SCI. MAR., 67 (Suppl. 2): 95-101 SCIENTIA MARINA 2003

MEDITERRANEAN SEABIRDS AND THEIR CONSERVATION. *E. MÍNGUEZ, D. ORO, E. DE JUANA and A. MARTÍNEZ-ABRAÍN (eds.)*

Predation on common tern eggs by the yellow-legged gull at the Ebro Delta*

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SUMMARY: The Ebro Delta holds a large seabird community, including a common tern (*Sterna hirundo*) local population of 3,085 pairs in 2000 which breeds scattered in several colonies. At *El Canalot* colony, 1,178 (1999) and 1,156 pairs (2000) of this species bred distributed in 32 and 38 sub-colonies respectively. These sub-colonies varied in size from 1 to 223 pairs and were placed near the main breeding colonies of yellow-legged gulls (*Larus cachinnans*) and Audouin's gulls (*L. audouinii*), which are potential egg-predators of terns. We studied egg predation during 1999 (6 sub-colonies) and 2000 (27 sub-colonies). Overall, we found that 10.6% of the nests in 1999 and 16.7% in 2000 suffered partial or total egg predation, being total in 81.1% of the predatory events. Predation was significantly higher in small sub-colonies (<11 pairs): 49.4% in 1999 and 75.5% in 2000. Only attacks from yellow-legged gulls were observed, and defence behaviour of terns was significantly more frequent against this gull species (40.5 hours of observation), suggesting that in most cases the egg predation recorded was due to this species. Probability of egg predation was significantly and negatively correlated with distance to the nearest yellow-legged gull sub-colony, although this relationship was no more significant after adjustment for sub-colony size. On the other hand, distance to the nearest Audouin's gull sub-colony did not show any effect. Our results suggest that the impact of large gulls (at least yellow-legged gulls) upon smaller seabirds breeding in the area might be important, especially when they are breeding in small sub-colonies. Further studies are needed to analyse the general impact of large gulls upon the breeding populations of other colonial bird species in the area.

Key words: conservation, seabird community, colonialism, nest losses.

RESUMEN: DEPREDACIÓN DE HUEVOS DE CHARRÁN COMUN POR PARTE DE LA GAVIOTA PATIAMARILLA EN EL DELTA DEL EBRO. – El Delta del Ebro mantiene una importante comunidad de aves marinas, incluyendo una colonia de charrán común (*Sterna hirundo*) de 3085 parejas en el año 2000, que se divide en diversas subcolonias. En la colonia de El Canalot criaron 1178 parejas en el año 1999 y 1156 en el año 2000, distribuidas en 32 y 38 subcolonias respectivamente. Estas subcolonias oscilaron entre 1 y 223 parejas y se situaron cerca de las principales colonias de gaviota patiamarilla *Larus cachinnans* y gaviota de Audouin *Larus audouinii*, que son potenciales depredadores de huevos de charrán. La depredación de huevos se estudió en 6 subcolonias en 1999 y en 27 en el año 2000. En conjunto, encontramos que el 10,6% de los nidos en 1999 y el 16,7% en el año 2000 sufrieron predación total o parcial de huevos, siendo total en el 81,1% de los eventos predatorios. La depredación fue significativamente mayor en las subcolonias pequeñas (<11 parejas): 49,4% en 1999 y 75,5% en el año 2000. Sólo se observaron ataques por parte de gaviotas patiamarillas y la conducta defensiva de los charranes fue significativamente más frecuente frente a esta especie (40,5 horas de observación), sugiriendo que en la mayoría de los casos la depredación de huevos registrada se debió a esta especie. La probabilidad de depredación de huevos estuvo significativa y negativamente correlacionada con la distancia a la subcolonia de gaviota patiamarilla más cercana, aunque esta relación no fue significativa tras corregir en función del tamaño de la subcolonia. La distancia a la subcolonia más cercana de gaviota de Audouin no mostró ningún efecto. Nuestros resultados sugieren que el impacto local de las gaviotas de gran tamaño (al menos las gaviotas patiamarillas) sobre otras aves marinas de menor tamaño podría ser importante, especialmente cuando críen en pequeñas subcolonias. Son necesarios más estudios para analizar el impacto general de las gaviotas de gran talla sobre otras aves marinas reproductoras en el delta del Ebro.

Palabras clave: conservación, comunidades de aves marinas, colonialismo, pérdidas en nido.

*Received September 26, 2001. Accepted September 8, 2002.

INTRODUCTION

Most seabird species breed in colonies, resulting in conspicuous aggregations of adult individuals, eggs and/or chicks, which are a readily exploitable source of food for many predators. Predators can have a number of detrimental effects on seabird populations (see Croxall *et al.*, 1984; Nettleship *et al.*, 1994 for examples). Excluding direct predation by man, the strongest negative effects have been caused by introduced terrestrial predators, which can lead to dramatic decreases in local populations of seabirds (Moors and Atkinson, 1984), including both local and total extinctions. Avian species which prey on seabird colonies are usually natural predators, and their effects are commonly weak (Burger and Gochfeld, 1994). Environmental changes induced by man, however, have favoured the proliferation of some avian predators, especially large gulls (e.g. Blokpoel and Spaans, 1991; Furness *et al.*, 1992; Pons, 1992), which have reduced the productivity and hence the conservation status of some other seabird species (Blokpoel and Spaans, 1991; Spear, 1993; Hario, 1994). Terns seem to be highly sensitive species owing to their small size (Burger and Gochfeld, 1994), and because their traditional breeding areas are not uncommonly placed close to large gulleries (e.g. Burger and Gochfeld, 1991; Becker, 1995). Indeed, many studies have reported adverse effects of large gulls on tern species, including kleptoparasitism (Stienen and Brenninkmeyer, 2002), nest site competition (Kress *et al.*, 1983; Sadoul *et al.*, 1996), and predation on eggs and chicks (e.g. Saliva and Burger, 1989; Burger and Gochfeld, 1991; Becker, 1995, Guillemette and Brousseau, 2001).

In the Mediterranean basin, the yellow-legged gull (*Larus cachinnans*) has undergone a widespread demographic increase in the last few decades (Thibault *et al.*, 1996; Bosch *et al.*, 2000). A number of deleterious effects of this species have been reported to affect other bird species to different degrees in this area (e.g. Bosch, 1996; Oro and Martínez-Vilalta, 1994; González-Solís *et al.*, 1997; review in Vidal *et al.*, 1998). With respect to terns, previous studies have reported that some tern species are displaced to poor breeding habitats by large gulls (Sadoul *et al.*, 1996), thus resulting in a reduced breeding performance of these colonies. However, although predation has been recognised as a possible threat for some tern species (Tucker and Heath, 1994), few studies have reported the magnitude of predation by large gulls on tern species in this area.

TABLE 1. – Number of breeding pairs of tern species and large gulls, which potentially might prey on tern nests (data from year 2000; sources: PN Delta de l'Ebre, Daniel Oro, and authors).

	Punta de la Banya	Ebro Delta (total)
Sterna hirundo	1,465	3,085
Sterna albifrons	53	244
Larus audouinii	10,558	10,558
Larus cachinnans	3,352	3,419

The Ebro Delta holds one of the largest seabird communities in the western Mediterranean (Oro and Ruiz, 1997). In this area, common terns (*Sterna hirundo*) and little terns (*Sterna albifrons*) breed syntopically with large gulls (yellow-legged *Larus cachinnans* and Audouin's gulls *L. audouinii*) scattered in several colonies (see Table 1). At *El Canalot* colony (see Fig. 1), 1,178 pairs (1999) and 1,156 pairs (2000) of common terns bred distributed in 32 to 38 sub-colonies, which varied in size between 1 and 223 pairs. Furthermore, in the year 2000 some gull sub-colonies occupied new areas, which were closer to the common tern colony (personal observation).

The main aims of this study were 1) to estimate the extent of egg predation in the colonies of common tern at *El Canalot*, 2) to ascertain which species are causing this predation, and 3) to study the relationship between egg predation and distance to the nesting grounds of potential predators.

STUDY AREA AND METHODS

Fieldwork was carried out at *El Canalot*, a marshland area of ca. 2 km^2 composed of 160 small islets in the southern sector of the Ebro Delta (Fig. 1). This is the second main area of reproduction for common terns at the Delta (Hernández and Ruiz, 1999). Egg predation was studied in 1999 (at 6 sub-colonies) and 2000 (at 27 sub-colonies). Sub-colonies were defined as groups of terns that bred on islets completely surrounded by water (minimum distances ranged from 25 to 204 m), where individuals from different sub-colonies typically did not interact with birds of other islets during mobbing of predators. Sub-colonies were selected with a view to obtaining a significant sample of the total number of nests and sub-colony sizes. 217 and 772 nests were marked in 1999 and 2000 respectively. This represented 18% and 67% of

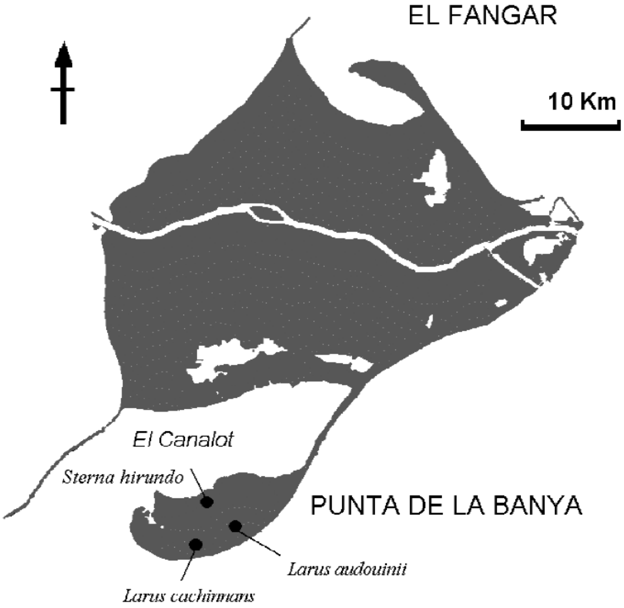

FIG. 1. – Map of the Ebro delta. Marks indicate the centre of the colonies of common tern, Audouin's and yellow-legged gulls.

all nests in the area. Furthermore, differences in size between monitored and non-monitored sub-colonies were not significant in any year (Mann-Whitney Test: 1999: Z = -0.169, n = 32, P = 0.869; 2000: Z = -0.451, n = 38, P = 0.657).

All nests of the studied sub-colonies were marked with a plastic tag the day on which the first egg was laid (except in one sub-colony, where only 73 of the 223 nests were marked). In order to record egg losses, nests were checked at intervals of two days during the laying period. When egg losses took place and no signals of flooding were detected, we assumed that eggs had been predated. To quantify egg predation we calculated the proportion of nests which suffered any kind of egg predation with respect to the total number of nests marked. Additionally we calculated the probability of predation as the number of nests that suffered egg predation over the total number of nests, excluding those nests that had been flooded or deserted due to unknown causes.

In order to know which species were involved in predation events, we performed 40.5 hours of direct observation from a blind in 1999, recording the presence and behaviour of other bird species and the response of terns to them. To determine whether terns reacted in a different way against the presence of yellow-legged or Audouin's gulls, chi-square analyses were performed (responses of terns were divided into two categories: 'no reaction' and 'defence behaviour', which included an increase of vocalisations, panic flies and mobbing of predators).

In order to discover whether distance to nesting grounds of potential predators was related to the probability of egg predation, we proceeded in two ways. First, we performed simple correlations between the probability of predation and distance to nearest sub-colonies of large gulls using data from the year 2000. Additionally, we used partial correlation to adjust for sub-colony size, since many studies have reported a decrease in predation in larger breeding groups (review in Brown and Brown, 2001). Both sub-colony size and probability of predation were transformed in order to normalise them, using logarithmic and arcsine transformations respectively (see Zar, 1996). Finally, a chi-squared test was used to determine whether the number of nests predated differed between the two years of study, since the distance to the nearest sub-colony of large gulls was shorter in the year 2000. For this purpose, only the five sub-colonies studied in both years were considered.

RESULTS

The percentage of nests that suffered either total or partial predation ranged from 2.3 to 80.0% (1999) and from 0 to 100% (2000) in the sub-colonies studied (see Table 2). In most cases, predation was total (81.1% of predated nests), 9.2 and 13.9% of all nests marked being completely predated in 1999 and 2000 respectively. Other causes of nest loss included flooding (3.0%) and desertion for unknown causes (2.6%).

The results of our observations from the hide are given in Table 3 (observed attitude of birds present

TABLE 2. – Mean ± SD of the percentage of predated nests by sub-colony.

Year	Sub-colony Size <11 pairs	11 – 40 pairs	>40 pairs
1999	49.41 ± 35.08	N.A.	6.24 ± 3.56
number of sub-colonies	n = 3		n = 3
2000	75.48 ± 35.30	18.60 ± 12.11	11.26 ± 9.84
Number of sub-colonies	n = 11	n = 8	n = 9

TABLE 3. – Observed attitude of birds present in tern sub-colonies. The category 'other species' includes *Larus ridibundus*, *Larus genei, Sterna sandvicensis*, *Gelochelidon nilotica*, *Egretta garzetta*, *Anas platyrhynchos* and *Tadorna tadorna*.

Species	Normal flight	Landed in/near sub-colonies	Attitude of the bird Patrolling flight	Attempts of attacks	Predation event	Total
Larus cachinnans	52	5	6	3	1	67
Larus audouinii	19		1			20
Other species	10	8				18
Total	81	13	7	3	1	105

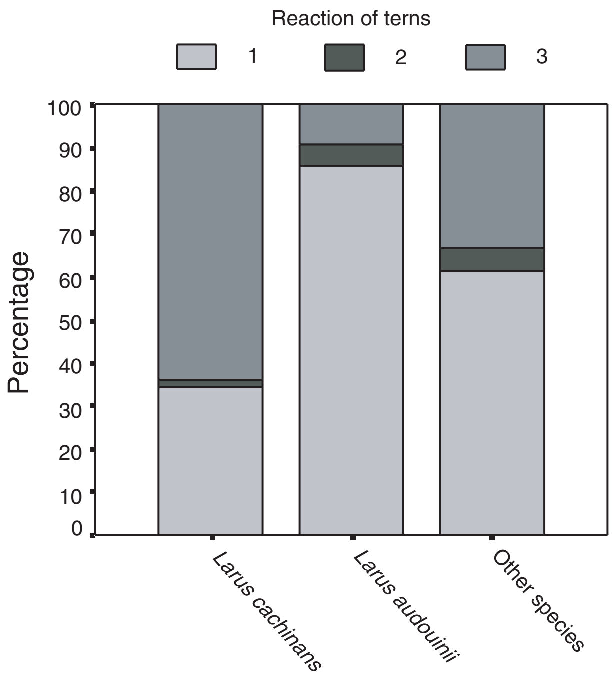

FIG. 2. – Behaviour of terns (1 'no response', 2 'increase of vocalisations', 3 'behaviour of defence') with the presence of individuals of other bird species. The category 'other species' includes *Larus ridibundus*, *Larus genei, Sterna sandvicensis*, *Gelochelidon nilotica*, *Egretta garzetta*, *Anas platyrhynchos and Tadorna tadorna.* Sample sizes are those reported in Table 3.

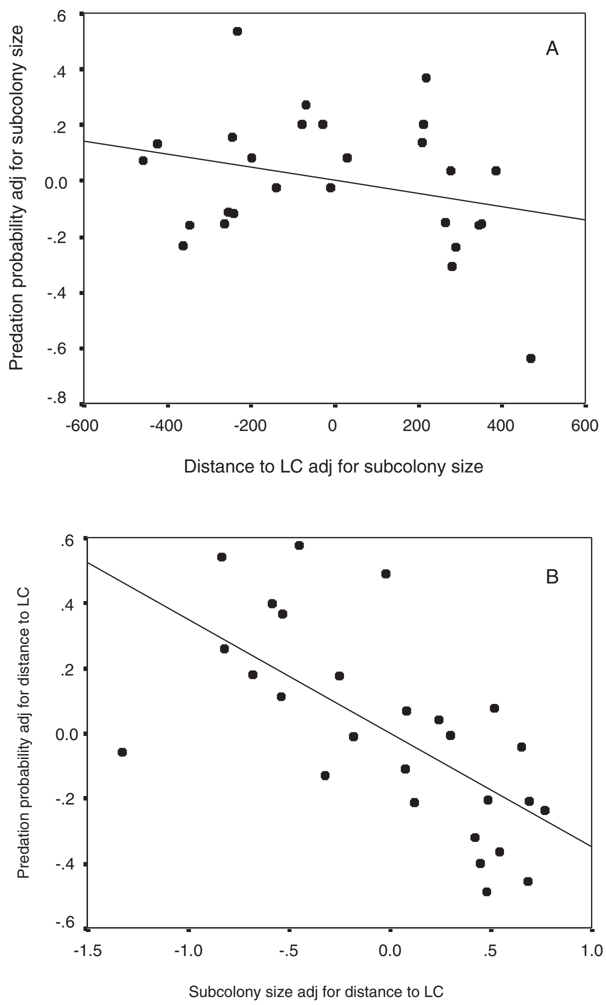

FIG. 3. – (A) Relationship between the probability of predation and distance to nearest sub-colony of yellow-legged gulls adjusted for subcolony size (Partial correlation, r = -0.282, n = 27, d.f. = 24, p = 0.163). (B) Relationship between the probability of predation and subcolony size adjusted for distance to nearest sub-colony of yellow-legged gulls (Partial correlation, r = -0.668, n = 27, d.f. = 24, p < 0.001).

at tern sub-colonies) and Figure 2 (reaction of terns to the presence of other bird species). Reaction of terns was significantly different against the presence of yellow-legged or Audouin's gulls at the sub-colony ($\chi^2_{1\ df} = 17.0$, $p < 0.001$).

Distance to sub-colonies of large gulls did not seem to affect the risk of egg predation. First, distance to nearest sub-colonies of Audouin's gull was not correlated with probability of predation (Pearson's Correlation, r = -0.198, n = 27, p = 0.323). On the other hand, distance to yellow-legged gull sub-colonies was negatively correlated with probability of predation (Pearson's Correlation, r = -0.554, n = 27, p = 0.003). However, this relationship was no more significant after adjustment for sub-colony size (Partial correlation, r = -0.282, n = 27, d.f. = 24, p = 0.163; see Fig. 3a). Indeed, sub-colony size was significantly correlated with the probability of predation even after adjustment for distance to the nearest sub-colony of yellow-legged gull (Partial corre-

TABLE 4. – Frequencies and percentages of predated and unpredated nests for the considered sub-colony size categories and for both years. Predation was significantly lower in large than in small sub-colonies (1999: $\chi^2_{1\ df} = 25.532$, $p < 0.001$; 2000: $\chi^2_{2\ df} = 98.441$, $p < 0.001$).

Sub-colony size	Year		Nest predation		Total
			Not predated	Predated	
<11 pairs	1999	Count	12	9	21
		%	57.1	42.9	
>40 pairs		Count	182	14	196
		%	92.9	7.1	
Total		Count	194	23	217
		%	89.4	10.6	
<11 pairs	2000	Count	14	31	45
		%	31.1	68.9	
11-40 pairs		Count	152	35	187
		%	81.3	18.7	
>40 pairs		Count	477	63	540
		%	88.3	11.7	
Total		Count	643	129	772
		%	83.3	16.7	

lation, r = -0.668, n = 27, d.f. = 24, P < 0.001; see Fig. 3b). In agreement with this, predation was significantly lower in large than in small sub-colonies in both years (see Table 4). However, there were no significant differences in the distribution of frequencies of predated and unpredated nests between the two years of study ($\chi^2_{1\ df} = 1.313$, n = 341 , P = 0.252) in the same sub-colonies.

DISCUSSION

Our results suggest that egg losses caused by predation in the colony under study were mainly caused by the yellow-legged gull. The behaviour of gulls and the reaction of terns supported this hypothesis, although a single predation event was observed. The general impact of egg predation seems not to be of concern, although it was the main cause of nest loss during the study period (see Results). The impact was especially important in small sub-colonies, where all nests were predated in some cases. Further causes of nest loss were nest desertion and flooding. The latter can cause substantial nest losses in some years, depending on the weather (Hernández and Ruiz, 1999).

Apart from gulls, other potential egg predators were present in the area, such as some species of egrets (e.g. Nisbet and Welton, 1984) or waders (e.g. Morris and Wiggins, 1986). However, these species were quite scarce in the nesting grounds of terns. Furthermore, neither data from direct observation, nor observations during nest surveys showed any evidence that these species caused egg predation. Thus, it seems likely that most records of egg predation were caused by gulls.

Previous studies have shown that large gulls can cause substantial breeding losses in colonies of some seabird species (Blokpoel and Spaans, 1991; Spear, 1993; Hario, 1994), including the common tern (Burger and Gochfeld, 1991; Becker, 1995; Guillemette and Brousseau, 2001). Reduction in breeding performance can be caused by direct predation on eggs or young, but also by either restricting terns to breeding in poor quality breeding places (e.g. Kress *et al.* 1983; Sadoul *et al.*, 1996), or stealing their food, thus reducing energy intake (e.g. Stienen and Brenninkmeyer, 2002). These deleterious effects can be especially important after population expansion of large gull populations (e.g. Blokpoel and Spaans, 1991; Guillemette and Brousseau, 2001). In the study area, the local yellow-legged gull population increased rapidly until 1997 reaching 4,041 pairs. In the following years, breeding numbers ranged between 2,771 in year 1999 and 3,419 pairs in the year 2000 (Daniel Oro, pers. comm.). Further, some individuals became established in previously unused nesting grounds in the year 2000, closer to common tern colonies. Nevertheless, our results show that total egg losses due to predation were relatively low for the whole colony (see Results). It is not possible to exclude the possibility that the observed predation rates were artificially increased for disturbances due to investigators. If this happened, however, the proportion of nests predated would be even lower. Moreover, only in a few cases did large gulls attack sub-colonies during nest surveys, and when this happened, the attacking gulls were successfully repelled by the terns.

In order to evaluate the impact that egg predation caused on this species, it is necessary to consider several aspects. First, eggs belonging to partially predated nests were incubated until hatching in most cases (personal observation). Second, common terns are able to lay replacement clutches, although they are less likely to lay when nest loss happens late in the season (Wendeln and Becker, 2000). Third, chick predation was very low (unpublished data). Fourth, recorded breeding success in the area ranged between 0.54 and 1.08 chicks per pair in 1998 and 1999 respectively (Hernández and Ruiz, 1999), which are normal values for the species (see Burger and Gochfeld, 1991). Thus, although from our data it is not possible to exactly assess the extent to which the breeding success of the species was reduced due to predation by large gulls, predation does not seem to be a threat for the common terns studied.

Our results also suggest that distance to nearest sub-colony of yellow-legged gulls did not affect the probability of predation, which could be caused either because of high flight capabilities of gulls with respect to the small area occupied by terns, or because predation is usually carried out by specialised individuals (see González-Solís *et al.*, 1997; Guillemette and Brousseau, 2001). However, additional interactions other than predation may negatively affect terns, such as competition for breeding sites (e.g. Kress *et al.*, 1983; Burger and Gochfeld, 1994; Sadoul *et al.*, 1996).

Finally, our results show that the probability of predation decreased greatly when terns were breeding in large groups (see Fig. 3b). The avoidance of predators has long been suggested as a major force in the evolution of coloniality (see reviews in Brown and Brown, 2001; Coulson, 2002). However, studies aiming to explain the relationship between predation and breeding group size are controversial (Oro, 1996; Brown and Brown, 2001). Our results support the hypothesis that colonial breeding confers protection against aerial predators. In addition to its theoretical interest, the observed relationship between sub-colony size and probability of predation also has implications for conservation, since predation by yellow-legged gulls could affect the productivity of other bird species in the area, especially those that breed in small colonies, such as the little tern. Indeed, gull predation has been considered a threat for this tern species (see Tucker and Heath, 1994). Therefore, further studies to study the impact of large gulls upon colonies of other small seabird species should be carried out.

ACKNOWLEDGEMENTS

We gratefully thank Albert Bertolero and Jordi González for their fieldwork collaboration. We also thank Daniel Oro, Jose Luís Tella, Jose Manuel Arcos, Jacob Gónzalez-Solís and Jordi Prieto for comments on earlier drafts, Lluís Jover for his help on statistical analyses, Daniel Oro for data census of Audouin's and yellow-legged gulls, PN Delta de l'Ebre for data census on little tern and logistical support during the study, and Dirección General de Investigación Científica del Ministerio de Educación y Ciencia (Project PB96-0995-C02-01, grant AP–97 33917810).

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