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NEST-SITE SELECTION AND BREEDING BIOLOGY OF KENTISH PLOVER *CHARADRIUS ALEXANDRINUS* ON SANDY BEACHES OF THE PORTUGUESE WEST COAST

Ana C. NORTE* & Jaime A. RAMOS*[1]

SUMMARY.—*Nest-site selection and breeding biology of Kentish Plover* Charadrius alexandrinus *on sandy beaches of the Portuguese west coast.*
Aims: The nest-site selection and breeding biology of Kentish Plover *Charadrius alexandrinus* were studied on sandy beaches of the Portuguese West coast.
Methods: Nest-site characteristics were compared with those of random points and between successful and unsuccessful nests. Breeding parameters (timing of laying, nesting success and egg size) were examined on sandy beaches and these data combined with a literature review to provide a comparison of Kentish Plovers' breeding parameters between natural (sandy beaches, saline lakes) and man-made coastal habitats (salinas and fish-farms).
Results and Conclusions: Three temporal peaks of breeding activity were distinguished: end of April, mid May and end of June. Most nests were located less than 100 meters from the nearest active nest. The dimensions (breadth and volume) of the eggs from late clutches were significantly smaller than those from eggs of early and intermediate clutches. Nesting success was 32% (12.3% using the Mayfield method). There were significant differences in nesting success between the four studied beaches (56% of all clutches produced chicks in Gala while only 18% of all clutches produced chicks in Costinha). Despite the lower success of intermediate clutches no significant difference in nesting success was found between early, intermediate and late clutches. There was a higher probability of finding nest-sites near objects and in areas with a higher cover of sparse vegetation and objects than were random points. Successful nests were placed farther from the nearest mammal footprint, were closer to the nearest vehicle sandmark and had a lower cover of shells and pebbles than did unsuccessful nests. Nesting success was highly variable for both natural and man-made coastal habitats and affected mainly by predation and flooding. In terms of conservation it seems important to maintain habitat diversity for Kentish Plovers.

Key words: Breeding biology, breeding success, Charadrii, *Charadrius alexandrinus*, Kentish Plover, nest-site selection.

RESUMEN.—*Selección de nido y biología reproductiva del Chorlitejo Patinegro* (Charadrius alexandrinus) *en playas de la costa oeste de Portugal.*
Objetivos: Se estudia la selección de nido y la biología reproductiva del Chorlitejo Patinegro en playas de la costa oeste de Portugal.
Métodos: Las características del emplazamiento de nidos tanto exitosos como fracasados se comparan con las características de puntos tomados al azar. Se analizaron variables descriptoras de la reproducción tales como, fecha de puesta, éxito y tamaño de los huevos. Así mismo, se utilizaron los datos obtenidos además de datos procedentes de la bibliografía para realizar una comparación de la reproducción en hábitats naturales (playas y lagos salinos) y en hábitats artificiales (salinas y piscifactorías).
Resultados y conclusiones: Se distinguieron tres máximos temporales durante la reproducción: finales de abril, mediados de mayo y finales de junio. La mayor parte de los nidos se situaron a menos de 100 metros de otro nido ocupado. Los huevos de las puestas tardías fueron significativamente más pequeños (anchura y volumen) que los huevos procedentes de puestas tempranas o intermedias. El éxito reproductivo fue del 32% (12,3% utilizando el método de Mayfield). Se encontraron diferencias significativas en el éxito de los nidos entre las cuatro playas estudiadas (el 56% de las puestas produjeron pollos en Gala mientras que solo el 18% de las puestas produjeron pollos en Costinha). A pesar del bajo éxito de las puestas intermedias no se encontraron diferencias significativas entre las puestas tempranas, intermedias o tardías. Los nidos se situaron con una mayor probabilidad en la proximidad de objetos o en zonas con una menor cobertura de vegetación en comparación con los puntos tomados al azar. Los nidos exitosos se situaron en los lugares más alejados de huellas de mamíferos, estuvieron más cerca de lugares donde se encontraron huellas de vehículos y tuvieron una menor

* Institute of Marine Research, Departamento de Zoologia, Universidade de Coimbra, 3004-517 Coimbra, Portugal.
[1] Corresponding author: E-mail: jramos@ci.uc.pt

cobertura de piedras y/o conchas que los nidos fracasados. El éxito reproductor fue muy variable tanto en los hábitats naturales como en los artificiales, y fueron afectados fundamentalmente por depredación e inundación. En relación a la conservación del Chorlitejo Patinegro, parece importante conservar hábitats diversos.

Palabras clave: Biología de la reproducción, Charadrii, *Charadrius alexandrinus*, éxito reproductivo, selección de emplazamiento de nido.

INTRODUCTION

The habitats of coastal areas are amongst those that have been most influenced by human activities, including ongoing habitat destruction and strong disturbance. These human activities have important effects on the ecology of organisms inhabiting coastal areas (Carter, 1995; Catry *et al.*, 2004).

The Kentish Plover *Charadrius alexandrinus* is a typical coastal bird species that breeds throughout Europe in beaches, marshes, saltpans, lagoons and inland on lakes, alkaline grasslands and seasonal watercourses (Cramp & Simmons, 1983). Recent declines in European populations were attributed to habitat transformations and disturbance (Cramp & Simmons, 1983; Meininger & Arts, 1995; Shulz, 1995; Székely & Nozáli, 1995), which has led to the disappearance of some subpopulations, such as those of Northern Spain (Amat, 1993).

Several aspects of the breeding ecology of this species in natural habitats have been studied in alkaline grasslands in Hungary (Székely, 1992), in marshes (Jackson & Felgueiras, 1994; Székely & Cuthill, 1999) and an inland saline lake in Spain (Fraga & Amat, 1996) but there are few studies on sandy beaches, one of the most common habitats (but see Valle *et al.*, 1995; Domínguez & Vidal, 2003). In Southern European countries, such as Portugal, sandy beaches are the most important natural breeding habitats for Kentish Plovers, although man-made habitats such as salinas (artificial saltpans) and fish farms (Pardal, 2000) are also used (Rufino, 1989).

Nesting success and nest-site selection by Kentish Plover was studied in sandy beaches of central Portugal. This study investigated whether Kentish Plovers exhibited nest-site selection, compared their nest-site characteristics between successful and unsuccessful nests, described their breeding parameters in sandy beaches and compared them between natural (sandy beaches and saline lakes) and man-made (salinas and fish-farms) coastal habitats, using data from the literature. This comparison enabled an assessment of the relative importance of natural and man-made coastal habitats for Kentish Plovers, because a more favourable habitat should allow an earlier or longer breeding season, larger egg dimensions and higher nesting success. This study is relevant for the conservation of Kentish Plovers because coastal habitats are one of the most important natural habitats for the species but simultaneously one of the most disturbed by human activities.

MATERIAL AND METHODS

Study area

This study was carried out between 18 April - 14 July 2002 at four sandy beaches (including the adjacent primary dune) of the Portuguese West coast (40°19'N, 8°50'W to 40°07'N, 8°51'W): Tocha, Costinha, Quiaios and Gala. The total length of beach studied was 9.13 km. The length of each beach ranged from 1.68 km (Tocha) to 2.70 km (Costinha). Data on nesting success in man-made coastal habitats, salinas and fish farms was obtained from studies conducted in the nearby Mondego estuary between the beaches of Gala and Quiaios (Neves, 1997; Pardal, 2000) and at Ria de Aveiro (Ribeiro, 2001).

The beaches of Tocha, Costinha and Quiaios, together with the dunes of S. Jacinto (Aveiro), are included in the longest stretch of sandy beaches (paralleled by primary and secondary sand dunes) in Continental Portugal (Cruz, 1984). South of the Mondego estuary the sandy beaches differ from those mentioned above as they are narrower, with a sloping outline caused by strong sea erosion (Almeida *et al.*, 1990; Cunha *et al.*, 1997). In the study area there are commonly only two dry months (July and August), with an average temperature of 20°C in August (Ribeiro *et al.*, 1988). Moving up the beach, there is a vegetation community gradient, in which the most common plants in order of appearance are *Cakile maritima*, *Elymus farctus*, *Ammophila arenaria*, *Euphorbia paralias*, *Othanthus maritimus*, *Eryngium maritima* and *Calystegia soldanella* (Martins, 1999).

Methods

Each beach was walked along once a week (after 25 May only every 15 days), searching for nests directly or by watching the birds' behaviour with binoculars (8x42). As the male constructs several nests and the female chooses one of them to lay the eggs (Cramp & Simmons, 1983), the nests that were found with at least one egg were denominated «nests» and those with no eggs were denominated «scrapes». Nests were marked with wooden tongue depressors and their coordinates were obtained with a GPS (Flight Pro from Trimble Navigation). These coordinates were used to obtain the position of the nest on a 1:25000 map and to measure the distance to the nearest active nest, when this was greater than 100 meters. During visits to each beach, the number of people present was also recorded to calculate an index of disturbance as number of humans/km of beach per hour.

Nest density for each beach was calculated dividing the total number of nests by the area of each beach, which was estimated by multiplying the length of the beach by its average width. Average beach width was calculated as the mean of distances from the high tide sand mark to the primary dune (assessed when *Cakile maritima* was firstly present or when the slope increased suddenly), measured along a line passing through each active nest.

The first 25% of the total clutches found were considered early clutches (from 18-April to 2-May), the second 50% of the total clutches were considered intermediate clutches (from 2-May to 20-June) and the last 25% of the total clutches were considered late clutches (from 20-June to 14-July). Incubation period was defined as the period since the laying of the last egg of the clutch until the hatching of the first egg (Gill, 1994). Eggs were marked with numbers from 1 to 3 with an indelible marker pen and their length and breadth were measured with callipers, to the nearest 0.1mm. Eggs were also measured in the salinas of the nearby Mondego estuary. Egg measurements between beaches and salinas were also compared. Egg dimensions are likely to reflect food resources and parental quality/ experience (Coulson, 1963), and were used to assess possible differences between these two habitats. Egg volume (Ve) and egg shape index (Is) were calculated using the following formulas: $V_e = [0.5236 - (0.5236x\ 2(L/W)/100)]\ x\ L\ x\ W^2$ (Douglas, 1990), and Is = (W/L) x 100 (Coulson, 1963), where L = egg length (cm) and W = egg width (cm).

To monitor the outcome of the nests, nests were visited once a week (after 25 May only every 15 days but an effort was made to match the date of the visit to the day prior to hatching). A nest was defined as successful if there was evidence for the hatching of at least one egg. The evidences considered for success were: (1) the hatching of at least one chick, (2) the sight of at least one chick in the nest or in the vicinity of the nest, (3) the presence of egg-pipping holes or fissures made by the chick, (4) the presence of small eggshell fragments (1-2 mm) from the first hole in the shell made by the chick, (5) breeding pair displays of flight inability, distraction flights, mobbing and demonstrations of anxiety associated with the disappearance of the eggs within four days of the mean hatching date, and/or egg flotation when immersed in water within 4 days of the mean hatching date (this last evidence was only used at six nests, since it was impossible to visit them just prior to hatching). Nests were considered to have failed if: (a) nests disappeared up to four days before hatching was due, (b) the eggs were cold or out of the nest and no adults were seen in the vicinity of the nest, (c) a new nest was found within 5 meters of the old nest that disappeared (because, if the previous nest had been successful, the breeding pair and chicks would remain in the vicinity of the nest avoiding other breeding pair to start a new clutch in the surroundings). The nesting success was calculated as the number of successful nests divided by the total number of nests (traditional method) and by the method developed by Mayfield (1961, 1975). Exposure was measured in relation to the outcome of the nests. Successful nests and failed nests had an exposure equal to the number of days since the discovery of the nest, until the day in the middle of the period between the day that the clutch disappeared and the last day the nest was known to be active. Nests with an unknown outcome had an exposure equal to the number of days since their discovery until their last active known day (Manolis *et al.*, 2000).

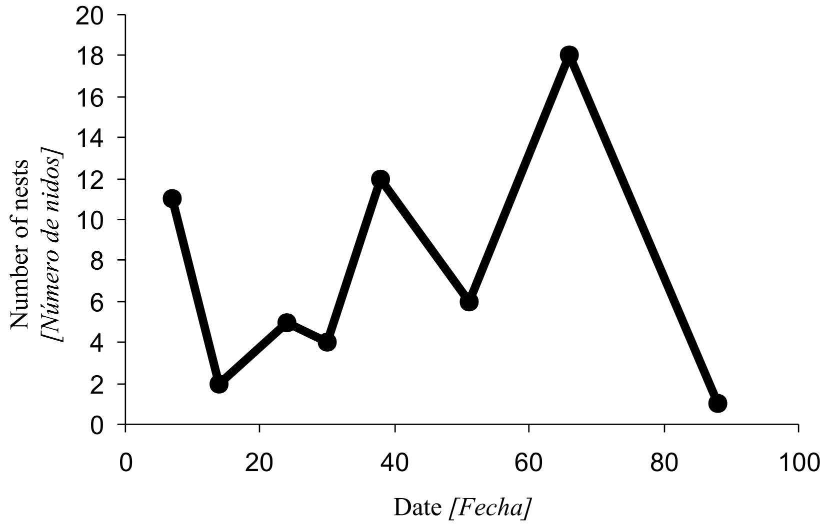

FIG. 1.—Temporal distribution of new clutches found throughout the breeding season (day 1 = 18 April). *[Distribución temporal de las puestas encontradas a lo largo de la estación reproductiva (día 1 = 18 de abril).]*

Nest-site characteristics were studied by comparison with random points located in the surroundings of nest-sites. A random point was selected for each nest, by sorting a number between 0° and 360° for the direction and another number between 1 m and 20 m for the distance to the nest. The variables measured at nests-sites and random points are listed in Table 1. Since birds were not individually marked, it is possible that some individuals would be present more than once in the data. The minimum number of breeding pairs in May was estimated using the total number of active nests (with eggs or chicks) associated with a minimum period of 23 days (Fraga & Amat, 1996) between replacement clutches, *i.e.* to take into account recently failed breeders that had no time to lay a replacement clutch.

The distance to the nearest conspecific nest was assessed to see if it was significantly different between successful and failed nests using Kruskal-Wallis H test and a chi-square was used to assess differences in the number of successful clutches between early, intermediate and late clutches. Measurements of early, intermediate and late eggs were compared with one-way ANOVA (followed by a post-hoc Tukey test). A t-test was used to compare measurements of eggs laid in sandy beaches with those laid in salinas. In these two analyses only eggs from three egg clutches (complete clutches) were used in order to overcome an influence due to differences in egg dimensions related to laying order.

Two logistic regression models were built to compare habitat characteristics between: (a) nest-sites and random points and (b) successful and failed nest-sites. The models were fitted using the purposeful selection procedure described by Hosmer & Lemeshow (2000). Firstly, Spearman coefficient of correlation was used to exclude highly correlated variables ($r_s > 0.7$).

A univariate analysis was used to measure the association of each independent variable with the response variable (nest-site (1) and random point (0); successful (1) and unsuccessful nest (0)), using the Wald Chi-square. Afterwards, a multivariate analysis (*enter* method) was fitted using all variables with $P < 0.25$ in the univariate analysis. The variables retained in the final model were those that had a significant effect at $P < 0.05$ in this multivariate analysis (main effects model). Subsequently, checks were made for significant interactions among the variables in the main effects model. Only interactions that would improve the power of the model were to be retained. To assess the fit of the model the Hosmer and Lemes-

TABLE 1

List of variables measured at each nest-site of Kentish Plovers and at random points.
[Variables medidas en cada emplazamiento de nido de Chorlitejos Patinegros y en los lugares tomados al azar]

Variable *[Variable]*	Description *[Descripción]*
HUMANFPDIST	Distance to the nearest human footprint (m) *[Distancia al punto más cercano de huellas humanas (m)]*
MAMMALFPDIST	Distance to the nearest mammal footprint (m) *[Distancia al punto más cercano de huellas de mamíferos (m)]*
VEHICLEDIST	Distance to the nearest vehicle mark (m) *[Distancia al punto más cercano de marcas de vehículos (m)]*
DUNESLOPE	Dune slope, with a clinometer placed at the beginning of the primary dune (°) *[Inclinación de la duna, con un clinómetro colocado al principio de la duna primaria (°)]*
NESTSLOPE	Nest's slope, with a clinometer placed beside the nest (°) *[Inclinación del nido, con un clinómetro colocado al lado del nido (°)]*
OBJDIST	Distance to the nearest object (cm) *[Distancia al objeto más cercano (cm)]*
OBJHEIGHT	Height of the nearest object (cm) *[Altura del objeto más cercano (cm)]*
VEGDIST	Distance to the nearest vegetation (m) *[Distancia a la vegetación más cercana (m)]*
VEGHEIGHT	Height of the nearest vegetation (cm) *[Altura de la vegetación más cercana (cm)]*
VEGHEIGHT1m^2	Maximum vegetation height in a 1 m^2 area (cm) *[Altura máxima de la vegetación en un área de 1 m^2 (cm)]*
VEGHEIGHT30cm^2	Maximum vegetation height in a 30 cm^2 area (cm) *[Altura máxima de la vegetación en un área de 30* cm^2 *(cm)]*
VEGCOVER1m^2	Vegetation cover within 1 m^2 of the nest (%) *[Cobertura de vegetación en un área alrededor del nido de 1 m^2 (%)]*
VEGCOVER30cm^2	Vegetation cover within 30 cm^2 of the nest (%) *[Cobertura de vegetación en un área alrededor del nido de 30 cm^2 (%)]*
OBJCOVER1m^2	Cover of objects within 1 m^2 of the nest (%) *[Cobertura de objetos en un área alrededor del nido de 1 m^2 (%)]*
OBJCOVER30cm^2	Cover of objects within 30 cm^2 of the nest (%) *[Cobertura de objetos en un área alrededor del nido de 30 cm^2 (%)]*
S/PCOVER1m^2	% of shells and pebbles within 1 m^2 of the nest (%) *[% de conchas y piedras en un área alrededor del nido de 1 m^2 (%)]*
S/PCOVER30cm^2	% of shells and pebble within 30 cm^2 of the nest (%) *[% de conchas y piedras un área alrededor del nido de 30 cm^2 (%)]*
SUBSTRATE	Nests substrate: fine sand or gravel *[Sustrato del nido: arena fina o gravilla]*

how goodness-of-fit test (this tests the null hypothesis that the model fits the data) was used and a classification table (using a cut-off probability of 0.25) to assess how well the model predicts each category of the response variable in terms of percentage of cases classified correctly (Hosmer & Lemeshow, 2000).

A literature survey of studies on Kentish Plover in natural (beaches and saline lakes) and man-made (salinas, fish farms) coastal habitats was carried out in order to assess the influence of habitat type in nesting success and other Kentish Plovers breeding parameters. All results are presented as mean ± 1 SD.

RESULTS

Temporal and spatial distribution of nests

The first clutch was found on 18-April at Tocha and by mid-July only two new clutches were present. Three peaks of breeding activity were identified: end of April, mid-May and late June (Fig. 1). The beaches that contributed the most for the early clutches were the southern beaches (Gala and Quiaios) and the beaches that contributed the most for the intermediate clutches were the northern beaches (Tocha and Costinha). 59 nests were found but only 58 were used for studying habitat selection. From all active nests found in mid-May, and considering that replacement clutches are laid within a period of at least 23 days a minimum population of 32 breeding pairs was estimated. At Tocha there were more nests (n = 21) than on the other beaches (Costinha: n = 13; Quiaios: n = 15; Gala: n = 10). The nest density at Tocha (3.60 nests/ha) was greater than that on the other beaches (Costinha: 1.54 nests/ha; Quiaios: 3.0 nests/ha; Gala: 1.70 nests/ha). The frequency distribution of the distance to the nearest nest is presented in Fig. 2. Most of the nests were less than 100 meters apart. At Tocha there were two nests 5 meters apart and two nests 10 meters apart. The longest distance found between nearest nests was 1.14 km at Quiaios.

Nest-site selection

The mean distance from the nests to the dune and to the high tide sandmark was 8.2 ± 11.2 meters and 20.5 ± 18.4 meters, respectively. The estimated probability of occurrence of a nest-site in the study area was influenced positively by the vegetation cover within 30 cm^2 of the site and by the cover of objects within 1 m^2 of the site. There was also a higher probability of finding a nest-site in the vicinity of an object (Table 2 and 3). The Hosmer and Lemeshow goodness-of-fit test (χ^2_4 = 3.4, P = 0.5) supports the fit of this model, which classified correctly 81% of the sites. It must be noticed that the height of the nearest object within 10 cm of the nest did not exceed 5 cm and that the average vegetation cover around the nest did not exceed 8%. Significant differences were not found in the disturbance index (number of humans/km/h) between the four beaches ($F_{3, 31}$ = 0.86, P > 0.05) nor any significant variation

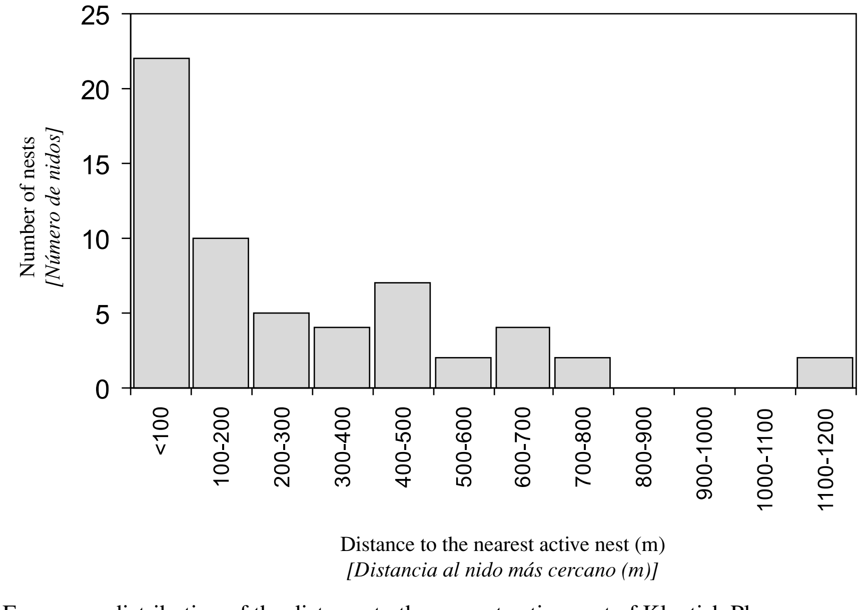

FIG. 2.—Frequency distribution of the distance to the nearest active nest of Klentish Plovers.
[Distribución de frecuencias de las distancias al nido más cercano de Chorlitejos Patinegros.]

TABLE 2

Comparison of nest-site characteristics (mean ± *SD*) between (a) nest-sites and random points (n = 58) and b) successful (n = 14) and unsuccessful (n = 30) nests. See Table 1 for variable codes.
[Comparación de las características del nido (media ± DT*) entre(a) emplazamiento de nidos y puntos tomados al azar (n = 58) y b) nidos existosos (n = 14) y nidos fallidos (n = 30). Ver Tabla 1 para los códigos de las variables.]*

Variable *[Variable]*	Nests *[Nidos]*	Random points *[Puntos al azar]*	Successful nests *[Nidos exitosos]*	Failed nests *[Nidos fallidos]*
HUMANFPDIST	11.2 ± 18.0	9.2 ± 15.3	8.6 ± 17.6	16.6 ± 20.7
MAMMALFPDIST	4.6 ± 8.1	4.0 ± 6.9	8.6 ± 12.1	3.2 ± 5.7
VEHICLEDIST	24.0 ± 18.8	22.7 ± 19.4	17.0 ± 19.4	23.9 ± 17.6
DUNESLOPE	16.7 ± 12.6	16.2 ± 12.2	8.9 ± 5.6	10.5 ± 12.3
NESTSLOPE	4.3 ± 4.4	5.8 ± 5.7	5.1 ± 5.5	2.6 ± 3.3
OBJDIST	40.1 ± 110.4	221.2 ± 264.8	16.6 ± 20.2	32.8 ± 128.1
OBJHEIGHT	3.9 ± 4.6	3.4 ± 2.6	4.3 ± 3.5	2.8 ± 1.1
VEGDIST	7.3 ± 7.4	8.4 ± 8.4	5.6 ± 6.5	10.2 ± 8.4
VEGHEIGHT	30.7 ± 11.2	27.4 ± 11.0	28.4 ± 13.8	30.3 ± 10.8
VEGHEIGHT1m^2	7.4 ± 14.4	10.1 ± 19.9	8.0 ± 15.6	2.8 ± 9.0
VEGHEIGHT30cm^2	6.3 ± 13.6	5.3 ± 12.6	6.5 ± 14.9	2.6 ± 8.5
VEGCOVER1m^2	4.9 ± 12.1	6.2 ± 14.4	7.4 ± 19.2	1.2 ± 3.6
VEGCOVER30cm^2	8.0 ± 21.1	2.3 ± 8.5	12.6 ± 31.8	1.4 ± 5.2
OBJCOVER1m^2	16.5 ± 17.4	5.1 ± 16.8	21.7 ± 21.3	13.6 ± 10.9
OBJCOVER30cm^2	22.1 ± 22.7	1.7 ± 6.9	26.9 ± 26.5	18.1 ± 11.6
S/PCOVER1m^2	6.0 ± 14.4	2.8 ± 13.2	2.6 ± 3.4	6.7 ± 9.5
S/PCOVER30cm^2	5.4 ± 13.7	2.0 ± 13.1	3.4 ± 4.6	5.4 ± 6.4
SUBSTRATE[1]	74.1	74.1	71.4	76.9

[1] Percentage of nests with fine sand *[Porcentaje de nidos en arena fina]*

TABLE 3

Logistic regression models showing those variables that best separated nest-sites from random points and successful from unsuccessful nests. See Table 1 for variable codes.
[Modelo de regresión logística en el que se muestran las variables que mejor diferencian los emplazamientos de los nidos de los puntos al azar, y los nidos exitosos de los nidos fallidos. Ver Tabla 1 para los códigos de las variables]

Model *[Modelo]*	Variable *[Variable]*	Coefficient *[Coeficiente]*	SE	Wald	*P*
Nest-sites and random points *[Emplazamiento de los nidos y puntos al azar]*	Constant	1.056	1.000	1.1	0.291
	OBJDIST	–1.256	0.338	13.8	0.000
	VEGCOVER30cm^2	1.407	0.441	10.2	0.001
	OBJCOVER1m^2	1.427	0.438	10.6	0.001
Successful and unsuccessful nests *[Nidos exitosos y nidos fallidos]*	Constant	1.673	1.358	1.5	0.218
	MAMMALFPDIST	1.062	0.559	3.6	0.058
	VEHICLEDIST	–1.378	0.564	6.0	0.015
	S/PCOVER1m^2	–1.456	0.552	7.0	0.008

in this index throughout the breeding season. During the whole breeding season there was an average value of 1.9 persons/km/h along the beach.

Breeding parameters

The average length (in mm), breadth (in mm), volume (in cm^3) and shape index of eggs laid in sandy beaches was 32.48 ± 1.19, 23.27 ± 0.68, 8.96 ± 0.64 and 71.73 ± 3.16, respectively. The coefficient of variation (CV) for volume of eggs from intermediate clutches (8%) was slightly higher than those from early (6%) and late clutches (5%). The breadth and volume of eggs laid in the sandy beaches differed significantly between early, intermediate and late clutches (Breadth: $F_{2,99} = 4.836$, $P < 0.001$; Volume: $F_{2,99} = 7.248$, $P < 0.01$; Table 4). The average length, breadth, volume and shape index of eggs laid in the salinas was 32.47 ± 1.46, 23.20 ± 0.56, 8.91 ± 0.68 and 71.56 ± 3.04, respectively. Overall there was no significant difference in egg dimensions between salinas and beaches (*t-test*: length = 0.025, $P > 0.05$; breadth = 0.523, $P > 0.05$; volume = 0.41, $P > 0.05$; shape index = 0.27, $P > 0.05$).

The possible removal of eggshells by the parents, the disappearance of eggshell fragments and membranes in the sand because of the wind and the chicks' camouflage made impossible the determination of the success of 15 nests whose clutches simply disappeared without any trace. The exact reason of nest failure in 15 nests was also impossible to determinate. There were significant differences in the number of successful and failed nests between the four beaches (Fisher's exact Test: $P = 0.008$). Using both the Traditional Method and the Mayfield Method, the beaches with higher and lower reproductive success were respectively Gala and Costinha (Table 5).

The nesting success was higher for early clutches (traditional method: 41.7%; Mayfield Method: 39.4%) and late clutches (traditional method: 50%; Mayfield Method: 16.8%) and lower for intermediate clutches (traditional method: 18.2%; Mayfield Method: 1.1%) although no significant difference in the number of successful and failed nests between early, intermediate and late clutches was found ($\chi^2_2 = 3.94$, $P > 0.05$). In the study area, successful nests were placed farther from the nearest mammal footprint, were closer to nearest vehicle sandmark and had a lower cover of shells/pebbles than did unsuccessful nests (Tables 2 and 3). The Hosmer and Lemeshow goodness-of-fit test $\chi^2_8 = 6.7$, $P = 0.6$) supports the fit of this model, which classified correctly 75% of the nests.

TABLE 4

Comparison of egg measurements (mean ± *SD* of length, breadth, volume and shape index) between early, intermediate and late clutches using one-way ANOVA followed by a post-hoc Tuckey test. Columns sharing the same letter are not significantly different.

[Comparación de las medidas de los huevos (media ± SD *de la longitud, anchura, volumen e índice de forma) entre las puestas tempranas, intermedias y tardías por medio de ANOVA de una vía y una prueba de-Tuckey a posteriori. Las columnas con la misma letra indican que no hay diferencias significativas]*

	Length (mm) *[Longitud (mm)]*	Breadth (mm) *[Anchura (mm)]*	Volume (cm^3) *[Volumen cm^3)]*	Shape Index *[Índice de forma]*
Early *[Tempranas]* (*n* = 39)	32.70 ± 1.20[a]	23.36 ± 0.51[a]	9.09 ± 0.55[a]	71.51 + 2.86[a]
Intermediate *[Intermedias]* (*n* = 45)	32.50 ± 0.96[a]	23.36 ± 0.82[a]	9,04 ± 0.70[a]	71.94 + 2.98[a]
Late *[Tardías]* (*n* = 18)	31.94 ± 1.53[a]	22.83 ± 0.41[b]	8.47 ± 0.40[b]	71.67 + 4.24[a]
F	2.636	4.836	7.248	0.199
P	ns	< 0.001	< 0.01	ns

TABLE 5

Kentish Plover nesting success in each of the four beaches and in the whole area using the Mayfield and Traditional methods. N = total number of nests; I = number of failed nests; E = exposure of nests; TI = I/E (number of nests/day); TS = 1 – TI (number of nests/day); PEN = $(TS)^n$; n = average number of days that an egg must be active, since laying till hatching; NT = total number of nests; NS = number of nests with success; S = nesting success (NS/NT).
[Éxito reproductor del Chorlitejo Patinegro en cada una de las cuatro playas y en total utilizando el método de Mayfield y el método tradicional. N = número total de nidos; I = número de nidos fallidos; E = Exposición de los nidos; TI = I/E (número de nidos/día); TS = 1-TI (número de nidos(día); PEN = $(TS)^n$; n = promedio de días que un huevo puede estar activo desde la puesta hasta la eclosión; NT = número total de nidos; NS = número de nidos con éxito; S = éxito reproductor (NS/NT).]

		Tocha	Costinha	Quiaios	Gala	Total
Nests outcome *[Nidos]* (n = 59)	Hatched *[Eclosionado]*	6	2	1	5	14
	Failed *[Fallido]*	12	9	4	4	30
	Unknown *[Desconocido]*	3	2	9	1	15
Mayfield Method *[Método de Mayfield]*	N	21	13	14	10	59
	I	12	9	4	4	30
	E	192	56	53	156	452
	TI	0.0625	0.1607	0.0755	0.0256	0.0664
	TS	0.9375	0.8393	0.9245	0.9744	0.9336
	PEN	**0.1397**	**0.0048**	**0.0913**	**0.4532**	**0.1231**
Traditional Method *[Método Tradicional]*	NT	18	11	6	9	44
	NS	6	2	1	5	14
	S	**0.33**	**0.18**	**0.17**	**0.56**	**0.32**

Comparison of breeding parameters between natural and coastal man-made habitats

The two major causes of nest failure in both habitats were predation and flooding (Table 6). No significant differences were found in nesting success between man-made (56.5 ± 21.5%) and natural (41.7 ± 32.7%) habitats (Mann-Whitney U = 7.0, P = 0.25, $n_1 = n_2 = 5$; Table 6). When comparing the two habitats, birds seem to begin breeding earlier in man-made habitats (19.33 ± 17.0 days after 1 March) than in natural habitats (37.67 ± 10.26 days after 1 March, both n = 3, Table 6). In terms of egg biometrics there was no difference between man-made habitats and sandy beaches (see above).

DISCUSSION

In this study, the average distance to nearest conspecific nest (279.6 ± 266.8 m) was higher than the value estimated by Powell (2001) in Southern California (113 ± 86 m), for three types of habitats: beaches, saltpans and fill habitats. In this study, most of the nests were less than 100 m. In an inland saline lake most nests were within 25 m of the nearest neighbour (Fraga & Amat, 1996), and there was no influence of the distance to the nearest conspecific nest on nesting success, but Page *et al.* (1983) found that nests in higher density areas were predated significantly more than those in lower density areas. Powell (2001) obtained a higher reproductive success for nests at distances less than 100 m, in Southern California because of the beneficial effect of the anti-predator behaviour of neighbouring Little Terns *Sterna antillarum*.

Nest-sites were closer to an object and had a higher cover of objects within 1 m^2 than did the random points. Overall, most birds that breed in beaches select nest-sites close to objects (Warnock *et al.*, 2002). An object near the nest,

TABLE 6

Comparison of breeding parameters of Kentish Plover between natural and man-made habitats of coastal areas.
[Comparación de los parámetros reproductivos del Chorlitejo Patinegro entre hábitats naturales y artificiales en zonas costeras].

Habitat	First Clutch *[Primera puesta]*	Number of nests *[Número de nidos]*	Nesting success *[Éxito]*	Causes of faillure (%)[1] *[Causas de fallo (%)[1]]*					Reference
				Predation *[Preda-ción]*	Flood *[Inunda-ción]*	Human causes *[Causas humanas]*	Other *[Otras]*	Unknown *[Descono-cidas]*	
Natural habitats ***[Hábitat natural]***									
Portuguese West coast *[Costa oeste portuguesa]*	18 April	44	32	(a)	31.8	0	0	36.4[(b)]	This study
Portuguese South coast *[Costa sur portuguesa]*	4 April	22	69.7	—	—	—	—	—	Barton, *unpub. data.*
Galicia coast (Spain) *[Costa de Galicia (España)]*	—	70	5.7	41	13	11	—	35	Domínguez & Vidal, 2003
Valencia (Spain) *[Valencia (España)]*	—	33	81.8	0	3.0	9.0	0	6.1	Ruano *et al.*, 1993
Saline lake (Spain) *[Lago salino (España)]*	29 March	316[(c)]	19.3[(c)]	62.6	3.8 [(d)]	0	14.2	0	Fraga & Amat, 1996
Man-made habitats ***[Hábitat sartificiales]***	20 March	106	43.4	33.0	16.0	4.7	2.8	0	Pardal, 2000
Salt pan (Mondego, Portugal) *[Salinas (Mondego, Portugal)]*	2 March	65	36.9	30 - 40	15 - 25	0	15-20	0	Neves, 1997
Salt pan (Aveiro, Portugal) *[Salinas (Aveiro, Portugal)]*	5 April	185	75.7	1.6	4.3	11.9	0	6.5	Ribeiro, 2001
Fishfarms (Mondego, Portugal) *[Piscifactoría (Mondego,Portugal]*	—	7	42.9	14.3	28.6	0	14.3	0	Neves, 1997; Pardal, 2000
Fishfarms (Aveiro, Portugal) *[Piscifactoría (Aveiro,Portugal]*	2[nd] half of April	37	83.8	0	10.8	0	0	5.4	Ribeiro, 2001

(1) proportion of failed nests in relation to total number of nests; (a) we were unable to identify the proportion of nests that were predated; (b) includes unknown % of nests that were predated; (c) data from a two years study (1991-92); (d) maximum value as it may include other unidentified causes of nest failure; (-) no data.
[(1) Proporción de nidos fallidos en relación con el número total de nidos; (a) no fuimos capaces de identificar la proporción de nidos que fue depredada; (b) incluye un porcentaje de nidos desconocidos que fue depredado; (c) datos de un estudio de dos años (1991-92); (d) máximo valor al incluir otras causas de deserción de nido; (-) no existen datos.]

with certain dimensions which allow a good visibility of possible predators, becomes useful by working as a shelter to the North/Northwest wind (most objects were oriented to the North of the nest, *pers. obs.*). Another possible explanation, as referred by Warnock *et al.* (2002), is that it may help birds finding their nests as there are few orientation references in this type of habitat. This last explanation does not seem adequate in this study area because the number of objects on the beach was very high. Some nests were found below tall boxes and net structures, but these had interruptions which should allow good visibility around the nests; this kind of object also offered an additional protection to the incubating bird and eggs.

Fourteen nests were sheltered by some sparse vegetation. The probability of occurrence of a nest-site in the study area was influenced positively by the vegetation cover within 30 cm^2 of the site, but it should be noted that, overall, the vegetation cover was very low in the vicinity of nest-sites. Some vegetation, not far from the nest, is advantageous as it can shelter the chicks after hatching (Lorenzo & González, 1993) and also helps to dissimulate the nest-site. Though, the preference for open and sparsely vegetated areas had been referred for all habitats by Cramp & Simmons (1983), Casini (1986), Székely (1991), Neves (1997), Pardal (2000), Powell (2001) and Ribeiro (2001), and is related to the detection of possible terrestrial predators by incubating birds (Perrins, 1977; Walters, 1984). Vegetation overgrowth may lead to habitat loss and abandonment of breeding territories (Page & Stenzel, 1981; Székely, 1992; Pardal, 2001). Pardal (2001) indicated the high vegetation cover in abandoned salinas as a possible cause of a lower nest density in this type of habitat, in comparison with active salinas. The invasive grass *Ammophila arenaria* was the major cause of the Kentish Plover's habitat loss, in Northern California beaches (Page & Stenzel, 1981) and in Hungary, the height and growth of the vegetation was one of the causes for the abandonment of breeding territories in alkaline grasslands (Székely, 1992). Although the absence of vegetation near the nests may reduce the terrestrial predation it can facilitate predation by birds such as gulls, as the nests and chicks become exposed (Ribeiro, 2001). Therefore there may be a trade-off between these two opposite forces related with vegetation cover.

There was no evidence that human disturbance may have influenced nest-site selection in terms of the microscale nest-site characteristics that were studied. Overall, the failure or success of nests may depend on weather conditions, number and type of predators present in the breeding area, human activities and food availability. In this study, the most important identified cause of nest failure was flooding by high tides, which led to the failure of 14 nests in May, and explains why intermediate clutches had a much lower success than early and late clutches. Another possible cause of failure was predation, presumably by foxes or dogs. Although signs of broken shells or egg contents were found there were not mammal footprints near three nests. In 1999, in the salinas of the Mondego estuary, nest survival rate was higher in late clutches than in early and intermediate clutches because these were flooded by rainfall (Pardal, 2000). Destruction by man when preparing the salinas for the salt exploitation contributed also to the failure of some clutches (Pardal, 2000).

The fact that successful nests were farther from mammal footprints than unsuccessful nests suggests the importance of nest predation in nest outcome. The fact that successful nests had lower cover of shell and pebbles within 1 m^2 may be related to the fact that nests within an area with a higher cover of shells may be less camouflaged. It was surprising to find that nests nearer to vehicle sandmarks had a higher probability of success than those farther from vehicle sandmarks. There is no explanation for this.

The length, breadth and volume of eggs laid on beaches were smaller for late clutches. Egg volume is related to the chicks' survival as larger eggs produce heavier chicks that survive better than their lighter siblings (Amat *et al.*, 2001a). However, there are opposite selective forces that may counterbalance this tendency as clutches with larger eggs may take longer to complete and this may be particularly important for species that experience heavy nest predation (Amat *et al.*, 1999, 2001a). In shorebirds, females apparently acquire nutrients and energy for egg-laying just before or during egg laying (Erckmann, 1983), so, the conditions to which females are exposed during this period may influence egg dimensions. This means that the food availability, and female body condition (Amat *et al*., 2001b), may have decreased by the end of the season. The higher coefficient of variation for volume of eggs from intermediate clutches can reflect a greater parental heterogeneity at this time of the season. The fact that egg dimensions were similar between beaches and salinas suggests that these two types of habitats are similar in relation to food resources and quality of breeding females. The egg measurements obtained in this study were also similar to those obtained by Fraga & Amat (1996), Amat *et al*. (2001a) in a saline lake in Spain and by Ribeiro (2001) in the salinas and in the fish farms of Ria de Aveiro, Portugal.

Influence of disturbance on nesting success was not detected but this issue should be studied in more detail. The effect of disturbance may be more evident in beaches under a greater recreational pressure in comparison with those studied here.

Kentish Plover breeds in both natural and man-made habitats and nesting success shows great variation in both habitats. No consistent differences in breeding parameters between these two types of habitats were found. The characteristics of each site are presumably more important to explain nesting success than habitat type per se. For example, nests in beaches may be flooded or not at high tide depending on beach length. Nests may also be flooded in salinas depending on the height of the dikes where Kentish Plovers nest. In Southern Europe, the salinas have been progressively abandoned (Múrias *et al*., 2002), leading to vegetation overgrowth and flooding, which does not benefit Kentish Plovers. On the other hand, beaches are more susceptible to disturbance by human activities. Therefore, the management of both types of habitats is important for Kentish Plovers. Although the influence of human activities on breeding success could not be detected, similar studies have suggested that reducing human activities during the Kentish Plover breeding season would benefit this species (Powell, 2001). In terms of conservation, this study suggests that the removal of the totality of objects from the beaches, especially with vehicles equipped with a large shovel, as it is usually done, will not favour Kentish Plovers. Removing objects from the areas closer to the water and selectively removing only man-made objects and leaving wooden branches along the stretch of beach closer to the dunes mostly used by this species would be adequate. With regard to salinas, preventing abandonment is the most urgent action in order to maintain nesting habitat for Kentish Plovers and other shorebird species (Murias *et al*., 2002).

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Ana Cláudia Norte is a PhD student at the Universities of Coimbra and Oxford. Her undergraduate thesis was about the reproductive biology and habitat selection in Kentish plover. Presently she is carrying out research on health profile and enzymatic biomarkers in Great tit populations, in order to assess their exposure to stress inducers. **Jaime Ramos** is Assistant Professor at the Department of Zoology, University of Coimbra. Most of his research is on conservation biology, reproductive biology and habitat selection of coastal and pelagic seabirds. This work was carried out within a project to assess the use of birds as bioindicators of environmental changes in coastal environments.

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