The Biology of the Little Tern in the Ebro Delta (Northwestern Mediterranean)

DANIEL ORO[1], ALBERT BERTOLERO[1], ALBERT MARTÍNEZ VILALTA[2,3] AND MIQUEL ANGEL LÓPEZ[2]

[1]Institut Mediterràni d'Estudis Avançats IMEDEA (CSIC-UIB)
Miquel Marquès 21, 07190 Esporles (Mallorca), Spain
Internet: d.oro@uib.es

[2]Parc Natural Delta de l'Ebre, Plaça 20 de Maig 2, 43580 Deltebre, Spain

[3]Institut Català d'Ornitologia, Museu de Zoologia, Passeig Picasso s/n, 08003 Barcelona, Spain

Abstract.—Aspects of the biology of the Little Tern (*Sterna albifrons*) were studied at the Ebro Delta (northwestern Mediterranean) during 1996-1997, including colony site selection, clutch size and egg size. Using a single visit to avoid disturbances, average number of eggs was 2.62 eggs per nest, and was significantly larger in 1996 than in 1997, when the modal clutch size was only two eggs. Mean egg volume was 8.88 cm^3 (SD ± 0.57), and mean egg size in a clutch (for both two- and three-egg clutches) was also significantly larger in 1996 than in 1997. Furthermore, average egg volume in three-egg clutches (clutches that were probably completed) was significantly different among the four main breeding areas within the delta. Clutch size was not significantly different among breeding areas in either year. Little Terns bred associated with other colonial Charadriiforms more than in other Mediterranean breeding areas. The terns associated with all the commonest colonial species of shorebirds, but never associated with the Yellow-legged Gull (*Larus michahellis*), Audouin's Gull (*L. audouinii*) or Black-headed Gull (*L. ridibundus*). The number of breeding pairs decreased from 625 in 1961 to 332 in 2003, this decline occurring mainly since the early 1990s. Mean population declined significantly by 2% per year for the whole period. During the last decade, the number of breeding areas has increased from four to nine, despite the decrease in breeding numbers (rate of decrease 7.1% per year). Nothing is known about the factors driving this decrease, but changes are probably linked to processes in other colonies at a metapopulation level. *Received 27 November 2003, accepted 28 May 2004.*

Key words.—Little Tern, colony site selection, *Sterna albifrons*, breeding parameters.

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The Little Tern (*Sterna albifrons*) has suffered a decline in the Palearctic in the last few decades (Muselet 1997). The main factors causing this decline are probably the loss of sandy beaches, interspecific competition for nesting sites with increasing gulls, other terns and shorebirds, human disturbances at breeding sites, and predation by birds and mammals (Sears and Avery 1993; Muselet 1997; Ratcliffe *et al.* 2000; Sánchez 2003). The species breeds from Senegal and Mauritania throughout the Mediterranean, the Black Sea, Minor Asia, and Middle East to western India (Cramp 1985; Fasola *et al.* 2002). Most of the published information for the Mediterranean region has been collected on the Italian colonies (Fasola *et al.* 1989; Fasola and Bogliani 1990; Bogliani *et al.* 1992, 1994; Fasola and Canova 1992; Fasola 1993; Valle and Scarton 1999). For instance, the diet, foraging rhythms and selection of prey, foraging habitat and colony sites are well known (see also Goutner 1990). Data on breeding numbers are also recorded for a number of localities (Fasola 1986; Ferrer and Martínez Vilalta 1986; Fasola *et al.* 1989; Chernichko 1993; Scarton *et al.* 1994; Calado 1996). However, trends at population dynamics level and breeding parameters (especially reproductive success) are less known (Fasola *et al.* 1993; Holloway 1993; Sadoul *et al.* 1996; Ratcliffe *et al.* 2000). In the present study, an account of several parameters of the biology of Little Terns at the Ebro Delta (northwestern Mediterranean) is provided. Selection of breeding habitat (during 1996-1997) and foraging areas (during 1998), clutch size and egg size (data from 1996 and 1997) have been recorded, as well as the number of breeders during the study and their population dynamics, using data from 1961 to 2003. The knowledge of these biological parameters is important for the management and conservation of the species not only at the study site, but also at other colonies.

METHODS

Study Area and Data Recording

The study was conducted at the Ebro Delta Natural Park (NE Spain: 40°37'N, 00°35'E) (see Fig. 1). The breeding areas (Fig. 1) were observed from mid April until late July during 1996-1997. The census of breeding pairs was performed in two ways: 1) entering the colony and counting the nests, or 2) counting the incubating adults from a distance using a telescope. Only one entry per year was made to minimize disturbance, and was made three weeks after the first breeding pair started incubating. In 1996, the census was carried out between late May and mid June, and between mid June and early July in 1997. This difference was due to adverse weather in 1997 that delayed breeding. When entering a colony, the number of eggs at each nest was recorded as an estimation of clutch size. The limitations of this method are high: some clutches may have lost eggs, and late breeders (mostly young breeders) may not have laid yet. Thus, the number of pairs and the number of eggs per nest may be underestimated. These potential biases were not assessed in order to avoid further disturbance, but it was assumed that they were constant during the two years. Eggs from a sample of clutches (mainly of two and three eggs, the most common clutch sizes) were measured (length and maximum width in mm), by the same researcher, to the nearest 0.1 mm using a digital caliper. Egg size was estimated by internal egg volume (cm^3) as determined by the equation: $V = 0.00051 \cdot \text{length} \cdot \text{breadth}^2$. Egg constant was not available for Little Terns so we used a value for gulls *Larus* spp. (Bolton *et al.* 1992).

The breeding species of colonial Charadriiforms associated with Little Terns and the main features of the breeding habitat were recorded using the following features: 1) habitat type; 2) substrate; 3) presence of vegetation; and 4) minimum distance to the nearest water mass and type (fresh or marine). Sites occupied for more than one year were described only once. The minimum distance to the water was estimated from aerial photographs at scale 1:5000.

Association between Little Terns and other species was examined in several ways. First, we built a contingency table taking into account the total number of subcolonies established during the study and the frequency of association with the other species. The colonial species considered were: Avocet (*Recurvirostra avosetta*), Pratincole (*Glareola pratincola*), Black-winged Stilt (*Himantopus himantopus*), and Redshank (*Tringa totanus*), Yellow-legged Gull, Audouin's Gull (*L. audouinii*), Slender-billed Gull (*L. genei*), and Black-headed Gull (*L. ridibundus*); Gull-billed Tern (*Sterna nilotica*), Sandwich Tern (*S. sandvicensis*) and Common Tern (*S. hirundo*). A chi-square statistic was applied to test the null hypothesis that the proportion of colonies where Little Terns associated with one species was the same as the proportion of colonies where Little Terns associated with the other species (see for instance Margalef 1982, p. 405). This analysis assessed which species were closely associated with Little Terns, but it precluded conclusions about whether there was a positive or negative association of Little Terns with other species. To analyze the associations between species, location of colonies of the species mentioned above was necessary to score the presence or absence of Little Terns and associated species in each, taking into account all the sites where at least one of the species bred. This was possible only in 1997 when a complete seabird and shorebird census was carried out on the whole delta (PNDE 1997/1998). We calculated a chi-square statistic applied to two contingency tables with and without double absences (Cole 1949; Margalef 1982, p. 414) for each of the associated species. Finally, and to take into account the abundance of each species, a goodness-of-fit test was applied to a contingency table of frequencies of colonies associated with each species and an expected value taking into account the value of the counts of all the other species.

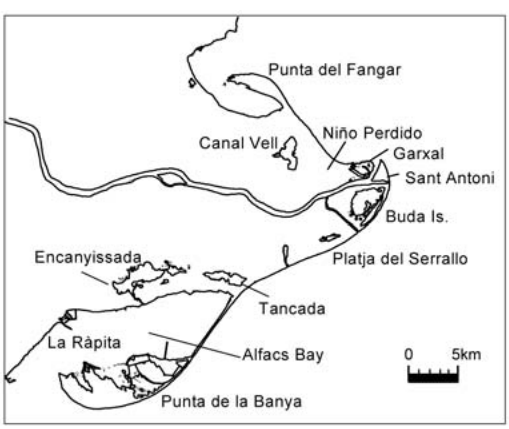

Figure 1. Map of the Ebro Delta (northwestern Mediterranean) showing the breeding areas where Little Terns have bred at least once during 1960-2001.

Data Analysis

Chi-square tests (when tables had 2 × 2 dimensions) and G-tests (when tables were larger than 2 × 2) were carried out for comparisons involving frequency data such as clutch size. The few four and five-egg clutches were not considered to avoid the violation about minimum expected frequencies of contingency tables and their applied statistics. We used mean egg volume in the clutch to perform all analyses at the inter-clutch level. One-way ANOVA and, when appropriate, an *a posteriori* Student-Newman-Keuls test procedure was used to compare colonies and years. Mean and standard errors are presented unless otherwise stated.

Mean annual population change (λ) in Little Tern colonies and for the whole Ebro Delta were calculated as:

$$\lambda = (N_{t+1}/N_t)^{1/T}$$

where N_t is the local estimated colony size at time t, N_{t+1} is the local estimated colony size at time $t+1$, and T the number of years between t and $t+1$. The counts of Little Terns at the Ebro Delta from 1961 to 2003 (see Ferrer and Martínez Vilalta 1986; Martínez Vilalta 1988; PNDE 1997/1998; PNDE, unpubl. data) were used to estimate λ. To assess whether the change rate was significantly different from unity (i.e., from stability), a regression analysis of $\log(N_t)$ with time was made to obtain the slope of the model and its confidence interval, and their exponentials corresponded to the realized population change rate and its confidence intervals. This method is suitable because it is robust to both stochastic environments and census errors, and it allows for unequal time interval.

RESULTS

Clutch and Egg Size

Clutch size was significantly different between 1996 and 1997 ($G_3 = 28.5$, $P < 0.0001$), with modal clutch size of three eggs in 1996 and two eggs in 1997 (Table 1). In 1997, three-egg clutches were at significant lower frequencies, whereas in 1996 their frequency was significantly higher. Clutch size was not significantly different among colonies in 1996 ($G_4 = 3.3$, n.s.), or in 1997 ($G_6 = 6.68$, n.s.).

Mean egg size in a clutch was significantly larger in 1996 than in 1997 (9% on average; $F_{1,143} = 3.91$, $P < 0.05$), but no effects of either clutch size ($F_{2,143} = 1.07$, n.s.) or of its interaction with the year were found ($F_{2,143} = 1.10$, n.s., see Table 2). Mean egg volume in clutches of three-eggs (clutches that were probably completed) was significantly different between the breeding areas of La Tancada, El Fangar, La Banya and Buda Island in 1997, but not in 1996 ($F_{3,33} = 3.77$, $p < 0.05$, $F_{2,44} = 2.09$, n.s. respectively, see Fig. 2); in 1997, volumes at La Tancada were larger than those at El Fangar, La Banya or Buda (9.26 ± 0.16, N = 10; 8.84 ± 0.13, N = 8; 8.65 ± 0.16, N = 9; 8.64 ± 0.15, N = 7, respectively) (mean and SE, in cm^3) (Fig. 2).

Colony Site Features

A total of 28 colonies of different sizes were found during 1996-1997 (Fig. 3). From the 18 different sites occupied at least once during these two years, Little Terns occupied four types of breeding habitats: beaches (63% of the cases), salt marshes (25%), salinas (6%) and fish farms (6%). The two last habitats are of man-made origin. Beaches and salt marshes were used more than expected by their area, whereas the contrary applied to both salinas and fish farm sites (Goodness-of-fit $\chi_3^2 = 17.8$, $P < 0.0001$).

Colonies contained a mean of 31 pairs (range 1-110) in 1996 and 23 pairs (range 1-109) in 1997. The mean number of pairs in a colony was not significantly different among the different breeding habitats (Kruskal-Wallis $H_3 = 3.12$, n.s., in 1996; $H_3 = 5.89$, n.s., in 1997) (Table 3).

From the 18 colony sites analyzed with respect to the nest substrate, 33% were on sand, 11% on sand covered by bivalve shells (mainly *Donax trunculus*), 11% in mud, 33% on a mixture of mud and sand, 6% on gravel, and 6% on a mixture of sand and gravel. Colonies were located on bare areas (56%) or in areas with infrequent halophilous vegetation, mainly small plants of Glasswort (*Arthrocnemum fruticosum*). The distance of colonies to the closest water body ranged between 1-700 m (Table 3). Although colonies located on fish farm and salinas dikes were always close to water, we did not find significant differences in distance to water among the different breeding habitats (Kruskal-Wallis $H_3 = 5.75$, n.s.).

Colonies of Little Terns were associated with all the colonial commonest species of shorebirds and in 79% of the cases (from the 28 colonies occupied during the study) also with the Kentish Plover (*Charadrius alexandrinus*). Terns never associated with Yellow-legged Gull, Audouin's Gull or Black-headed Gull. Little Terns bred in a single species col-

Table 1. Clutch size as number of eggs per nest of Little Terns at the Ebro Delta during the study. Percentages of clutch size for each year are shown in parentheses.

	Clutch size						
Year	1	2	3	4	5	N	Mean
1996	13 (7)	32 (17)	129 (69)	10	2	186	2.76
1997	11 (11)	46 (45)	45 (44)	1	0	103	2.35
Total	24 (8)	78 (27)	174 (60)	11	2	289	2.62

Table 2. Average egg length, width (mm) and volume (mean and SD) (in cm^3) in one-, two- and three-egg clutches of Little Terns at the Ebro Delta for the period 1996-1997. The number of clutches sampled (N) is shown.

Year	Clutch size	N	Length	SD	Width	SD	Volume	SD
1996	1	2	32.94	1.17	23.86	0.76	9.58	0.95
	2	13	31.43	0.99	23.52	0.69	8.88	0.63
	3	45	31.67	1.11	23.53	0.60	8.95	0.47
Total		60	31.68	1.10	23.54	0.61	8.96	0.52
1997	1	11	31.65	1.04	23.34	0.82	8.81	0.75
	2	37	31.55	1.07	23.38	0.73	8.81	0.60
	3	36	31.43	1.12	23.44	0.63	8.82	0.56
Total		84	31.51	1.11	23.42	0.67	8.82	0.60
Total 1996-1997		144	31.59	1.10	23.47	0.65	8.88	0.57

ony only in five cases (18%). Common Tern, Gull-billed Tern and Avocet were the commonest species associated with the Little Tern (in 64%, 39% and 32% of 28 colonies respectively). Significant differences were found in the frequency of association depending on the species ($G_{11} = 73.8$, $P < 0.0001$). Common Tern and Gull-billed Tern were positively associated ($\chi_1^2 = 13.4$, $P < 0.001$ and $\chi_1^2 = 8.7$, $P < 0.005$ respectively), and all three gulls were negatively associated, and the association with the rest of the species were not significant. Finally, statistical differences were found between the observed and expected number of associations depending on the abundance of each species ($\chi_{10}^2 = 1{,}823$, $P < 0.0001$), and in this case the Little Tern was positively associated with all the species except Common Tern, Yellow-legged Gull, Audouin's Gull and Black-headed Gull.

Colony Size and Growth

Using historical data on breeding numbers since 1961, the lowest number of pairs (338 nests) was recorded in 1997, whereas the maximum number was 652 pairs in 1980 (Fig. 4). Nine breeding areas were used since 1961. Although five of these breeding areas have been colonized during the 1990s, the total number of pairs has decreased during this decade since the first census in 1961. The number of pairs per breeding area has decreased since these colonizations. During 1961-2003, mean colony change rate was 0.980 and it was significantly lower than unity (95% confidence intervals: [0.971; 0.990]). This represents a decline of 2% per year. A stability in numbers occurred until the late 1980s (mean colony change = 1% from 1961 to 1988, although only three censuses were

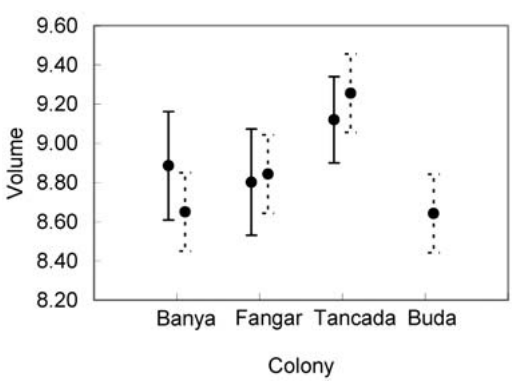

Figure 2. Average mean volume (cm^3 with 95% CI) in three-egg clutches of Little Terns for each of the breeding areas at the Ebro Delta in 1996 (dashed line) and 1997 (solid line).

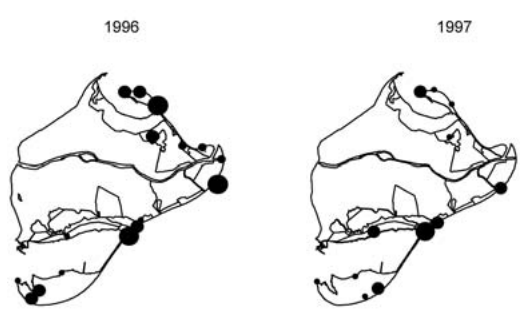

Figure 3. Location of the colonies of Little Tern occupied during 1996-1997 at the Ebro Delta. Small dots show the colonies with less than 20 breeding pairs, medium dots the colonies with 20-50 pairs, and large dots the colonies with more than 50 pairs.

Table 3. Mean number of Little Tern pairs at each breeding habitat, and mean distance (in m) of colonies to the closest water mass.

Habitat	Colony size 1996	Colony size 1997	Distance
Beach	31	10.3	204 ± 140
Fish farm	17	20	34 ± 57
Salt marsh	29	27	289 ± 233
Salina	87	78	203 ± 279

carried out). Since then, a decrease has occurred at a rate of 7% per year. Despite the high turnover rate of colony sites, all the three main breeding areas have been always occupied in the last three decades.

DISCUSSION

Clutch Size and Egg Size

In some birds, clutch size and egg size are normally good indicators of the environmental conditions during laying, and both parameters increase as food availability increases, at least until a plateau (Bolton *et al.* 1992). Results of egg parameters suggest that food was less available in 1997 than in 1996. Abundance of small pelagic marine fish off the Ebro Delta during the pre-laying period of Little Terns was double in 1996 than in 1997 (Oro 1999), but terns foraged only marginally at sea during breeding, and nothing is known about fish stocks in fresh water bodies. Egg size also suggest that food availability may vary not only between years, but also among breeding areas within a year, where environmental conditions could be different due to the reduced foraging range of the species (see also Fasola *et al.* 1989; Fasola and Bogliani 1990; Bogliani *et al.* 1994). Studies on other Charadriiforms species show that egg size is reduced before clutch size when resources for egg formation are limited (Bolton *et al.* 1992), and this may explain why effects of breeding areas were not detected in clutch size (see also Oro 2002). Other factors influencing egg size, such as age, can also explain such differences. There is little information available on egg and egg contents (as actual biased estimator of clutch size) in Little Terns in other geographical areas, but egg parameters at the Ebro Delta seemed to be normal values, except clutch size in 1996, which was the highest value recorded compared to other six European localities (Fasola *et al.* 2002). Nevertheless, these comparisons should be regarded with caution because most of the studies obtained estimates of egg parameters with a single visit, as in our case, and this can have a number of biases. The very similar Least Tern of North America also showed similar values of clutch sizes, although colonies can be much larger (Szell and Woodrey 2003).

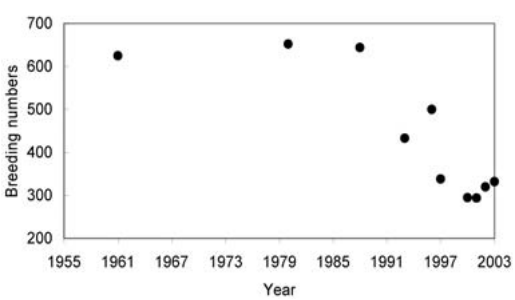

Figure 4. Total breeding numbers of Little Terns in the whole Ebro Delta, 1961-2003.

Colony Features, Size and Growth

Little Terns selected beaches and salt marshes for breeding, whereas salinas were surprisingly avoided. This is probably related to the vicinity of foraging areas close to the colonies and the fact that nesting habitat may influence breeding success (Mallach and Leberg 1999). Little Terns probably avoid interspecific competition for breeding space with large and medium gulls, from which they can suffer predation and kleptoparasitism (see also Sadoul *et al.* 1996; Oro 1996; Fasola *et al.* 2002; Sánchez 2003). Little Terns bred in association with other small size colonial Charadriiforms, more so than in other Mediterranean breeding areas (see also Fasola and Canova 1992; Fasola *et al.* 2002). Size of colonies recorded at the Ebro Delta was independent of the breeding area selected, and seemed normal for the species, which prefers to breed in small loose colonies (Fasola *et al.* 2002).

Population dynamics of Little Terns at the Ebro Delta during the last four decades show two distinct periods: one before the 1990s when the initial and final numbers did not change (although successive declines and recoveries could have occurred), and one since the early 1990s when a sharp decrease started and continued at an average rate of 7% per year. Garrido (1996) suggests that changes in numbers in southwest Spain are related to rainfall levels each year. However, nothing is known about the factors driving the decrease at the Ebro Delta. An increase in the number of pairs was recorded in the colony of Albufera, just 150 km further south, during the late 1980s (Dies 2000). Sharp changes in local numbers have been recorded in most European colonies (Chernichko 1993; Fasola 1993; Fasola *et al.* 1993; Rudenko and Yaremchenko 2000; Sánchez 2003). It is known that small tern species are prone to change colony frequently and that philopatry is relatively low (Renten and Smith 1995). Changes at the Ebro Delta might be related to movements between other colonies at a metapopulation level, since the Spanish population seems rather stable (Fasola *et al.* 2002; Sánchez 2003).

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