybrids are also included.

INTRODUCTION

This paper summarizes nest, chick, and adult data for Roseate Terns, (*Sterna dougallii*) nesting on Great Gull Island (GGI), Suffolk Co., New York, from 1988 to 2021. Before the Roseate Tern was listed on the endangered species list on 2 November 1987 (U.S. Fish and Wildlife Service [USFWS], 1987), Common (*S. hirundo*) and Roseate Tern nest surveys were done simultaneously and the records kept by Helen Hays, director of the GGI Project. When Roseate Terns were listed, Hays invited me to lead a Roseate team to monitor their population separately. Throughout the years we've worked closely together, consulting about strategies for nest marking, chick banding, trapping, observations, and habitat management. Information herein is taken from banding data submitted to the Bird Banding Lab (BBL) from my annual reports submitted to the American Museum of Natural History (AMNH) and the U.S. Fish and Wildlife Service (USFWS) Roseate Tern Working Group, and from my notes.

METHODS

Most Roseate Terns nest on the perimeter of the island, many among the huge rip-rap boulders the U.S. government used to stabilize the shoreline when Fort Michie was built on GGI (Cooper et al., 1970). Others nest along the inside edge of the boulders among

Keywords: banding, clutch size, erosion, Great Gull Island, hatching, hybrids, nest boxes, nest habitats, population, predators, productivity, PFR bands, resighting, Roseate Terns, *Sterna dougallii*, terraces, trapping

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smaller rocks and vegetation. For example, the distribution of nests in 2015, based on GPS locations, is shown by the black dots in Figure 1.

In the 1980s nesting habitat was expanded in an effort to increase the number of nesting Roseate Terns and to provide a place where nests could be easily observed. (H. Hays, personal commun.). The team oversaw the construction of terraces below the south edge of the biggest gun emplacement. Nest boxes were placed on the terraces. Also in the 1980s, nest boxes were placed on a western retaining wall and an eastern retaining wall, and new terraces were built on the north side of the island. When funding from the U.S. Fish and Wildlife Service became available in 2014 (Cormons, 2022), additional terraces with nest boxes were built on the south side of the island (Figure 1). As of 2019, there were 1,495 nest boxes including those on terraces. In addition, other efforts were made to encourage Roseates to nest in different areas. These included “A” frame wooden shelters and peck-size peach baskets partially buried in the sand. We purposely left wood from fallen blinds on the ground, providing additional nesting habitat.

Each year (except 2020) during this study period I led the Roseate team to census nests, band chicks, and trap adults. The team usually consisted of three or four people working together to search for nests under the boulders and along the rock/vegetation edge, then spreading out to check nest boxes on terraced sections and retaining walls. Terraced sections were identified with letters A–Z and individual boxes were numbered.

Weather permitting, we checked the western half of the island one day and the eastern half the following day, from early June until early July. Exceptions to this schedule occurred in 2020 and 2021. In 2020, because of Covid-19 restrictions, I was not able to be on GGI; no total island count comparable to other years was done but a team (see Acknowledgments) went out for one day to mark a sample section of nests. Because the number they marked in their sample compared with the number marked in those areas in 2019, I estimated the total for the island might be the same as in 2019. In 2021, I led a team for a few days marking nests and they continued for several days after I left; all sections of the island (except the northeast rocks, described below) were checked once 7–15 June.



Figure 1. Roseate Tern nests on GGI in 2015 (black dots) with Backline shown.

In 2017 we discontinued our check of a section of boulders along the northeast edge of the island (referred to as the NE rocks). It had become too unstable for team members to safely climb on the boulders. In this and subsequent years I tried to estimate how many nests were there. This area is very difficult to observe; it is steep and juts out, so there is no view of the whole area from elsewhere on the island. The best way to observe it is from a boat, but because of strong currents boat captains don't want to stay in that area too long. When the boat passed the area each year I looked to see if birds were going down under the boulders, and estimated numbers standing on the boulders. I also approached the area from above, on the island, estimating the number of birds that flew off. However, since no nests have been marked there since 2016, I have not included my estimate for this area in nest numbers since that date.

During our surveys we marked each new nest with a numbered tongue depressor and recorded its number, general location, habitat (rocks, vegetation, boxes, "other"), and clutch size. "R" on tongue depressors for Roseate Tern nests distinguished them from those marking Common Tern nests. Distinguishing Roseate Tern nests from Common Tern nests was occasionally challenging, especially if they were in a habitat utilized by both species, such as the inner edge of the rocks with some vegetation. In case of a question of species, we put a question mark on the tongue depressor and in our notes. Once a chick hatched, we identified the species and updated our notes.

Nest counts are separated into "peak" counts and "total" counts. I followed the protocol for peak nest numbers as recommended for all Roseate Tern colonies in the northeast. As explained in USFWS (2010), "a nest count is made at the end of the 'peak period' of nesting (the interval between the date when the first nest is started and a date early in the hatching period 23 to 28 days later)." While members of the Roseate team were not always on GGI to find first nests, we were there to find the first chicks that hatched. There were often several days between first chick hatch and those following. I used the date when about a score of chicks had hatched to determine GGI's date of peak count (number of nests marked by that day). I consider that number to represent about 80 percent of the total nests on the island. This method of estimating was first suggested by Ralph Andrews, former Roseate Tern Recovery Team Leader, when visiting GGI in 1989. When he joined the GGI Roseate team to mark nests, he realized the impossibility of locating all Roseate nests under the boulders.

Calculating the GGI estimated total number of nests, I followed guidelines suggested by Ian Nisbet (personal commun.): take the estimated peak number, divide the number of nests marked after peak by 0.9, then add to the estimated peak number for an estimated total.

Beginning in 2014, GPS locations were taken for all nests. Throughout checks we recorded desertion, predation, and changes in clutch size. Normal Roseate full clutch size is two eggs (Gochfeld, et al., 1998). If there were two or more eggs, we wrote that number on the tongue depressor. When we checked these nests two or more days later

(depending on weather), we updated our clutch-size notes; if there was still only one egg, we considered it a one-egg clutch; if another egg, or eggs, had been laid, we updated our notes and the tongue depressor accordingly.

The “clutch size sample” number for each year is the number of nests used to calculate the mean clutch size. It is smaller than the total number of nests marked at peak because it only includes nests checked two days apart and does not include nests with eggs laid after chicks began to hatch. The year 2021 is an exception; due to our limited time on GGI, nests were not rechecked for added eggs.

Once hatching began, we banded all the chicks we found during our daily check. In addition to a BBL band, beginning in 1988 we put on a single plastic band to identify colony site (yellow for GGI). In the early 90s we transitioned to using Field Readable (FR) bands which allowed observers to identify individuals from a distance. Single four-character Metal Field-readable (MFR) bands were used until 2013, when we began to use colored three-character Plastic Field-readable (PFR) bands.

We recorded each chick’s band numbers, nest number, and order in brood: S (single), A (first of two or three), B (second of two or three) and C (third chick from a three-egg clutch). We recorded dead chicks whenever we encountered them. If banded, we removed the band(s), recorded the numbers, and buried the chicks. Daily checks usually ended in the beginning of July; after that, disturbance might have caused fledglings to fly out and become easy prey for gulls.

Productivity was measured as the number of chicks raised to fledging per nesting pair per year. For example, if you have identified ten nests and you know that a single young fledged from five of those nests, while two young fledged from each of the other five nests, there would have been a total of 15 chicks fledged from ten nests. Fifteen chicks divided by ten nests gives a mean of 1.5 chicks per nest. That is the “productivity figure” for those nests. On GGI (and other colonies), it was not possible to determine precisely how many chicks fledged from each nest. Nisbet et al. (1990) described five methods for estimating productivity. I used variations of method 1 and method 5 to derive productivity estimates: both methods depend on counting peak nests and banding as many chicks from peak nests as possible. Method 1 uses number of banded chicks minus the number of dead chicks, divided by the number of nests marked at peak. Method 5 uses surveys to observe the number of banded and the number of unbanded fledglings. Those numbers then establish a ratio of banded fledglings to unbanded ones. That ratio is applied to the number of chicks known to have been banded to estimate the number of chicks that were not banded. The number of chicks banded and the ratio-derived number of chicks that were not banded together establish the overall total number of chicks. That figure in turn is divided by the number of nests to establish the chick-per-nest productivity ratio.

In some years, it was possible to take this a step further by resighting PFR-banded fledglings on GGI and/or on the staging grounds (Spendelow, 2018, 2019, 2020). This

assumes survival of all A-chicks (Nisbet et al., 1999), then calculates the proportion of fledged B-chicks.

During our daily chick census we placed tape on rocks near nests with newly hatched chicks if they were located where it was possible to set a trap to capture the parents. We set the traps late in the day or early in the morning. When we trapped a bird, we recorded its nest number and reset the trap, hoping to catch its mate. We brought trapped birds to the processing area where we recorded, or put on, bands. Usually there was a mix of unbanded and previously banded birds. From 1988 through the early 1990s we used three color bands in unique combinations with BBL bands, transitioning to a BBL band on one leg and a single MFR on the other, and later to a PFR instead of a MFR band (Spendelow, 2018). If time allowed, we measured the culmen and weighed the bird. We then rechecked the traps to collect any birds caught and removed the traps whether or not a second bird had been captured. We did not trap those nests again that season.

Observers used spotting scopes from blinds in many different locations to read bands of adults and fledglings, watch the birds' behavior, and note what prey fish were brought in. In most years Hays and others arrived on the island by late April to read bands and record the terns' early season activities.

From 1995 through 2005 I returned to the island for a week-long, late-season census in late July or early August to mark any new nests, look for dead chicks, and read bands.

RESULTS

The estimated number of nests each year 1988–2021 (Table 1 and Figure 2) ranged from 1,080 (1992) to 2,200 (2019–2021).

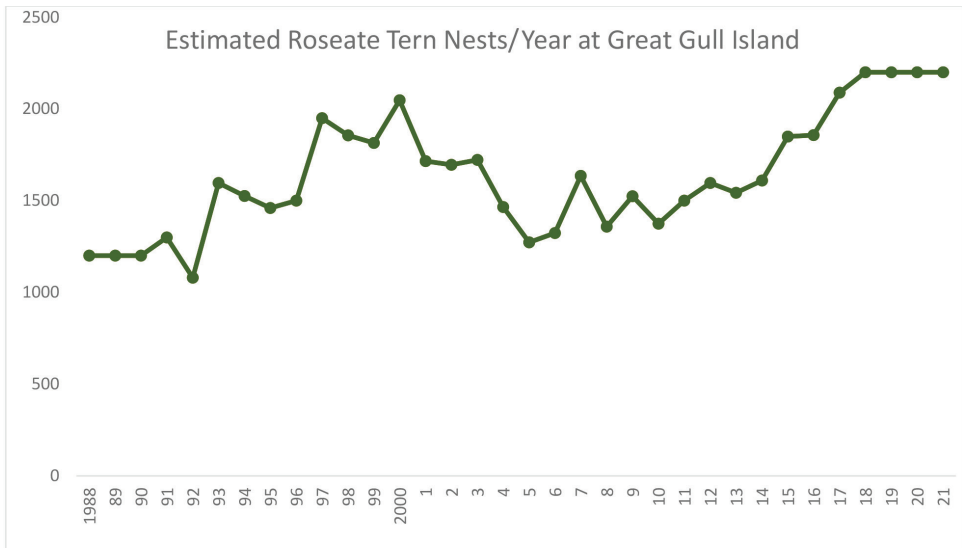


Figure 2. Estimated number of Roseate Tern nests per year.

Table 1. Roseate Terns Nest per Year

Year	Marked Nests Peak	Estimated Nests Peak	Marked Nests Total	Estimated Nests Total
1988	803	1004	960	1200
1989	800	960	950	1200
1990	821	1026	NA	1200
1991	963	1204	1180	1300
1992	771	964	980	1080
1993	1040	1300	1310	1597
1994	1133	1422	1221	1526
1995	845	1056	1170	1460
1996	851	1200	1141	1500
1997	1164	1455	1557	1950
1998	1352	1690	1502	1856
1999	1398	1747	1458	1814
2000	1410	1762	1667	2047
2001	1250	1562	1388	1715
2002	1205	1505	1376	1695
2003	1291	1613	1390	1723
2004	1082	1352	1185	1466
2005	956	1195	1027	1273
2006	979	1227	1071	1324
2007	1237	1546	1319	1636
2008	1030	1288	1094	1359
2009	1130	1413	1230	1524
2010	1045	1303	1110	1375
2011	1151	1439	1206	1500
2012	1277	1596	1277	1596
2013	1024	1280	1234	1543
2014	1167	1459	1304	1610
2015	1327	1659	1500	1849
2016	1331	1664	1506	1858
2017	1435	1793	1703	2089
2018	1522	1903	1792	2200
2019	1546	1932	NA	2200
2020	COVID - NO FULL COUNT-			2200
2021	1496	1870	NA	2200

I estimated that the NE rocks area, not marked 2017–2021, still had about the same number of nests, 50 (3% of total marked nests), that it had when it had been marked in 2016. From a boat I established each year that Roseates were going under the boulders, presumably to nests. On the island, when I approached from above, it seemed to me that the group flying off was about the same size as it had been when we marked 50 nests in that area. However, since no nests have been marked there since 2016, my estimates for this area, 2017–2021, are not included in Table 1.

The terns' use of nest boxes gradually increased over the years (as had the number of boxes). In 2013, 154 nests (12.5% of the marked nests) were in boxes, and in 2021, 340 nests (22.7% of marked nests) were in boxes. Nevertheless, the distribution of nests continued to be primarily around the perimeter of the island, on the map (Figure 1) for 2015.

In almost all years the number of two-egg clutches exceeded the number of one-egg clutches (Table 2 and Figure 3). Exceptions were in 1997 when 51% were one-egg clutches, and 2014 when 62% were one-egg. In Figure 3 the relatively small numbers of three-egg and four-egg clutches are combined; they are often referred to as “supernormal” clutches (Nisbet & Hatch, 1999). Five-egg clutches (not included in the clutch size table), probably laid by two females, are rare. We found one in 2000 and another in 2004.

The dates the first chicks hatched (Table 3) varied from the earliest, 9 June in 1998, to the latest, 21 June 1992 (mean 15 June, $N = 32$). Normally, Common Tern chicks begin to hatch about two days before Roseate Tern chicks (H. Hays, personal commun.). However, the Roseate Tern chick banded on 9 June 1998 hatched before any Common Tern chicks. This was the only year we know of when a Roseate Tern chick hatched before a Common Tern chick (H. Hays, personal commun.).

From 2013–2019 I took notes on the nest locations and clutch sizes of the first chicks to hatch. Of the ten “first-hatched” chicks, three were single chicks, and seven were A-chicks. Three had hatched in boxes, three were deep under boulders, one under small rocks, and three on the edge of rocks/vegetation. Five were on the eastern end of the is-

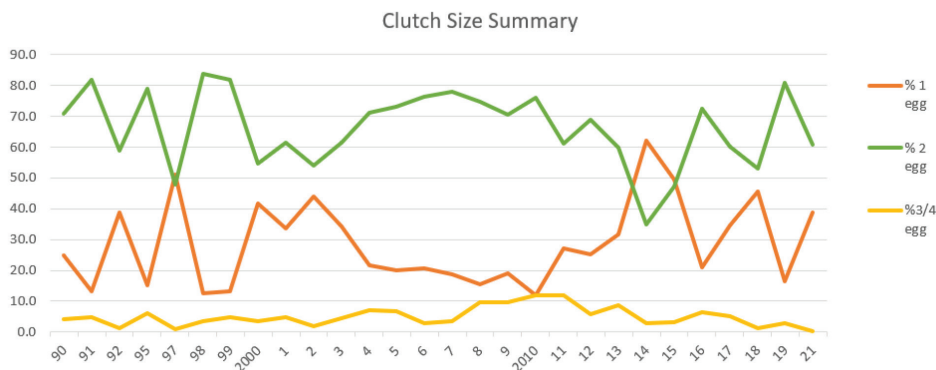


Figure 3. Percents of clutches with one, two, and three/four eggs.

Table 2. Clutch Size

Year	# 1-egg (%)	# 2-egg (%)	# 3-egg (%)	# 4-egg (%)	Mean	Sample Size
1988	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA
1990	140 (24.9)	397 (70.8%)	24 (4.3)	*	1.79	561
1991	98 (13.1)	613 (8)	37 (4.9)	*	1.92	748
1992	258 (38.7)	398 (59.7)	9 (1.3)	2 (.03%)	1.63	667
1993	NA	NA	NA	NA	NA	NA
1994	NA	NA	NA	NA	NA	NA
1995	111 (15)	587 (79)	45 (6)	*	1.91	743
1996	NA	NA	NA	NA	NA	NA
1997	414 (51)	388 (48)	6 (0.7)	3 (0.3%)	1.5	811
1998	137 (12.5)	923 (83.9)	29 (2.6)	11 (1)	1.92	1100
1999	98 (13.1)	613 (82)	31 (4.1)	6 (0.8)	1.93	748
2000	537 (41.8)	703 (54.8)	36 (2.8)	8 (0.6)	1.62	1284
2001	315 (33.5)	579 (61.6)	36 (3.8)	10 (1.1)	1.72	940
2002	456 (44)	560 (54)	20 (1.9)	1 (0.15)	1.58	1037
2003	328 (34.1)	591 (61.4)	38(4)	5 (0.5%)	1.71	962
2004	232 (21.5)	772 (71.3)	49 (4.5)	29 (2.7)	1.88	1082
2005	182 (19.9)	669 (73.2)	47 (5.1)	16 (1.8)	1.89	914
2006	176 (20.8)	645 (76.4)	17 (2.05)	7 (0.8%)	1.83	845
2007	194 (18.7)	807 (77.9)	28 (2.7)	7 (0.7%)	1.85	1036
2008	133 (15.4)	644 (74.8)	58 (6.7)	26 (3.0)	1.97	861
2009	181 (19.9)	642 (70.5)	67 (7.4)	20 (2.3)	1.92	910
2010	70 (12.2)	434 (75.5)	45 (7.8)	26 (4.5)	2.05	575
2011	244 (27.1)	550 (61.1)	83 (9.2)	23 (2.6)	1.87	900
2012	197 (25.1)	541 (69.0)	39 (5.0)	7 (0.9%)	1.82	784
2013	228 (31.6)	431 (59.7)	52 (7.2)	11 (1.5)	1.87	722
2014	493 (61.8)	282 35.4)	20 (2.5)	2 (0.3)	1.41	797
2015	575 (49.6)	546 (47.1)	37 (3.2)	1 (0.1%)	1.54	1159
2017	356 (34.6)	621 (60.3)	38 (3.7)	15 (1.4)	1.72	1030
2018	537 (45.5)	625 (53)	15 (1.3)	3 (0.2)	1.56	1179
2019	196 (16.4)	965 (80.8)	27 (2.3%)	6 (0.5)	1.87	1194
2020	NA	NA	NA			NA
2021	580 (38.8)	911 (60.9)	3 (0.2)	1 (0.1)	1.62	1495
Mean	N=28 28.6%	N=28 66.3%	N=28 4.0%	N=25 1.18	N=28 1.78	N=28 937

NA: data not available

* Number of 3-egg and 4-egg clutches combined

land, (three on the south and two on the north), and five on the western end (four on the south and one on the north).

Productivity estimates (Table 4) ranged from 0.75 chicks per nest to 1.8 (mean 1.2, $N = 23$). The number of dead chicks included both banded and unbanded dead.

PFR bands on hundreds of near-fledglings and recent fledglings were read both on GGI and Cape Cod, 2014–2018. These combined results, with data on how many were A, B, or S chicks, will enable us to do a more refined productivity estimate.

The number of adults trapped (Table 5) includes both retraps (previously banded birds) and unbanded birds. Some retraps had been first-banded as adults, others, as chicks; the latter are known age.

Hybrids have been trapped and observed. The first one was described by Hays (1975). In 1991–2005 I trapped and observed several hybrids. In recent years, less time was spent looking for them; few were identified.

DISCUSSION

Table 1 shows the considerable variation in the number of nests over the years. Figure 2 illustrates the number of nests generally increasing to a high of 2,000 pairs in the year 2000, decreasing to fewer than 1,300 pairs in 2005, then increasing to 2,200 pairs in 2018, where it remained through 2021. The reasons for these fluctuations are not clear. They follow a general trend shown in a comprehensive graph of many colonies, including GGI: (Mostello).

Table 3. Chicks Banded/First Hatch

Year	Number of chicks banded	First Hatch
1988	351	15-Jun
1989	330	12-Jun
1990	496	17-Jun
1991	902	17-Jun
1992	753	21-Jun
1993	1087	16-Jun
1994	1024	17-Jun
1995	1079	16-Jun
1996	795	18-Jun
1997	973	17-Jun
1998	1704	9-Jun
1999	1548	17-Jun
2000	1352	13-Jun
2001	1265	14-Jun
2002	1246	17-Jun
2003	1230	20-Jun
2004	1353	16-Jun
2005	968	19-Jun
2006	1117	18-Jun
2007	1363	15-Jun
2008	1034	16-Jun
2009	1239	13-Jun
2010	1191	12-Jun
2011	1119	12-Jun
2012	902	9-Jun
2013	799	13-Jun
2014	767	14-Jun
2015	846	16-Jun
2016	1422	13-Jun
2017	1600	13-Jun
2018	1171	10-Jun
2019	301	12-Jun
2020	0	NA
2021	0	NA

Table 4. Productivity

Year	Number of dead chicks	Productivity Chicks Per Nest
1988-1996	NA	NA
1997	very few	1.0-1.2
1998	48	1.5-1.6
1999	118	1.4
2000	9	1.27
2001	32	1.13
2002	70	0.9
2003	25	1
2004	72	1.17
2005	27	1.6
2006	84	1.3
2007	23	0.9
2008	27	0.98
2009	21	1.1
2010	5	1.4-1.8
2011	6	1.2-4.0
2012	106	0.8
2013	2	1.16
2014	6	1
2015	6	1.25
2016	38	1.36
2017	21	1.44
2018	5	1.48
2019	NA	0.75-0.80
2020	NA	NA
2021	NA	NA
Total	745	27.43
Mean	35.47	1.2

On GGI, there were two known instances where predators apparently contributed to lower nest numbers. Two raccoons (*Procyon lotor*) in 2004 and 2005 predated many nests in certain areas, contributing to low nest counts in those years. I found headless adult Roseate Terns near their empty nests. Tracks suggested the predator was a raccoon. This was confirmed when two raccoons were caught in the spring of 2006. The number of nests in those areas remained low in 2006, even after the raccoons were removed. (Nest numbers in Buzzard Bay, MA [BBMA], colonies were slightly lower in those years, but less so than on GGI).

In another instance, a pair of Great Black-backed Gulls (*Larus marinus*) attempted to nest several times in 2018 near a section of boxes on terraces, resulting in fewer nests in those boxes in that and the following year. While this area is difficult to observe and we did not find direct evidence of predation by the gulls, we have often observed fledging terns taken by the gulls. In my experience, when a predator has destroyed nests in an area, no terns nest there for several years. In contrast, Spendelow et al. (2002) found that older pairs continued to use tire sites even after several years of Black-crowned Night-Heron (*Nycticorax nycticorax*) predation, while younger pairs did not develop fidelity to that area.

Another factor influencing the number of nests is the availability of suitable sites. Erosion of nesting areas has occurred in several areas. The section of boulders along the northeast edge of the island was so severely eroded by storms that we stopped checking there in 2017. Hurricane Sandy, 29–30 October 2012, washed over many sections of the island, altering about half of the areas where Roseates normally nested. Consequently, birds whose former nest sites had not been affected nested on time, as expected, and were part of our peak count. Displaced birds had to find new

Table 5. Adults Banded

Year	Number adults trapped	Number previously banded	Number unbanded
1988	247	NA	NA
1989	205	NA	NA
1990	186	NA	NA
1991	339	162	177
1992	255	NA	NA
1993	386	NA	NA
1994	299	107	192
1995	268	178	90
1996	160	111	49
1997	197	124	73
1998	207	141	66
1999	120	81	39
2000	203	137	66
2001	217	143	74
2002	221	139	82
2003	231	167	64
2004	259	176	83
2005	229	168	61
2006	209	157	52
2007	279	208	71
2008	202	138	64
2009	116	65	51
2010	205	120	85
2011	158	108	50
2012	19	11	8
2013	183	110	73
2014	151	95	56
2015	124	87	37
2016	240	162	78
2017	217	157	60
2018	51	32	19
NO ADULTS TRAPPED OR BANDED 2019-2021			
TOTALS	6383	3284	1820

sites, delaying their nesting and lowering our peak count; ultimately, however, the total count for 2013 was only slightly lower than other years.

To counterbalance the loss of nesting habitat, additional nesting areas were made available in 2015 on new terraces with nest boxes (Cormons, 2022). In addition, after Hurricane Sandy, at Hays' suggestion, we increased our efforts at habitat enhancement as described in Methods. There were not enough of any one kind of new nesting habitat to do a study, but all types were used and young fledged from them. In addition, there are many available sites under the boulders and along the edge. Trapping and observing these areas have shown that a site may be used by the same pair for many years, be unoccupied for a number of years, then occupied by a different pair. Perhaps when one or both members of the original pair dies it takes time before a new pair finds its way under the boulders to claim that site, which then is often occupied again for many years.

In general, clutch sizes were larger in years when the supply of prey fish appeared to be plentiful. In 2005 Hays noted an apparently good fish supply, which correlated with 73% of nests having two eggs (personal commun.). In contrast, in 2014 the number of two-egg clutches was unusually low (35%). Hays noted an apparent shortage of prey fish and found Common Tern clutch sizes were also smaller that year (personal commun.).



Figure 4. Roseate Tern showing blue and white PFR band on left leg. Photo courtesy of Matthew Male.

In 2021, unlike previous years when we were able to recheck nests and adjust clutch size a couple days after the initial marking, nests were only checked once. Therefore, some one-egg clutches might have become two-egg clutches had we done a second check. The 2021 data might be biased toward lower clutch sizes compared to other years.

The differences in first hatching dates probably correlate to weather as well as to food supply at the time of laying. I do not have specific data on this.

I had long been interested in the nest location of the first chick to hatch, as this indicates the nest site preferences of early nesters for particular habitats. The first-hatched chicks were found in different habitats and different parts of the island. No one habitat nor island location was preferred by early-nesting birds. It had been suggested to me that Roseate Terns nest among the boulders because they can't find suitable nest sites elsewhere. However, the nest locations of the first-hatched chicks indicates that nesting under the boulders is often a first choice for early nesters.

Occasionally there appeared to be a drop in food supply at critical times for the growing chicks. During those years we found a number of dead chicks during check. For example, in 2012 (Table 4) nearly all of the 106 dead were found during the third week of June, when apparently there was a severe lack of food.

As we usually did not check after about 4 July, we have little data on chicks that may have died later in the season. However, from 1995 until 2005, when I returned to GGI in late July/early August for a final check, I searched for dead chicks and found very few (0–6) each year.

In my opinion, the best way to get good productivity figures is to band as many chicks as possible with PFR bands, then do as much resighting as possible on GGI and, in collaboration with others, at important staging areas where it is relatively easy to read PFR bands on terns on sandy beaches, e.g., at Cape Cod, MA (see Spendelov, 2018, 2019, 2020). Resighting is the only sure way to know which young birds have fledged, left GGI, and made it to staging areas prior to their departure for South America.

The numbers of adults and chicks banded each year (Table 3) has varied depending on the weather, as well as on how many people were on the Roseate team. Numbers banded in 2012 were low because I had to leave the island early due to a family emergency. Beginning in 2018 limits were placed by USFWS on how many chicks and adults could be banded. For many years funders had requested that we trap at least 200 adults and as many chicks as possible each year, to achieve a good sample for metapopulation studies (Spendelov et al., 1995, 2002, 2008; Lebreton et al., 2003; Davis et al., 2019). Banding has yielded valuable information about non-breeding birds in Brazil, Puerto Rico, and Colombia (Hays et al., 1997, 1999, 2000, 2002a, b, 2010; Azpiroz et al., 2020). It is important that anyone encountering a banded bird (including PFR bands read in the field) report the band number(s), date, and location to the BBL (www.reportband.gov). Unfortunately, banding restrictions in recent years have resulted in less opportunity to better understand the movements and population dynamics of Roseate Terns in this metapopulation.

Managing the colony for the recovery of the endangered Roseate Tern meant constantly being aware of the terns' actions and needs. We adjusted our activities in response to changes in weather, were aware of the terns' stress level, and remained flexible to alter our schedule as necessary. Undesirable vegetation was controlled and, anticipating sea-level rise, nesting areas higher up were provided. As the data presented here show, the colony thrived under Hays' insightful management.

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Joe DiCostanzo assigned the BBL bands for use on Roseate Terns, meticulously entered our banding data, and submitted it each year to the BBL. Joe is always helpful, answering my questions and providing information as needed. In addition, he carefully read and revised this manuscript. Jeff Spendelow assigned and supplied the MFR and PFR bands we used and keeps those extensive records. He is always ready to look up the information on resighted birds and share data on those he has seen or that have been reported by others; it is a pleasure to work with him. Jeff did extensive editing on this manuscript and made valuable suggestions; I am very grateful.

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Oceanic Birds of the New York Bight

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ABSTRACT

New York City and the adjacent coastlines of Long Island and New Jersey are strongly influenced by the Atlantic Ocean, a vast open ocean habitat that is home to a remarkable variety of marine wildlife, much of which is unfamiliar to terrestrial observers. This article provides an overview of the biologically rich seascape formed by a sharp indentation in the North American coastline known as the New York Bight. Extending from Cape May at the southern tip of New Jersey to Montauk at the eastern tip of Long Island and diagonally bisected by the submarine Hudson Canyon, these waters extend across the relatively shallow continental shelf before plunging into the depths of the North Atlantic basin. The seasonal movements and ecology of more than thirty predominantly oceanic bird species, including shearwaters, *Pterodroma* petrels, storm-petrels, skuas, alcids, and various others, are discussed with notes on anticipated vagrants and the potential threats to this vibrant marine environment.

INTRODUCTION

The New York Bight (NYB) is a sharp indentation in the Atlantic coastline of North America, extending from the mouth of the Delaware estuary at Cape May, New Jersey, to the eastern tip of Long Island at Montauk Point, New York (Figure 1). Encompassing close to 45,000 square kilometers of open ocean, this oceanographic feature is formed by an abrupt shift in the orientation of the mid-Atlantic coastline, switching from a roughly south to north direction along the coast of New Jersey to a more west to east orientation across coastal New York including Long Island and Connecticut. At the apex lies the mouth of the Hudson River, which over the millennia has carved a large submarine canyon that extends southeast across the relatively shallow continental shelf for more than 100 kilometers to the continental slope or shelf break whereupon it drops to the floor of the much deeper Atlantic basin. The Hudson Canyon is the largest submarine canyon in the western Atlantic and is flanked by at least sixteen smaller canyons that project across the shelf, either roughly east of the New Jersey coastline or south of

Keywords: New York Bight, Oceanic Birds, Seabirds, Submarine Canyon, Gulf Stream, Pelagic Birds, Hudson Canyon, Labrador Current

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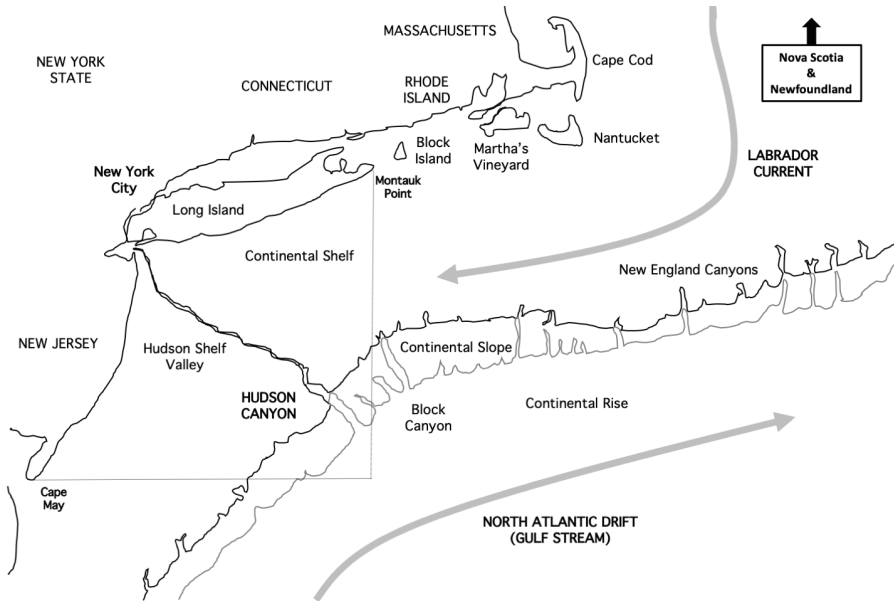


Figure 1. Principal features of the New York Bight. This oceanographic feature is formed by a sharp deflection in the coastline of eastern North America with the mouth of the Hudson River at its apex. The submerged rim of the continental shelf is shown along with the major submarine canyons that cut through the shelf break and drop to the abyssal plain. Coastal waters are cooled by a branch of the Labrador Current that flows southwest and are opposed by warm water emanating from the Gulf Stream that runs northeast but well beyond the Continental margin. The friction of surface winds and the sloping terrain of the shelf edge create transient zones of upwelling that support a large and diverse biomass that in turn attract apex predators including oceanic birds.

Long Island and Rhode Island. The continental slope is further indented by numerous gullies, ridges, and landslide scars, creating very complex patterns of water circulation. The NYB itself sits within an even larger indentation known as the Mid-Atlantic Bight, which extends from Cape Hatteras, North Carolina, to Cape Cod, Massachusetts, that shares a relatively consistent assemblage of seabirds, fish, marine mammals, invertebrate animals, and plankton.

Initiated by the action of rivers during the Pleistocene, when sea levels were approximately 45 meters lower than today, the submarine canyons and other steep-sided valleys are thought to have been further deepened by erosive turbidity currents that are created when loose, wet sediment tumbles down the slope at high speed in the form of submarine landslides (Daly, 1936; Fildani, 2017). This carving action is sustained by the relentless accumulation of sand and other sediment carried down by rivers at the heads of these submerged valleys and pushed across the shelf by perpendicular currents known as the longshore drift before ultimately falling into the upper reaches of the canyons.

The waters over the continental shelf are relatively shallow, averaging 25 meters close to shore but progressively deepening to 200 meters at the shelf break before plunging to 3,000 meters or more. Superimposed over the topography of the shelf break and the canyons is the continuous flow of oceanic current systems that bring both cold, nutrient-rich (green) water and warm, nutrient-poor (blue) water into the bight. The mixing of these currents and their complex interactions with the shelf break and the canyons create numerous hotspots for marine plankton and invertebrates that in turn attract a wide variety of predatory fish, cetaceans, and pelagic birds. Although invisible from the surface, these submarine features are well known to commercial and amateur fishermen alike because of the recurring abundance of marine wildlife.

The Gulf Stream or North Atlantic Drift is the most influential current influencing the region. Aptly named the "Great Blue River" by Ernest Hemingway, a fervent game-fishing enthusiast (Hemingway, 1949), this immense body of warm (blue) water moves north from the tropical Caribbean past the Atlantic coast of North America at the rate of about 2 m per second, slightly faster than the Hudson River as it passes Manhattan, before deflecting eastward across the North Atlantic toward Europe. The current only skims the outer margins of the NYB, well beyond the shelf break, but it is highly influential nonetheless. Although strong and continuous, the flow is unstable and wobbles north and south of its mean position, sometimes bringing warm water closer to the shelf and at other times pushing it farther away (Richardson, 2001).

Occasionally large meanders will fuse and detach from the main current in the form of eddies or current rings. Those released north of the current are influenced by the Coriolis effect and rotate clockwise as they drift westward as large bubbles of warm water that gradually cool and decay over periods of months. Similarly, linear filaments of Gulf Stream water can extend away from the current. From time to time, eddies and filaments will rub up against the continental slope, and may even flow onto the shelf itself, helped by the funneling action of the canyons.

Opposing the warm Gulf Stream is the Labrador Current, an oceanic river of cold water that originates in the Arctic Ocean. As it flows past Newfoundland, one arm is deflected westward by the shallow waters of the Grand Banks and Flemish Cap, continuing past the New England coastline into the NYB and eventually as far south as the Outer Banks of the Carolinas. The juxtaposition of water from these different sources helps produce the "temperature breaks" (thermal fronts) that attract predatory fish, marine mammals, and of course oceanic birds. These ever-changing boundaries are also much sought after by game fishermen and naturalists. Nowadays, satellite-based imagery provides detailed maps of sea surface temperatures in near real time, simplifying the task of finding sharp temperature transitions where the effects of mixing are greatest. Nutrient-rich water is also brought to the surface where it is exposed to sunlight through the phenomenon of coastal upwelling caused by the movement of surface water across the shelf driven by winds as well as the shearing forces of opposing cur-

rents. As the surface water moves it is replaced by water drawn up from deeper depths creating a vertical circulation. River outflow contains less salt than true oceanic water and is therefore less dense. The relentless discharge from the Hudson River forms a surface plume of riverine water and suspended particulates that extends over the shelf at the apex of the bight. In general, this plume drifts eastward along the south coast of Long Island where it can collect in bays, but the exact shape and extent of this dispersal fluctuates in response to the changing volumes of estuarine water emerging from the river mouth and the prevailing offshore winds (Chant et al., 2008).

During the late 1970s, some of the largest aggregations of oceanic birds off the eastern United States were associated with factory trawler fleets, often sailing from ports in Asia, Europe, or the former Soviet Union, that fished for silver hake (*Merluccius bilinearis*) and other bottom-foraging fish in the NYB (Lear, 1998). These fleets disappeared in the 1980s with the implementation of the 200 nautical mile Exclusive Economic Zone (EEZ) and with them disappeared the massive flocks of feeding gulls and other seabirds that fed on discards from the fishing fleet. Commercial fishing continues on a more local scale including bottom dragging for a variety of species including longfin inshore squid (*Doryteuthis pealeii*), flounder (*Paralichthys dentatus* and *Pseudopleuronectes americanus*), skate (*Dipturus* sp.), and sand dab (*Citharichthys* sp.) or by using baited pots for American lobster (*Homarus americanus*), crab (*Cancer pagurus*), scup (*Stenotomus chrysops*), and blackfish/tautog (*Tautoga onitis*). Favored fishing methods and locations vary through the year, concentrating over more inshore waters and the shelf break in the summer, but spreading out across most of the shelf and canyons in other seasons (Scotti et al., 2012). Longfin inshore squid are abundant over both shelf and slope waters at depths between 100 and 168 m, arriving in May or June but moving back to deeper waters along the shelf edge by late November/early December (Macy and Brodziak, 2001). As will be discussed below, the distribution and abundance of oceanic seabirds is strongly influenced by the complex migrations of these fish, squid, and numerous prey species, resulting in a dynamic and ever-changing marine ecosystem.

OCEANIC BIRDS

This article discusses the seasonal occurrence of oceanic birds recorded within the NYB and adjacent waters of New Jersey and New York. The accounts draw on the extensive scientific and popular literature, open access sightings databases, and my own experiences of watching marine wildlife both at sea and from shore over more than three decades as well as from extensive travels in all the world's oceans. From a taxonomic standpoint oceanic birds represent an arbitrary grouping, here focusing on thirty-five species that are most often encountered beyond a few kilometers or more from land during at least part of the year. For space reasons, species found mostly within ten kilometers of shore or within sheltered bays and estuaries such as eiders and other marine ducks, cormorants, loons, grebes, the majority of gulls and terns, and Black Guillemot (*Cepphus grylle*) will

not be discussed but interested readers are directed to an excellent monograph by Jan Nisbet and colleagues (Nisbet et al., 2013). Accounts of regional avifaunas also provide good syntheses of historical data (see Veit and Peterson, 1993; Levine, 1998; Boyle, 2011). With only a few deviations, the taxonomy and species names follow the American Ornithological Society (AOS) Checklist (Chesser et al., 2019) and the names for marine fish follow the American Fisheries Society Checklist (Page et al., 2013).

Our knowledge of the oceanic birds found in the NYB is constantly evolving. This reflects both a changing environment and the ever-improving knowledge of observers. Field data come from at least four primary sources, all of which are incomplete and offer rich opportunities for discovery. Over the years, numerous enthusiasts have made irregular offshore excursions (known colloquially as “pelagics”) in search of oceanic birds and other air-breathing vertebrates, most notably whales and dolphins (Brady, 2009). Typically, these relatively short trips have relied on chartered head boats, slow-moving fishing vessels specifically designed to take paying passengers (“heads”) to offshore fishing spots including artificial reefs or other structures on the seabed that attract edible fish. These charters provide useful sightings, but unless dedicated to wildlife watching are inclined to linger over preferred fishing spots and, in the winter months, often travel back and forth in darkness, limiting the opportunities to detect oceanic birds aside from gulls and other species that scavenge around the vessel. Dedicated pelagic birding charters offer the advantage of actively seeking out bird and cetacean activity and often dispense fish scraps, diced suet, and other morsels known as chum (or confusingly as chowder) in order to attract birds closer to the vessel. During the warmer months, pelagic charters may also deploy a surface film of fish oil mixed with fish or suet fragments that act as strong attractants to foraging birds by mimicking the particulate slicks created by predatory fish, decaying marine carcasses, and defecating whales. Effective chumming is more of an art than a science and the composition of the inevitably smelly concoctions as well as the means for dispensing them are often considered closely guarded secrets that are refined over time. Some of the increases in sightings of warm-water *Pterodroma* petrels and rarer storm-petrels can be attributed to more skillful deployment of fish oil slicks based on years of trial and error, especially by innovators of the art such as Paul Guris and Brian Patteson.

During the summer, sport fishermen, often using their own faster boats, venture farther offshore to the shelf break or beyond in search of larger game fish such as tuna (*Thunnini* sp.), Atlantic blue marlin (*Makaira nigricans*), white marlin (*Kajikia albida*), swordfish (*Xiphias gladius*), and dolphinfish/mahi-mahi (*Coryphaena hippurus*). A few are knowledgeable birders and provide useful data. Many of the skills required to find and ultimately catch gamefish apply also to finding birds and much of this knowledge is artisanal in nature. Locating temperature breaks and current boundaries that concentrate both prey and predators is important along with a knowledge of reliable sites of upwelling or other sources of turbulence within the water column.

Additionally, there are dedicated scientific survey trips using larger research vessels that perform a variety of studies and regularly include experienced field observers who undertake careful censuses of birds and/or marine mammals. Being more stable and higher off the water, research vessels offer superior viewing conditions and some are equipped with mounted 25 × 150 “big eye” binoculars that greatly expand the detection range. Although survey ships are often limited to predetermined transects, they can spend much longer periods in deep water than is possible in smaller sport fishing vessels or charters. Commercial cruise ships also offer height, stability, and overall comfort but travel at comparatively high speeds and never deviate course to examine feeding flocks or other phenomena that might serve as focal points for oceanic birds. Observers on these larger vessels have provided the bulk of information on birdlife in the outermost sectors of the NYB including the edge of the Gulf Stream, revealing a more tropical avifauna than is usually encountered closer to the continental shelf or the shelf break.

Last but not least, land-based observation (“seawatching”) provides the bulk of information on seabird migration through the region. This involves observers surveying the ocean from a terrestrial vantage point, using spotting scopes or binoculars. Obviously, these observations are limited to a very narrow band of no more than 1–3 km along the coastline, corresponding to the limits of the optics used. These observations are ideal for monitoring inshore species such as scoters and loons as well as species favoring shallower water such as Razorbill (*Alca torda*), Northern Gannet (*Morus bassanus*), Parasitic Jaeger (*Stercorarius parasiticus*), and, in season, a variety of shearwaters. Detection of deep-water species by terrestrial observers usually requires strong onshore winds such as those associated with Nor’easters and hurricanes. When cyclonic storms make landfall they can deposit a variety of oceanic birds at coastal sites and inland bodies of water sometimes as far inland as the eastern Great Lakes. The species composition is not necessarily representative of the birdlife immediately offshore, favoring those species better able to travel long distances within the confines of the eye of cyclonic storms such as medium-sized *Pterodroma* petrels, South Polar Skuas (*Stercorarius maccormicki*), tropicbirds (*Phaethon* sp.), Bridled Tern (*Onychoprion anaethetus*), and Sooty Tern (*O. fuscatus*). Relatively abundant summer visitors such as Audubon’s Shearwater (*Puffinus lherminieri*) and Wilson’s Storm-Petrel (*Oceanites oceanicus*) are noticeably under-represented in hurricanes, suggesting they are able to avoid these immensely powerful weather systems or are able to escape from the storm if they get caught up by them. Nonetheless, an exciting variety of species has been recorded by land-based observers during these extreme weather events, giving some information about the species present offshore.

The nuances of at-sea identification of the species discussed are beyond the scope of this article but many excellent treatments are available (Onley and Scofield, 2007; Flood and Fisher, 2011; 2013; 2016; 2020; Howell, 2012; Howell and Zufelt, 2019). Careful study of the key identification criteria for the more likely species prior to venturing into

the field is strongly recommended. Digital photography has also made it much easier to obtain images that can be studied later to verify identifications or to document unusual sightings. Organized pelagic trips generally include a number of experienced observers (“leaders”) who are there to help you see the different species being encountered and are always happy to discuss the features being used for identification.

SEASONAL GROUPINGS

Rather than follow a conventional systematic approach, I have grouped the thirty-five species to be discussed according to season of peak occurrence. Although imperfect, this helps paint a more coherent picture of the species likely to be encountered at any particular time of year and acknowledges the fact that different species may utilize the waters of NYB for similar reasons. Of course, there is much overlap across these divisions and plenty of exceptions, especially during transitional periods. Details of specific sighting as well as photo-documentation can often be found in open access databases such as Cornell Lab of Ornithology’s eBird (<https://ebird.org/home>), in regional bird record committee reports published online, or in journals such as *The Kingbird* and *Records of New Jersey Birds*, seasonal summaries in *North American Birds*, or in the accounts of regional avifauna listed above. In a few instances, an eBird checklist accession number is included after the sighting date allowing the reader to access more details or photographic documentation.

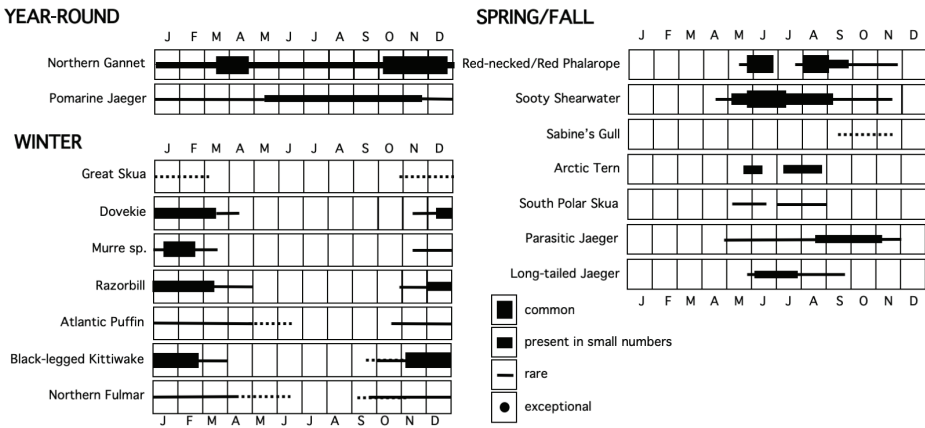


Figure 2. Seasonal occurrence charts for oceanic bird species found year-round, in winter or in spring/fall. Assessments are based on offshore data from 2010 to 2019 compiled from eBird and regional summaries covering the area shown in Figure 1. This corresponds to the US exclusive economic zone (EEZ) seaward of New Jersey (Ocean and Monmouth Counties), New York (Queens, Nassau, and Suffolk Counties), Rhode Island (Washington and Newport Counties) and Massachusetts (Dukes, Nantucket, and Barnstable Counties). Shore-based observations are used only in the context of coastal observations (seawatching). Bars indicate the general likelihood of encountering the species within this diverse area in a given week. In reality, most species will be restricted to specific habitats and oceanographic features as discussed in the text.

Year-round

Northern Gannet (*Morus bassanus*): As visually distinctive fish-catching machines, Northern Gannets are abundant over continental shelf waters on both sides of the North Atlantic. Present in the NYB for much of the year, large numbers migrate up and down the nearshore coast en route between their breeding colonies in maritime Canada and Iceland, and their wintering grounds off the Mid-Atlantic states, Florida, and the Gulf of Mexico (Fifield et al., 2014). Although most of the birds from North American colonies follow this coastal route, there is evidence that individuals nesting in Newfoundland regularly cross the Atlantic to winter off West Africa. Gannets are more frequently encountered close to shore than over deeper water, often following the annual migrations of forage fish including Atlantic menhaden or bunker (*Brevoortia tyrannus*) and Atlantic mackerel (*Scomber scombrus*). During migration, tens of thousands of gannets are routinely logged from coastal watch points in both New Jersey and New York. In November 2009, 16,946 were logged in a single day passing Avalon, New Jersey (Boyle, 2011), and on 27 October 2019 an estimated 21,350 passed a watchpoint on eastern Long Island (eBird S60971040). Atlantic Gannets are scarce in midsummer but numbers begin to climb in September as the large nesting colonies in the maritime provinces disperse and move south. Capture studies have shown that females reach the Mid-Atlantic region a day or two before males and that birds breeding in the Gulf of St. Lawrence arrive slightly earlier than birds from Newfoundland colonies (Speigel et al., 2017). Adults start returning northward from late February onward and are followed by subadult birds that will likely not breed in the calendar year, some of whom linger into May. In general, males push northward a week or so ahead of the females, presumably allowing them to establish nest sites within the crowded colonies. Medium-sized schooling fish are targeted using dramatic plunge dives from the air, as well as by swimming down from the surface. In many places, large feeding flocks or “frenzies” can be observed from shore, often working in tandem with marine mammals and larger predatory fish such as striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*) to corral huge schools of bait fish for easy capture. Hotspots for these spectacular mass feeding events include Raritan Bay, between Sandy Hook, New Jersey, and Staten Island, New York, and Block Island Sound, situated between the eastern tip of Long Island and the coast of Connecticut and Rhode Island. Satellite tagging studies by Iain Stenhouse and colleagues of wintering gannets captured using night-lighting techniques have demonstrated regional scale movements within the Mid-Atlantic, switching to a more focused northward movement in April (Speigel et al., 2017). Interestingly, females make greater use of coastal waters than males.

Pomarine Jaeger (*Stercorarius pomarinus*): After nesting on the High Arctic tundra, Pomarine Jaegers undertake a remarkable change of diet as they return to the North Atlantic for the remainder of the year. On the tundra they feed almost exclusively on brown lemmings (*Lemmus trimucronatus/sibiricus*) but switch to a fish-

dominated diet when at sea, using physical aggression to force shearwaters and other seabirds to regurgitate their recent captures. Occasionally they are seen to catch and consume small birds, notably migrant passerines carried out to sea by fall winds, along with smaller waterbirds such as Dovekie, small gulls, and phalaropes. Adults and subadults may be encountered at almost any time of the year, reflecting small numbers of over-wintering birds as well as a protracted period of migration that begins with northbound adults and subadults in the spring and early summer followed almost immediately by failed breeders and non-breeders, early departing adults, and finally juveniles from late August through to December. Wintering individuals were more common in the 1970s when the large foreign fishing fleets were still active in the NYB.

Winter

The colder months (December to February) feature a variety of species that are more frequently encountered in the Gulf of Maine and Canadian maritime provinces but extend southward in variable numbers. At-sea observations at this time of year are limited, especially from the shelf break and outward because of the infrequent periods of stable weather. Most observations are made from around commercial fishing vessels, which act as strong attractants to seabirds due to the abundance of bycatch and other discards. Gulls are especially numerous during these months and often follow draggers and other fishing vessels in their thousands. Indeed, many of the gulls seen resting on coastal beaches in the winter commute tens of kilometers offshore to feed. These assemblages can attract fierce kleptoparasites such as Great Skua (*Stercorarius skua*) and Pomarine Jaeger (*S. pomarinus*), as well as “white-winged” gulls and smaller species such as flocks of Bonaparte’s Gull (*Chroicocephalus philadelphia*) that sometimes include exotics like Little Gull (*Hydrocoloeus minutus*) and, very rarely, Ross’s Gull (*Rhodostethia rosea*).

Great Skua (*Stercorarius skua*): This formidable kleptoparasite is a much sought-after winter specialty for North American birders. Great Skuas are endemic to the northeastern Atlantic with major nesting colonies in Iceland, the Faroe Islands, western Scotland, and the Svalbard archipelago in the Barents Sea. At a global level this is a relatively scarce seabird, with an estimated world population of only 16,300 to 17,200 nesting pairs, which equates to no more than 35,000 mature individuals (BirdLife International, 2020). Sightings in the waters surrounding the NYB occur primarily between November and December with a few in early March. Most often, these are associated with active fishing vessels and the accompanying flocks of large gulls attracted to the abundant fishy discards. Although the information is still incomplete, recent use of geolocation data loggers found that adults wintering on the Grand Banks off Newfoundland were almost exclusively from colonies in Iceland and Svalbard rather than from colonies in Scotland, which preferentially winter off West Africa (Magnusdottir et al., 2012). Great Skua is one of the few seabird species

negatively impacted by changes in commercial fishery regulations that have reduced excessive bycatch, noncommercial fish, squid, and crustaceans that are discarded at sea (Votier et al., 2004).

Dovekie (*Alle alle*): **Dovekie** (or *Little Auk*) is widely touted as the most abundant bird species of the Arctic, with a population of up to 80 million individuals. Nesting colonies are restricted to the High Arctic (from 60°N in south Greenland to 82°N in Franz Josef Land) with the majority being on the northern coasts of Greenland and in Spitzbergen, primarily in the nooks and crannies of rocky slopes and cliffs. During the winter most move southward into the fragmented pack ice of the Barents Sea and westward into the Gulf of Maine, Georges Bank, and waters of the NYB with smaller numbers occurring as far south as the Outer Banks of the Carolinas. Those in North American waters are likely of the smaller nominate subspecies *A. a. alle*. Offshore trips in winter (December to early March) regularly encounter Dovekie on the outer shelf. This is more dependent on water temperature than distance, reflecting the local abundance of near-surface zooplankton that comprise the bulk of their diet. Although sightings of tens to hundreds in a day are typical, an organized pelagic on 10 February 2007 recorded 9,000 in 43°F shelf water south of Jones Beach. Sightings from land likely reflect the presence of much larger numbers offshore. Occasionally weather conditions will produce displacement events when flocks are seen moving along the coastline. These are distinct from “wrecks” when weakened or moribund birds appear on beaches or even inland (Underwood and Stowe, 1984). As happened in the winter of 1932/33, wrecks can be massive in scale and extend across much of the Eastern Seaboard (Murphy and Vogt, 1933). Wrecks are often associated with deep depressions producing periods of sustained gale-force winds that hamper feeding or displace birds from optimal foraging areas (Stenhouse and Montevecchi, 1996). Large gulls, especially Great Black-backed Gulls (*Larus marinus*), make short work of these starling-sized seabirds, often swallowing them whole, making it difficult to assess the full extent or causes of such incursions. Although tiny, Dovekies are tough birds, able to thrive in very harsh and frigid conditions as long as suitable prey is available.

Common Murre (*Uria aalge*) and **Thick-billed Murre** (*Uria lomvia*): Historically, Common Murre was among the least frequently encountered alcid species in the NYB. This changed in the late 1990s and early 2000s, when sightings of Common Murres during winter pelagic trips increased dramatically (Veit and Guris, 2008). Encounters are most frequent mid-shelf (30 to 50 km offshore) and sightings from land remain relatively rare. Thick-billed Murre has shown the opposite trend, becoming scarcer with the majority of recent records being seen from shore, including some birds in poor health found in tidal creeks and even on freshwater lakes. The reasons for this switch in the status of the two murres are uncertain but might reflect changes in the availability of favored prey species. The origin of Thick-billed Murres wintering in the NYB has not been addressed in the literature but probably involves the nominate population (*U. l.*

lomvia), which nests in Greenland and the Canadian Arctic as far south as the Gulf of St. Lawrence. The diet and feeding strategies of both species appear to be similar and involve deep dives to 100 or even 200 m and can last up 3 minutes. This means that murrens can reach the sea floor over much of the continental shelf, allowing them to more effectively exploit the benthic zone.

Razorbill (*Alca torda*): In contrast to the other alcids being discussed, this is a more inshore species, found favoring shallow reefs and the discharge plumes of rivers and coastal bays. Razorbills can be encountered anywhere on the shelf (usually within 15 km of shore) and only rarely beyond the shelf-break. Arrivals begin in late November and by later March many adults are in alternate (breeding) plumage with fully developed bills. The diet is quite varied including a variety of forage fish such as Atlantic herring (*Clupea harengus*), small Atlantic cod (*Gadus morhua*), and sandeels (*Ammodytes*), as well as krill-like euphausiids. Most return to the breeding colonies in the Gulf of St. Lawrence, eastern Newfoundland, and Labrador by mid-April into early May unless there are delays in the breakup of local sea ice.

Atlantic Puffin (*Fratercula arctica*): Both immature and adult Atlantic Puffins winter in small numbers over the outer shelf but are extremely rare close to shore. They are usually found in ones or twos but very calm conditions may reveal them to be widely scattered over areas of similar water temperature (low to high 40s) and water depth. Area high counts include 58 over Block Canyon (water 37-43°F) on 4 Mar 1995 and 33 over the outer shelf on 13 Jan 2013. Many birds remain into late May, some achieving full alternate plumage and bill color.

Black-legged Kittiwake (*Rissa tridactyla*): This cliff-nesting gull nests widely across the rim of the North Atlantic, with some 50% of the population nesting in western Europe. In the British Isles they have colonized coastal cities using buildings, bridges, and other man-made structures in addition to natural cliffs (Coulson and Thomas, 1985). Black-legged Kittiwakes often feed in association with Razorbills, presumably catching small fish and other prey driven to the surface to escape the foraging alcids or possibly by snatching fish that are dropped accidentally. Kittiwake numbers are highly variable; in some years they are present in the thousands but in others they are relatively scarce.

Northern Fulmar (*Fulmarus glacialis*): Formerly breeding predominantly in the High Arctic, fulmars underwent a dramatic range and population expansion into the eastern Atlantic during the 1800s and 1900s, colonizing the coastline of the British Isles and parts of northwest France. However, it was not until the 1970s that sustained colonies were established in eastern Canada and southwest Greenland (Stenhouse and Montevecchi, 1999). Interestingly, almost all the breeding birds are light morph (double light or LL on James Fisher's scale, see Fisher, 1939), immigrants from colonies in western Greenland, Iceland, or the British Isles rather than from the Canadian High Arctic, where dark-morph (D and DD) birds predominate. Band recoveries support the

movement of fulmars from Greenland or Scotland into Canadian waters (Tuck, 1971). As opportunistic feeders, Northern Fulmars are attracted to fishing discards and other sources of offal such as dead cetaceans or marine turtles. Fulmar numbers, together with those of Great Shearwaters, have declined over the past 30 years in parallel with changes in commercial fishing (Veit et al., 2015). During the breeding period they also feed on capelin (*Mallotus villosus*) and short-finned squid (*Illex illecebrosus*), a highly migratory, warm-water pelagic species. Northern Fulmar comprises two subspecies, one in the North Atlantic (Atlantic Fulmar, *F. g. glacialis*) and the other in the North Pacific (Pacific Fulmar, *F. g. rodgersii*). The latter has not been definitively recorded in the North Atlantic. However, because of advances in field identification of the subspecies, reductions in ice coverage in the Arctic Ocean accompanied by increased commercial shipping, and the increasing use of digital photography, it seems only a matter of time before Pacific Fulmars are discovered in the North Atlantic (see Wilson and Flood, 2018, for discussion).

Spring and Fall

As with terrestrial birds, the spring (March to May) and the fall (September to November) are exciting transition periods for oceanic species, especially those that migrate through the NYB between their breeding and nonbreeding grounds.

Red-necked Phalarope (*Phalaropus lobatus*) and **Red Phalarope** (*P. fulicarius*): Both of these shorebirds are highly pelagic, spending most of their lives at sea and coming to land only during the very short high arctic nesting season. As migrants through the region, they are probably under-detected at sea because of their small size and ability to feed on the surface even in rough conditions. Although they are often flushed from the water by an approaching boat, phalaropes are more easily seen resting on the water in calm conditions, especially in areas rich in small planktonic crustaceans that also attract Dovekies and small gulls. In the context of the NYB, Red Phalaropes have at times been recorded in very large numbers during spring migration, such as an estimated 17,000 in April 1980 about 80 km east of Atlantic City (Walsh et al., 1999).

Sooty Shearwater (*Ardenna grisea*): These dark brown and highly mobile shearwaters breed exclusively in the Southern Hemisphere, with substantial populations nesting on islets off New Zealand, southeast Australia, southern Chile, and the Falkland Islands. The global population is thought to be in the order of 20 million birds, although there is evidence for a decline in numbers over the past 30 years (Brook, 2004). Drowning in fishing nets remains a high source of mortality, with a study in New Zealand finding 98% of seabird bycatch from commercial fishing to be this species. By virtue of their annual migrations into the North Pacific and North Atlantic, Sooty Shearwaters are of great scientific importance because they integrate resources over whole ocean scales so, through careful monitoring, they provide a valuable indicator of ocean health (Shaffer et al., 2006). After departing the breeding grounds, Sooty Shearwaters

commence a rapid northward migration (500–900 km per day, Hedd et al., 2012) that is followed by an extended period of residence (143 ± 10 days) in the North Atlantic. Birds typically arrive in the NYB in late April in advance of the mass spawning of capelin (*Mallotus villosus*) around Newfoundland that can attract flocks of hundreds of thousands of shearwaters (Brown et al., 1981). Sooty Shearwaters also exploit dense swarms of northern krill (*Meganyctiphanes norvegica*), which are common off Nova Scotia in late August (Brown et al., 1979). Small numbers linger in the NYB throughout the summer (June to September) with some remaining into November and even December. On the return journey, the majority cross the North Atlantic before looping southwest into the South Atlantic and South Pacific, returning to their colonies in December. Because of this remarkable migration strategy Sooty Shearwaters experience what amounts to an endless summer, a trait shared by other transequatorial migrants including Arctic Terns (see below).

Sabine's Gull (*Xema sabini*): In contrast to the inshore waters of the eastern Pacific, this attractive and distinctive small gull is only occasionally encountered at sea in the NYB in late summer and early fall, although there is a 9 May 1976 sighting from Maryland shelf waters. Sabine's Gulls nest in the High Arctic and after breeding, migrate rapidly across the North Atlantic to staging areas in European waters, principally the Bay of Biscay, before traveling down the west coast of Africa to areas of high productivity upwelling in the Benguela Current off Namibia and South Africa. Remarkably, birds from the same nesting colony on Nasaruaalik Island, Nunavut, may also travel westward into the Pacific and then down the west coast of North America to similar wintering habitat in the Humboldt Current off Peru (Davis, 2016). As with Sooty Shearwaters, this is a striking example of connectivity between major oceanic basins via the High Arctic. There are only a handful of at-sea records for the NYB occurring primarily in September at or close to the shelf edge. The species is encountered more frequently over the Stellwagen Bank through August into October, especially when there are concentrations of feeding humpback whales.

Arctic Tern (*Sterna paradisaea*): This deceptively delicate tern is famed for its extraordinary annual 50,000 km migration from its Arctic and Subarctic nesting grounds down to the Antarctic pack-ice and back again. Use of geolocators has provided a wealth of detailed information about these epic journeys, providing insights into the underlying ecological strategies (Egevang et al., 2010; Alerstam et al., 2019). Although Arctic Terns nest from the Gulf of Maine northward across the Arctic coastline of North America, they are not found in large numbers along the Eastern Seaboard but instead migrate across the middle of the North Atlantic to the west coast of Africa. A similar route is followed in reverse during the northward migration in the boreal spring. In April 2011 I had the luck to travel with what amounted to a visible river of tens of thousands of Arctic Terns, Sabine's Gulls, and Pomarine Jaegers moving northward through the seas off Senegal and Mauritania that suddenly turned to the northwest as if rounding an

invisible marker as our vessel paralleled the coast of Western Sahara. Regardless of this preferred route, northbound adults are occasionally photographed at sea in the NYB during late spring and early summer. Caution is always warranted as Common Terns (*S. hirundo*) are also observed well offshore during migration, sometimes in association with Arctic Terns, and for this reason it is advisable to photograph any terns that are encountered beyond sight of land.

South Polar Skua (*Stercorarius maccormicki*): Resembling Great Skua, especially in juvenile and immature plumages, these aerial pirates undertake a remarkable annual migration from their nesting grounds among the penguins in Antarctica to high productivity areas in the North Atlantic and North Pacific. Most encounters with boats are fleeting but occasionally individuals will linger around groups of shearwaters attracted to chum or even join rafting shearwater to roost. As with Sabine's Gulls, individuals from the same nesting colony do not necessarily migrate to the same ocean, although individuals remain faithful to their chosen nonbreeding grounds in successive years (Kopp et al., 2011). Migration routes within the Atlantic basin are similar to the figure-eight loop followed by Sooty Shearwaters, with adult South Polar Skuas reaching the Grand Banks by the end of May where they remain until initiating the returning migration in late August and early September. The dispersal of immatures is very poorly understood, in part because of their close similarity in appearance to Brown and Great Skuas of the same age class (Newell et al., 2013).

Parasitic Jaeger (*Stercorarius parasiticus*): This is the most numerous jaeger in the spring, late summer, and fall (mainly September and October), occurring most commonly inshore, where they relentlessly harass flocks of terns and Laughing Gulls (*Leucophaeus atricilla*). As its common and scientific name imply, kleptoparasitism ("parasitism by theft") is central to the ecology of this species and takes place on the breeding grounds, during migration, and on the nonbreeding grounds, which are typically in the Southern Hemisphere. Populations seem to be relatively stable but fluctuate in synchrony with the food supplies of the species they parasitize (Phillips et al., 1996). Those encountered in the NYB during June and July are likely to be subadults or nonbreeding adults performing a truncated migration.

Long-tailed Jaeger (*Stercorarius longicaudus*): Spring adults are highly distinctive due to their long tail streamers, solid black cap, and yellow wash across the throat, but become harder to distinguish from Parasitic Jaeger in late summer when the streamers of both species are reduced to spikes and the plumage becomes more subdued and more similar to the juvenile and immature plumages of the other two jaegers. Although less reliant on thievery than their larger cousins, Long-tails will frequently chase other seabirds including members of their own species, and deliberate predation of Wilson's Storm-Petrel has been observed (Flood et al., 2015). They typically migrate much farther offshore than Parasitic Jaegers and have been observed catching small fish, crustaceans, and even large insects such as terrestrial moths.

SUMMER

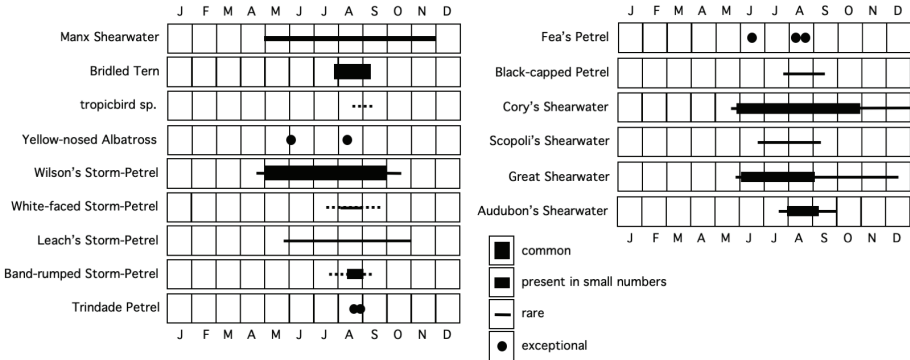


Figure 3. Seasonal occurrence charts for oceanic bird species found primarily in summer. These seven species are rarely encountered outside of the hottest months (May to October) and as discussed in the text, the chances of finding any of them are heavily dependent on water depth and temperature, proximity to the shelf edge or current boundaries, concentrations of *Sargassum* weed, and so on. Note: the data for Trindade Petrel (*Pterodroma arminjoniana*) and Fea's Petrel (*P. feae*) are based on only a handful of documented individuals.

Summer

June to August is the premier season for offshore observations, in part because of extended periods of stable weather and in part because of the interesting variety of species that can be found. Although inshore waters can remain relatively cool, temperatures offshore become much warmer (70–80°F), especially when there are infusions of “hot water” from the Gulf Stream. These conditions create sharp temperature breaks that concentrate marine wildlife, including oceanic birds. Currents sometimes gather large quantities of *Sargassum*, a brown macroalgae often referred to as “grass” by fishermen, which can form island-sized mats that spread over many kilometers. These are holopelagic seaweeds, meaning that they reproduce without attaching to solid substrates such as the seafloor, and provide habitat for a constellation of small fish (81 species from 36 families) and crustaceans that in turn attract a variety of predatory fish. Many oceanic birds are attracted to these mats, including *Sargassum* specialists such as Audubon's Shearwater and Bridled Tern.

Manx Shearwater (*Puffinus puffinus*): This is a European species that for close to five decades has seemed poised to colonize North America as a regular nesting species. Once considered only a casual visitor to eastern North America, there was a dramatic increase in sightings during the 1960s and 1970s. The first successful nesting record from the Western Hemisphere came from near Martha's Vineyard, MA, in 1973 but was not sustained (Bierregard et al., 1975). Later a small colony was established on Middle Lawn Island located off Newfoundland's Burin Peninsula (Storey and Lien, 1985; Robertson, 2002). To this day, modest evening flocks (up to 50) gather in the bays outside of Boston Harbor and summer counts of 150–200 off Cape Cod are not exceptional. Although additional nests have not been found, the tantalizing possibility that a few

birds are nesting on small islands in the northeast remains viable. Manx Shearwaters are found regularly in cooler inshore waters along the coasts of Long Island and New Jersey and across the shelf. Although possible year-round, the majority of sightings occur between June and October, and it is suspected that a majority of birds visiting the NYB are nonbreeders but could include foraging adults from the small number of nesting sites (Lee, 1995). Most are encountered as lone individuals but occasionally small rafts are found, sometimes in loose affiliation with other shearwaters. Small fish, squid, and crustaceans are caught by pursuit-plunging and pursuit-diving. This is reliant on visual detection and thus limited to daylight. The major nesting colonies are in the British Isles (at least 333,000 pairs in roughly 40 colonies) with smaller numbers in Iceland, Madeira, and the Canary Islands. After nesting, most of the world's Manx Shearwaters move into the South Atlantic to spend October to February in the shelf waters off Brazil and Argentina. Interestingly, there are numerous records of Manx Shearwater in the eastern Pacific, especially from the 1990s onward, prompting speculation that the species is now nesting in southwest Alaska, British Columbia, or Washington State (Mlodinow, 2004).

Sooty Tern (*Onychoprion fuscatus*): Although this is a signature species of many of the hurricanes or other strong tropical disturbances that have impacted the tristate area, there are very few if any at sea sightings in the NYB. This is surprising in view of the fact that upward of 500,000 pairs nest in the Caribbean and many nonbreeders are present in the Gulf Stream off North Carolina during the summer (June to August) (Wallace and Wigh, 2007; Nisbet et al., 2013). Presumably those reaching land during cyclonic storms enter the eye as it passes over the Gulf Stream, potentially well south of the region, and as strong fliers are able to remain aloft within the storm until carried over land. The paucity of at-sea records within the NYB may simply reflect the lack of visits by experienced observers to bona fide Gulf Stream water, which is usually too far offshore for anything but larger research vessels. Cruise ships en route from New York City to Bermuda pass through suitable waters but will not necessarily intersect with concentrations of *Sargassum* weed or predatory fish such as tuna that attract this species. Use of wet/dry sensors in the Indian Ocean has shown that Sooty Terns spend less than 4% of their lives in contact with water, implying that they remain continuously aloft when away from their nesting islands, an impressive statistic given that the average lifespan for this species is about 30 years (Jaeger et al., 2017).

Bridled Tern (*Onychoprion anaethetus*): This tropical tern is regularly encountered over warm, deep water during August and September, favoring areas with accumulations of *Sargassum* and other floating items. Typically, they patrol the edges of weed lines, dropping to snatch small fish that venture into the open. Bridled Terns also show a strong propensity to rest on floating debris such as pieces of wood or plastic containers and when approached will wait to the very last second before relinquishing their valued perch (see Fig. 4). Like Sooty Terns, Bridled Terns are frequent casualties



Figure 4. Bridled Terns (*Onychoprion anaethetus*) are strongly associated with aggregations of *sargassum* weed and cannot resist the lure of natural or in this case, unnatural flotsam that they can use as a perch. Photographed off Long Island by John Shemilt.

of hurricanes and the similarities in appearance can make correct identification difficult at times.

White-tailed Tropicbird (*Phaethon lepturus*) and **Red-billed Tropicbird** (*P. aethereus*): Within the western North Atlantic, colonies of nesting tropicbirds are limited to a number of Caribbean Islands from Puerto Rico to Panama, with 2,500–3,000 nesting pairs of White-tailed Tropicbird on Bermuda, only 1,246 km from New York City (Schreiber and Lee, 2000). Post-breeding dispersal from these colonies sends small numbers of both species into the Gulf Stream, the remainder dispersing into the tropical Mid-Atlantic and Gulf of Mexico. With the exception of sightings associated with hurricanes, there are only a few at-sea records of tropicbirds in the NYB (eBird S93352254). This is despite the fact for a number of years single adult Red-billed Tropicbirds have returned to potential nesting habitat just to the north of this region. One made summer visits between 1986 and 1988 to a cliff on Martha's Vineyard and (presumably) another visited islands in the Gulf of Maine and Bay of Fundy including Machias Seal Island in 2005 (S61549643) and then annually on Matinicus Rock and nearby Seal Island from 2005 to at least 2021. At-sea sightings of both species increase farther to the east, especially over the outer New England canyons and seamounts in July and August, consistent with a tight association with the Gulf Stream (e.g. eBird S24750035; S99185579; S93414656).

Yellow-nosed Albatross (*Thalassarche chlororhynchos*) and **Black-browed Albatross** (*T. melanophris*): Only two species of albatross are accepted as natural vagrants

to the western North Atlantic (Davis, 2014). Of these, only the smaller Yellow-nosed has been recorded with any certainty within the NYB, including both inshore and onshore sightings (Buckley and Schairer, 2000; Laux, 2000). On 2 Dec 2012 an adult Black-browed Albatross was photographed 48 km south of Martha's Vineyard, Massachusetts (eBird S12286236) and another 113 km east of Cape Henlopen, Delaware (eBird S45207754), both just outside the NYB boundary. There are also multiple records of both Yellow-nosed and Black-browed Albatrosses from Virginia and North Carolina, raising the likelihood of further encounters in the NYB (Patteson et al., 1999; Tove and Patteson, 2002; Davis, 2014). One of the most famous albatross encounters in the NYB took place on 29 May 1960 when a pelagic organized by the Linnaean Society of New York encountered an adult Yellow-nosed Albatross about 3 km off Jones Beach, Long Island (Bull, 1961). Many of the onshore sightings have occurred in May and early June, with widely separated sightings on the same day implying the presence of multiple birds (Tove and Patteson, 2002). Even more remarkable perhaps, Yellow-nosed Albatrosses have been recorded at Cape Point, North Carolina, on 11 April 2004 (Chat 68:116) and then again on the same date in 2006 (Chat 70:94–95). Why Yellow-nosed Albatross rather than Black-browed Albatross accounts for the vast majority of records off eastern North America is a mystery. In western Europe the frequencies are exactly reversed (Rowlands et al., 2010). Some have argued that this reflects a number of long-staying Black-browed Albatross associated with Northern Gannet colonies in Scotland and Iceland, returning in some cases for decades, but this is clearly not the full explanation.

Wilson's Storm-Petrel (*Oceanites oceanicus*): By far the most abundant storm-petrel in the NYB during the boreal summer, this species actually travels the farthest as it



Figure 5. An abundant summer visitor to the NYB from Antarctica, Wilson's Storm-Petrel (*Oceanites oceanicus*) is readily attracted to fish oil slicks and other discards. When feeding, birds will often face into the breeze with their wings held open and will patter or hop with their webbed feet to maintain position and stir food particles and oil droplets. These four individuals were photographed over the McMaster Canyon on 7 Aug 2021 by Angus Wilson.

nests on the coasts of the Antarctic continent and on sub-Antarctic islands during the austral summer (December to April). From mid-March onward, Wilson's Storm-Petrels move northward through the central Atlantic and arrive in the NYB in significant numbers by May or June. There are records from as early as March, presumably reflecting non- or failed-breeders that lingered in the mid-Atlantic or at least departed Antarctic waters earlier than the breeders. Peak numbers occur during June to September and are sometimes concentrated in areas of strong upwelling or cetacean activity providing ample feeding (Brown, 1988). An estimated 50,000–75,000 were over the Hudson Canyon on 28 May 1983 (Boyle, 2011). Although capable of shallow dives, Wilson's Storm-Petrels typically feed by pecking small items off the water surface including droplets of fish oil and items released from cetacean feces. To do this, birds will face into the wind with wings raised, bouncing and pattering with their feet to hold position, often undertaking rapid loops and returning to the same spot. During the nesting season the diet is more dominated by pelagic crustaceans (principally euphausiids and amphipods) and small fish (Harper, 1987).

White-faced Storm-Petrel (*Pelagodroma marina*): These extraordinary seabirds are found in very small numbers over the deeper portions of the canyons and beyond the shelf break during late summer (late July to early October, water temperatures 70–80°F). They are paler than most other storm-petrels, with broad paddlelike wings and extremely long legs. With their wings held out stiffly, White-faced Storm-Petrels move very rapidly over the ocean surface in long glides, kicking off from the surf of the water with both feet to maintain altitude or execute sharp changes in direction. To other observers and me, this combination of skipping and gliding gives the impression of a tiny marine kangaroo. It is likely that most sightings in the northeast Atlantic are of the nominate subspecies (*P. m. hypoleuca*), which nests in the Salvage Islands near Madeira and in the Canary Islands (20,000–36,000 breeding pairs). That said, some may also originate in the Cape Verde Islands (subspecies *P. m. eadesorum*), which support 50,000 breeding pairs (see Watson et al., 1986). The diet outside of the chick provisioning period is not well known but likely includes a variety of planktonic crustaceans, small fish or squid, and marine insects such as sea-skaters (*Halobates* spp.). As with other storm-petrels they feed on the wing by pattering and surface-seizing but are capable of short dives into the water, a tactic that is also used in aerial predatory avoidance. It is suspected that feeding takes place mostly at night but this needs to be corroborated. In general, White-faced Storm-Petrels are shy of moving boats but are sometimes attracted to slicks of fish oil mixed with finely ground chum. They may also be encountered in rafts of roosting storm-petrels, especially during the warmest part of the day, and are readily picked out by virtue of the paler plumage.

Leach's Storm-Petrel (*Oceanodroma leucorhoa*): This is the only species of Storm-Petrel to breed in the northwestern Atlantic, with estimates of up to 5 million pairs in eastern Canada, principally on Baccalieu Island off Newfoundland



Figure 6. Much sought after by North American birders, White-faced Storm-Petrels (*Pelagodroma marin*) stay close to the sea surface moving rapidly by gliding on outstretched wings. Sharp changes of direction are achieved with swift kicks with their long legs and toes. Photographed east of Block Canyon on 18 August 2014 by Angus Wilson.

(Sklepkovych and Montevecchi, 1989). Many of these colonies are in decline, possibly due to increased predation by gulls and foxes as well as other factors (Wilhelm et al., 2019). Considering the location of these immense colonies, it is surprising that the species has always been considered rare to uncommon in the NYB, with records clustered in late spring and early summer (Levine, 1998; Boyle, 2011). Interestingly, the status has changed dramatically within the last decade with regular sightings, sometimes in modest numbers, at the shelf break and beyond. Whether these are adults that are feeding chicks back in the nesting colonies or are nonbreeding birds is not clear. Studies from colonies in Nova Scotia indicate that nesting birds from different colonies forage in different areas and make round trips of 1,000–2,600 km (Pollet et al., 2014b). Analysis of regurgitation samples suggests the diet includes a variety of small fish, cephalopods, crustaceans, amphipods and jellyfish. An abundance of mesopelagic myctophid fish that undertake a vertical migration into surface (epipelagic) waters at night suggests that feeding is mainly nocturnal, although Leach's Storm-Petrels are attracted to fish oil slicks during daylight. The combination of at sea surveys, stable isotope data, and geolocator studies all support the idea that Leach's Storm-Petrels from Canadian colonies follow a roughly clockwise circuit around the North Atlantic during winter in deep ($\geq 4,000$ m) equatorial waters between South America and West Africa (Pollet et al., 2014a). During October to December an estimated 300,000 to 2,000,000 stage in the Bay of Biscay, most likely representing a mix of birds from North American and European colonies (Hémery and Jouanin, 1988). Both the Grand Banks and Georges Bank appear to be important feeding areas in spring and fall but birds may linger relatively far north (Newfoundland Basin) in December.



Figure 7. The regular occurrence of modest numbers of Leach's Storm-Petrel (*Oceanodroma leucorhoa*) in the NYB during the summer is a relatively new phenomenon. The presumption is that these are breeding birds from colonies in the Canadian Maritimes on extended chick-provisioning expeditions. Journeys of more than 2,000 km are not uncommon. The abraded outer wing and tail feathers of this Leach's Storm-Petrel (*Oceanodroma leucorhoa*) photographed on 7 Aug 2021 at the shelf break south of eastern Long Island NY is typical of the damaged endured by breeding adults as they crawl in and out of nesting burrows. Photo by Angus Wilson.

Band-rumped Storm-Petrel (*Oceanodroma castro*). Members of this enigmatic species cluster are found in tropical and subtropical waters in both the Atlantic and Pacific Oceans. The taxonomy is not fully understood, but there is evidence for at least five distinct populations in the Atlantic alone (see Flood and Fisher, 2011 and Howell, 2012 for extensive discussion). Careful scrutiny of storm-petrel flocks has documented modest numbers over warm water along the shelf break and outer canyons in late summer. Many individuals have been photographed well enough for an assessment of molt and this may allow tentative assignment, at least in aggregate, to the different populations. Those nesting on the Azores, Berlengas, Canaries, and Madeiran archipelago and Selvagens in our winter (between October and May) are known informally as "Grant's Storm-Petrel" and seem the most likely, based on population size, progression of wing molt, and life cycle timing to visit the NYB in late summer (see Howell, 2012). The challenge is eliminating nonbreeding individuals from the "Maderian" population which nests later in the year. That said, there is a lot of conjecture and a lack of appreciation by many observers for the confounding effects of differences in age (adults versus juveniles) and simple individual variation. Ultimately the use of geolocator tags combined with analysis of the ever-growing collections of at-sea photographs should solve this interesting open puzzle.

Trindade Petrel (*Pterodroma arminjoniana*): This poorly known tropical species breeds below the equator on Trindade and Martim Vaz, a cluster of tiny, rarely visited, and very rugged islets situated about 1,400 km east of Rio de Janeiro, Brazil. There are now a small number of documented sightings from Maryland to Massachusetts in late summer (26 July to 25 August) invariably at or beyond the shelf break. These exciting records include an extensively photographed light morph found on 20 August 2018 visiting a fish oil slick laid some 16 or so km beyond the mouth of the Hudson Canyon (eBird S47981753). The sea surface temperature was noted as 77.5°F with a water depth of about 1,800 m. These various records suggest Trindade Petrel is regular along the northwestern edge of the Gulf Stream, which is accessible to small craft from time to time. In 2015 the AOU acknowledged what many seabird authorities already felt and split this taxon away from Herald Petrel (*P. heraldica*), which is found in the central Pacific (Chesser et al., 2015). Prior reticence to make this split came from the fact that there is also a population of Trindade Petrels breeding on Round Island near Mauritius in the Indian Ocean, where they hybridize with Herald Petrels producing intermediates known informally as Round Island Petrels. This intermixing implies recent speciation and the possibility of continued gene flow (Krüger et al., 2016). Population estimates based on extrapolation from nest surveys puts the Brazilian population at 1,228 pairs and recent geolocator studies support a trans-equatorial migration into the northwest Atlantic during the nonbreeding season, favoring deep low-productive waters (Krüger et al., 2018). The geolocators also indicate that foraging takes place primarily at night, presumably targeting deep water squid and small fish that move up the water column under cover of darkness.

Fea's Petrel (*Pterodroma feae*): To date, there have been three photo-documented sightings in the NYB and adjacent waters: two over warm water (76.8–79°F) just beyond the shelf break on 12 August 2014 (eBird S19459656) and 18 August 2015 (eBird S24685973) as well as an inshore record from 19 June 2012 (eBird S11008333) of one bird that was associating with feeding blue fin tuna *Thunnus thynnus*. There is an additional unpublished sighting from the region from a NOAA research cruise on 14 June 2011 (see Dias, 2014). These are in keeping with an emerging pattern of mid-May to mid-September sightings along the edge of the Gulf Stream from Florida to Virginia, and cooler water sightings off Nova Scotia on 7 July 1997 (Hooker and Baird, 1997) and Newfoundland (13 August 2000 and 9 July 2007, North American Birds 55:21 and 61:560, respectively) and over the Stellwagen Bank, Massachusetts, on 18 July 2015 (eBird S24306506). Befitting the genus name (*Pterodroma* or “wing runner”), these medium-sized gadfly petrels are masters of dynamic soaring in which they exploit vertical wind speed gradients near the sea surface. As such *Pterodroma* and other small to medium-sized petrels are able to travel extraordinary distances with minimal expenditure of energy. Tracking studies have shown that the population of Fea's Petrels nesting in the Madeiran archipelago (Desertas Petrel *P. f. desertae*) undertake long foraging trips

of up to 12,000 km and almost entirely over deep, relatively food-poor pelagic waters (Ventura et al., 2020). These trips do not seem to focus on reliable feeding hotspots, but instead are sculpted by local wind conditions that allow sustained high-speed travel. This suggests that foraging birds need to cover as much area as possible to maximize the probability of randomly encountering suitable food on the sea surface.

Black-capped Petrel (*Pterodroma hasitata*): This very striking seabird is the most frequently encountered *Pterodroma* in the NYB, showing a noticeable but unexplained increase in July and August sightings within the past decade. The majority of encounters have been over very deep (1,000 fathoms or 1,830 m) and warm (71–82°F) water. Historically, Black-capped Petrels were a relatively abundant breeder on several of the mountainous islands in the Lesser Antilles, especially Hispaniola (Haiti and the Dominican Republic), where it is known locally as Diablotín. Sadly, only a few colonies remain due to human encroachment into the nesting habitat resulting in destruction of the native forest and presence of non-native predators in the form of feral cats, dogs, rats, and mongooses (Jean et al., 2018). Harvesting for human consumption is also documented (Wingate, 1964). Currently the world population barely exceeds 2,000 individuals, warranting recognition as a globally endangered species. At sea, Black-capped Petrels are regularly encountered in the western North Atlantic between ~30–40° N latitude on both sides of the Gulf Stream as well as in the Caribbean Sea and northeastern Gulf of Mexico (Jodice et al., 2021). Interestingly, the 83 known nests—burrows and crevices in the understory of montane forests at 1,500–2,000 m above sea level—cannot account for the observed population, implying the existence of undiscovered colonies, possibly in Dominica and Cuba. To better understand the population structure, satellite tags have been deployed on nesting birds (Jodice et al., 2015), and more recently on birds caught at sea off North Carolina (Serrano, 2019). It is hoped that this will identify key feeding areas and help researchers locate new colonies so they can be protected. In the spring of 2021, the carefully monitored colony of nearly 30 nests at Loma del Toro in the Dominican Republic’s Sierra de Bahoruco National Park was decimated by packs of feral dogs that predated both adults and chicks and physically destroyed nesting burrows (Wheeler, 2021). This same colony had endured predation of multiple chicks by a single feral cat in 2018. While trail cameras have proven effective in identifying the sources of nocturnal predation, the sheer inaccessibility of these colonies makes active protection extremely difficult.

Although the species is considered monotypic, astute observers have noticed differences in the distribution of dark feathering on the head and nape, allowing individuals to be categorized as “dark-faced,” “white-faced,” and “intermediate” (Howell and Paterson, 2008). All three categories have been photographed in the NYB. Interestingly these types differ slightly in molt timing and there are early hints from the satellite transmitter studies that white-faced individuals nest earlier than dark-faced birds and that both nest on Hispaniola. Whether this represents age- or sex-dependent variation



Figure 8. Cory's Shearwater (*Calonectris diomedea*) is a common visitor to the NYB during the summer and can be separated from other shearwaters by the more ponderous flight style and heavy yellow bill. The species is particularly adept at snatching flying fish and squid as they break the sea surface to escape submerged predators such as tuna or dolphins. This adult was photographed near a breeding colony in the Azores on 21 Jun 2021 by Angus Wilson.

or different “hot” and “cold” season breeding populations analogous to a number of other seabird species remains unclear (Manly et al., 2013).

Cory's Shearwater (*Calonectris diomedea*): This large shearwater is relatively common in near-shore and offshore waters of the NYB from mid-May to early November with peak numbers occurring from June to the end of September, coincident with the warmest sea surface temperatures. It is likely that most individuals originate in the Azores, where some 100,000 pairs, equivalent to 70% of the world population, nest in large colonies scattered across multiple islands. Other nesting areas include the Madeiran archipelago, the Canary Islands, and several smaller islets close to the Iberian Peninsula (see Fig. 8). Breeding takes place between June and October, meaning that birds visiting the western North Atlantic are most likely subadults or nonbreeding adults. Large-scale geolocator studies have revealed a surprisingly complex and flexible migration strategy (Dias et al., 2011; 2012). During the nonbreeding months most Cory's Shearwaters move into the South Atlantic, concentrating in the coastal upwelling zones of either the Benguela and Agulhas currents around the southern tip of Africa or the Brazilian current in the central South Atlantic. Roughly 4% move more directly into the Northwest Atlantic and are later joined by birds returning from the South American and South African sides of the South Atlantic. Which of these areas is chosen depends on both the age and prior experience, without a detectable bias between males and females. As is the case with Sooty Shearwater, the trans-equatorial migration of roughly 13,000 km is very rapid with few, if any, stopovers (Dias et al., 2012). Contrastingly, oth-

er species with similar migration routes, such as the Arctic Terns, Long-tailed Jaegers, South Polar Skuas, and Manx Shearwaters, make frequent feeding stops. The diet of Cory's Shearwater consists of epipelagic and mesopelagic fishes such as small mackerel and bonito, snipefish (*Macrorhamphosus* sp.), cephalopods, and crustaceans (Xavier et al., 2011). These are caught by shallow dives or are snatched from the air when escaping subsurface predators such as tuna or dolphins. Birds are often concentrated along current boundaries and temperature breaks where turbulence and upwelling draw plankton and larval fish toward the surface making them more available to medium-sized predators (Haney and McGillivray, 1985).

Scopoli's Shearwater (*Calonectris diomedea*): This is the central and eastern Mediterranean counterpart of Cory's Shearwater but is genetically and morphologically distinct. A number of specimens have been identified among beached carcasses, going back as far 1920 (Bull, 1964), suggesting that this has been a long-standing but chronically under-recorded taxon within the NYB. Advances in field identification (see Gutiérrez, 1998) have accompanied the still somewhat controversial splitting into two species, with the upside of increasing field documentation within the NYB especially in the late summer. Unfortunately, active molt in Cory's can blur the differences and ideally field identification should be supported by multiple correctly exposed photographs showing the undersides of the primaries (Flood and Fisher, 2020). Although the majority nest within the Mediterranean, most spend the nonbreeding months in the Atlantic, passing through the Straits of Gibraltar in a near continuous stream in late October and early November. In contrast to Cory's Shearwater, most Scopoli's Shearwaters winter in the Canary Current. However, some do cross the Atlantic to the east coast of North America, whereas others continue down to the coasts of South American and South Africa where they are mixed in with the more numerous Cory's (Navarro et al., 2009).

Great Shearwater (*Ardenna gravis*): This is one of the more frequently encountered shearwaters in the NYB during the summer and fall months, occurring over both the shelf and deep waters. With a population in excess of 15 million individuals, Great Shearwaters nest exclusively in the South Atlantic, the vast majority (at least 5 million nesting pairs) within the remote archipelago of Gough and Tristan da Cunha as well as 100 or so pairs nesting in the Falkland Islands (Brooke, 2004). At the end of the breeding season, adults initiate a trans-equatorial migration beginning in April and are followed by juveniles in May. Moving quickly, they reach North American waters in late May and early June, with the greatest concentrations occurring over the Grand Banks and productive cold waters around Newfoundland where their diet consists mostly of forage fish such as Atlantic mackerel (*Scomber scombrus*) and capelin (*Mallotus villosus*), as well as small squid, especially northern shortfin squid (*Illex illecebrosus*) (Brown et al., 1981). However, this species is also an opportunistic feeder and is readily attracted to fishing discards including chum. The return to the South Atlantic begins in late summer and follows an arc across toward the British Isles and Iberian coastline with some loop-

ing down past the northeast coast of South America and other traveling down the west coast of Africa. Pairs return to their breeding burrows in September.

Audubon's Shearwater (*Puffinus lherminieri*): This medium-sized shearwater is endemic to the tropical waters of the Caribbean region and Gulf Stream and reaches the NYB in moderate numbers during August and September, often in association with areas rich in *Sargassum* mats. It feeds on small fish and crustaceans captured using shallow plunges and by peering under clumps of weed. Predominantly nonbreeders, many individuals show active wing molt in midsummer, creating a somewhat worn and ratty appearance, but this is generally completed by September. It is presumed that individuals visiting the NYB are from the Bahamian population (*P. i. auduboni*), although a specimen from Canada is attributed to *loyemilleri*, which breeds on islets along the coasts of Panama, Columbia, and Venezuela (Howell, 2012). Although occasionally encountered in the tens or hundreds, numbers have declined in recent decades, paralleling declines in the Bahamas (Mackin, 2016).

VAGRANTS: DOCUMENTED AND ANTICIPATED

The connectivity of the oceans and the high mobility of most oceanic birds means that almost any species might eventually occur in the NYB as a rare vagrant. A perfect example is the lone Buller's Shearwater (*Ardenna bulleri*) found with a flock of Great Shearwaters on 28 October 1984 by the lucky participants on an organized pelagic some 50 km ESE of Barnegat Light, New Jersey (see Boyle, 2011). This remains the sole North Atlantic record of this attractive and distinctive New Zealand nesting endemic. How this individual came to be in the Atlantic (rather than the North Pacific) will never be known, but conceivably it might have followed Sooty Shearwaters around the southern tip of South America into the South Atlantic before encountering Great Shearwaters, with which it has closer affinities.

There have been a number of sightings of Barolo Shearwater (*Puffinus baroli*) along the shelf break to the north and south of the NYB, with the most recent records coming from the shelf break and canyons southeast of Massachusetts and southwest of Nova Scotia during a two-week window (12–26 August). On 17 August 2012 (eBird S11361357; S11366011; S11366268) a total of four individuals were photographed from a NOAA survey ship traversing from deep warm (78°F) water to cooler (70°F) shelf water 200 km south of Clark's Harbour, Nova Scotia. There are additional records from 12 August 2016 (eBird S38578386), 20 August 2019 (eBird S59141014) and 26 August 2012 (eBird S11454815) along this section of the continental margin, an area that is noteworthy for its concentrations of beaked whales and is suggestive of a hotspot for Barolo Shearwater and other rare pelagic species. Until recently Barolo Shearwater was one of several small black-and-white shearwaters lumped under the banner of Little Shearwater (*P. assimilis*), a name that is now reserved for a cluster of populations found in cooler waters around Australia and New Zealand. There are two very similar spe-

cies in the North Atlantic basin, Barolo Shearwater and Boyd's Shearwater (*P. boydi*), that are only separable in the field with great difficulty (Flood and van der Vliet, 2019). However, geolocator data indicate that while the range of Barolo extends farther north and south in the nonbreeding season, Boyd's tends to move from the Cape Verde archipelago off West Africa toward the northwest coast of South America, supporting the dogma that Barolo is the species occurring off northeastern North America. Barolo Shearwater nests in relatively small, ill-defined colonies in the Azores, Madeiran archipelago, and Canary Islands. The use of geolocators at a colony in the Azores has shown that during the nesting season adults forage relatively close to the colonies but during the post-breeding period disperse more widely within the North Atlantic (Neves et al., 2012). Interestingly, Barolo Shearwaters forage primarily over very deep water, seeking small cephalopods and seemingly avoid seamounts and other areas of high productivity. This might be a strategy to minimize competition with the much larger Cory's Shearwater (*Calonectris diomedea*), which nests in vast numbers on many of the same islands or, alternatively, to avoid direct predation by large gulls or migrating *Stercorarius* skuas that might be attracted to concentrations of feeding shearwaters (Neves et al., 2012).

There is reason to think that Bermuda Petrel (*Pterodroma cahow*) might also occur as a regular but under-recorded visitor to the NYB. This endangered and visually attractive gadfly petrel was probably quite abundant in the North Atlantic prior to European discovery of Bermuda, its only known breeding site. However, the species was quickly brought to near extinction through the combined effects of human consumption, habitat destruction, and the careless introduction of mammalian predators (Wilkinson, 1950). After tantalizing hints, a few pairs were discovered in 1951 on low reefs in Castle Harbour (Murphy & Mowbray, 1951). This led to decades of intense conservation efforts by Conservation Officer Dr. David Wingate (who as a 15-year-old schoolboy took part in the rediscovery) that is now continued by his successor Jeremy Madeiros (Madeiros et al., 2014). Despite chronic underfunding and numerous logistical challenges, these efforts have restored the breeding population to more than a hundred nesting pairs, a true conservation triumph. Recent placement of Lotek data-loggers on a small number of nesting birds has shown that they disperse throughout the North Atlantic, with some traveling westward toward the Gulf Stream off the Carolinas and Florida, with others moving northeast to a productive seabird feeding area near the Azores. Birds with chicks may travel north across the Gulf Stream to feed in cooler waters over the Grand Banks and Flemish Cap, a round trip journey of at least 5,000 km (summarized in Flood and Fisher, 2013). Some of these foraging trips are likely to pass through the deeper portions of the NYB, although typically in the winter and spring months when difficult sea conditions limit the observation possibilities. That said, there is a recent well-documented record for the NYB (17 Oct 2022, eBird S120896559), and others have been photographed southeast of Cape May New Jersey on 27 August 2022 (eBird S117672913) as well as to the south in Virginia waters on 12 August 2013 (eBird



Figure 9. With a world breeding population of less than 250 pairs, Bermuda Petrel (*Pterodroma cahow*) remains one of the world's rarest seabirds. Although similar to Black-capped Petrel (*P. hasitata*), the dark cowl, absence of chest spurs and generally dark upper tail coverts (not visible here) allow identification at sea. This spectacular adult was photographed off Bermuda on 8 Nov 2018 by Derek Rogers.

S14910491), and to the northeast in Massachusetts/Nova Scotia waters on 28 June 2010 (Duley, 2010) and 21 September 2019 (eBird S60062838) as well as to south of Cape Sable, Nova Scotia on 21 April 2014 (eBird S40382789). In the case of these New England and Canadian sightings, single Bermuda Petrels were in association with other seabirds such as Black-capped Petrel and Cory's Shearwater following feeding tuna or cetaceans.

In terms of other future additions to the NYB avifauna there are many plausible candidates. These include Cape Verde Shearwater (*Calonectris edwardsii*), European Storm-Petrel (*Hydrobates pelagicus*), Swinhoe's Storm-Petrel (*Hydrobates monorhis*) and Black-bellied Storm-Petrel (*Fregetta tropica*), all of which have been reliably documented just outside the region. More outlandish possibilities, again based on vagrants elsewhere on the Eastern Seaboard, are White-chinned Petrel (*Procellaria aequinoctialis*), Tahiti Petrel (*Pseudobulweria rostrata*), Zino's Petrel (*Pterodroma madeira*), Bulwer's Petrel (*Bulweria bulwerii*), Red-footed Booby (*Sula sula*), Masked Booby (*Sula dactylatra*), and Brown Noddy (*Anous stolidus*). Two cryptic possibilities that have yet

to be confirmed in North American waters are Monteiro's Storm-Petrel (*Oceanodroma monteiroi*), a globally rare endemic to the Azores, and the more numerous and widespread Brown Skua (*Catharacta antarctica*) from the Southern Hemisphere.

THREATS AND CONSERVATION PRIORITIES

Oceans are highly dynamic ecosystems and local populations of both flora and fauna are subject to complex fluctuations in response to natural and anthropogenic influences. It is now well established that oceanic birds serve as valuable indicators of these fluctuations and the overall health of the food chain (Parsons et al., 2008). Climate change is arguably the most significant threat, acting across a broad range of temporal scales (months to decades). Changing sea surface temperatures can have profound impacts on the distribution and survival of oceanic birds by altering the movements of both warm-water and cold-water pelagic fish and invertebrates (Montevecchi and Myers, 1996; Veit et al., 1996; Pershing et al., 2015). Similarly, changing water temperatures can have a profound impact on breeding success either by increasing the distances between suitable nesting habitat and optimal feeding areas or by changing the species composition of prey available to adults foraging for their chicks (Kress et al., 2016). More research is needed to determine if this has any effect on the oceanic species using the NYB. Climate change rather than overfishing has been implicated in major nesting failures in Atlantic Puffins and Black-legged Kittiwakes (Wanless et al., 2007). Essentially all of the species using the NYB breed elsewhere, with many nesting in high latitudes where the impact of climate change is greatest (Pithan and Mauritsen, 2014). In 2018 late-melting snow resulted in the near-complete reproductive failure of the terrestrial ecosystem in northwest Greenland, impacting tundra-nesting species such as jaegers, Sabine's Gull, and phalaropes (Schmidt et al., 2019).

There are many threats derived from human activity within and around the margins of the NYB. The shelf waters are crisscrossed by major commercial shipping lanes and remain high-density fishing areas. Although the fishery is now only a shadow of its former self, more than 500 million menhaden are legally harvested each year, raising the concern that another catastrophic collapse of the population could be triggered by excessive exploitation (Newman, 2018). In recent years, small sections of the NYB have been partitioned off for offshore wind energy production. The potential impact of these structures is largely unknown, although Northern Gannets, which occupy the low- to mid-range airspace (0–70 m), are considered vulnerable to collisions with wind turbines and studies have shown that they actively avoid areas containing marine wind farms (Vanermen et al., 2015; Garthe et al., 2017). Use of geolocators and satellite telemetry to study interactions with existing windfarms, such as those to the south of Block Island, may shed light on these timely questions.

Oil pollution remains a signature threat to marine birds worldwide (Votier et al., 2005). The impact can be direct, such as through plumage contamination or ingestion,

or it can be indirect through damage to prey populations. Systematic monitoring of beached seabirds has found the rates of oiling are decreasing but the potential for catastrophe remains high as exemplified by many instances of illegal dumping or spillage by tankers and major failures at production sites such as the 2010 Deepwater Horizon explosion (Haney et al., 2014). Other potential pollutants include effluent carried by the numerous rivers that flow into the NYB such as the Hudson River, as well as the intentional dumping of waste (Bothner et al., 1994). In recent years the detrimental effects of plastic ingestion have gained public attention but the impact of these widespread unnatural contaminants on oceanic birds is very poorly understood. In European waters, Northern Fulmars (*Fulmarus glacialis*) are being used as an indicator species to monitor levels of plastics in the marine environment. The current measure of acceptable quality is for less than 10% of the birds sampled to be carrying 0.1 g or more of plastic in their stomachs. Currently, more than 60% of Northern Fulmars exceed this amount (van Franeker et al., 2011). Of course, this does not address the largely unknown consequences of particulate plastics on the marine environment. These can be small enough to enter individual cells and are produced by the degradation of macro-plastics or the intentional use in abrasive cleaning products.

CLOSING THE REMAINING GAPS IN KNOWLEDGE

These are exciting times for marine ornithology, driven in good part by advances in technology. These range from the application of cost-effective DNA sequencing to investigate taxonomic affinities and population structures to the near-universal usage of digital photography in field studies that has greatly aided in the detection of cryptic species. The deployment of geolocators, miniature daylight level and activity recorders, represents one of the most exciting advances in the study of oceanic wildlife across the board (Harrison et al., 2018). With respect to oceanic birds these long-lasting devices have already provided a wealth of new information about seasonal migrations and the locations of critical feeding areas of many species, information that is extremely difficult to gather by other means. One drawback of small geolocators is the need to recapture the bird in order to recover the stored data. This can be very hit-or-miss and limits the study on immature birds, which may not return to the natal colonies for several years. However, improvements in data compression now permit data collection over long periods, which is extremely useful when there are long intervals between captures. This is also a limitation of stable isotope analysis, which can provide valuable information on changes in diet associated with geographical movement and reveal sex-specific foraging behavior (Rubenstein and Hobson, 2004). The ^{13}C isotope of carbon tends to be depleted toward the poles; the resulting differences in the carbon signature of newly grown feathers can provide information about north–south movements. Similarly, the proportion of ^{13}C in oceanic particulate organic matter tends to be lower in inshore environments such as shelf waters compared to deep water (benthic) environments.

Slightly heavier devices that can be carried by larger species such as gannets, albatrosses, shearwaters, and *Pterodroma* petrels use satellite or radio telemetry to offload data without recapture, allowing near real-time monitoring. Important questions that can be addressed with these exciting technologies include the impact, if any, of wind farms on the movements of oceanic birds through the NYB. Geolocators will also provide more detailed maps of feeding hotspots and thereby improve our understanding of how conditions influence feeding behavior and whether these are subject to anthropogenic disturbance. This information will in turn benefit at-sea observers by making it easier to locate and follow species of interest.

At the local level there is still a lot to be learned. Advances in knowledge are being driven by amateur observers working in concert with professional ornithologists. Citizen science projects such as eBird provide an extraordinary open-access resource for the collection and sharing of valuable at-sea observations, especially when submitted checklists include precise effort and positional information (Sullivan et al., 2009). Sampling across the NYB, especially beyond the shelf break, remains very limited during the spring and fall and many pelagic specialists are interested in targeting these transitional periods but need support from others to help underwrite the cost of boat charters. Likewise, at-sea observations tend to be focused on a few major hotspots, such as the outer portions of the Hudson and Block Canyons, with less consistent study of other canyons and the inner edge of the Gulf Stream, which is generally too far offshore for day trips or even overnight trips. As discussed above there are a number of species that seem likely to occur in the NYB but have yet to be reliably detected. For those it seems only a matter of time and this promise is what keeps many dedicated seabird enthusiasts heading offshore year after year. Every trip is different and new discoveries are always possible.

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The Linnaean Society of New York

Established by amateur naturalists in 1878, the Linnaean Society of New York has worked to foster learning about, and stewardship of, the natural world. Its original members included H.B. Bailey, E.P. Bicknell, Ernest Ingersoll, C. Hart Merriam, and John Burroughs. The Society focuses particularly on birds and their place in nature. It organizes regular birding field trips to various destinations in the New York City area and beyond, sponsors lectures from experts on birding and natural history topics, and offers a variety of birding resources, including a rare bird alert. It also takes a leadership role in addressing local conservation issues of concern to birders and natural history enthusiasts. Its aspirations are reflected in its highest award, the Eisenmann Medal, which is given each year to honor “excellence in ornithology and encouragement of the amateur.”

