MEASURING BREEDING SUCCESS IN COMMON AND ROSEATE TERNS[a]

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In 1968 we started to study the populations of Common Terns (*Sterna hirundo*) and Roseate Terns (*S. dougallii*) breeding in New England. One of our first requirements was to develop a method of determining the average breeding success in a large colony with a minimum of disturbance and a minimum expenditure of time, so that several colonies could be monitored each year. After some experimentation, we have evolved a method in which a sample plot containing 30-80 nests is marked out at the peak period of laying. Nests are counted late in the incubation period and a low wire fence is erected round the plot to prevent the young hatched inside from mixing with those hatched outside. Young are banded and counted late in the fledging period, at an age when they have a high probability of fledging successfully. Because of asynchronous hatching, it is usually necessary to make at least two visits to count young hatched at different times, and a third visit to search for chicks that die after the last count. The main limitation of the method is that it does not sample late nesting birds, which are numerous in some tern colonies.

The method could be used with only minor modifications to make quick measurements of breeding success in other colonial species, especially gulls and other terns. Pearson (1968) and Langham (1968) have used fences to isolate chicks of Arctic Terns (*S. paradisaea*) and Lesser Black-backed Gulls (*Larus fuscus*) for detailed study, without untoward effects. However, they were unable to fence in Sandwich Terns (*S. sandvicensis*), because their chicks have a tendency to move away from the nesting area. We have used the method to measure breeding success in Herring Gulls (*L. argentatus*) (Kadlec and Drury, 1968), but generally found it unnecessary to fence the study plots because Herring Gulls nest more sparsely than terns and their chicks scatter less when disturbed.

During 1970 and 1971 we made observations in 17 fenced plots in six tern colonies in southeastern Massachusetts (Tables 1 and 2). In each year two plots were selected for detailed studies, and were subdivided into smaller enclosures for ease in locating chicks. Each of these subdivided plots was matched with a control plot of similar size and vegetation in the same colony; each control plot comprised a single enclosure and was visited only four or five times. These procedures thus permit comparison of breeding success between small, medium and large enclosures, between disturbed and undisturbed plots in the same colony, and between colonies.

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TABLE 1. Breeding success of Common Terns in fenced plots in Massachusetts colonies, 1970-71.

Plot No.	Colony and Plot†	Year	Plot area (m²)	No. of pens	No. of visits	No. of nests	Apparent mean clutch-size	Known hatching failures	Fledging success chicks/nest	Fledging success chicks/egg
1	Plymouth Cs	1970	130	18	28	41	2.27	4%	0.54	0.24
2	Plymouth Cc	1970	110	1	4	61	2.28	3%	0.62	0.27
3	Bird Island Cs	1970	90	17	20	39	2.87	5%	1.59	0.55
4	Bird Island Cc	1970	ca. 400[a]	1	5	78	2.76	—	ca. 1.85[a]	0.62
5	Bird Island R	1970	50	1	5	8	—	—	ca. 1.87[b]	—
6	Ram Island C	1970	120	1	5	71	—	—	0.99	—
8	Plymouth C	1971	ca. 350	1	5	62	2.27	—	0.06	0.03
9	Bird Island Cs	1971	130	7	60	35(+2)[c]	2.94	3%(+3)[c]	2.09	0.71
10	Bird Island Cc	1971	70	1	4	28	2.96	2%	2.07	0.70
13	Ram Island C	1971	80	1	4	37	2.95	3%	1.86	0.63
15	Gray's Beach CR	1971	200	1	6	42[d]	—	—	ca. 2.10[d]	—
16	Tern Island C	1971	250	1	4	61	2.33	—	0.02	0.01
17	Monomoy (South end) C	1971	180	1	2	87	—	—	0.00	0.00

†C, a plot containing mostly Common Terns; R, a plot containing mostly Roseate Terns; CR, a plot containing substantial numbers of both; s, detailed study plot; c, control plot.

[a]Fenced only on 2 sides, natural boundaries on 2 sides: uncertainty 10%.

[b]Small sample.

[c]Clutches deserted before incubation included in parentheses.

[d]10% uncertainty because laying was incomplete at time of nest count.

Location of colonies: Bird Island, Marion; Ram Island, Mattapoisett; Gray's Beach, Yarmouth; Tern and Monomoy Islands, Chatham.

TABLE 2. Breeding success of Roseate Terns in fenced plots in Massachusetts colonies, 1970-71.

Plot No.	Colony and Plot†	Year	Plot area (m^2)	No. of pens	No. of visits	No. of nests	Apparent mean clutch-size	Known hatching failures	Fledging success chicks/nest	Fledging success chicks/egg
1+2	Plymouth Cs+Cc	1970	130	4	32	5	ca. 1.60[b]	0%	ca. 0.80[b]	0.50
5	Bird Island R	1970	51	1	5	53	—	—	1.34	—
6	Ram Island C	1970	120	1	5	5	ca. 1.60[b]	0%	ca. 1.00[b]	0.62
7	Ram Island R	1970	21	1	5	85	1.82	—	0.88	0.48
11	Bird Island Rs	1971	28	3	60	50(+6)[c]	1.84	12%(+6)[c]	1.12	0.61
12	Bird Island Rc	1971	43	1	4	57	1.75	3%	1.17	0.67
14	Ram Island R	1971	19	1	4	26	1.65	7%	1.21	0.73
15	Gray's Beach CR	1971	200	1	6	41[d]	—	—	1.32[d]	—

†C, a plot containing mostly Common Terns; R, a plot containing mostly Roseate Terns; CR, a plot containing substantial numbers of both; s, detailed study plot; c, control plot.

[a]Fenced only on 2 sides, natural boundaries on 2 sides: uncertainty 10%.

[b]Small sample.

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Location of colonies: Bird Island, Marion; Ram Island, Mattapoisett; Gray's Beach, Yarmouth; Tern and Monomoy Islands, Chatham.

METHODS

Fencing.

The best material for the fences is 1-inch (2.5 cm) hexagonal mesh chicken-wire. Although small chicks (less than four days old) can pass through mesh of this size, they consistently return to their territories to be fed and brooded. Materials of smaller mesh have proved unsatisfactory: half-inch hardware cloth interferes more with feeding, and a double layer of chicken-wire caused several casualties (see next section). The best height for the fences is about 9 inches (23 cm): higher fences (up to 45 cm) obstruct the adults when they fly in and lower fences can be scaled by large chicks. The most convenient procedure is to cut a 2-foot (60 cm) roll of wire longitudinally and to bury the cut ends to avoid injury to the chicks. The bottom of the wire must be buried at least 2 inches (5 cm) in the ground, to prevent chicks from digging their way out.

Procedure in detailed study-plots.

In the plots used for detailed study, nests and broods were checked daily or near-daily, so that the full clutch-size in each nest and the exact number of young raised to fledging were determined. A chick was considered fledged when it flew over one of the fences, either spontaneously or in response to disturbance: observed fledging-periods are summarized in Table 3. In one case (plot 1) several chicks disappeared from the enclosure late in the fledging-period, presumably taken by a predator. Those that disappeared before the age of 22 days (the earliest observed age of fledging, Table 3) were considered victims of a predator; those that disappeared subsequently were listed as fledged.

Procedure in other plots.

In the remaining plots, the number of nests and fledging young was estimated from observations made during four or five visits only. Each of these visits had to be timed carefully in relation to the phenology of the colony. Figure 1 illustrates a typical sequence of events in a study plot, and shows the most desirable timing for the visits. In some plots a few clutches were started after the earliest clutches hatched. When this occurs an additional visit might be required, as noted below.

The first visit, to fence the plot and to count nests, is timed immediately before the first eggs are due to hatch. In Massachusetts this means about 9 June for Common Terns, about 14 June for Roseate Terns, unless it is known that the first eggs have been laid later than usual. (An exploratory visit, about 22 May for Common Terns or 27 May for Roseate Terns, will indicate whether the season is early or late.) If many empty scrapes or single-egg clutches are found at the time of the nest count, this will suggest that some nests are incomplete. It is then desirable to repeat the nest count in about eight days. Two nest counts are necessary if both Common and Roseate terns are nesting in numbers in the same plot. Each nest is marked, preferably with a wooden stake, and the clutch-

TABLE 3. Plumage classes, characters, and ages of Common and Roseate tern chicks. Data for a few retarded chicks (third chicks in Common Tern broods and second chicks in Roseate Tern broods) are given in parentheses.

Plumage Class	Characters	Ages (in days) Common Terns	Roseate Terns†
1	Newly-hatched. Legs short, fat. Egg tooth present. Chin black.	0-1 (2)	0-2 (2)
2A	Egg tooth gone. Legs elongated, narrow shank between foot and joint. No pin feathers on hand.	2-5 (6)	few data
2B	Pin feathers present on hand but not erupted. Black chin almost gone.	6-9 (11-12)	few data (12)
3A	Pin feathers erupted on hand.	8-12 (13-19)	11-13 (14)
3B	Tail feathers erupted (shaft visible), but less than 6 mm long (white not visible). Black feathers not visible on nape.	12-15 (13-20)	13-16
4A	Tail feathers longer than 6 mm (white visible), but down still present on tips. A few speckles of black show through down on nape when brushed.	15-18 (22-23)	15-20 (21)
4B	No down on tips of tail, but down present on tail coverts. Black appearing on nape. Mantle feathered with some down tips.	17-23 (21-28)	18-22 (23)
5A	Nape black with speckles. No down on back, but a little down on tail coverts. Older birds fly when frightened.	21-25 (21-31)	20-24 (28)
5B	Fully feathered, free flying. No down except on forehead.	24 onwards	23 onwards
Ages at fledging		22-28 (25-33)	22-30 (31)
Peak of fledging		25-26 (64%)	27-30 (70%)

†Plumage characters were defined primarily for Common Terns. In Roseate Terns the head plumage develops relatively faster and the flight-feathers relatively slower. Age classes summarized in the table are based on the latter.

size noted. We now consider it desirable to mark the clutch-size on the stake, but we did not do so in the studies reported here.

In the detailed study plots, very few chicks (less than 7 per cent of those hatched) died after reaching the age of 10 days, and most of the carcasses of these older chicks remained recognizable on the ground for a number of days after death. Accordingly, in the remaining plots visits were timed in order to determine the number of chicks which reached the age of 10 days. The first banding visit was timed immediately before the first chicks were due to fledge

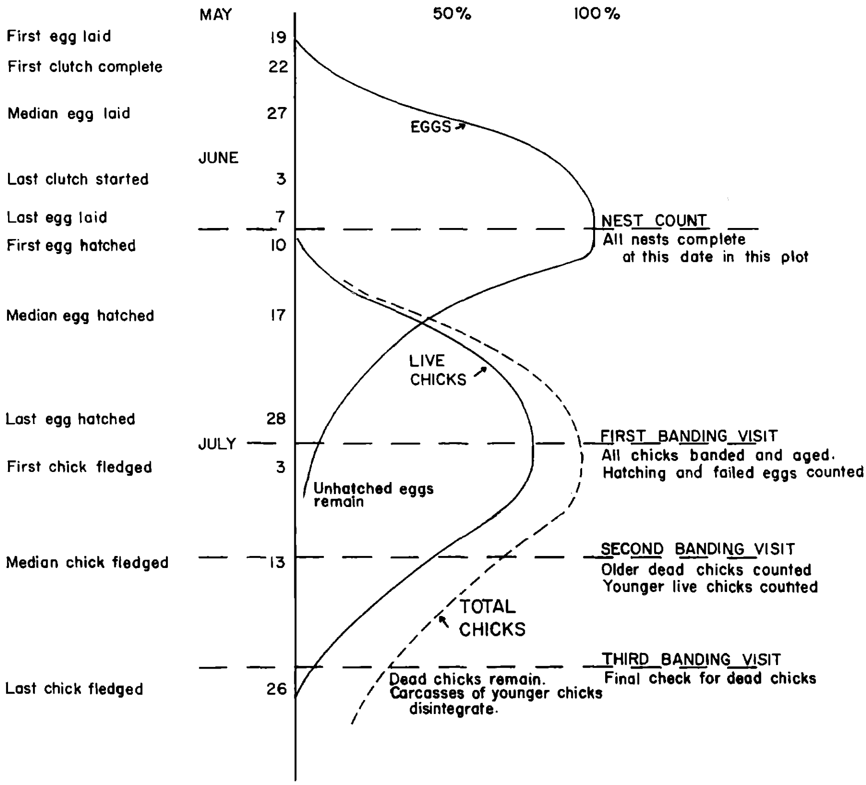

FIGURE 1. Seasonal changes in numbers of eggs and chicks in a plot settled at the peak period of the season, showing how the four visits are timed to obtain the best possible counts of eggs and young. Data given are for Common Terns in plot 9. In other plots a small amount of overlap between laying and hatching might occur. Roseate Terns are a few days later.

(i.e. 21-23 days after the nest count). At this time the chicks hatched in the earlier part of the hatching period were 10-21 days old and could be banded and counted. Chicks less than 10 days old were banded at this time, and their survival was checked in a second banding visit 12 days later. In a few cases where significant numbers of chicks younger than 10 days were found on the second banding visit, a third visit was made 12 days later to check their progress. In any case a final visit is needed to search for dead banded chicks and to remove the fences.

During the first banding visit, two or three banders search through the plot, banding as many chicks as they can find. After an interval to allow the birds to settle down they search through the plot again, banding chicks missed on the first visit and recording the band numbers of banded chicks, so that the total number of chicks present can be estimated by a capture-recapture method. With two exceptions (plots 4 and 15) we have found that 90-95 per cent of the chicks in our small plots are found and banded in 40-60 minutes on the first search, and 98-100 per cent are accounted for in the two searches. The stage of development of each chick is noted according to the criteria set out in Table 3. New nests with eggs are marked and recorded. Unhatched eggs in marked nests are examined. Eggs that are not pipped or cracked are recorded as hatching failures.

During the second and third banding visits it usually suffices to make one search through the study plot. All chicks are checked and aged, unbanded chicks are banded, the band numbers of banded chicks are recorded, and dead chicks are checked for bands and removed from the plot. Unbanded chicks of plumage-classes 5A and 5B are assumed to have flown into the plot from outside and are not recorded.

Calculation of results and sources of error.

When the visits are timed as described above, all nests in which eggs have been fully incubated are marked and counted. The only nests likely to be missed are those destroyed before the nest count, or those started after the nest count and destroyed before the first banding visit. However, we have recorded no such losses in our detailed study plots.

Chicks are counted as fledged if they are known to have reached class 3B (12 days or more), unless they were found dead on a subsequent visit. Chicks banded in classes 1-2B (less than nine days) and missing on the next visit are assumed to have died and disintegrated. Birds banded in class 3A and not found dead on subsequent visits are usually treated as fledged, unless heavy mortality has occurred in class 2B. This procedure should give a good estimate of the number of chicks fledged, except in cases where predation on the older chicks left no traces. This is thought to have occurred in plots 2 and 15. However, late predation cannot be detected except by daily checks on marked chicks of known age.

ADVERSE CONSEQUENCES OF FENCING

Of some 2000 chicks hatched within the enclosures, six were found dead, entangled in the fences. Of these, five were caught in fences made of a double layer of chicken wire, a type now discontinued. About five chicks died in plot 3 by being trapped in the wrong enclosures after a human intruder had tripped over the fences, pulling them partly out of the ground. Other injuries attributable to fencing were trivial, except for one chick found with a broken leg and two found unable to fly, with apparently irreversible damage to the patagium.

Langham (1968 and pers. comm.) had to remove wire fences from enclosures containing Roseate Terns because the chicks made repeated attempts to escape, damaging their feathers at the base. We experienced no such problems with Roseate Terns in this study. However, two broods of Roseate Terns in plot 11 moved through the fence from one enclosure to another soon after hatching, and were successfully raised in the new area. Three broods of Common Terns fenced into plots fully occupied by the dense vegetation preferred by Roseate Terns (plots 11, 12 and 14) disappeared without trace and are believed to have been led out of the plot. Such movements of chicks out of (or into) study plots may have caused minor errors in estimates of breeding success, but we obtained no other evidence that they occurred.

Watching Common Terns from a blind, we observed a certain amount of interference with feeding. Some adults frequently landed on the "wrong" side of the fences and attempted to feed their chicks through the mesh. Although the chicks eventually learned how to pull fish through the mesh, and some parents habitually fed them in this way, this substantially increased the time required by the chick to handle and swallow the fish. Consequently more fish than usual were stolen by other adults. Other fish were dropped outside the fence and some were not picked up.

RESULTS AND DISCUSSION

If the adverse effects described above were significant in reducing breeding success, one would expect greater effects in subdivided plots, in which more territories are bounded or intersected by fences, than in larger enclosures. In fact, Tables 1 and 2 show that in three cases breeding success was lower in the subdivided plots (1, 3 and 11) than in the corresponding control plots (2, 4 and 12). Breeding success in plot 9 would have been lower than that in the control plot 10 if the deserted nests had been included in the calculation.

However, the differences were very small and in only one case (plots 3 and 4) can they be attributed plausibly to the fencing (see above). The differences between plots 9 and 10, and between plots 11 and 12, are attributable entirely to desertions in plots 9 and 11. These desertions took place at the time of laying, before the fences were put up, and were presumably due to the disturbance involved in daily nest-checks, erection of a blind, etc. The difference between plots 1 and 2 is attributable entirely to predation of four chicks in plot 1 late in the fledging-period, too late to have been recorded in plot 2.

Another way to assess possible effects of fencing on productivity is to compare the success of birds in individual small enclosures with those fenced in groups within the same plot. In plot 3 the 12 pairs fenced individually raised an average of 1.75 chicks/nest, not significantly different ($P > 0.05$) from the average of 1.52 chicks/nest for the other 27 pairs. In plot 1 the 12 pairs fenced individually raised an average of 0.83 chicks/nest, whereas the remaining 29 pairs raised an average of only 0.41 chicks/nest: the difference is statistically significant ($P < 0.05$). The most likely explanation for this unexpected difference is that all the individual enclosures were on open sand with very little cover, and that we had provided these broods (but only two of the others) with artificial cover in the form of open wooden boxes, in an attempt to avoid early losses due to overheating.

Thus the effect of the fences on overall breeding success was in fact very small, and was outweighed by the effects of disturbance in plots 9 and 11, and by the provision of shelter in plot 1. Except for the accident in plot 3, mean productivity in the four detailed study plots would have been extremely similar to that in the four control plots. This similarity suggests further that measurements in the small plots used in this study are representative of the success of the colony as a whole, or at least of those birds nesting at the peak period of the season.

It should be stressed, however, that such a sample does not provide complete information about the performance of the colony. In colonies of Common and Roseate terns, laying is characteristically prolonged, with new eggs appearing even as late as mid-July, after the earliest chicks have fledged. Some of the late nests are made by young birds nesting for the first time and others by birds renesting after failure earlier in the season. Without an extraordinarily detailed study, it would be impossible to determine the number of birds in each category and hence the total number of birds nesting in the colony during the year. The late nests are usually scattered and it would be difficult to measure their success by the method described in this paper.

Finally, the degree of success indicated by the figures in Tables 1 and 2 merits comment. Austin and Austin (1956) estimated that the mean annual mortality rate of adult Common Terns in Massachusetts was 25 per cent, and they calculated that an average annual productivity of about two young per pair was required to maintain the population. However, only three of the 12 samples of Common Terns listed in Table 1 raised as many as two young per pair, the overall mean (weighted according to the numbers of birds in each colony) being only 0.92 young per pair. Other documented measurements for breeding success in Common Terns have been in the same range (Boecker, 1967; Langham, 1968; Chestney, 1970; Switzer *et al.* 1971), the highest recorded value being only 1.6 young per pair (Chestney, 1970). If the estimate of mortality given by Austin and Austin is still valid, modern populations must be either decreasing or maintained by immigration. We have found no published records of breeding success in Roseate Terns, but unpublished data of Langham (1968) are similar to our own.

The striking differences indicated in Table 1 between the productivities of Common Terns in different colonies in 1970 and 1971 were apparent also in less precise measurements in 1968 and 1969. The differences appear to be attributable, at least in part, to differences in predation and food supply, and are being studied further.

SUMMARY

Breeding success of Common and Roseate terns was measured in 17 small plots (26-85 nests) surrounded with low wire fences to isolate chicks hatched inside. Chick productivity can be measured in only four or five visits if these are carefully timed. The resulting estimates of productivity agree well with those obtained in detailed studies except where there is late predation. Fences caused a few injuries and interfered somewhat with feeding, but their overall effect on breeding success was negligible. Daily visits apparently

caused some desertions of nests early in incubation. Provision of shelter appears to have augmented breeding success in one plot on open sand. Late nests, which are numerous in some tern colonies, are difficult to sample with the technique described here.

Breeding success of Common Terns varied markedly between colonies, from zero to 2.1 chicks per nest, with a mean of about 0.9. The differences appear to be correlated with differences in predation and food supply. Breeding success of Roseate Terns varied between 0.88 and 1.34 chicks per nest in four colonies sampled.

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