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HABITAT SELECTION AND NESTING ASSOCIATION IN FOUR SPECIES OF CHARADRIIFORMES IN THE PO DELTA (ITALY)

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SUMMARY.—*Habitat selection and nesting association in four species of Charadriiformes in the Po Delta (Italy)*. Colony, nest site selection and interspecific associations of four breeding Charadriiformes were studied in the Po Delta, Italy, in 1991. Physical characteristics (such as length, size, distance from mainland and other islands, occurrence of small dunes, etc.) of eighteen islands and two peninsulas were considered; random points were selected on the islands, and several parameters (such as distance from the shore, apparent elevation above sea level, vegetation cover, kind of substrate, etc.) compared with those of a similar number of nest sites. Apart from Yellow-legged Gulls *Larus cachinnans,* which selected the longest and largest islands, the other species (Oystercatchers *Haematopus ostralegus,* Kentish Plovers *Charadrius alexandrinus* and Little Terns *Sterna albifrons*) did not show particular preferences at this level. With regard to nest site characteristics of each species, they were often different from random points and, less frequently, from those of the other species. Yellow-legged Gulls preferred sites with less sand, higher vegetation cover and taller plants; the opposite was true for Kentish Plovers. Intermediate characteristics were selected by Oystercatchers and Little Terns. Significant associations were found between Oystercatchers and Yellow-legged Gulls, Oystercatchers and Kentish Plovers, Kentish Plovers and Little Terns. Our study suggests that physical factors (i.e. nest site features) and behavioral factors (association resulting in better protection from predators, or due to a limited feeding overlap in the nearby intertidal areas) interact in the habitat selection of the four species studied in the Po Delta. The observed association between oystercatchers and gulls deserves further research.

Key words: association, Charadriiformes, nesting, Po Delta.

RESUMEN.—*Selección de hábitat y asociación en los lugares de nidificación de cuatro especies de Charadriiformes en el Delta del Po (Italia).* Se estudió la selección del lugar de nidificación y las asociaciones interespecíficas de cuatro especies reproductoras de Charadriiformes en el delta del Po, Italia, en 1991. Las características físicas (longitud, tamaño, distancia a tierra firme y a otras islas, presencia de pequeñas dunas, etc.) de ocho islas y dos penínsulas fueron estudiadas. Dentro de las islas se seleccionaron al azar una serie de puntos donde se estimaron unos parámetros (distancia a la playa, elevación sobre el nivel del mar, cobertura vegetal, tipo de sustrato) que fueron comparados con los de una serie de nidos. Aparte de la Gaviota Patiamarilla *Larus cachinnans*, que seleccionó las islas más largas y grandes, el resto de especies estudiadas (Ostrero Euroasiático *Haematopus ostralegus,* Chorlitejo Patinegro *Charadrius alexandrinus* y Charrancito *Sterna albifrons*) no mostró preferencias a este nivel de estudio. Las características a nivel de especie en el lugar donde ubicar el nido, difirieron en términos generales de los puntos aleatorios y, menos frecuentemente, de las otras especies. Las Gaviotas Patiamarillas prefieren los sitios con menos arena, mayor cobertura de vegetación y con presencia de plantas altas, lo contrario que seleccionó el Chorlitejo Patinegro. El Ostrero y el Charrancito seleccionaron valores intermedios entre los seleccionados por las dos especies anteriores. Nuestro estudio sugiere que los factores físicos (p.e. características del sustrato donde construir el nido) y factores de comportamiento (la asociación entre especies se puede ver reflejada en una mejor protección frente a los predadores, o debido a un limitado solapamiento alimentario en las zonas intermareales próximas) interaccionan con la selección del hábitat de las cuatro especies estudiadas en el Delta del Po. Para conocer la asociación observada entre Ostreros y Gaviotas Patiamarillas serían necesarios más estudios específicos.

Palabras clave: asociación, Charadriiformes, Delta del Po, lugar de nidificación.

INTRODUCTION

Gulls and terns breed colonially, due to similar habitat preferences, mutual advantages provided by better predator avoidance, and the possibility of exchange of information for food acquisition (Erwin, 1979; Burger & Gochfeld, 1990b; Oro, 1996; Rolland *et al.*, 1998). On the other hand, colonial birds may compete for resources, and colonies may attract predators

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(Wittenberger & Hunt, 1985; Krebs & Davies, 1987; Siegel-Causey & Kharitonov, 1990). The advantages of breeding in gull and tern colonies also attract waders (Hildén & Vuolanto, 1972; Göransson *et al.*, 1975; Brearey & Hilden, 1985), ducks (Evans, 1970; Dwernychuck & Boag, 1972; Götmark & Ahlund, 1988; Götmark, 1989) and grebes (Burger, 1984a; Young & Titman, 1986; Hill *et al.*, 1997). In the Mediterranean Region few data are available on the nesting habitat selection of waders and seabirds, despite a recent increase in papers dealing with this subject (Fasola & Bogliani, 1984; Monbailliu & Torre, 1986; Goutner & Goutner, 1987; Goutner, 1987, 1990, 1992; Martinez-Vilalta, 1989, 1991, 1997; Bosch *et al.*, 1994; Scarton & Valle, 1996; Valle & Scarton, 1996; Bosch & Sol, 1998) and only two studies have investigated the interrelationships among several seabird species in this Region (Fasola & Canova, 1991, 1992).

This study aims to describe breeding habitat and nest site selection of four Charadriiformes species in the Po Delta, Italy. Our main goals were: (1) to characterize large and small- scale habitat features (both at the level of islands used for nesting and at nest site characteristics level) for each species; (2) to analyze if they preferred some particular characteristics, i.e. showed significant differences from a random distribution; and (3) if there were particular associations among two or more of them, suggesting in this case possible causal explanations.

STUDY AREA AND METHODS

On the barrier islands of the Po Delta (62,000 ha in surface, the largest Italian delta and one of the largest in the Mediterranean) four Charadriiformes breed: Oystercatchers *Haematopus ostralegus*, Kentish Plovers *Charadrius alexandrinus*, Yellow-legged Gulls *Larus cachinnans* and Little Terns *Sterna albifrons* (Fasola, 1986; Scarton *et al.*, 1994a; Valle & Scarton, 1996). This area is one of the most important breeding sites in the Mediterranean for Oystercatchers (Scarton *et al.*, 1993, 1998), and in the 1980's it supported about 30% of the population of Little Terns of the Western Palearctic (ca. 3000 nests according to Fasola (1986) although it has decreased in the following years; Fasola & Canova, 1996). In the Po Delta, Oystercatchers nest in open areas, both on dunes and on beaches, as reported for other Mediterranean sites (Martinez-Vilalta *et al.*, 1983; Goutner & Goutner, 1987). Kentish Plovers are found mainly on the beaches, both isolated and in small colonies, frequently with Little Terns and Oystercatchers (Valle *et al.*, 1995). Yellow-legged Gulls colonized this area at the beginning of the 1980s (Scarton & Valle, 1996). In the inner part of the Delta, where fish farms are the most characteristic feature, the above reported gulls and waders (but not the Oystercatchers) and other species (such as Common Terns *Sterna hirundo*) nest as well.

The nesting habitat studied in our area consists of several narrow, sandy barrier-islands at the seaward limit of the Po Delta (Fig. 1). Eighteen islands and two peninsulas lie between the mouths of the Adige (45°09′N - 12°20′E) and Po di Volano (44°49′N - 12°17′E) rivers, over some 50 km. Distance between the islands and the mainland ranges between 0.7 and 3.1 km. The islands range in size from 0.6 to 418 ha (63.1 ± 92.4, mean ± SD) and from 0.1 to 8.5 km (3.2 ± 2.4) in length. In the statistical treatment, peninsulas were considered as «islands», with distance from mainland equal to zero. One island and part of one peninsula are completely urbanized. Sandy beaches and low dunes, covered with psammophilous vegetation (such as *Ammophila arenaria, Agropyron junceum* and *Cakile maritima*) are the most characteristic features of the habitat. Inland the islands are often covered with bushes and small trees, and reedbeds can fringe the inner coastline. Between the islands and the mainland lie large shallow lagoons with tidal flats, often used as feeding grounds by the birds. Possible egg or chick predators breeding in the islands are Marsh Harriers *Circus aeruginosus*, Montagu's Harriers *Circus pygargus*, Magpies *Pica pica* and Hooded Crows *Corvus corone cornix*. Among mammals, we often observed brown rats *Rattus norvegicus*, whereas red foxes *Vulpes vulpes* or their footprints were never seen. In late spring and in summer some of the Po Delta islands are heavily disturbed by visiting tourists and fishermen.

The field work was conducted during the 1991 breeding season, visiting all islands by boat and on foot. During these field trips, data

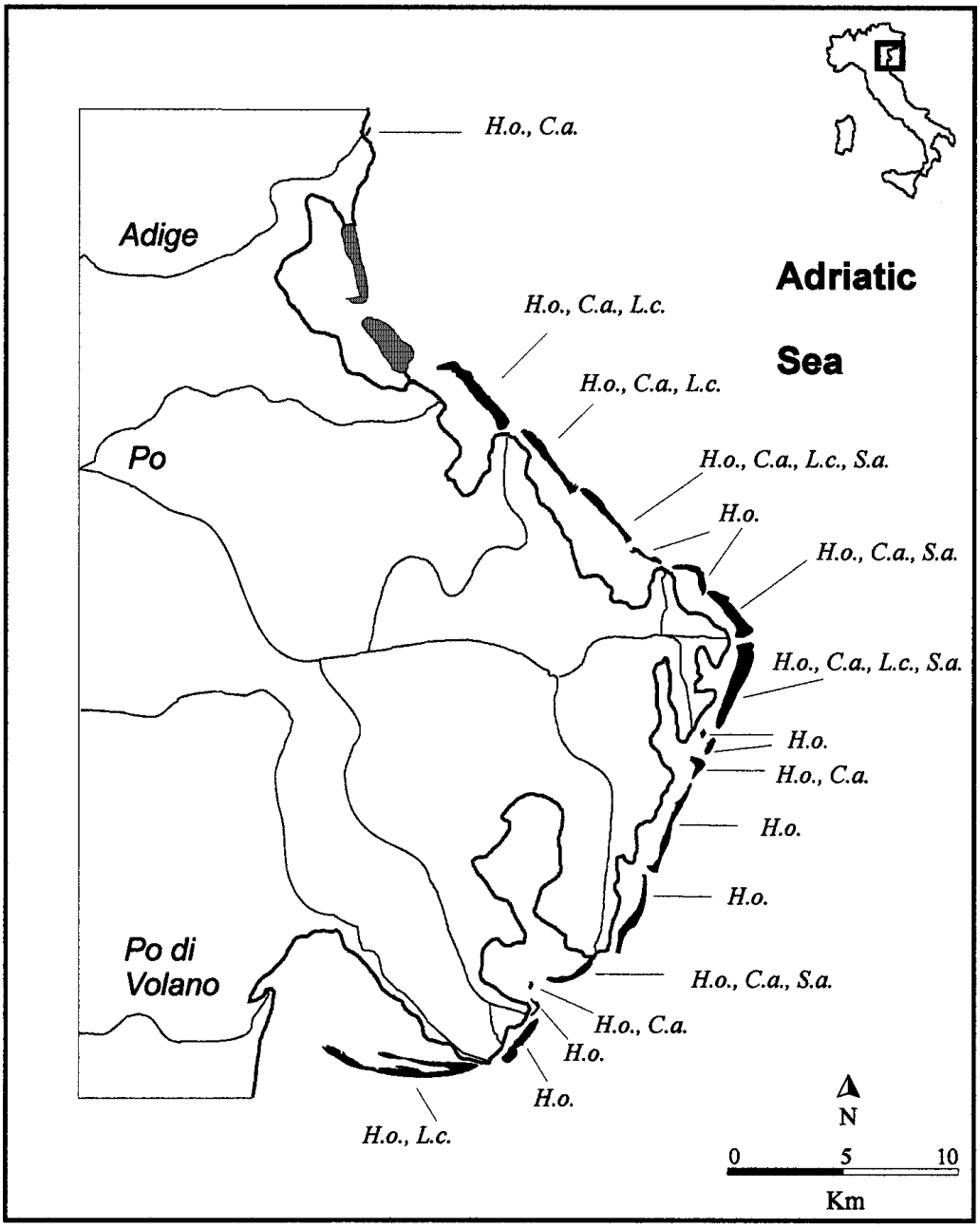

FIG. 1.—Map of the Po Delta, which shows the barrier islands and the peninsulas, where data for this study were collected. Urbanized peninsulas and islands are marked in gray whereas the non urbanized ones are marked in black. Abbreviations (as in table 1) refers to the islands and peninsulas occupied by each species. *[Mapa del delta del Po donde aparecen la barra de islas y las penínsulas donde se ha desarrollado este estudio. Las penínsulas e islas urbanizadas están marcadas en gris, por otro lado, las zonas no urbanizadas están representadas en negro.]*

were collected for random sites and nest sites of each species, as described as follows: 1) location, classified in dune or beach; 2) distance from the sea; 3) elevation: we visually divided nest site elevation, in relation to the apparent level of the sea, into three arbitrary classes: < 0.2 m (referred to as low), 0.2-1 m (intermediate) and more than 1 m (high); 4) substrate, classified into six categories: sand, bivalve shells, wrack, sand-shells, sand-wrack and wrack-shells. The substrates were assigned to a single name-type when the latter covered more than 70% of the surface and to a double-name type when each covered at least 30% (Fasola & Canova, 1991); 5) percentage (to the nearest 5% in a radius of 1 m and 5 m around nests and random points), of sand, wrack, bivalve shells, bare ground (that is, sand + wrack + bivalve shells); 6) vegetation structure, i.e. height, coverage and species occurrence; 7) other species nesting in the surroundings (in a radius of 100 m).

For Oystercatchers and Kentish Plovers all the nests found were included in the analysis; for Yellow-legged Gulls and Little Terns only a randomly chosen sample of nests in the colonies was considered. Random sites were chosen by throwing a 1 × 1 m quadrat along transects at each study site; all the data were collected on the side of the island facing the sea, since that facing the lagoons is completely covered with thick and high vegetation, thus being unsuitable for the selected species as breeding site.

A colony was defined as any aggregation of breeding birds (Burger & Gochfeld, 1990a); for the purposes of our study a single pair of a species was considered a «colony» (Burger & Gochfeld, 1990b). Colony site refers to a place where a group of bird breeds. Each colony was recorded on maps of scale 1:10,000. From these we calculated island size and length, minimum, maximum and mean distance from the mainland. Statistical analysis was performed with a loglinear model (HILOGLINEAR, SPSS/PC+ package) to test interactions among variables rather than the main effects (see Siegel-Causey, 1991). We tested if species selected nesting habitat independently of social and environmental variables, and we looked for significant interactions between species and their environment. To apply this analysis the islands were divided into sectors of 250 m (which was the maximum observed length of a colony of Yellow-legged Gulls), in which we recorded the occurrence of each species (classified as present or absent). Sectors were delimited starting from the northern tip of the islands and categorized as «peripheral» (less than 250 m from the tip) and «central» (more than 250 m; Valle & Scarton, 1996).

Mann-Whitney U-test, Wilcoxon test and Kruskall-Wallis ANOVA were used where appropriate. A non-parametric Tukey test (Zar, 1996) was used to perform *a posteriori* multiple comparisons; data in the text are expressed as mean $\pm$ SD, and a P value <0.05 was considered significant.

RESULTS

Distribution

We found 16 nests of Oystercatchers (out of 36 pairs breeding in 1991; Scarton *et al.*, 1993), 19 nests of Kentish Plovers (out of 75-100 estimated breeding in the early nineties; Valle *et al.*, 1996), five colonies of Yellow-legged Gulls and 4 colonies of Little Terns. One sector hosted all the species, five sectors three species (two with Oystercatchers, Kentish Plovers, and Yellow-legged Gulls; three with Oystercatchers, Kentish Plovers and Little Terns) and 13 sectors two species (11 sectors with Oystercatchers and Kentish Plovers, two sectors with Oystercatchers and Yellow-legged Gulls).

All the islands were colonized, except the one which was completely urbanized. The species distribution was different both considering the area as a whole and at a larger scale, i.e. on the islands. Oystercatchers were found all along the coastline, though not homogeneously distributed; in the occupied islands, density ranged between 0.4 and 5.3 pairs km^{-1} of shore (with a mean of 1.9 ± 1.7). The number of breeding pairs on each barrier island was correlated to the number of breeding species ($r = 0.50$, $P < 0.05$, $n = 20$). The distribution of Kentish Plovers was also not homogeneous, with large stretches of coast completely deserted and clusters of nests at other sites. Overall, the density of Kentish Plovers in the occupied islands was 2.3 pairs km^{-1} of shoreline and the mean size of nest clusters was 5.1 ± 5.4. Nests were also found on the peninsula which is urbanized.

A significant correlation was found between Kentish Plovers pairs and number of species breeding in the same island ($r = 0.79$, $n = 20$, $P < 0.001$).

Yellow-legged Gulls were concentrated in five large colonies, homogeneously spaced along the coastline, at 10-12 km intervals; peninsulas and urbanized islands were not colonized by gulls. Colony size was estimated to vary between 250 and 500 pairs. Little Terns concentrated in four colonies; colony sizes ranged between 50 and 500 pairs. The urbanized island was avoided, whilst the peninsula which was not urbanized was colonized.

Island selection

Oystercatchers occupied all the islands or peninsulas, except those urbanized. No significant difference was found in the physical parameters between occupied and non occupied islands (Mann Whitney U-test and χ^2 test; table 1). The species bred both on dunes and on beaches, without any significant preference. Kentish Plovers were found both on small and large islands and both in peripheral and central sectors, without significant preferences (Mann Whitney U-test and test; Table 1). Yellow-legged Gulls significantly selected the largest (85.3 ± 43.2 *vs* 56.7 ± 104.2 ha, Mann-Whitney $U = 15.0$, $n = 20$, $P < 0.05$) and longest islands (5.1 ± 2.1 *vs* 2.6 ± 2.0 km, Mann-Whitney $U = 14.5$, $n = 20$, $P < 0.05$; Table 1). Little Tern colonies were only found at the ends of the islands and on low sites, with no significant difference found among the physical parameters of the islands (Mann Whitney U-test and χ^2 test; Table 1).

Nest site selection

Nests of Oystercatchers, Kentish Plovers and Little Terns were located in the most open areas (Table 2), those of the Kentish Plovers frequently on shells and on low sites. Yellow-legged Gull nests were found both in peripheral and central sites, this species always preferring areas with the highest vegetation cover (Tables 2, 3 and 4). Nests were almost always found under *A. arenaria* tussocks. Kentish Plovers nested on low vegetated areas with nests frequently located under small plants (such as *Cakile maritima*), which partially hid the eggs. The occurrence and height of vegetation were significantly more important for Yellow-legged Gull nests than for the other species.

Considering the habitat features in a 1-m radius, the location of Oystercatcher nests had more proportion of sand, less vegetation cover and more bare ground than random points, whereas Kentish Plover nest surroundings had less vegetation cover, more proportion of shells and a lower vegetation height (Table 2). Differences were very marked for Yellow-legged Gulls, with less proportion of sand, more vegetation cover and taller plants; conversely, Little Terns showed a slightly significant preference for sites with less wrack coverage (Table 2). Nest site and random point characteristics were more similar among them in a 5-m radius, with only Yellow-legged Gulls and Kentish Plovers still showing several significant differences for vegetation cover, shell cover, proportion of bare ground and distance to the sea (Table 2).

In Table 3 the results are reported according to the nature of the substrate of nests and random points. Since categories such as «wrack» and «sand-shells» represented only one case each, they were pooled with «sand» and «shells» respectively. The distribution of nests on the substrates showed a higher occurrence of «shells», in comparison with random points, for Kentish Plovers ($\chi^2_1 = 8.38$, $P < 0.01$, Yates' correction) and Little Terns ($\chi^2_1 = 3.17$, $P < 0.05$, Yates' correction), whereas Oystercatchers and Yellow-legged Gulls did not select any particular substrate. In Table 4 the results are presented according to the estimated nest-site elevation. Kentish Plovers and Little Terns were found only at low sites, whereas Yellow-legged Gulls mostly at high sites and Oystercatchers at low and intermediate sites. Nevertheless, statistical significant preferences were observed only for Yellow-legged Gulls ($\chi^2_2 = 115.2$, $P < 0.0001$) and Oystercatchers ($\chi^2_2 = 9.5$, $P < 0.01$).

The four species studied differed in the distance at which they nested from the sea, the distance increasing from Little Terns through Kentish Plovers and Oystercatchers to Yellow-legged Gulls. Nevertheless, only for the last species were distances significantly different, i.e. farther from the shoreline, as compared

TABLE 1

Comparisons between characteristics of occupied and non occupied islands, $n = 20$ (mean ± SD is shown). Significantly different values are indicated in bold type (Mann Whitney U-test and χ^2 test: all $P < 0.05$). *H.o.*: *Haematopus ostralegus*, *C.a.*: *Charadrius alexandrinus*, *L.c.*: *Larus cachinnans*, *S.a.*: *Sterna albifrons. [Características de las islas ocupadas y sin ocupar*, n = *20 (media + DS). Las diferencias significativas son mostradas en negrita (Test de la U de Mann Whitney y test de* χ^2: P < *0,05.* H.o.: Haematopus ostralegus, C.a.: Charadrius alexandrinus, L.c.: Larus cachinnans, S.a.: Sterna albifrons.*]*

	H.o.	*C.a.*	*L.c.*	*S.a.*
No. of occupied islands *[n.º de islas ocupadas]*	18	9	5	4
Length (km) *[Longitud]* occupied *[ocupadas]*	3.0 ± 2.3	3.4 ± 2.2	**5.1 ± 2.1**	3.7 ± 1.2
non-occupied *[no ocupadas]*	5.4 ± 3.0	3.0 ± 2.8	**2.6 ± 2.0**	3.1 ± 2.7
Area (ha) *[Superficie]* occupied *[ocupadas]*	44.3 ± 42.1	43.3 ± 34.6	**85.3 ± 43.2**	64.8 ± 42.4
non-occupied *[no ocupadas]*	33.3 ± 262.6	87.3 ± 13.6	**56.7 ± 104.2**	63.2 ± 102.3
Mean distance to mainland (km) *[Distancia media a tierra firme (km)]* occupied *[ocupadas]*	1.8 ± 1.0	1.9 ± 1.2	2.4 ± 0.7	1.6 ± 0.7
non-occupied *[no ocupadas]*	1.7 ± 0.5	1.7 ± 0.6	1.6 ± 0.9	2.5 ± 1.5
Distance to the nearest island (km) *[Distancia a la isla más próxima (km)]* occupied *[ocupadas]*	0.27 ± 0.26	0.33 ± 0.32	0.25 ± 0.22	0.20 ± 0.16
non-occupied *[no ocupadas]*	0.16 ± 0.5	0.18 ± 0.7	0.27 ± 0.27	0.28 ± 0.27
Islands with dunes, % *[% de islas con dunas]* occupied (n) *[ocupadas]*	61 (11)	73 (8)	80 (4)	75 (3)
non-occupied (n) *[no ocupadas]*	50 (1)	44 (4)	53 (8)	56 (9)

with those of random points (Table 2). Significant differences were observed between the species pairs Oystercatchers and Yellow-legged Gulls, Kentish Plovers and Yellow-legged Gulls, Yellow-legged Gulls and Little Terns.

Associations

In the five colonies present, Yellow-legged Gull nests were never intermixed with those of the other species, the latter being found only at the edge of the colonies. The nearest neighbor distances from a Yellow-legged Gull nest were 24 m for Oystercatchers, 79 m for Kentish Plovers and 59 m for Little Terns. A single Yellow-legged Gull nest was found at the edge of a colony of Little Terns. The four sites of Little Terns also hosted Kentish Plovers and had been previously occupied by Oystercatchers. Three significant associations were found among the four species: Oystercatchers were associated

TABLE 2

Nest site characteristics in four Charadriiformes breeding in the Po Delta; only significantly different comparisons are marked. *P* refers to Kruskal-Wallis ANOVA. * : $P < 0.05$ or $P = 0.05$ for non-parametric Tukey-test. # : $P < 0.05$ for 1-m *vs* 5-m parameter comparison, Wilcoxon test. *H.o.*: *Haematopus ostralegus*, *C.a.*: *Charadrius alexandrinus*, *L.c.*: *Larus cachinnans*, *S.a.*: *Sterna albifrons.*
*[Características del lugar donde construyen los nidos las cuatro especies de Charadriiformes reproductores en el delta del Po. Unicamente se marcan las diferencias significativas. * :* $P < 0,05$ *o* $P = 0,05$ *valores de significación en un análisis no paramétrico de Tukey. # :* $P < 0,05$ *para la comparación entre 1-m* vs *5-m con el test de Wilcoxon.* H.o.: Haematopus ostralegus, C.a.: Charadrius alexandrinus, L.c.: Larus cachinnans, S.a.: Sterna albifrons.*]*

	H.o.	*C.a.*	*L.c.*	*S.a.*
No. of nests	16	19	20	21
1 m circle (%)				
Sand *[Arena]*	85 ± 24	62 ± 23 *	48 ± 21#	80 ± 23 *
Vegetation *[Vegetación]*	4 ± 8 *	4 ± 12 *	47 ± 20# *	1 ± 2 *
Wrack *[Algas]*	3 ± 5	9 ± 10	5 ± 11	5 ± 7#
Shells *[Conchas]*	8 ± 21 *	24 ± 17 *	1 ± 1 *	14 ± 25 *
Bare ground *[Suelo desnudo]*	96 ± 8 *	94 ± 12 *	53 ± 21# *	99 ± 2 *
Vegetation height (cm) *[Altura de la vegetación]*	8 ± 15 *	7 ± 17 *	51 ± 21 *	4 ± 11 *
5 m circle (%)				
Sand *[Arena]*	82 ± 26	62 ± 23	63 ± 20	81 ± 24
Vegetation *[Vegetación]*	5 ± 6 *	2 ± 6 *	35 ± 20 *	1 ± 4 *
Wrack *[Algas]*	4 ± 7	11 ± 11 *	3 ± 5 *	4 ± 5
Shells *[Conchas]*	9 ± 20 *	23 ± 18 *	1 ± 1 *	14 ± 26 *
Bare ground *[Suelo desnudo]*	95 ± 9 *	96 ± 7 *	66 ± 20 *	99 ± 4 *
Distance to the sea (m) *[Altura de la vegetación]*	48 ± 27 *	39 ± 15 *	62 ± 15 *	37 ± 10 *

TABLE 3

Nests and random points distribution according to the substrate nature (χ^2=9.7, 4 d.f., $P < 0.05$). *H.o.*: *Haematopus ostralegus*, *C.a.*: *Charadrius alexandrinus*, *L.c.*: *Larus cachinnans*, *S.a.*: *Sterna albifrons. [Distribución por sustratos de los nidos y los puntos aleatorios. ($\chi^2 = 9,7$, 4 g.l., $P < 0,05$).* H.o.: Haematopus ostralegus, C.a.: Charadrius alexandrinus, L.c.: Larus cachinnans, S.a.: Sterna albifrons*.]*

	Random	*H.o.*	*C.a.*	*L.c.*	*S.a.*
Substrate *[sustrato]*					
Sand *[arena]*	21	12	10	17	15
Shells/wrack *[conchas/algas]*	2	4	9	3	6
N	23	16	19	20	21

TABLE 4

Nests and random points distribution according to the class of estimated elevation above sea level (χ^2 = 41.5, 8 d.f., $P < 0.001$). Low = < 0.2 m; medium = 0.2-1 m, high = > 1 m. *H.o.*: *Haematopus ostralegus*, *C.a.*: *Charadrius alexandrinus*, *L.c.*: *Larus cachinnans*, *S.a.*: *Sterna albifrons.*
[Distribución por clases de elevación sobre el nivel del mar de los nidos y los puntos aleatorios. (χ^2 = 41,5, 8 g.l., $P < 0,001$). *Bajo= 0,2 m; medio = 0,2-1 m, alto = > 1 m.* H.o.: Haematopus ostralegus, C.a.: Charadrius alexandrinus, L.c.: Larus cachinnans, S.a.: Sterna albifrons*.]*

	Random	*H.o.*	*C.a.*	*L.c.*	*S.a.*
Elevation *[nivel]*					
Low *[bajo]*	19	9	17	3	19
Medium *[medio]*	2	5	1	7	1
High *[alto]*	2	2	1	10	1
N	23	16	19	20	21

both with Yellow-legged Gulls and Kentish Plovers, while the latter were associated with Little Terns (Table 5). No higher order interaction was significant. Neither the physical parameters examined nor the occurrence of other species influenced the observed associations, as it appears from the lack of significance in Table 5.

DISCUSSION

Habitat and nest site selection

Overall, the four species occurred along the whole stretch of coast, but their distribution along it and on each island was significantly different. Physical parameters of the islands do not seem to play an important role in nest habitat selection for Oystercatchers, Kentish Plovers and Little Terns in our study area. As previously reported for the Ebro Delta (Martinez-Vilalta *et al*., 1983), Oystercatchers nests were always near small, periodical stagnant pools**.** In the Po Delta, this species used both elevated (i.e. dunes) and low areas (i.e. beaches), but site selection is influenced by the availability of the former. No particular nest elevation was reported for Oystercatchers at other Mediterranean sites (Martinez-Vilalta *et al*., 1983; Goutner & Goutner, 1987), while a preference for high sites was reported for a similar species,

TABLE 5

Interrelationships among four species of Charadriiformes breeding in the Po Delta. Summary of interactions fitted by log-linear analysis; no higher order interaction, i.e. comparisons with three or four species, were significant. *H.o.*: *Haematopus ostralegus*, *C.a.*: *Charadrius alexandrinus*, *L.c.*: *Larus cachinnans*, *S.a.*: *Sterna albifrons.*

[Relación entre las cuatro especies de Charadriiformes reproductoras en el delta del Po. Resumen de las interacciones del análisis log-linear; ninguna de las interacciones de orden mayor a dos especies fueron significativas. H.o.: Haematopus ostralegus, C.a.: Charadrius alexandrinus, L.c.: Larus cachinnans, S.a.: Sterna albifrons.*]*

K	*d.f.*	*Pearson Chi-square*	*P value*
4	1	0.000	0.9999
3	5	0.001	1.0000
2	11	57.392	0.0000
1	15	256.706	0.0000
*H.o. * C.a.*		8.164	<0.01
*C.a. * S.a.*		7.592	<0.01
*H.o. * L.c.*		4.016	<0.05

the American Oystercatcher *Haematopus palliatus*, in the USA (Lauro & Burger, 1989). The Pied Oystercatcher *Haematopus longirostris* preferred open, lower elevated sites to higher, shrubby sites in a study carried out by Lauro & Nol (1993) in Tasmania. These authors found that low sites implied a lower breeding success and represented a suboptimal habitat, which was occupied by younger and less experienced birds. In the Po Delta, by nesting on sites of intermediate elevation and vegetation cover, Oystercatchers seem to achieve a compromise which provides safety from flooding by normal high tides, but still guarantees adequate visibility for predator detection (Valle & Scarton, 1996).

Kentish Plovers were found in open areas of large and small islands, and on central and peripheral sites, with no significant differences. The preference for open areas is well known (Cramp & Simmons, 1983; Page *et al*., 1995), though its significance is unclear. Schultz & Stock (1993) have recently reported a lower breeding success in low vegetated areas than in higher ones. As for both Kentish Plovers and Little Terns, preferential location of eggs on shells has been explained with a better camouflage, giving rise to a lower predation rate (Goutner, 1990).

Yellow-legged Gulls occupied the larger islands, mostly on elevated, highly vegetated zones, as previously reported for other Mediterranean sites (Perco *et al*., 1986; Fasola & Canova, 1991, 1992; Goutner, 1992; Bosch & Sol, 1998). Similar locations led to lower rates of clutch losses from tidal flooding, aerial predators and adverse weather conditions for the related species *Larus argentatus* in North American colonies (Burger & Shisler, 1978).

Associations

No quantitative investigation has been carried out on the association among species of Charadriiformes in Mediterranean sites, even when aggregation of several species usually occurs there. In the Ebro Delta few interactions were noticed among Oystercatchers and the other nesting Charadriiformes (Kentish Plovers, Common Terns, Avocets *Recurvirostra avosetta*, Yellow-legged Gulls; Martinez-Vilalta *et al.*, 1983), while in the Evros Delta it has been suggested that nesting together (by more than ten species of Charadriiformes including Oystercatchers, Kentish Plovers and Terns) might reflect common habitat preferences (Goutner & Goutner, 1987).

The significant association between Oystercatchers and Kentish Plovers, whose nests were found within a few meters (nearest neighbor distance: 8 m), might be explained by the partial overlap in feeding habitat and prey (such as *Carcinus*, *Littorina*, *Cardium*; Cramp & Simmons, 1983). This might cause a simultaneous and identical choice of sites close to optimal feeding areas. We hypothesize that Kentish Plovers, which are known to join more demonstrative and aggressive species (Cramp & Simmons, 1983), might benefit from a lower predation rate, due to the aggressiveness of Oystercatchers, as reported for other «timid» waders joining more aggressive congeners (Dyrcz *et al*., 1981). However, it is known that Oystercatchers may prey upon Kentish Plover eggs (Schulz & Stock, 1993).

Kentish Plovers were also associated with Little Terns, which on some occasions were defined as «monospecific colonialists» (Fasola & Canova, 1991; Goutner, 1990). Nevertheless, the latter has been as reported being significantly associated both with other terns (Common Tern; Fasola & Canova, 1992; Scarton *et al*., 1994b) and with waders (Redshanks *Tringa totanus*, Valle & Scarton, 1995). Little Terns and Kentish Plovers were frequently found breeding together on the northern Adriatic coastline (Fasola, 1986; Valle *et al.*, 1995), though the significance of this association was never analyzed. Kentish Plovers are ideal associates for Little Terns. They breed well before Little Terns and they could indicate a safe site to them. In turn, Kentish Plovers could benefit from greater egg predation on the terns' nests, which are more easily detectable by predators and humans, as reported for the Venetian Lagoon (Valle *et al.*, 1995).

The Yellow-legged Gull was also reported as a «monospecific colonialist» (Fasola & Canova, 1991), in view of its size and predatory habits on eggs and chicks. Nevertheless, in our area Yellow-legged Gulls and Oystercatchers were significantly associated (Table 5). In the years following that of this study, we observed Oystercatcher nests at less than five meters from Yellow-legged Gull nests on several occasions. The reasons for this possible association were never analyzed, even when the two species nest together as it occurs at several Mediterranean sites, e.g. the Ebro Delta and the Evros Delta (Martinez-Vilalta *et al*., 1983; Goutner & Goutner, 1987). On the Canadian coastline, Black Oystercatchers *Haematopus bachmani* and Glaucous-winged Gulls *Larus glaucescens* (similar in size and habits to European Oystercatchers and Yellow-legged Gulls, respectively) are significantly associated (Vermeer *et al*., 1992a). Nevertheless, where gull numbers increase (as is the case for the Po Delta), Oystercatchers are displaced toward the tideline and so they are more exposed to spring storms and flooding (Vermeer *et al*., 1992b). In the Po Delta the distance from the sea of Oystercatcher nests is not influenced by nesting Yellow-legged Gulls, so it seems this is not the case for our study area. The observed association between the two species clearly deserves further research. Indeed, our study indicates that physical and behavioral factors interact in the habitat selection of Oystercatchers, Kentish Plovers, Yellow-legged Gulls and Little Terns in the Po Delta.

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BIBLIOGRAPHY

BOSCH, M., PEDROCCHI, V., GONZÁLEZ-SOLÍS, J. E. & JOVER, L. 1994. Densidad y distribución de los nidos de la Gaviota patiamarilla *Larus cachinnans* en las islas Medes. Efectos asociados al hábitat y al descaste. *Doñana, Acta Vertebrata*, 21: 39-51.

BOSCH, M. & SOL, D. 1998. Habitat selection and breeding success in Yellow-legged Gulls *Larus cachinnans*. *Ibis*, 140: 415-421.

BREAREY, D. & HILDÉN O. 1985. Nesting and egg predation by Turnstones *Arenaria interpres* in larid colonies. *Ornis Scandinavica*, 16 : 283-292.

BURGER, J. 1984a. Grebes nesting in Gull colonies: protective associations and early warning. *American Naturalist*, 123: 317-327.

BURGER, J. 1984b. Colonial stability in Least Terns. *Condor*, 86: 61-67.

BURGER, J. & GOCHFELD, M. 1990a. Nest site selection in Least Tern *Sterna antillarum* in New Jersey and New York. *Colonial Waterbirds*,13: 31-40.

BURGER, J. & GOCHFELD, M. 1990b. *The Black Skimmer: social dynamics of a colonial species*. Columbia University Press. New York.

BURGER, J. & SHISLER, J. 1978. Nest site selection and competitive interactions of Herring and Laughing Gulls in New Jersey. *Auk*, 95: 252-266.

CRAMP, S. & SIMMONS, K. E. L. 1983. *The birds of the Western Palearctic*. Vol.5. Oxford University Press. Oxford.

DWERNYCHUCK, L. W. & BOAG, D. A. 1972. Ducks nesting in association with gulls - an ecological trap? *Canadian Journal of Zoology*, 50: 559-563.

DYRCZ, A., WITKOWSKI, J. & OKULEWICZ, J. 1981. Nesting of «timid» waders in the vicinity of «bold» ones as an antipredator adaptation. *Ibis*, 123: 542-545.

ERWIN, R. M. 1979. Species interaction in a mixed colony of Common Tern *Sterna hirundo* and Black Skimmers *Rynchops niger*. *Animal Behavior*, 27: 1054-1062.

EVANS, R. M. 1970. Oldsquaws nesting in association with Arctic Terns at Churchill, Manitoba. *Wilson Bulletin*, 82: 383-390.

FASOLA, M. 1986. Fraticello *Sterna albifrons*. In, M. Fasola (Ed.): *Distribuzione e popolazione dei Laridi e Sternidi nidificanti in Italia*, pp.: 107-119. *Supplemento Ricerche Biologia Selvaggina*, XI.

FASOLA, M. & BOGLIANI, G.1984. Habitat selection and distribution of nesting Common and Little Terns on the Po River (Italy). *Colonial Waterbirds*, 7: 127-133.

FASOLA, M. & CANOVA, L. 1991. Colony site selection by eight species of gulls and terns breeding in the «Valli di Comacchio» (Italy). *Bollettino di Zoologia*, 58: 261-266.

FASOLA, M. & CANOVA, L. 1992. Nest habitat selection by eight syntopic species of Mediterranean gulls and terns. *Colonial Waterbirds*, 15: 169-178.

FASOLA, M. & CANOVA, L. 1996. Conservation of Gull and Tern Colony sites in Northeastern Italy, an internationally important bird area. *Colonial Waterbirds*, 19: 59-67.

GÖRANSSON G., KARLSSON, J., NILSSON, S. G. & ULFSTRAND, S. 1975. Predation on birds nests in relation to antipredator aggression and nest density: an experimental study. *Oikos*, 26: 117-129.

GÖTMARK, F. 1989. Costs and benefits to Eiders nesting in Gull colonies: a field experiment. *Ornis Scandinavica*, 20: 283-288.

GÖTMARK, F. & AHLUND, S. 1988. Nest predation and nest site selection among Eiders *Somateria mollissima*: the influence of gulls. *Ibis*, 130: 111-123.

GOUTNER, V. 1987. Vegetation preferences by colonies of Mediterranean Gulls *Larus melanocephalus* and Gull-billed Terns *Gelochelidon nilotica* in the Evros Delta. *Seevögel*, 8: 29-31.

GOUTNER, V. 1990. Habitat selection of Little Terns in the Evros Delta, Greece. *Colonial Waterbirds*, 13: 108-114.

GOUTNER, V. 1992. Habitat use in Yellow-legged Gull *Larus cachinnans michahellis* coastal wetlands colonies of North-East Greece. *Avocetta*, 16: 81-85.

GOUTNER, V. & GOUTNER, C. 1987. Nest site selection of Oystercatchers *Haematopus ostralegus* in the Evros Delta. *Rivista italiana di Ornitologia*, 57: 187-192.

HILL, W. L., JONES, K. J., HARDENBERGH, C. L. & BROWNE, M. 1997. Nest distance mediates the costs of coloniality in Eared Grebes. *Colonial Waterbirds*, 20: 470-477.

HILDEN, O. & VUOLANTO, S. 1972. Breeding of the Red-necked Phalarope *Phalaropus lobatus* in Finland. *Ornis Fennica*, 49: 57-85.

KREBS, J. R. & DAVIES, N. B. 1987. *An introduction to behavioral ecology*. Blackwell. Oxford.

LAURO, B. & BURGER, J. 1989. Nest-site selection of American Oystercatchers *Haematopus palliatus* in salt marshes. *Auk*, 106: 185-192.

LAURO B. & NOL, E. 1993. The effect of prevailing wind direction and tidal flooding on the reproductive success of Pied Oystercatchers *Haematopus longirostris*. *Emu*, 93: 199-202.

MARTÍNEZ-VILALTA, A., MOTIS, A., MATHEU, F. & LLIMONA, F. 1983. Data on the breeding biology of the Oystercatcher *Haematopus ostralegus* in the Ebro Delta. *Ardea*, 71: 229-234.

MARTÍNEZ-VILALTA, A. 1989. Cens de limicoles colonials del Delta de l'Ebre. *Butlletí Parc natural del Delta de l' Ebre*, 4: 37-40.

MARTÍNEZ-VILALTA, A. 1991. Primer censo nacional de limícolas coloniales y Pagaza Piconegra. *Ecología*, 5: 321-327.

MARTÍNEZ-VILALTA, A. 1997. Situación de las poblaciones reproductoras de aves limícolas en España. In, A. Barbosa (Ed.): *Las aves limícolas en España*, pp. 157-173. Organismo Autónomo de Parques Nacionales. Ministerio de Medio Ambiente. Madrid.

MONBAILLIU, X. & TORRE, A. 1986. Nest site selection of Yellow-legged and Audouin's Gulls at Isola dell'Asinara. In, Medmaravis & X. Monbailliu (Eds.): *Mediterranean marine Avifauna*, pp. 245-263. Population Studies and Conservation. NATO ASI Series. Springer Verlag. Berlin.

ORO, D. 1998. Colonial seabird nesting in dense and small sub-colonies: an advantage against aerial predation. *Condor*, 98: 848-850.

PAGE, G. W., WARRINER, J. S., WARRINER, J. C. & PATON, P. W. C. 1995. Snowy Plover *Charadrius alexandrinus*. In, A. Poole & F. Gill (Eds.): *The Birds of North America*, No. 154. The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union. Washington.

PERCO, F., LAMBERTINI, M., LO VALVO, M. & MILONE, M. 1986. Gabbiano reale *Larus cachinnans*. In, M. Fasola (Ed.): *Distribuzione e popolazione dei Laridi e Sternidi nidificanti in Italia*, pp. 53-72. *Supplemento Ricerche Biologia Selvaggina*, IX.

PIENKOWSKI, M. W. 1988. Breeding biology and population dynamics of Ringed Plover *Charadrius hiaticula* in Britain and Greenland. *Journal of Zoology*, 202: 326-337.

ROLLAND, C., DANCHIN, E. & DE FRAIPONT, M. 1998. The evolution of coloniality in birds in relation to food, habitat, predation and life-history traits: a comparative analysis. *American Naturalist*, 151: 514-529.

SCARTON, F. & VALLE, R. 1996. Colony and nest site selection in Yellow-legged gulls *Larus cachinnans michahellis* in barrier islands of the Po Delta (NE Italy). *Vogelwelt*, 117: 9-13.

SCARTON, F., VALLE, R., BORELLA, S., VETTOREL, M. & UTMAR, P. 1993. Breeding population and distribution of Oystercatcher *Haematopus ostralegus* in Italy. *Avocetta*, 17: 15-17.

SCARTON, F., VALLE, R., RUSTICALI, R., UTMAR, P. & GRUSSU, M. 1998. Population growth and range expansion of the Oystercatchers *Haematopus ostralegus* breeding in Italy. *Die Vogelwarte*, 39: 190-195.

SCARTON, F., VALLE, R. & BORELLA, S. 1994a. Nesting parameters of Oystercatcher *Haematopus ostralegus* in the Po Delta (NE Italy). *Le Gerfaut*, 84: 3-6.

SCARTON, F., VALLE, R. & BORELLA, S. 1994b. Some comparative aspects of the breeding biology of Black-headed Gull, Common Tern and Little Tern in the Lagoon of Venice. *Avocetta*, 18: 119-124.

SCHULTZ, R. & STOCK, M. 1993. Kentish Plovers and tourists: competitors on sandy coasts. *Wader Study Group Bulletin*, 68: 83-91.

SIEGEL-CAUSEY, D. 1991. Foraging habitat selection by American and Magellanic Oystercatchers (*Haematopus palliatus* and *H. leucopodus*) on Patagonian tidal flats. *Canadian Journal of Zoology*, 69: 1636-1643.

SIEGEL-CAUSEY, D. & KHARITONOV, S. P. 1990 The evolution of coloniality. *Current Ornithology*, 7: 285-330.

VALLE, R., D' ESTE, A. & VETTOREL, M. 1995. Status and breeding biology of the Kentish Plover *Charadrius alexandrinus* along the northern Adriatic coastline. *Le Gerfaut*, 85: 37-40.

VALLE, R. & SCARTON, F. 1995. La Pettegola *Tringa totanus* nidificante nella laguna di Venezia: le ragioni di una scelta coloniale. *Avocetta*, 19: 36.

VALLE, R. & SCARTON, F. 1996. Nest-site selection and interspecific relationships of Oystercatchers *Haematopus ostralegus* on the Adriatic coast of Italy. *Vogelwelt*, 117: 75-81.

VALLE, R., SCARTON, F. & UTMAR, P. 1996. Recent counts of breeding waders along the north-eastern Italian coastline. *Wader Study Group Bulletin*, 80: 36-38.

VERMEER, K., EWINS, P. W., MORGAN, K. H. & SMITH, G. E. J. 1992a. *Populations, nesting habitat and reproductive success of American Black Oystercatchers on the west coast of Vancouver Island, British Columbia*. Canadian Wildlife Service Special Publication. Ottawa, Canada.

VERMEER, K., MORGAN, K. H. & SMITH, G. E. J. 1992b. Black Oystercatcher habitat selection, reproductive success, and their relationships with Glaucous-winged Gulls. *Colonial Waterbirds*, 15: 14-23.

WITTENBERGER, J. L. &. HUNT, G. L. 1985. The adaptative significance of coloniality in birds. In, D. S. Farner, J. R. King & K.S. Parkes (Eds): *Avian Biology*, pp. 1-78. Academic Press. New York.

YOUNG, A. D. & TITMAN, R. D. 1986. Costs and benefits to Red-breast Mergansers nesting in tern and gull colonies. *Canadian Journal of Zoology*, 64: 2339-2343.

ZAR, J. H. 1996. Biostatistical analysis. 3rd edition. Prentice Hall. New Jersey.

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