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Are salinas a suitable alternative breeding habitat for Little Terns *Sterna albifrons*?

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This paper describes the breeding population, breeding habitats and reproductive variables of Little Terns *Sterna albifrons* in natural (sandy beaches) and alternative (salinas) habitats. Studies of nesting success conducted between 1998 and 2002 in these two types of habitat were combined with a literature review of census work from the past 30 years in order to assess whether salinas are suitable alternative breeding habitat for Little Terns. Most of the Portuguese Little Tern population now breeds in salinas. Census data from the last 30 years show that this is a recent breeding behaviour, because until the 1990s most colonies were located on sandy beaches. Destruction and disturbance of the natural habitat has caused this habitat shift. Despite this shift, the Portuguese Little Tern breeding population did not decline during this period and no significant differences were found in nesting success between natural and alternative habitats. This might indicate that salinas are a suitable alternative breeding habitat for Little Terns, but differences in laying period, clutch size and egg size were recorded between birds nesting on sandy beaches and in salinas in the same area. Birds nested earlier on sandy beaches and laid larger clutches and eggs than in salinas. These data suggest that, when both habitats are available, older and/or higher quality birds prefer sandy beaches for breeding, presumably trying to re-nest in salinas when first breeding attempts failed. We discuss conservation priorities and management actions for both habitats.

The strong human pressure on estuarine and coastal habitats has led to dramatic changes in the distribution and abundance of birds inhabiting these areas (Davidson & Rothwell 1993). The Little Tern *Sterna albifrons* nests colonially in coastal areas such as beaches, lagoons and estuaries (Cramp 1985), and is a representative bird species of most coastal areas in Europe. Its distribution and abundance declined markedly in the 19th and 20th centuries (Tucker & Heath 1994) as a consequence of excessive habitat change and human disturbance at nesting sites, such as extensive recreational use, off-road vehicle traffic and construction (e.g. Haddon & Knight 1983, Lloyd *et al.* 1991).

An important response of breeding bird populations to habitat change is a shift to breed in alternative, including artificial, habitats (Tucker & Heath 1994). When birds move to alternative habitats, different variables may affect their breeding ecology and survival, and this may be important for their conservation. Such habitat shifts have been documented for coastal tern species with similar ecology to that of the Little Tern. For example, some Least Tern *Sterna antillarum* colonies in eastern North America moved from sandy beaches to dredge spoil and fill areas (Gochfeld 1983, Kotliar & Burger 1984), and Damara Terns *Sterna balaenarum* breeding on the south coast of Namibia shifted from gravel plains to salinas (Simmons *et al.* 1998). This subject has not been examined in detail for the Little Tern. In southern Europe, the main alternative habitat for coastal birds is artificial salt-pans (salinas), which are important breeding and wintering habitats for waders and other coastal birds including Little Terns (Britton & Johnson 1987, Neves & Rufino 1994, Masero & Pérez-Furtado 2001).

Censuses of Little Terns have been carried out in the whole of Portugal since the 1970s, enabling us to

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assess a possible change in breeding habitat by this species. Historical records (Paulino d'Oliveira 1896; Tait 1924, Reis Júnior 1927, 1931, Coverley 1931) and available census reports (e.g. Araújo & Rufino 1981, Teixeira 1984, Calado 1995) enabled us to address this point. Little Tern populations are vulnerable to habitat change, disturbance and predation, and their conservation requires active habitat protection and site management (Ratcliffe *et al.* 2000). However, the implementation of conservation measures must be supported by a strong and specific knowledge of habitat characteristics, population status, breeding success and the main factors threatening the birds at the various breeding sites (Knight & Haddon 1982).

Given that the quality and availability of natural Little Tern nesting habitats appear to have declined in Europe because of human influence, the costs of changing from natural to alternative habitats need to be described and a decision made as to whether nesting sites in natural habitats should be restored or alternative habitats maintained or enhanced. We present such an analysis for sandy beaches (hereon: beaches) and salinas in Portugal. We have been studying Little Tern breeding variables in natural and alternative habitats throughout the country since 1998. This paper presents such data, together with an analysis of censuses carried out since the 1970s, and a review of reports on Little Tern breeding success, in order to determine whether salinas are a suitable alternative breeding habitat for Little Terns.

METHODS

Study areas

Fieldwork was carried out in Lagoa de Santo André Nature Reserve between 1998 and 2002, in Castro Marim Nature Reserve in 2000 and 2001, and in Ria Formosa Natural Park in 2002 (Fig. 1). Lagoa de Santo André is a coastal lagoon with an area of 150 ha located in the south-west of Portugal. Little Terns nest on the beach, on the lagoon's sandy shores and on two small sandy islets. Castro Marim has an area of 2089 ha located at the mouth of the Guadiana River, in the south-east of Portugal. Although saltmarshes and fish farms are present in this area, Little Terns nest only in salinas. Ria Formosa Natural Park, on the south coast of Portugal, covers up to 18 400 ha of a lagoon system, along 60 km of the coast. It includes a complex system of channels, marshes, five barrier-islands, salinas and extensive

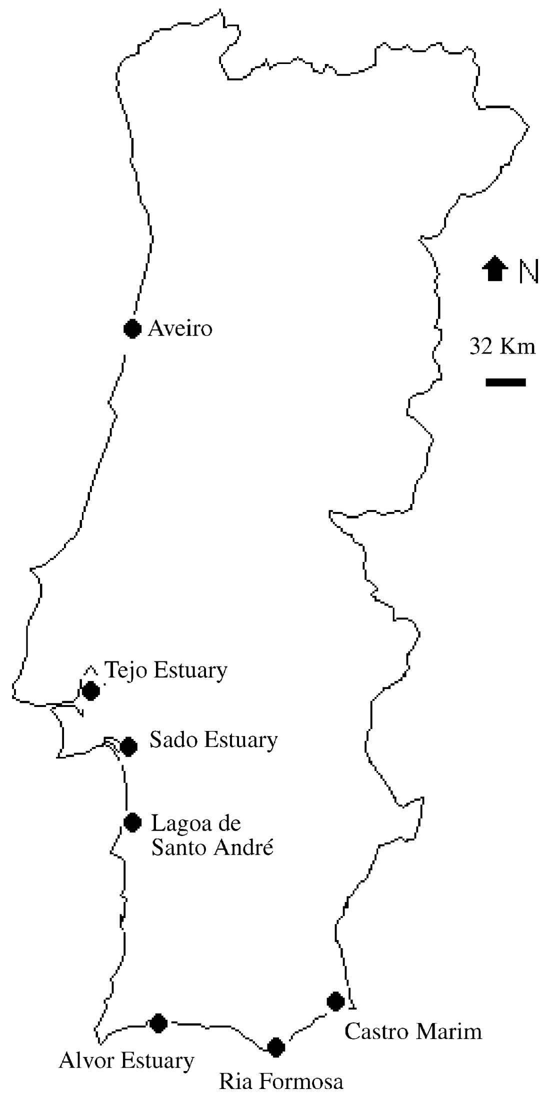

Figure 1. Location of the seven major Little Tern breeding areas in Portugal. Study areas were Lagoa de Santo André, Ria Formosa and Castro Marim.

fish farms. In this area the study was carried out on two barrier-islands (Barreta and Armona) and in a group of active salinas.

Because Ria Formosa is the only Portuguese Little Tern breeding area where the species currently breeds in both natural and alternative (artificial) habitats, we chose Ria Formosa for a more detailed comparison of breeding variables (laying period, clutch size, egg size and nesting success) between natural and alternative habitats.

Beaches, barrier-islands or primary dunes with variable proportions of shell, hereafter referred to as beaches, were classified as natural habitat and salinas as alternative habitat.

Review of historical records, census data and reports

We made an extensive bibliographic review of historical records and of published and unpublished reports of breeding Little Terns in Portugal in order to assess changes in habitat use during the last century. Data from three national censuses are presented. The first survey was carried out between 1976 and 1980 (Araújo & Rufino 1981), the second between 1981 and 1983 (Araújo & Pina 1984, Teixeira 1984) and the last between 2000 and 2002 (this study). In the first survey, Aveiro (Fig. 1) was not covered but we present data from this area in the other two censuses as we subsequently verified that the proportion of birds breeding on beaches and in salinas was similar whether or not Aveiro was included. For the barrier-islands of Ria Formosa, censuses were carried out in 1979, 1981, 1983, 1989, 1992, 1993 and 2002 (Araújo & Pina 1984, Teixeira 1984, Calado 1995, this study).

To compare breeding variables between different habitats we used and present data from three studies performed in 1995 and 1996 in the Alvor Estuary and Tejo Estuary (Wallis 1995, Gurney 1996, Mendes *et al.* 1996), and from our work carried out between 1998 and 2002 in Lagoa de Santo André, Castro Marim and Ria Formosa.

Evaluating breeding variables

Fieldwork was carried out between April and July in all study years. Little Tern nests were located by finding incubating adults or by systematically searching areas where birds showed associated nest behaviour (courtship, nest defence, feeding activity). Each nest was numbered and egg size was measured to the nearest 0.1 mm (length – L; breadth – B); the volume (V) and shape index (SI) were calculated using the formulae: $V\,(\mathrm{cm}^3) = K \times L\,(\mathrm{mm}) \times B^2\,(\mathrm{mm})$, where $K = 0.4866$ and $SI = 100 \times B/L$ (Coulson 1963).

The nesting area and all nests were visited every 4–5 days and daily when the hatching date was close. Clutch size and egg size were calculated using data from complete clutches only. In our experience virtually no clutch suffered partial depredation and the interval at which we checked all nests was sufficient to verify whether clutches were complete. To prevent problems as a result of pseudo-replication (Hulbert 1984) in relation to egg measurements, we first calculated the mean for each clutch and then the mean of all clutches.

Laying date, if unknown, was estimated by assuming a 21-day incubation period (Cramp 1985) and back-dating from the known hatching date. Laying period was defined as the range between the day that the first clutch was initiated and the day that the last clutch was found. Nesting success was defined as the proportion of nests, monitored from the beginning of egg laying, that hatched at least one egg. During each visit study areas were covered in a systematic way and only a few clutches found already contained three eggs. Some clutches may have been predated before they were found but, given our systematic search, this should not affect our results.

The high frequency of visits to each colony allowed the determination of clutch fate. For every clutch that disappeared before hatching was due, we identified if it was predated or destroyed by human activities or by natural causes (such as spring tides, excessive wind and rain). The most common predators, dogs *Canis familiaris*, Stone-curlews *Burhinus oedicnemus*, gulls *Larus* spp. and Brown Rats *Rattus norvegicus*, were easily identified from footprints and eggshell fragments around failed nests. Observations of the predation act and of Little Tern nest defence behaviour were also important to identify other predators such as Montagu's Harrier *Circus pygargus*. In cases where the reason for failure could not be identified, the nest fate was classified as unsuccessful with unknown cause. For a small proportion of clutches (see Results) we could not assess whether the eggs had hatched or had been destroyed, because they disappeared around their hatching date but no live or dead chicks or other traces were found. In these cases the fate was classified as unknown.

Chick survival, defined as the number of chicks per hatched clutch that survived to the fledging stage, could not be determined for the majority of clutches because chicks were highly mobile from 1 to 2 days and left their nest to find shelter elsewhere. However, in part of a salina at Ria Formosa, nests with chicks of 1–2 days of age were fenced with a 1.5–2.0-m-diameter, 15-cm-high and 1-cm^2 wire fence, to keep them in the nest area. For this small colony of 19 pairs, chick survival and breeding success (number of fledged chicks/total number of clutches) were determined. In order to identify each chick individually all chicks were ringed with metal rings (at 2–3 days of age).

Visits to the colonies lasted between 10 and 20 min and did not seem to cause undue disturbance. In all study areas nests were distributed in a linear fashion and, as we walked along each colony, the birds behind us returned quickly to their nests. We consider that any disturbance caused by our activities was similar in both habitats.

Data analysis

Chi-squared tests were used to test for differences in the number of breeding Little Terns in the two habitats between the three national surveys. Mann–Whitney tests were used to test for differences in breeding variables between natural and alternative habitats. A chi-squared test was used to assess the null hypothesis that the number of nests initiated within each period of 2 weeks was similar in natural and alternative habitats. One-way ANOVA, followed by *post-hoc* tests (Newman–Keuls), was used to analyse differences in egg measurements between nesting areas of Ria Formosa (salinas, Armona and Barreta). A chi-squared test was used to assess whether clutch size and nesting success differed significantly between the three areas.

We analysed data from Armona and Barreta separately because human disturbance differs between the two areas; whereas Armona has a small settlement and a heavily used beach, Barreta is isolated and only accessible by private boat.

RESULTS

Historical records

Historical records confirm that the Little Tern was a common breeder in Portugal at the end of the 19th century (Paulino d'Oliveira 1896) and the beginning of the 20th century (Tait 1924, Coverley 1931, Reis Júnior 1931). This species bred mainly on beaches on the north (Aveiro) and south coasts (Algarve: Ria Formosa) (Tait 1924, Reis Júnior 1927, 1931).

The Portuguese Little Tern breeding population is today estimated at about 440 pairs. Since 1970 Little Terns have bred more or less regularly in seven major areas of Portugal (Fig. 1). Natural and alternative habitats were both present in each of these breeding areas (except in Lagoa de Santo André and Castro Marim) and both habitats were used at least once in the 20th century.

The analysis of historical data showed important changes in breeding habitat use, namely (1) the abandonment or a reduction in the use of natural habitats and (2) a recent colonization and increase in Little Tern numbers in some areas with alternative habitats.

The first statement is supported by data from four breeding areas (Aveiro, Sado Estuary, Lagoa de Santo André and Ria Formosa). The Little Tern was a common breeder on the north coast, breeding on beaches in the area of Aveiro by the end of the 19th or beginning of the 20th century (Tait 1924, Reis Júnior 1927, Themido 1948). In Sado Estuary Little Terns also bred on beaches at least in the 1980s and early 1990s (Leitão *et al.* 1993). Today, in both locations this species breeds only in salinas (Fig. 2). In Lagoa de Santo André, Little Terns have nested on beaches at least since the 1970s (Teixeira 1984, Catry 1993). The number of pairs has been irregular and in the last 3 years only a single breeding pair was recorded (Fig. 2). The beaches of Ria Formosa have held the most important Little Tern colonies since the first decade of the 20th century (Tait 1924, Reis Júnior 1927). However, in the two most disturbed barrier-islands, Tavira and Cabanas, we found a negative trend during the last three decades (Araújo & Pina 1984, Teixeira 1984, Calado 1995) (Fig. 2). The increase of tourism in certain areas such as the Sado Estuary, Lagoa de Santo André and Ria Formosa has apparently contributed to the reduction in natural habitat use by Little Terns.

Recent colonization of salinas was recorded in the Tejo Estuary, where Little Terns first bred in 1985 (Teixeira & Xeira 1986). Data from the 1990s and from the beginning of the 21st century show a regular reproductive activity, despite the low number of breeding pairs (Fig. 2). Nesting in salinas of the Sado Estuary was described for the 1930s (Coverley 1931) but colony size was not mentioned. Between 1976 and 1980 only 1–5 pairs bred in this area and in 1984 breeding was not recorded. Apparently, the salinas of the Sado Estuary became one of the major Portuguese breeding areas only during the 1990s (Fig. 2). In Ria Formosa a slow increase in the number of pairs has occurred in salinas in the last 30 years (Fig. 2).

This change in habitat use is clear from the data for the three national censuses (Fig. 3), in which significant differences were found between the numbers of birds nesting in salinas and on beaches ($\chi^2_2 = 48.68$, $P < 0.01$). In the first census approximately 55% of the terns nested on beaches and 45% in salinas (Araújo & Rufino 1981). These proportions were similar in the second survey (57%

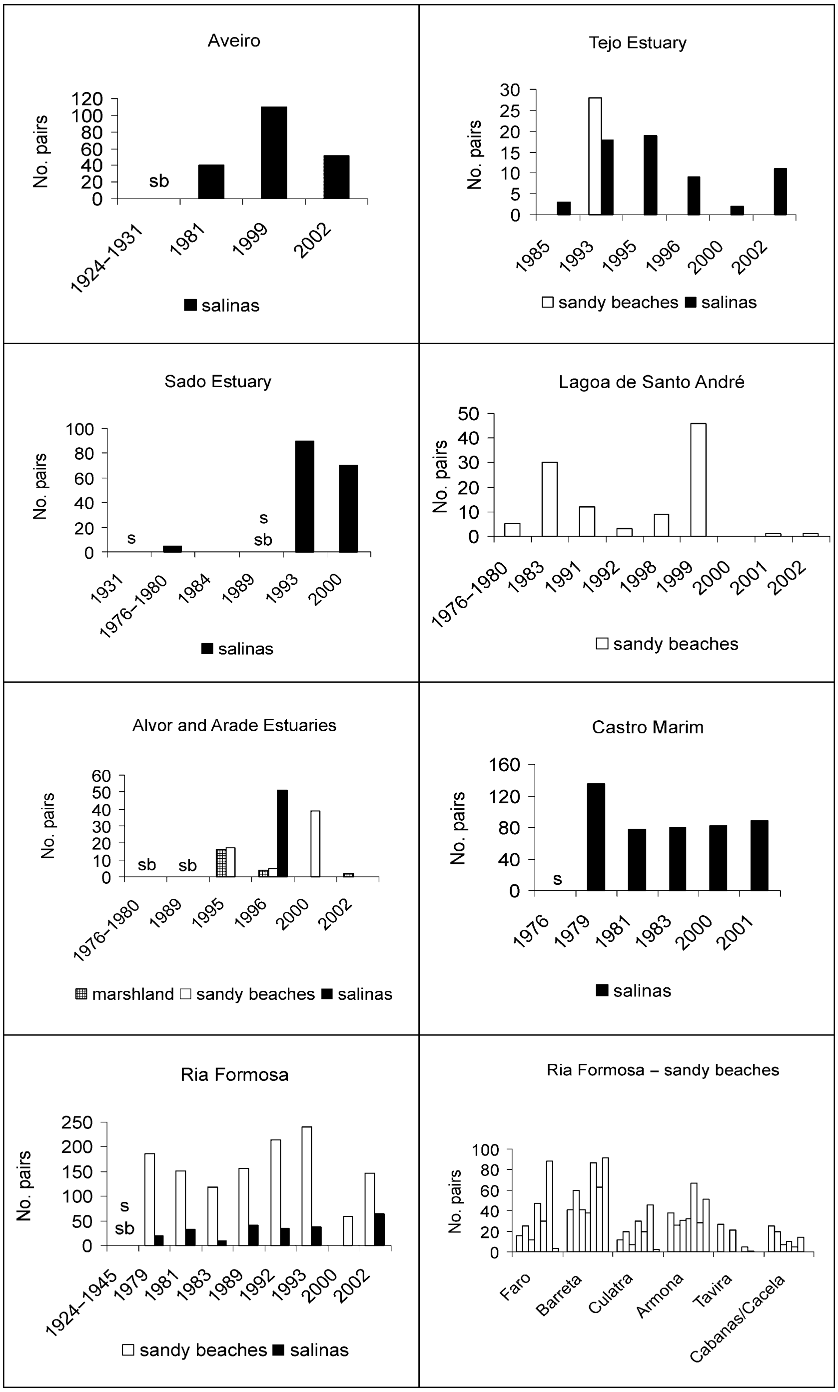

Figure 2. Number of Little Tern breeding pairs per habitat type in the seven major breeding areas of Portugal. Confirmed breeding without an estimation of the number of pairs on sandy beaches and in salinas is represented by 'sb' and 's', respectively. In Ria Formosa, in 2000, the survey was conducted only in salinas. Lack of values in other counts represents absence of breeding. Data for breeding pairs on sandy beaches of Ria Formosa come from censuses carried out in 1979, 1981, 1983, 1989, 1992, 1993 and 2002.

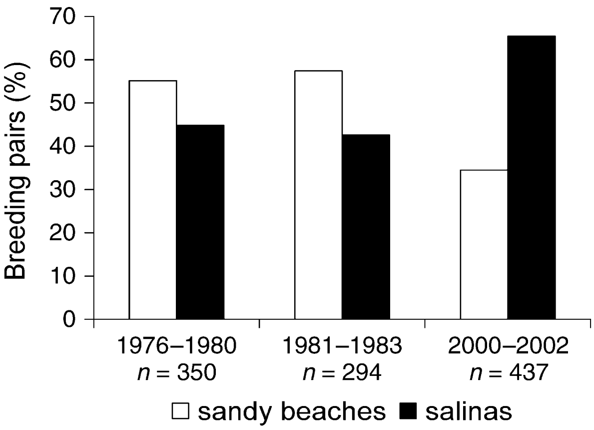

Figure 3. Proportion of Little Terns nesting in salinas and sandy beaches in the three national censuses carried out between 1976 and 2002 (*n* refers to the number of breeding pairs).

on beaches and 43% in salinas) (Araújo & Pina 1984, Teixeira 1984), but were reversed in the last census with only 34% of the birds nesting on beaches and 66% in salinas.

Breeding variables

We compared five breeding variables between natural and alternative habitats: laying period, period with more new clutches, clutch size, nesting success and predation rate.

The laying dates for the first and last clutch within a colony were variable and independent of habitat type (Mann–Whitney $U = 9.0$ for first clutches and 10.0 for last clutches, ns; Table 1). In the same colony, there were remarkable changes in the laying period (see Methods) between years. Most clutches were laid in the second half of May. Therefore, the period in which most clutches were initiated did not differ significantly between the two habitats. The mean clutch size per colony varied between 1.8 and 2.6 eggs/clutch and was higher for beaches [2.33 (sd = ±0.25)] than for salinas (2.18 [sd = ±0.36]; Mann–Whitney $U = 2.5$, $P < 0.05$; Table 1).

Nesting success was similar in salinas (30.1% [sd = ±10.4]) and on beaches (30.9% [sd = ±20.4]; Mann–Whitney $U = 4.0$, ns; Table 1). Nesting success in the natural habitat included both the lowest and the highest values recorded anywhere. The lowest values presumably corresponded to unsuitable nesting areas (with high disturbance) or to poor breeding seasons, because those rates appeared unusually low. However, nesting success was more regular within salinas (Table 1). The primary reason for egg loss was predation. A Mann–Whitney test showed that predation rates did not differ significantly between the two habitats (Mann–Whitney $U = 10.0$, ns; Table 1). On beaches the most common predators were dogs, Stone-curlews and gulls, and in salinas dogs, cats *Felis catus*, Brown Rats and birds including Montagu's Harrier, Turnstone *Arenaria interpres* and gulls.

Table 1 suggests that the characteristics of each area and year effects are important in explaining nesting success independent of habitat, because there were large differences in nesting success in

Table 1. Comparison of breeding variables between Little Tern colonies located on sandy beaches (natural habitat) and salinas (alternative habitat). I and II refer to the first and second fortnight of a month, respectively. – = no data.

	Sandy beaches					Salinas				
	Ria Formosa Armona 2002	Ria Formosa Barreta 2002	L.St. André 1999	L.St. André 1998	Alvor 1995	Ria Formosa 2002	C. Marim 2001	C. Marim 2000	Tejo Estuary 1996	Alvor 1996
No. of clutches	51	35	46	18	17	64	89	82	12	73
Laying period	10 May–9 June	3 May–15 June	20 May–28 July	7 June–28 July	5 June–15 July	9 May–8 July	5 May–4 July	13 May–5 July	1 May–10 July	7 June–8 July
Period with more new clutches	May II	May I	May II	July I	–	May II	May II	May II	–	June I
Clutch size	2.26 ($n = 23$)	2.57 ($n = 28$)	2.60 ($n = 42$)	2.00 ($n = 7$)	2.24 ($n = 17$)	1.87 ($n = 53$)	2.60 ($n = 70$)	2.50 ($n = 72$)	1.80 ($n = 12$)	2.13 ($n = 73$)
Nesting success (%)	11.8	45.7–48.6	41.0	6.0	50.0	46.9	32.6	23.2	20.8	27.0
Predation rate (%)	51.0	31.4	23.9	33.3	45.0	14.1	30.3	51.2	25.0	40.0

Santo André between 1998 and 1999, and also between the two beaches on Ria Formosa in 2002.

Comparisons of Little Tern breeding variables between sandy beaches and salinas in Ria Formosa

We followed 64 nests in salinas and 86 on beaches (51 in Armona and 35 in Barreta) in 2002. The first egg was laid on 3 May in Barreta and the last one on 8 July in salinas. The laying period commenced 1 week earlier in Barreta than in the other two colonies. On both islands it finished about 1 month earlier than in salinas. For both Armona and salinas (we do not have detailed data for Barreta) the number of clutches initiated differed significantly between each period of 2 weeks through the breeding season ($\chi^2_3 = 23.1$, $P < 0.01$; $\chi^2_3 = 51.0$, $P < 0.01$, respectively), with more new clutches in the second half of May (Fig. 4). The difference between Armona and the salinas was also significant ($\chi^2_3 = 28.2$, $P < 0.01$), mainly owing to the earlier and shorter laying period in Armona.

The mean clutch size was 1.87 (sd = ±0.63, $n = 53$), 2.26 (sd = ±0.86, $n = 28$) and 2.57 (sd = ±0.57, $n = 23$) eggs per clutch for the salinas, Armona and Barreta, respectively (Table 1). Clutch size in salinas was significantly smaller than those of Armona and Barreta ($\chi^2_4 = 25.3$, $P < 0.01$).

The analysis of egg measurements in the three colonies also showed significant differences between

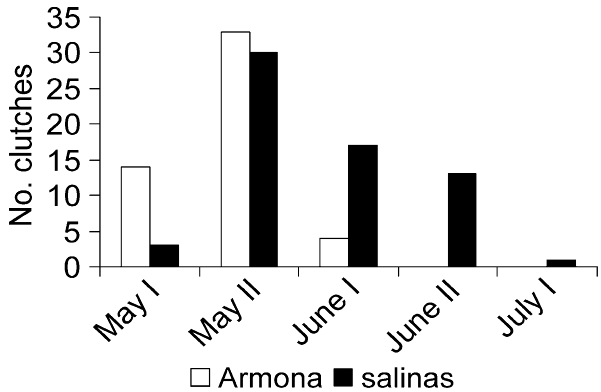

Figure 4. Number of clutches laid in the salinas and Armona colonies in each period of 2 weeks along the breeding season.

the two habitats. The eggs from the salinas were narrower and smaller than the eggs laid on beaches (Table 2). No differences were found for either length or shape index.

Nesting success differed significantly among the three colonies ($\chi^2_2 = 17.9$, $P < 0.01$). This difference was attributed to the lower success recorded in Armona because nesting success in salinas and Barreta were similar (Table 3). Predation was the main cause of egg mortality for the three colonies, but with higher values on Armona (51%) and Barreta (31.4%) than in salinas (14.1%). On Barreta all nests lost were predated by Stone-curlews and on Armona by dogs and Stone-curlews. On both islands 5.7–9.8%

Table 2. Comparison of mean (± sd) egg size and shape of Little Terns within the three studied colonies in Ria Formosa. Rows sharing different letters are significantly different (Newman–Keuls, $P < 0.05$).

	Salinas ($n = 24$)	Armona ($n = 23$)	Barreta ($n = 19$)	ANOVA ($F =$)	P value
Length (mm)	31.61 ± 1.16	31.97 ± 0.92	31.90 ± 1.23	0.52	ns
Breadth (mm)	22.98 ± 0.53^b	23.41 ± 0.70^a	23.51 ± 0.57^a	4.76	< 0.01
Volume (cm^3)	8.13 ± 0.53^b	8.54 ± 0.65^a	8.59 ± 0.64^a	3.65	< 0.03
Shape index	72.80 ± 2.92	73.26 ± 2.49	73.79 ± 2.68	0.87	ns

Table 3. Egg fate (nest success and cause of hatching failure) for the salinas, Armona and Barreta colonies.

	No. of clutches	% Clutch hatched	Unsuccessful clutches				% Clutch with fate unknown
			% predated	% flooded	% unknown cause	% abandoned	
Salinas	64	46.9	14.1	0	15.6	6.3	17.2
Armona	51	11.8	51.0	9.8	21.6	0	5.9
Barreta	35	45.7–48.6	31.4	5.7	14.3	0	0

of the nests were washed away by high tides. In the three nesting areas the cause of nest failure was unidentified. The rates of nest failure in the three sites were 14.3% on Barreta, 15.6% in salinas and 21.6% on Armona.

In salinas, we determined the chick survival and breeding success for 19 clutches. A total of 18 eggs hatched from ten nests, and of these ten chicks fledged (nesting success = 52.6%, fledging success = 1.0 chicks/clutch and breeding success = 0.53 chicks/clutch).

DISCUSSION

Little Tern breeding habitats in the Western Palearctic mainly include natural habitats, both coastal (beaches and delta marshes) and inland (lakes and rivers), but artificial habitats are also used (Lloyd *et al*. 1991, Tucker & Heath 1994). Breeding in salinas is reported in Europe for Portugal, Spain and Italy but, with the exception of Portugal, salinas do not appear to be an important habitat for the species (Fasola 1986, Purroy 1997).

In the 20th century, an important shift from breeding on beaches to salinas occurred in Portugal (this study). The progressive abandonment of the natural habitat was caused by habitat destruction and human disturbance. Construction and installation of recreational structures in some of the barrier-islands of Ria Formosa led to a high level of disturbance near Little Tern colonies and to their partial or complete abandonment. In Aveiro, Lagoa de Santo André and the Sado Estuary, tourism pressure is the main factor for habitat unsuitability (Ribeiro 2001, this study).

In contrast to many European countries, Portugal has few suitable breeding areas inland (such as lakes or rivers) and there is only one small colony away from the sea (in a large dam). Therefore, the only available habitat for birds abandoning beaches is salinas. Other alternative habitats are scarce and, in the case of fish farms, subjected to heavy disturbance. Artificial and modified wetlands can provide alternative foraging and breeding habitats for waterbirds (Davidson & Evans 1986, Britton & Johnson 1987) and salinas are recognized to perform this role worldwide (e.g. Britton & Johnson 1987, Velasquez 1992).

Despite the abandonment of many areas of natural habitat, in the last 30 years the Portuguese Little Tern breeding population has not declined. This supports the view that birds have moved from beaches to salinas. It also indicates that Little Terns have adapted quickly to breeding in salinas. In fact, we did not find a significant difference in nesting success between natural and alternative habitats, which might have indicated that salinas were a suitable alternative habitat for breeding Little Terns. However, Little Terns nesting on salinas bred later, laid smaller eggs and laid smaller clutches. Because these attributes are generally associated with lower reproductive output, and there are no data on breeding success for beaches, further studies on both nest and chick survival over several years are necessary to verify whether salinas are indeed an alternative habitat in terms of Little Tern productivity. Most natural habitats have been modified and birds breeding in those habitats are exposed to greater pressures, especially from predation and disturbance. In natural habitats, predation should have been the main factor affecting nesting success. Humans were responsible for the colonization of new types of predators on beaches such as rats and dogs, and predation levels may have increased. The interaction between human disturbance and predation, although difficult to demonstrate, is likely to have a disproportionate effect in explaining nesting success on beaches.

In Ria Formosa, birds nested earlier on beaches and laid larger clutches and eggs than those nesting in the salinas. The difference in laying period suggests that Little Terns prefer beaches, because the first breeding attempts occurred in this habitat. The laying period was shorter for the barrier-islands (possibly as a result of an increase in human disturbance through the breeding season), suggesting that most birds that failed to breed on Armona and Barreta may have tried to re-nest in the salinas (although later breeding in salinas was not entirely attributable to failed birds from beaches because the peak of laying for the two habitats occurred in the same fortnight). This is further supported by the fact that birds nesting in the barrier-islands laid larger clutches. It is well known for Little Terns that first clutches are larger than second clutches (Cramp 1985). Furthermore, Massey and Fancher (1989) have shown that approximately 50% of Least Terns that lost first clutches in a colony shifted to other colonies to re-nest. Apparently, site fidelity within the same season is related to colony stability and disturbance (Massey & Fancher 1989). This possible movement between habitats in Ria Formosa deserves further study, using marked birds.

Differences in breeding variables also suggest differences in the age structure of colonies in salinas and on beaches, with older and presumably higher quality birds nesting on beaches. In many bird species, young individuals breed later, lay smaller clutches and lay smaller eggs, and are less successful than older birds (e.g. Davis 1975, Massey & Atwood 1981, Coulson *et al.* 1982, Burger *et al.* 1996). This may happen because older birds are more efficient at finding food and/or invest more in breeding activities (Curio 1983, Forslund & Pärt 1995). An alternative hypothesis to explain the differences in these breeding variables between salinas and beaches could be the differential availability of food for birds nesting in these two types of habitat. Nisbet (1978) showed that for Common Terns *Sterna hirundo* nesting on two islands in the USA, differences in laying period and clutch and egg size were exclusively associated with food intake by females at the time of egg laying. In our study, however, this hypothesis does not seem important because the distance between nesting and main feeding grounds (the waters of the lagoon at low tide) was similar for birds breeding in salinas and on beaches (our pers. obs.).

We do not know whether birds in natural habitats had higher breeding success, because chick survival could not be assessed. However, the nesting success in salinas was similar to that of Barreta but higher than that of Armona. Assuming that chick survival was similar in the two habitats and that our assumptions are correct, why would presumably higher quality Little Terns choose to breed on beaches? More fieldwork is needed but it should be borne in mind that birds may be attracted to breed in the most familiar locations, partially as a result of an imprinting process (Brooke & Birkhead 1991). Therefore, as the quality of beaches for breeding Little Terns decreases progressively we can envisage a scenario in which most of the population will breed in salinas.

Conservation: action for which habitat?

Although Little Terns breed in salinas at present, there is no guarantee that they will do so in the future. In Portugal, during the last 30 years, the total area of salinas has been dramatically reduced through the abandonment and conversion of salinas into fish farms and rice fields (Pullan 1988, Neves & Rufino 1994). In most abandoned salinas the overgrowth of vegetation occurs rapidly and it is well known that, in such situations, colonies will be abandoned (Kotliar & Burger 1984). For fish farms, human disturbance is very high, making these areas unsuitable for breeding Little Terns. Therefore, despite changes in breeding habitat use, habitat loss is still the major threat to Little Terns.

What then are the conservation priorities? Conservation and management of natural and alternative habitats are both priorities because the maintenance of habitat diversity could be crucial for Little Tern survival in the future. Management of artificial wetlands such as salinas can increase their value as a foraging and nesting area for waterbirds (Velasquez 1992, Neves & Rufino 1994, Koenen *et al.* 1996). In Portugal, preventing abandonment and conversion of salinas into fish farms and controlling predation are the most urgent management actions for the future.

In relation to natural habitats, conservation efforts should first be directed to the barrier-islands of Ria Formosa, such as Barreta, where larger colonies and natural habitats occur. Access restriction, sign-posting and wardening to prevent human disturbance around the colonies as well as predation control have been the most widely implemented conservation measures for breeding Little Terns (Haddon & Knight 1983) and are most appropriate for barrier-islands. In Britain and Ireland many protection schemes have been established with success in this habitat (e.g. Knight & Haddon 1982, O'Briaim & Farrely 1990, Lloyd *et al.* 1991, Ratcliffe *et al.* 2000).

Throughout the world coastal birds have been forced to move from their preferred to alternative habitats, where disturbance may be less but a range of other threats exists. In eastern North America, for example, Common Terns and Black Skimmers *Rynchops niger* shifted from preferred beach habitats to salt marshes, and had total nest failure during years of high rainfall and flooding (Burger & Gochfeld 1991, Gochfeld & Burger 1994). In coastal areas under intense pressure the policy of most conservation organizations is to enhance the suitability of alternative habitats. Our study and other studies are now drawing attention to the fact that, although such actions may resolve short-term conflicts between human and conservation interests, in the long term it is not clear whether they will guarantee the conservation of many species of the littoral zone.

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