THE WILSON BULLETIN

A QUARTERLY MAGAZINE OF ORNITHOLOGY

Published by the Wilson Ornithological Society

VOL. 88, NO. 3 SEPTEMBER 1976 PAGES 377–528

ROSEATE TERN BILL COLOR CHANGE IN RELATION TO NESTING STATUS AND FOOD SUPPLY

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In a previous paper (Donaldson 1968) I described the change in bill color of Roseate Terns (*Sterna dougallii*) breeding on Great Gull Island, New York, (41°12′ N. Lat., 72°07′ W. Long.), at the eastern end of Long Island Sound. Briefly, when the Roseates arrive at the island in early May the bill is all black. During incubation red appears at the base of the bill. The extent of red increases until about the time the young fledge. At the end of the season the bill becomes all black again.

At the time of the 1968 paper, data were not available on the exact nesting status of most of the birds measured, and it had not been possible to follow the bill color change of individual Roseates. These data, and more, are now available.

In this paper I describe the bill color change of a marked pair of Roseate Terns followed from the time the first red began to appear during incubation through the time their young fledged. I compare the average of measurements of the extent of red on the bills of Roseate Terns trapped on Great Gull Island for 1968–1970, 1972, and 1974 and discuss these figures in relation to estimates of food available. I also present the bill color measurement data in relation to sex, weight, clutch size, and age. Finally, I discuss some data on bill color of Roseates in the Caribbean and speculate on the possible adaptive significance of bill color change in the Roseate Tern in light of the unique timing of this change.

METHODS

The pair of adult Roseate Terns illustrated in Plates 1 and 2 had been individually color-marked 21 June 1969 as part of our program of color-banding adult terns (Hays 1970b). The sexes of the pair were determined by H. Hays in late August 1972 when she observed one bird (USFWS 742–75155) mount the other (USFWS 742–75165). I refer to the former as M for male and the latter as F for female. This sexing was

consistent with observations in 1974 of their display behavior and their roles in incubation and feeding the young.

In 1971 and 1974 M and F nested in the grass at the top edge of a 4m high retaining wall opposite a tower from which they were observed and photographed. In 1971 I photographed this pair daily from 15 June–11 July, when they moved their young into the rocks below the tower. We then set up a blind near where they fed their young and I photographed them 18 July–14 August. This 1971 series showed no detectable difference in extent of red from day to day. Comparison of photographs taken at 3- and 4-day intervals did show a perceptible change. In 1974 Joan Black photographed M and F on 8 June. My husband and I then photographed them twice a week from 22 June through 18 July, and on 25 June I photographed M held in the hand.

In both years M and F were photographed through the last day they were seen on the island, and all photos both years were taken between 11:00 and 13:00. The slides from 1974 were sharper than those from 1971. The plates are based on the 1974 slides except for the figure of F on 14 August 1971.

J. Black photographed with a Nikon F2 camera body and 500 mm reflex lens. All other photos were taken with a Konika FP camera body with a 450 mm Soligor lens. In 1971 Kodachrome II film was used. In 1974 high speed Ektachrome was used for all photos except those taken 8 June, when Ektachrome X was used. I have included the 8 June 1974 and 14 August 1971 pictures in the plates, although they were taken with different films, because they show the extremes early and late in the change. In the 8 June slide the bills are almost completely black with only a trace of red at the base. The 14 August picture shows the faded red of the bill late in the season. That this color is not an artifact of the difference in film type is demonstrated by comparison of leg color (which does not change during this period); the legs appear identical in slides made with the 3 film types. Use of the Kodachrome II slide was further validated by comparisons of slides of the same birds taken in 1971 on Kodachrome II and in 1974 on high speed Ektachrome.

Referring to the slides for each date, Kathleen Duffin painted the tern heads using the guache technique with Guitar brand watercolors. In the case of the figures for the female on 8 and 18 July, the *extent* of red is as shown for these dates, but the *shade* of red is that of the slides from 5 and 15 July respectively, as the slides of her from 8 and 18 July were overexposed.

In 1968–1970, 1972, and 1974 I measured the extent of red on the bills of 872 Roseate Terns trapped on nests that had been numbered when the first egg was laid. Using dial calipers I measured to the nearest mm the red on the side of the upper mandible along a line from the edge of the feathering to the tip of the bill, passing along the line of the nostril. I use gross measurements rather than a percentage of red because the variation in distance from the base of the feathers to the distal end of the nares among Roseates is negligible (Donaldson 1968). As I measured adults only at the time their eggs hatched, the red on the bill rarely extended beyond the distal end of the nares.

I have compared the measured extent of red on the bills of the Roseates we trapped during the first part of each nesting season for all years (Table 3). The varying calendar dates of these periods reflect differences in the timing of first eggs and of the peak dates of newly established Roseate nests. The nesting status of the birds trapped in each of these periods was directly comparable. All adults were trapped on

newly hatched or 1-day-old chicks and the measurements of those birds trapped on the first nest to hatch each year are compared.

The 1972 season was exceptional. On 22 June 1972 Hurricane Agnes destroyed many nests; birds subsequently renested, so that there were more birds nesting late than in any other year of the study. We were able to continue trapping Roseates in August. I have, therefore, grouped the birds trapped after 7 July 1972 into a second and third period for that year: 8–22 July, and 23 July–1 August.

In 1970 and 1972 I weighed the birds to the nearest gram using a Pesola balance. In 1974 I weighed them to the nearest tenth of a gram on a triple beam balance.

RESULTS

Plates 1 and 2 show the bill color change of a pair of Roseate Terns from the middle of incubation to about 6 weeks after the young have hatched. I have notes on this pair taken 2 June, 6 days before the first picture in Plate 1 and 18 days before the first egg hatched: I describe M as having the bill completely black on both sides, and F as having a trace of red at the base on the right side with no red on the left.

Table 1 represents an expanded legend for Plates 1 and 2. The side of the bill actually illustrated in the plate is discussed first, then the opposite side if it was different.

In 1974 we did not see M and F after their second chick flew on 18 July. In 1971 they were seen through 14 August, thus allowing me to photograph the faded bill of F. The first slide from 1971 that shows fading of the red is that of F on 2 August. The red continued to fade as is shown in the slides for 7 August, yet between 27 July and 7 August in 1971 the extent of red on F's lower mandible increased to the amount shown for her on 14 August (Plate 2). The slide record of M's fading bill is not so complete as that of F, but his bill appears to have reached its maximum brightness about 27 July also, and was beginning to fade on 9 August.

In both 1971 and 1974 the extent of red on the female's bill was consistently greater than that of the male. It appears likely that there is no consistent sexual dimorphism in bill color, as in 10 of the 235 pairs trapped and measured, there was no difference in extent of red on the bills of mates (Table 2).

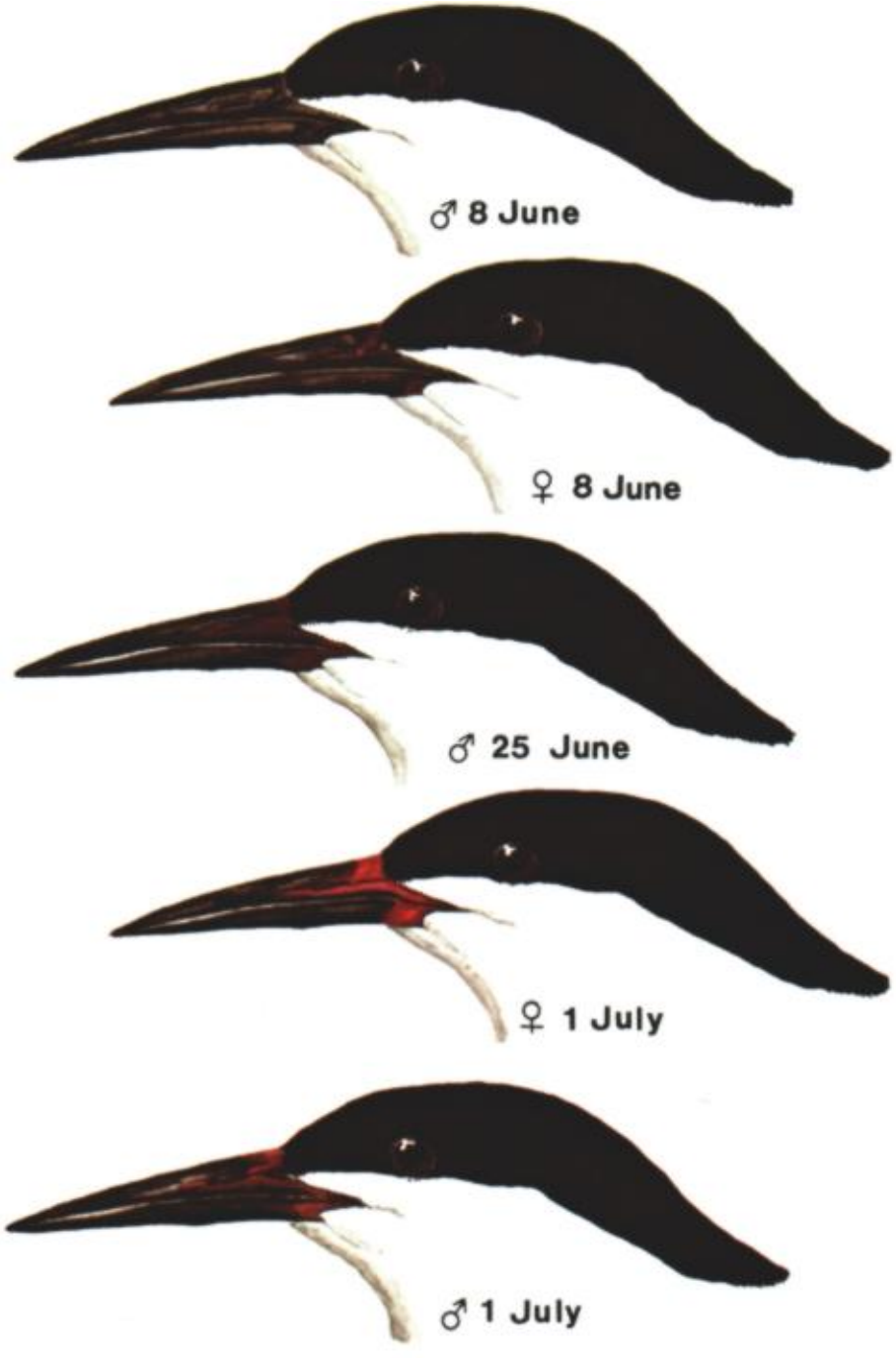
The acquisition of red for most Roseate Terns in the Great Gull Island colony appears to follow the pattern shown for M and F, the first red appearing at the base of the bill during incubation (Donaldson 1968). In 1969 I noted a single exception to this pattern. On 16 May I picked up a freshly dead Roseate Tern with 2 mm of red at the base of the bill. This bird had several developing ova, but no ruptured follicles. The first Roseate egg marked on Gull Island in 1969 was found on 21 May, 5 days later. The 15 May bird beginning to show red was thus exceptionally advanced.

TABLE 1

LEGEND FOR PLATES 1 AND 2

Date	Nest Status	Ind.	Side	Description
6/ 8/74	12 days before	M	L	LM*trace of dark red
	hatching	F	L	LM dark red coming in on lower part. UM** red extending down from base of culmen to distal end of nares.
6/25/74	chicks 3 and 5 days old	M	R	LM, red extending less than on side of UM, where it reaches beyond nares.
			L	No slide
		F		No slides
7/ 1/74	chicks 9 and 11 days old	F	L	Red now solidly filled in at base of bill and much increased in extent and brightness since 8 June.
			R	Same as left side, but with a light diffused red over the nares on culmen.
		M	L	Extent similar to that on 25 June, but red brighter.
7/ 8/74	chicks 16 and 18 days old	F	L	Red brightened and extended in last week, especially along culmen.
			R	Red extends 2mm farther beyond naris and 3mm more along cutting edge of LM, than on left side. This was the greatest difference between the sides for any date for either bird.
		M	L	Red brightened and filled in at base since 1 July, and extends somewhat farther along culmen.
7/18/74	chicks 26 and 28 days old (The elder had flown from the wall. The younger flew 18 July.)	F	L	Bright red extending along almost 50% of the side (i.e. from the point where the black and white feathers meet with the UM, to the distal point of red).
		M	L	Red extending along about 40% of the side of the upper mandible.
			R	No slide.
8/14/74	chicks 41 and 44 days old	F	L	Red is very faded, diffused with black and there is a definite area of black at the base of the UM.

* LM = lower mandible
** UM = upper mandible



KED 1975

Plate 1 (See Table 1)

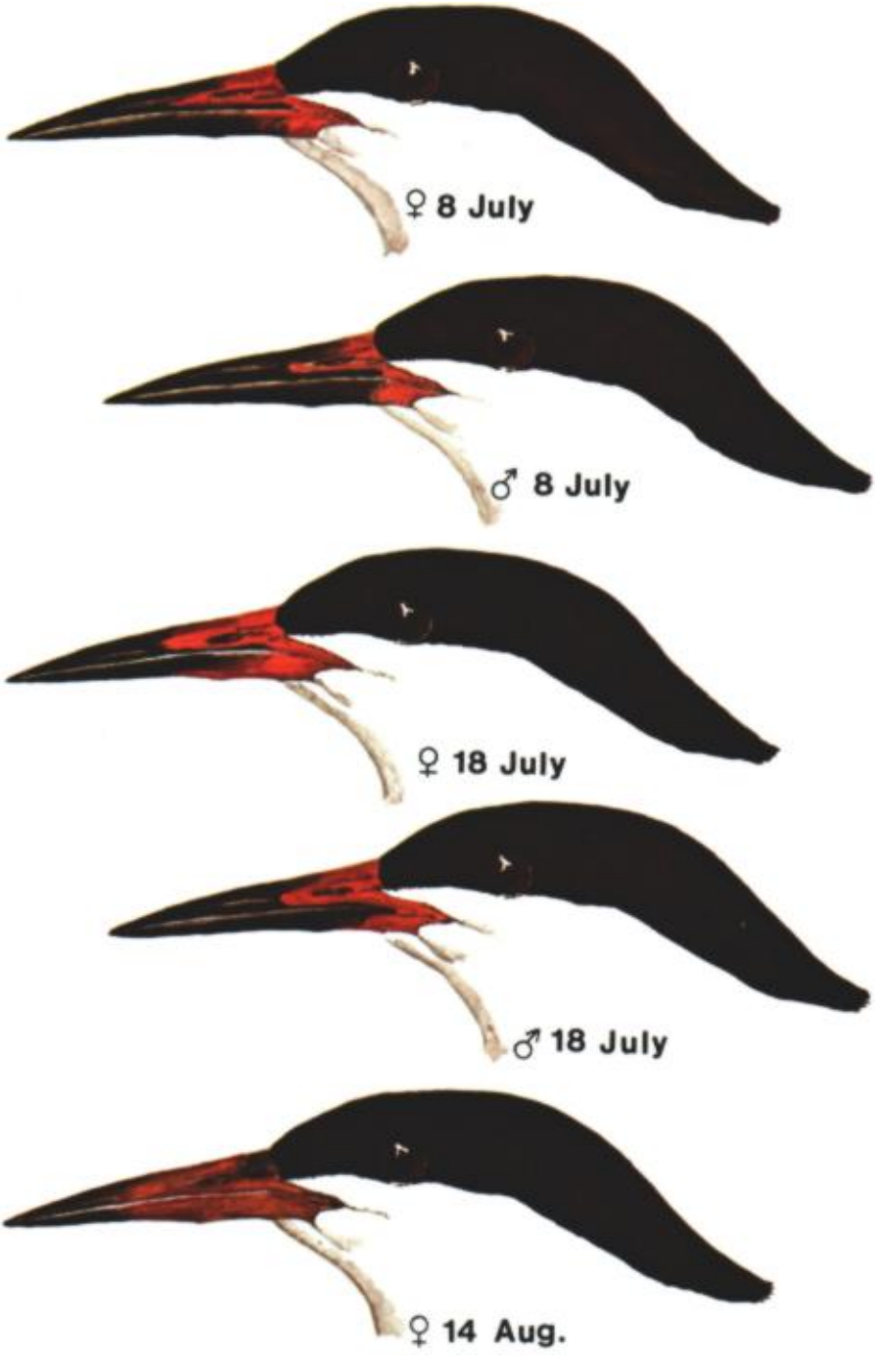


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Plate 2

TABLE 2

DIFFERENCE (MM) OF RED ON RIGHT SIDE, BETWEEN MEMBERS OF PAIRS TRAPPED WITHIN ONE DAY OF EACH OTHER

Difference	Number of Birds						
	1968	1969	1970	1972	1972*	1972**	1974
0	2	4	2				2
.1–1.0	4	12	15	6	8	13	10
1.1–2.0	8	17	9	6	7	10	7
2.1–3.0	4	8	7	2	5	6	9
3.1–4.0	3	5	3	1		3	3
4.1–5.0	1	4			2		3
5.1–6.0		3			4	1	1
6.1–7.0		1			2		1
7.1–8.0		1			3	2	
8.1–9.0						1	
9.1–10.0		1					1
11.1–12.0							2
12.1–13.0		1					

* Second period of 1972.
** Third period of 1972.
All other dates are for the first trapping periods, as detailed in the methods section.

TABLE 3

RED ON THE BILLS OF ROSEATE TERNS IN DIFFERENT YEARS[1]

Dates	No. of terns	Mean	S. D.	Range
14 June–3 July 1968	30	4.47	2.26	0–11.4
14 June–4 July 1969	115	6.24	2.53	0–17.4
15 June–5 July 1970	63	5.57	1.80	0–10.0
24 June–7 July 1972	84	5.56	3.07	0–15.4
22 June–5 July 1974	89	6.65	2.86	0–18.3

Significance of difference in means of extent of red between years:

	Value of t	P =
1968 vs. 1969	3.462	.01
1968 vs. 1970	2.502	.02
1968 vs. 1972	1.764	.1
1968 vs. 1974	3.763	.01
1969 vs. 1970	1.849	.1
1969 vs. 1972	1.701	.1
1969 vs. 1974	1.079	.3
1970 vs. 1972	0.024	.5
1970 vs. 1974	2.263	.05
1972 vs. 1974	2.404	.02

[1] Measurements (mm) of red on the side of the bill of birds whose first chick was newly hatched or one day old.

TABLE 4
WEIGHTS (G) OF ADULT ROSEATE TERNS

Dates	Number	Mean	S. D.	Range
15 June–5 July 1970	144	109.8	6.8	96–128
24 June–7 July 1972	72	107.9	6.4	96–120
22 June–7 July 1974	83	112.6	7.3	98–133

Table 3 compares the measurements of the extent of red on the bills of Roseate Terns trapped in all years. Comparison of the means for like periods shows significant differences: the 1974 mean is greatest (i.e. the bills had the greatest extent of red), followed closely by 1969, then by 1972 and 1970 which are very similar; 1968 is lowest. Individual Roseates remeasured in succeeding years (Fig. 1) tend to bear out the pattern of annual differences shown for the total sample in Table 3.

These differences in the extent of red from year to year coincide with apparent differences in the fish supply. For instance, in 1968, when the extent of red on the Roseates' bills was low, there was a scarcity of fish in the colony (Hays 1970a; LeCroy and Collins 1972). In 1969 and 1974, when the average extent of red was much greater, there were apparently more fish (LeCroy and LeCroy 1974; pers. observ.).

I found some correlation between weight and bill color, with heavier Roseates tending to have a greater extent of red on the bill. I compared the average weight of birds with 0–10 mm red with that of birds with 10–20 mm of red. The group with less red averaged lighter in weight, although the difference was not statistically significant.

There was a significant ($P = .05$) difference between the mean of the weights for 1974 and the mean of the weights for both 1970 and 1972 (Table 4). This pattern, with 1970 and 1972 similar and 1974 higher, is the same as the yearly pattern for extent of red on the bills. Both the weight and the bill color differences thus appear to reflect differences in food supply from year to year.

I found no consistent relationship between clutch size and bill color. In 1968, 1969, and 1974, birds on 1-egg clutches averaged slightly redder bills than birds on 2-egg clutches, but the differences were not statistically significant. In 1970 and all 3 periods of 1972, birds on 2-egg clutches had more red than did those on 1-egg clutches, but the difference approaches significance only for the last period of 1972.

Within the large samples of birds measured each year, there was considerable individual variation in the extent of red on the bills of birds of the same nest status. For instance, in 1972 (Fig. 2), some Roseates had

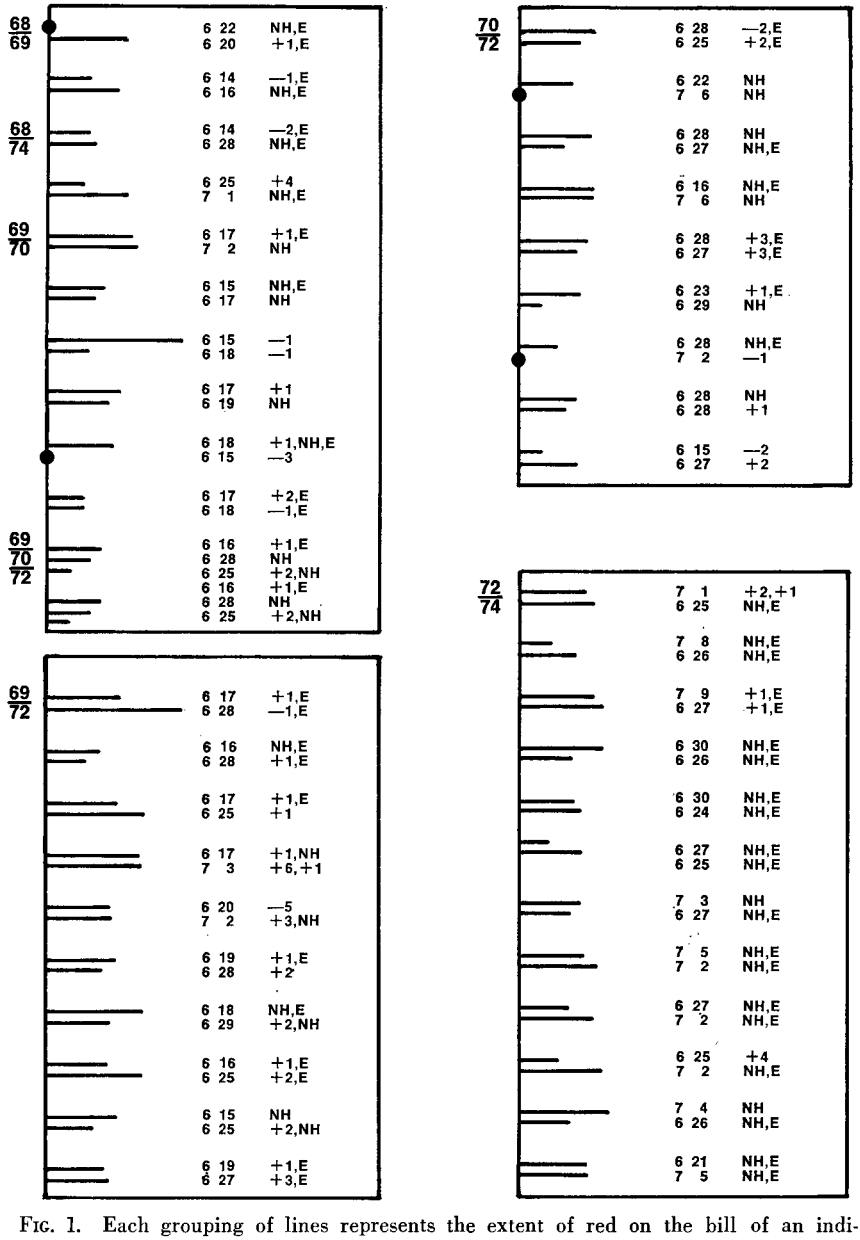

FIG. 1. Each grouping of lines represents the extent of red on the bill of an individual Roseate measured in more than 1 year, e.g. (19)68/(19)69, followed by the date on which it was measured each year and its nest status at the time of measurement. NH = newly hatched chick, E = egg, -5 to +4 = days before (–) or after (+) hatching.

TABLE 5

RANGES OF RED ON THE BILLS OF KNOWN AGE BIRDS WHOSE FIRST CHICK WAS NEWLY HATCHED OR ONE DAY OLD

Age in years	Extent of red (mm)[1]	No. of birds
2	1.5–17.0	3
3	2.5–14.5	13
4	3.4– 8.0	7
5	3.0–14.5	8

[1] These ranges are a summary taken from all years trapping was done (1968–1970, 1972, and 1974).

more than 10 mm of red in June while others had none. There was a marked increase in the number of birds having more than 10 mm of red that were trapped on new chicks late in the 1972 season (Fig. 2). It may be that these were birds that had first nested during June and their bills had already started to become red before the hurricane destroyed their nests.

Even birds of the same age, all measured at the time their first young hatched, varied in the extent of red on their bills (Table 5). Most of these known age birds were trapped in 1972, and are shown individually in Fig. 2, where their ages are indicated by the numeral next to their symbol. The two-year-olds are of particular interest. In addition to the one shown in Fig. 2, I have data on 3 two-year-olds from other years. One, trapped on a nest of unknown age 23 June 1967, had 1 mm of red on its culmen. Another, trapped over a 1-day-old chick, measured 17 mm of red on 3 August 1971 (Donaldson 1971). The third, also trapped 3 August 1971, one day before its chick hatched, had 17 mm red.

Roseate Terns in other parts of the world may differ from the Gull Island birds in the timing and rate of acquisition of red on their bills. Between 22 and 26 May 1968, Helen Hays and I surveyed 275 Roseate Terns on small islands off St. Thomas in the Virgin Islands. Thirty of these Roseates had all black bills. The rest had amounts of red on the bill varying from a few millimeters to ⅔ of the bill red. These birds were standing along the shores of the islands. The islanders are permitted to collect eggs of sea-birds until the end of May, and as our search of 4 islands where the birds breed yielded only 6 nests, it seemed likely that the first clutches of most of the birds we saw had been collected.

We aged the eggs by flotation (Hays and LeCroy 1971) in the 6 nests we found, and all but one, which had been incubated 1 or 2 days, were fresh. I trapped an adult on a fresh egg 22 May and the measured red on its culmen was 8.7 mm. These measurements are comparable in extent

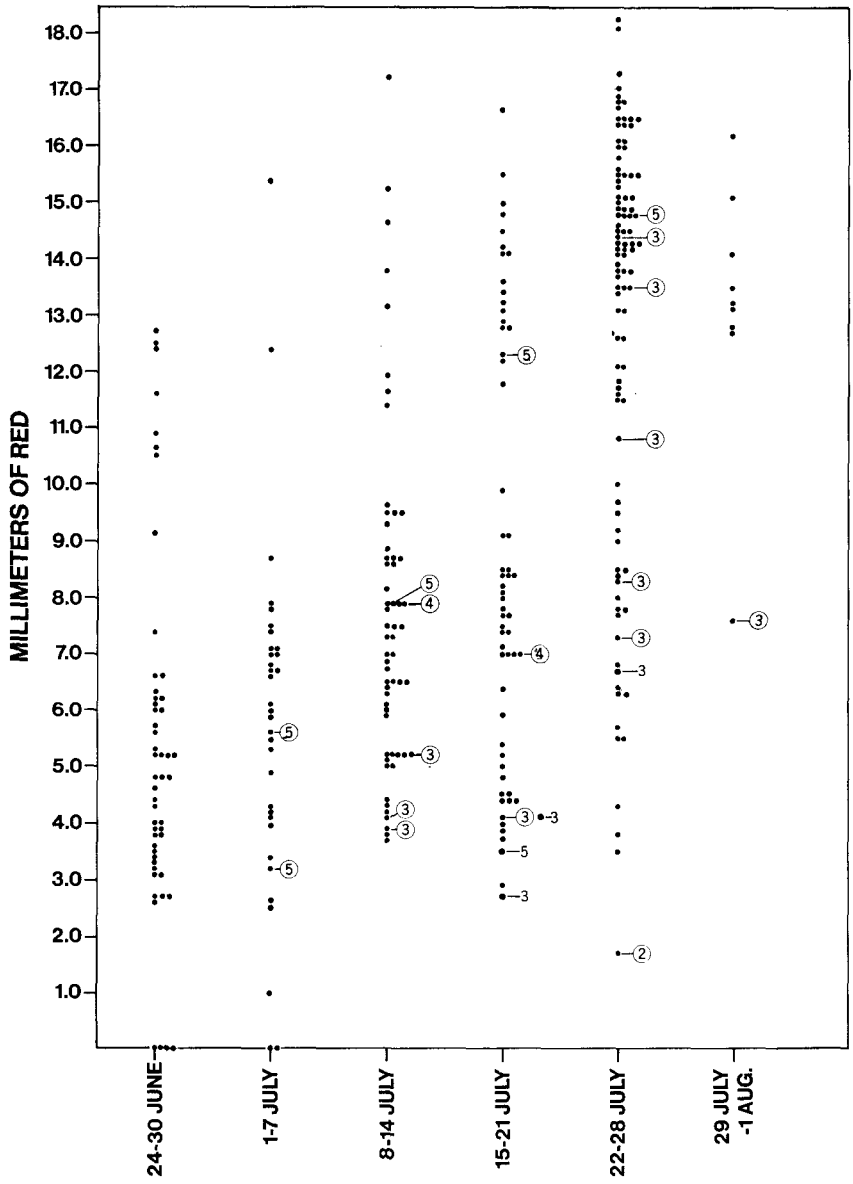

FIG. 2. Each Roseate Tern measured in 1972 is represented by a dot indicating the extent of red on its bill. The numerals indicate the age of known-age birds. Numerals without circles are known-age birds trapped over chicks 2–4 days old. All other birds were trapped when their first chick was newly hatched or one day old.

to those for M and F on Great Gull Island when their young were 16 and 18 days old.

I find little specific information on egg dates for Roseates in the Caribbean. Beatty (1941) said 200 Roseates nested at Bivoni Bay, St. Thomas, and had downy young 26 June 1939, and at Little Saba Cay a colony of 200 Roseates was nesting 2 July 1940. Wetmore and Swales (1931) reported 200 pairs of Roseates nesting in the Dominican Republic on 11 May, and Voous (1965) said eggs of Roseates may be found in the Netherlands Antilles May–July. According to Phelps and Phelps (1959), Roseate nests were found on the Islas Los Roques, Venezuela, 26 May, 14 and 24 June, and 25 July.

If the rate of acquisition of red for birds in the Virgin Islands was the same as that for Roseates on Great Gull Island, the bird I trapped 22 May would have had to start incubating its presumed first clutch in mid-April. If, as the scanty information on egg dates suggests, the birds in the Virgin Islands do not begin laying until early May, then their bills must become red faster than do those of the birds breeding on Great Gull Island, or, start to become red before the birds have eggs.

More specific data on the timing of bill color change are needed for populations of Roseate Terns in different parts of their range. Mack's (1969) observation at Isle of Palms, South Carolina 28 April 1968, further emphasizes this point. He describes a Roseate on this date with "basal 40 to 50% of bill reddish-orange." This extent of red is even more than that on the bills of most of the Roseate Terns we saw in the Virgin Islands at the end of May, and is comparable to the extent on a Great Gull Island Roseate in late July with a 6-week-old chick.

By contrast, a pair of Roseate Terns on a nest with eggs in North Carolina 23 May (Soots and Parnell 1975) had, as would be expected of Great Gull Island Roseates, entirely black bills. The authors misinterpreted my previous paper (Donaldson 1968) when they concluded that breeding Roseates at this stage should have partially red bills.

DISCUSSION

Bill color change in species like the Black-headed Gull (*Larus ridibundus*, Van Oordt and Junge 1933), House Sparrow (*Passer domesticus*, Keck 1934), and European Starling (*Sturnus vulgaris*, Wydoski 1964) takes place well before the birds are paired. As far as I know the Roseate Tern is unique in that the change in bill color takes place after the birds are in breeding plumage and pairing has taken place.

This unique timing of the bill color change in the Roseates may function in one or more ways. Possibly the Roseates' black bills early in the breeding

season serve as one means of species recognition where Roseates nest in colonies with other species of terns that are red-billed when mating takes place. Probable Common × Roseate hybrids have been described (Hays 1975), and it is interesting to speculate that if indeed bill color is used for species recognition, then hybridization would be most likely to occur involving a Roseate with a partially red bill, perhaps after the destruction of its initial clutch.

Another hypothesis, arrived at independently by Helen Hays and myself, is that the timing of the change may help reduce interspecific competition for nest sites in northern colonies where Roseates nest with Common Terns (*Sterna hirundo*) and/or Arctic Terns (*Sterna paradisaea*) in dense colonies. Common and Arctic terns are more aggressive species than Roseates and both arrive on the breeding ground with bills that have already changed from all black to all or partially red. The Roseates' all black bills at the time nest sites are chosen and laying begins may make them appear less aggressive, thus making it easier for them to establish themselves in areas where either Common or Arctic terns are nesting.

We further speculate that since the great increase in red on the Roseates' bills parallels the time they are bringing in increasing numbers of fish to feed the growing young, the red may serve an aggressive function. Interspecific piracy of fish has been observed in the Great Gull Island colony (D. Duffy, pers. comm.). It may be that at the time when they are carrying fish for the greatest distances as well as when interspecific competition for fish may be the greatest, the red on the Roseates' bills makes them better able to compete for food in feeding flocks of terns and permits them to deliver the fish to their young with a minimum of interference from other terns.

SUMMARY

The bill color change of Roseate Terns breeding on Great Gull Island, New York is illustrated and discussed. Bills of 872 Roseate Terns of known nesting status, including 235 mated pairs, were measured in 1968–1970, 1972, and 1974. The mates in 10 pairs had identical amounts of red, suggesting that there is not necessarily a sexual dimorphism in bill color. There is extensive variation in extent of red on individuals of similar nesting status measured within the same week, and also among birds of the same age. Significant differences in the extent of red in different years correlated with estimates of food available and weights of the birds. No consistent relationship was found between clutch size and extent of red.

The black bill of the Roseates when they are pairing may be a means of species recognition. It may also make the Roseates appear less aggressive when they are choosing nest sites and thus facilitate their establishment in mixed colonies with the more aggressive Common or Arctic terns. The extent of red on the bill of Roseates on Great Gull Island is greatest when their chicks are 4 to 6 weeks old. The presence

of red may serve an aggressive function at this time, helping the adults to deliver fish to their young when competition for food may be at a peak.

Roseate Terns in the Virgin Islands, where egg collecting obscures the normal breeding cycle, had bills as much as ⅔ red at the end of May. These appear to become red more quickly than do those of Great Gull Island Roseates.

ACKNOWLEDGMENTS

This research was supported by the Frank M. Chapman Fund and the Mae P. Smith Fund. This study would not have been possible without the understanding of Malcolm Arth, Chairman of the Education Department of the American Museum of Natural History, who granted me the time to work on Great Gull Island. I also wish to thank Joseph Sedacca, Manager of Graphics at the museum, for advising on, and Betty Halp, for executing, the graphs and the labels for the plates; and especially Helen Hays, Chairman of the Great Gull Island Project, for teaching me many field techniques, discussing with me all aspects of bill color change, and facilitating this study in countless other ways. Kenneth C. Parkes and Helen Hays critically read the manuscript. I am grateful to Mary LeCroy and Kenneth C. Parkes for suggesting references. I especially thank Kathleen Duffin for painting the tern heads for the plates, and Joan Black for photographing the pair on 8 June. Lou Di Paolo photographically reduced the graph. Benjamin and Joanne Trimble suggested where to find Roseates in the Virgin Islands, and Anne Chambers typed the tables. I am indebted to everyone who has worked on the Great Gull Island Project: all aspects of this project are so interrelated that I could not have done this study without the cooperation and contributions of everyone else. Finally, I thank my husband Matt, whose photographs of M and F and whose encouragement helped make this possible. This paper is contribution #44 from the Great Gull Island Project.

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NEW LIFE MEMBER

Mr. Martin K. McNicholl, a new life member of the Wilson Society, is presently working on a Ph.D. at the University of Alberta. His ornithological interests include behavior, ecology, and zoogeography, and he has published several of his studies. Mr. McNicholl's current research deals with the Blue Grouse. A member of many ornithological organizations, he has served as an officer of several. In addition to his ornithological interests, Mr. McNicholl enjoys flower photography, art, and music.