difference in the body composition between the Emperor and Adélie penguins (Fig. 1 and Table 1). The pectoral muscle of the Emperor Penguin, in proportion to the body volume, was much larger than that of the Adélie Penguin (29.68 and 17.61%, respectively), while the other muscles were similar (22.52 and 23.00%, respectively). The larger pectoral muscle may be beneficial because of the higher output of muscle power and/or the larger storage of oxygen bound to myoglobin in the muscle. The large size of the pectoral muscle in the Emperor Penguin reflects its requirement for deep and long diving rather than rapid swimming. We could find little difference in swimming velocities between Emperor and Adélie penguins (7.5 and 7.2 km/h, respectively; Kooyman et al. 1987); the large pectoral muscle of Emperor Penguin seemed not to work efficiently for swimming. However, because of obvious differences in maximum diving depths (265 and 80 m, respectively; Burger 1991), the larger pectoral muscle probably can store more oxygen. The allometric relationships of morphology and diving function to body size were not considered because more specimens would have been needed for such an analysis.

The body cavity of the Adélie Penguin, in proportion to its body volume, was about twice as large as that of the Emperor Penguin (43.19 and 24.49%, respectively). It is possible that the larger body cavity could be associated with greater food intake. However, because each organ in the body cavity was not clearly distinguishable in the CT images, we were not able to analyze this possibility in detail.

The subcutaneous tissue of the Emperor Penguin was proportionately much larger than that of the Adélie Penguin (15.45 and 5.63%, respectively). The subcutaneous tissue may vary seasonally and may be influenced by starvation during chick rearing. Therefore, our measurements may not represent specific differences between the two species because specimens were not obtained at the same time of year.

In conclusion, CT scanning can provide detailed information on internal morphology of birds the size of penguins. The technique may be useful in a number of different avian morphological studies.

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Literature Cited

Borkan, G. A., S. G. Gerzof, A. H. Robbins, D. E. Hults, C. K. Silbert, and J. E. Silbert. 1982. Assessment of abdominal fat content by computed tomography. Am. J. Clin. Nutr. 36:172–177.

Borkan, G. A., D. E. Hults, S. G. Gerzof, A. H. Robbins, and C. K. Silbert. 1983. Age changes in body composition revealed by computed tomography. J. Gerontol. 38:673–677.

Burger, A. E. 1991. Maximum diving depths and underwater foraging in alcids and penguins. Pages 9–15 *in* Studies of high-latitude seabirds. 1. Behavioural, energetic and oceanography aspects of seabird feeding ecology (W. A. Montevecchi and A. J. Gaston, Eds.). Canadian Wildlife Service, Ottawa.

Häggmark, T., E. Jansson, and B. Svane. 1978. Cross-sectional area of the thigh muscle in man measured by computed tomography. Scand. J. Clin. Lab. Invest. 38:355–360.

Kooyman, G. L., and R. W. Davis. 1987. Diving behavior and performance, with special reference to penguins. Pages 63–75 *in* Seabirds. Feeding ecology and role in marine ecosystems (J. P. Croxall, Ed.). Cambridge Univ. Press, Cambridge.

Schantz, P., E. Randall-Fox, W. Hutchison, A. Tydén, and P.-O. Åstrand. 1983. Muscle fibre type distribution, muscle cross-sectional area and maximal voluntary strength in humans. Acta Physiol. Scand. 117:219–226.

Schantz, P., E. Randall-Fox, P. Norgren, and A. Tydén. 1981. The relationship between the mean muscle fibre area and the muscle cross-sectional area of the thigh in subjects with large differences in thigh girth. Acta Physiol. Scand. 113:537–539.

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Roseate Tern Trio Fledges Three Young

Helen Hays

Department of Ornithology, American Museum of Natural History, New York, New York 10024, USA

Fitch and Shugart (1983) reviewed reports in the literature of trios in a number of species of larids, and Hemmings (1989) discussed breeding success of trios in the Brown Skua (*Catharacta lonnbergii*). Smith (1975) noted multiple birds at a number of nests of Sandwich Terns (*Sterna sandvicensis*), most of which were three years old; in none of the cases for this species did the multiple relations continue until the eggs hatched.

In this note I will discuss a Roseate Tern (*S. dougallii*) nest I found on Great Gull Island in 1991, where three adults incubated three eggs and raised three young. Roseate Terns nest on both sides of the North Atlantic.

In North America, 85% of the population nest on two islands: 1,500 pairs on Bird Island off Cape Cod, Massachusetts; and 1,300 pairs on Great Gull Island (41°12′N, 72°07′W) at the eastern end of Long Island Sound in New York.

On Great Gull Island both Common Terns (*S. hirundo*) and Roseate Terns nest on the remains of an old fort that covers most of the island (Cooper et al. 1970, Hays 1970). Common Terns, the more aggressive species, occupy abandoned gun emplacements and the open central areas of the island. Most of the Roseate Terns nest under boulders that line the shoreline, and a few nest along the edges of the fort's retaining walls.

As part of a long-term Roseate Tern monitoring project, nests have been marked each season since 1966, and records kept of nest initiation dates, intervals between eggs, final clutch sizes, and numbers of chicks hatched and fledged. Roseate Terns usually lay one or two eggs, although each year we find a few three- and four-egg clutches. In 1966, of 1,505 nests marked, 835 (55%) had one egg, 615 (41%) had two, 48 (3.2%) had three, and 7 (0.5%) had four (Cooper et al. 1970). Similar figures were noted in 1967 and 1968 (Hays 1970), as well as more recently. It is unusual to have all eggs in a three-egg clutch hatch, and we have no previous records of three chicks surviving. In no case have all eggs in a four-egg clutch hatched.

The Roseate Tern trio's nest was initiated on a retaining wall. The site was open and situated about 12 m east of a permanent blind from which it could be observed easily. It was in an area checked daily throughout the season by a team marking both Common and Roseate tern nests. From 9 through 11 June we watched the nest from a blind for short periods totaling a little over 3 h. I set up a formal watch at the nest on 15 June. Field assistants and volunteers took 2-h shifts beginning between 0500 and 0900 EST and ending between 1500 and 1900 on most days from 15 June through 27 July. From 9 June through 2 July, when the first chick hatched, the nest was watched for 133.3 h on 20 days. From 3 to 27 July, the day the first two chicks fledged, we observed the feeding behavior of the adults on 22 days for a total of 224 h. Students used a Kowa spotting scope and 8 × 40 binoculars to identify which bird incubated, as well as to determine the numbers of adults near the nest during any particular watch. Interactions between adults were noted. After the chicks hatched observers continued to note which birds were present at or near the nest. For each feeding, observers identified (whenever possible) the adult that brought in the fish and the young that received the fish. Fish seemed to be plentiful close to the island throughout July and August, and we observed large flocks of terns feeding off both ends of the island daily. We banded more Roseate Tern hatchlings in 1991 than in any previous season.

I will refer to the three adult Roseate Terns in this paper as follows: Inc, Blu, and Unb. Inc wore an incoloy U.S. Fish and Wildlife Service band and had been banded as a chick on Great Gull Island in 1985. I read its band number using the spotting scope. The second bird, Blu, was color banded. It had originally been banded as an adult in 1982 about 130 km west of Great Gull Island, then trapped on Great Gull Island in 1989 and color banded. The third bird, Unb, was unbanded.

At hatching, banders gave each chick in the trio's nest a steel U.S. Fish and Wildlife Service band on the right leg and a color plastic band on the left, using a different color for each chick: the first to hatch a yellow band, the second an orange, and the third a green. The chicks will be referred to by their color bands.

I have compared the incubating behavior of the 1991 trio with that of a sexed pair of Roseate Terns observed for 59 h from 12–15 June 1974; this period was five to eight days before hatching. Numbers of fish fed the young by the trio were compared with those fed to young by two different sexed pairs of Roseate Terns studied on Great Gull Island in 1972 and 1974. During the 1972 and 1974 watches, observers took 2-h shifts daily beginning between 0400 and 0500, and ending at 1900. In 1972 we watched from 19 July through 13 August for 364 h and, in 1974, from 22 June through 19 July for 394 h.

I will refer to incubation bouts, successful and unsuccessful nudges, and feeding bouts. An incubation bout begins when an adult gets on the nest and ends when it changes with another adult. While one bird incubated, observers often saw a second bird push into the nest and attempt to displace it. If the attempt was successful and the incubating bird left we called it a successful nudge, if the attempt failed it was called an unsuccessful nudge. A feeding bout refers to the number of feedings completed in less than an hour by the same adult. A feeding bout may include three to six or more feedings, typically 1 to 13 min apart. The end of a feeding bout is marked by a period of an hour or more when the adult does not feed.

On the evening of 7 June 1991, I went to a blind at the eastern end of Great Gull Island to observe Roseate Terns nesting on a small retaining wall. At the end of the wall I noticed two Roseate Terns standing together, one wearing a standard band (Inc) and the other unbanded (Unb). A Roseate Tern wearing a color-band combination (Blu) stood about 2 m behind them.

On 9 June during the daily check of the island, a team member marked an egg on the wall where I had seen Inc and Unb standing. That afternoon I went to the nearby blind to try to identify the birds at the nest. To my surprise there were three birds at the site (Inc, Unb, and Blu). Each sat for a short time on the egg. This was unusual on two counts. First, I had never seen three Roseate Terns trying to incubate one egg. Second, it is unusual for Roseate Terns to begin

TABLE 1. Incubation and feeding by 1974 pair and 1991 triple.

	1974 pair[a]		1991 triple[b]		
	Male	Female	Inc	Unb	Blu
Hours on nest	36.8 (61%)	22.4 (39%)	46.3 (34%)	39.6 (29%)	51.4 (37%)
Average bout (h)	2.6	2.2	0.57	0.40	0.62
No. fish delivered	287	171	291	48	43
Fish/h	0.7	0.4	1.3	0.2	0.2

[a] Incubation period involved 59 h of observation, and feeding was assessed during 394 h.
[b] Incubation period involved 133.3 h of observation, and feeding was assessed during 224 h.

incubating the day the first egg is laid. They usually wait a day and often longer before they begin to sit on the eggs. On 10 June a second egg was marked and on 12 June a third egg completed the clutch.

The three chicks Yellow, Orange and Green hatched, 3, 4 and 6 July, respectively. The first and third were covered with dark gray down. In contrast, the second chick was blonde, its down straw-colored. We were struck by the difference in down color of the second chick. Usually Roseate Tern chicks within a clutch have similar down color. The first two young fledged 23 and 24 days after hatching, the third 26 days.

Behavioral and mensural characters suggested Blu and Unb were females and Inc was a male. Both Blu and Unb begged to Inc on several occasions, assuming a posture similar to that of females soliciting copulation. Coulter (1986) found within pairs of Common Terns, females had shorter bills than males. In 12 Roseate Tern pairs sexed by observing copulation, bill measurements of the females were shorter than those of the males (Cormons in prep). Measurement of Blu and her mate in 1990 suggested Blu was a female.

Inc brought in 76% of the fish fed to the young, and Unb and Blu 13 and 11%, respectively (Table 1). During the 1972 and 1974 watches at Roseate Tern nests, observers noted males brought in 140 (57%) and 287 (63%) of the fish, respectively, and the females 108 (43%) and 171 (37%). These data suggest that males bring in more fish than females. On this basis, the disproportionate number of fish brought by Inc compared to the other members of the trio would suggest Inc was a male. Unb and Blu not only brought very few fish, but very similar numbers of fish, further suggesting that both were females.

We recorded more aggressive interactions between the adults at the nest during the first eight days of incubation (76, which were 82% of the total), than during the subsequent two weeks (16, which represented 17%). During the first eight days, 72% of the interactions (Table 2) were between Unb and Blu, with Unb attacking or threatening Blu 40.7% of the time and Blu attacking or threatening Unb 31.4%. Inc directed about the same number of attacks against both females during this period. On 11 June, I watched a fight between Blu and Unb, while Blu was on the nest. Unb approached and they locked bills. Blu jumped toward Unb, and Unb still holding Blu's bill flapped onto the nest and remained there. In contrast, between 16 June and 2 July we observed very few aggressive interactions at the nest.

TABLE 2. Number of aggressive interactions between adults from 10–17 June.

	Target		
Aggressor	Inc	Unb	Blu
Inc	—	10 (11.6%)	11 (12.8%)
Unb	0 (0.0%)	—	25 (40.7%)
Blu	3 (3.8%)	27 (31.4%)	—

Although we watched the nest for only a total of 8 h during the laying period of 9 to 11 June, the amount of time each adult spent on the nest differed from the average time for each adult for the entire watch: Inc, 52% of time; Unb, 25%; and Blu, 19.9%. The aggressive interactions between Blu and Unb took them off the nest quite often during this period, which might have given Inc more chances to get on the eggs. It also looked as if during the first week the females were more apt to change on the nest with Inc than with each other.

Table 1 contrasts the time the birds on the 1974 and 1991 nests were observed incubating, and compares the average incubation bout for the birds on both nests. There is no significant difference in the amount of time members of the 1974 pair ($X^2 = 3.03$, df = 1, $P = 0.082$) and members of the trio ($X^2 = 1.53$, df = 2, $P = 0.465$) spent incubating at their respective nests; however, the average incubation bout for each member of the trio was one-fifth the average bout for either member of the 1974 pair.

During incubation observers often recorded all three birds in the nest at once, jockeying for position on the eggs. Commonly, one adult incubated the eggs while one or both of the other adults stood near the nest. Inc was observed standing in the nest area 150.1 h (45%), Unb 99.5 h (29%), and Blu 86.6 h (26%) throughout the incubation period. Sometimes a standing bird would attempt to push onto the eggs. If the incubating bird did not get up, the other bird might stretch its head and neck over the back of the incubating bird. If the bird on the eggs still sat, the standing bird often walked over the back of the incubating bird, then turned around and walked over

TABLE 3. Successful and unsuccessful nudges by adults from 9 June to 2 July (20 days, 133.3 h).

Bird	Successful nudges	Mean time/ nudge (min)	Unsuccessful nudges	Mean time/ nudge (min)
Inc	21 (36.2%)	2.7	49 (45.0%)	8.4
Unb	13 (22.4%)	4.2	48 (44.0%)	5.8
Blu	24 (41.4%)	2.1	12 (11.0%)	1.4

the incubating bird again. After this, the incubating bird might rise from the eggs then resettle. At the time the incubating bird stood up, the standing bird evidently could see the eggs clearly and gently would poke its bill under the incubating bird, often drawing out one egg. It would then settle on the egg beside the incubating bird, and they would incubate one and two eggs, respectively. Sometimes, the bird attempting to nudge the incubating bird off succeeded, and the birds changed places on the nest. A nudge was considered successful only if the birds changed places.

Table 3 shows successful and unsuccessful nudges by members of the trio during the incubation period. Inc and Unb made more nudge attempts than Blu, and were less successful in these attempts, suggesting that Blu was the dominant bird during incubation. The number of successful nudges between the three birds is not significantly different ($X^2 = 3.34$, df = 2, $P = 0.188$). However, Blu performed significantly fewer unsuccessful nudges than Inc or Unb ($X^2 = 24.46$, df = 2, $P < 0.001$). Inc and Unb performed significantly more unsuccessful nudges than successful ones ($X^2 = 10.41$, df = 1, $P = 0.001$, and $X^2 = 18.95$, df = 1, $P < 0.001$, respectively) and spent more time in these attempts than did Blu.

The members of the 1974 pair, if not incubating, were almost never seen standing near the nest, and were not observed attempting to nudge one another off the nest. When they changed on the nest, the bird arriving walked directly onto the nest as the incubating bird walked off. The bird leaving the nest then flew off and did not return until it once again took over incubation. The fact that members of the trio were commonly observed standing near the nest while another member incubated, combined with their frequent attempts to nudge each other off the nest, suggests that their short incubation bouts did not give them enough time on the eggs to be ready to change with another bird.

Table 4 shows the number of fish delivered to the young by Inc, Blu and Unb. Interestingly, Inc and Unb brought about equal numbers of fish (no significant difference) to each chick, although Unb fed young far less often than Inc. Blu fed more fish to Yellow and Orange than she fed to Green. The differences for fish delivered by Blu approached being significant ($X^2 = 5.68$, df = 2, $P = 0.058$).

TABLE 4. Number of fish fed to young by three parents.

Young	Parent		
	Inc	Unb	Blu
Yellow	91	13	16
Orange	87	11	11
Green	84	12	5

Between the time the chicks hatched and fledged, Inc again spent more time at the site than either female: Inc, 107.6 h, 50%; Blu 55.2 h, 25%; and Unb, 53.4 h, 25%. Since Inc delivered most of the fish fed to the young, observers had a good opportunity to observe his feeding behavior. During many of his feeding bouts Inc brought in five to seven fish in rapid succession, often within a 7- to 10-min period, feeding each of the chicks one fish and probably two of them a second. Of the 226 fish delivered to the chicks by Inc, 83% were delivered at intervals under an hour, while 47 (17%) were delivered at intervals of an hour or more. Inc averaged 13 min between fish deliveries during his feeding bouts. In most instances, when Inc arrived with a fish, the young in the nest did not run out and snatch the fish as we had observed Roseate Tern young do during previous watches where the period between feedings was longer. Inc appeared to "decide" which chick would get the fish. Often he ignored a begging chick at the edge of the nest, passing it to feed a chick standing toward the back of the nest site.

One observation suggested Inc responded to the call of the chick that might be the hungriest when he delivered fish. Green was observed in the nest as a wet chick at 0645 on 6 July. Inc delivered the first fish to Green at 1230. By this time Yellow had received four fish and Orange three. At 1345, Inc landed on the wall with a fish. He darted past Blu as she sat brooding Green and headed for some grass where both Yellow and Orange were sitting. As Inc walked by Blu, Green stuck its head out and opened its bill. I could not hear any sound because the blind was too far from the nest, but I assumed Green had called. As soon as Green opened its bill, Inc stopped, turned back and fed Green the fish.

Figure 1 shows the percentages of fish delivered to each chick during watches where observers were able to identify the chick receiving the fish: 6–10 July, 17–22 July and 24–27 July. Here too, the changes in total number of fish delivered to each chick by day suggests Inc's feeding pattern enabled him to feed all the chicks enough fish so that they did not have to aggressively compete with one another. For example, from 6–10 July Green, as might be expected, received the lowest percentage of fish delivered on four of the five days. What is not so expected, however, is that Green at three days old received 45% of the fish delivered on 8 July, while the older chicks Yellow (five days old)

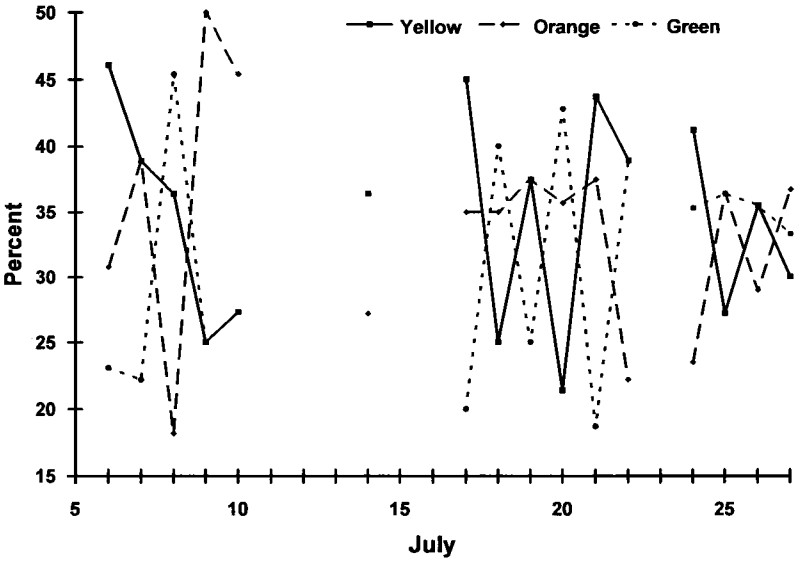

Fig. 1. Percentage of fish delivered to Yellow, Orange and Green.

and Orange (four days old) received 36 and 18%, respectively. For the two final periods shown in Figure 1, one chick (a different one in each period) received a little over 35% of the fish daily, while the other two chicks alternated in receiving the highest and the lowest percentage of the fish delivered on successive days.

Table 1 compares the fish delivered by the three birds in 1991 with those delivered by the 1974 pair. Inc brought in almost the same number of fish as the 1974 male in a little more than one-half of the time observed. The average number of fish per hour brought in by Inc alone (1.3) was even more than that for the 1974 pair (1.1). The difference in feeding rate between Inc and the 1974 male could be due to individual differences in the males or to differences in food availability in the two years, or both.

Figure 2 compares intervals within feeding bouts for Inc and the 1974 pair. Inc averaged 13.02 ± SD of 12.40 min between fish, the 1974 male averaged 33.78 ± 14.21 min, and the 1974 female averaged 33.38 ± 13.66 min. Inc's average interval was significantly shorter than the average intervals of the 1974 pair (one-way ANOVA, $F = 126.12$, df = 2 and 413, $P < 0.001$). The range in intervals for Inc are strongly skewed toward shorter intervals.

We have found Roseate Tern three- and four-egg clutches regularly on Great Gull Island. In the past, we assumed that Roseate Tern females sometimes lay three and four eggs. This is still a possibility; however, in the nest described here a male and two females incubated the eggs in a three-egg clutch and fledged three young. The appearance of the first two eggs on successive days, as well as the difference in down color of the chicks, suggests that both females contributed to the clutch. In late June 1991, Grace Cormons made some observations suggesting that some four-egg clutches also may have more than two birds associated with them. She distinguished three adults on a four-egg clutch, identifying the birds by the amounts of red on their bills.

During the period we have worked on Great Gull Island many of the edge sites formerly used by Roseate Terns have become overgrown. We trap infrequently, but regularly, Roseate × Common tern hybrids (Hays 1975), as well as mixed pairs at sites that might be used by Roseate Terns one year and Common Terns the next. These sites are always on the border between the open areas used by the Common Terns and the rocky areas used by the Roseate Terns. It appears that not only have the sites where Roseate Terns can nest been reduced on Great Gull Island, but Roseate Terns are competing with Common Terns for edge sites. The use of a site by more than one female Roseate Tern could be another response by the species to crowding.

The lack of success we have observed in three- and four-egg clutches suggests that in most situations, when more than one female or more than one pair attempt to use a site, it is disruptive. Often only some of the eggs hatch and few if any young survive. The success of the trio of Roseate Terns described in this paper is due to a coincidence of factors. The eggs were laid in a normal sequence, and all birds began incubating on the same day. Hostile interactions between the females seldom occurred after the first week of incubation. Blu's incubating behavior suggested that she became dominant, which might explain why Inc and Unb (assuming they were the original pair) tolerated her. In 1991 there were good supplies of baitfish just

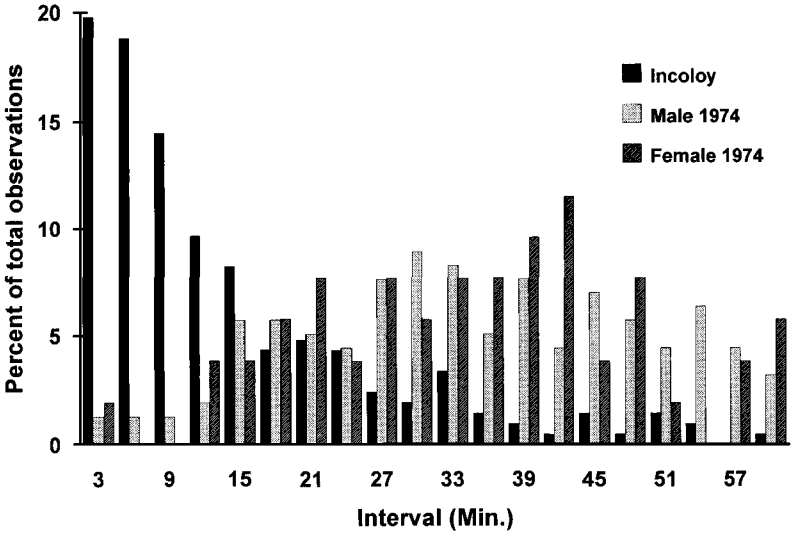

Fig. 2. Comparison of intervals between feedings for Incoloy, a 1974 male, and a 1974 female.

off the island. Inc was able to exploit this food supply and, with the additional fish brought in by the females, was able to fledge three young.

To evaluate trios as a breeding strategy for Roseate Terns, it is essential to determine the incidence and success of trios in colonies where Roseate Terns nest. Future observations should help to clarify these points.

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Literature Cited

Cooper, D. M., H. Hays, and C. Pessino. 1970. Breeding of the Common and Roseate terns on Great Gull Island. Proc. Linn. Soc. N.Y. 71:83–104.

Coulter, M. 1986. Assortative mating and sexual dimorphism in the Common Tern. Wilson Bull. 98:93–100.

Fitch, M. A., and G. W. Shugart. 1983. Comparative biology and behavior of monogamous pairs of one male-two female trios of Herring Gulls. Behav. Ecol. Sociobiol. 14:1–7.

Hays, H. 1970. Great Gull Island report on nesting species 1967–68. Proc. Linn. Soc. N.Y. 71:105–118.

Hays, H. 1975. Probable Common × Roseate tern hybrids. Auk 92:219–234.

Hemmings, A. D. 1989. Communally breeding skuas: Breeding success of pairs, trios and groups of *Catharacta lonnbergii* on the Chatham Islands, New Zealand. J. Zool. (Lond.) 218:393–405.

Smith, A. J. M. 1975. Studies of breeding Sandwich Terns. Br. Birds 68:142–156.

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