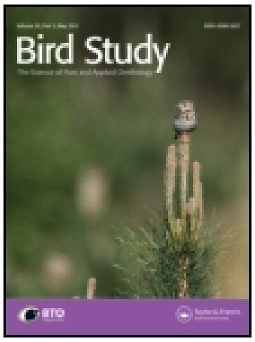

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Breeding ecology of Collared Pratincoles *Glareola pratincola* in two coastal habitats in northwest Morocco

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Capsule Rocky platforms provide better nesting conditions than sandy beaches.
Aim To investigate the breeding ecology of Collared Pratincoles *Glareola pratincola* in two different coastal Atlantic habitats in northwest Morocco.
Methods Collared Pratincole nests were monitored in two coastal Atlantic habitats (sandy and rocky habitats) during two years (2003 and 2004). Breeding phenology, colony size and density, clutch size, egg dimensions, nest survival rates and breeding success were determined and compared between habitats.
Results Breeding started earlier compared with colonies in Europe. Nest density, clutch size, nest survival rates and breeding success were higher in the rocky habitat compared with the sandy one. In the latter habitat nests suffered higher losses owing to human disturbance.
Conclusion Rocky platforms confer better nesting conditions than sandy beaches. Beach sites suffer relatively higher human disturbance, resulting in lower nest survival rates. There is a need for urgent management and conservation efforts aimed at reducing the negative impact of humans on these birds along the Moroccan Atlantic coast.

INTRODUCTION

Collared Pratincoles *Glareola pratincola* have a large and fragmented breeding distribution in the Palearctic (Cramp & Simmons 1983, Del Hoyo *et al.* 1996). In European breeding areas most populations are declining (Cramp & Simmons 1983, Dolz 1994), particularly because of human-induced habitat changes (Walmsley 1978, Cramp & Simmons 1983, Calvo *et al.* 1993, Dolz 1994, Del Hoyo *et al.* 1996). In Mediterranean Europe, especially Spain and France, numerous studies have investigated the ecology and breeding success of this species in relation to such changes (Calvo & Alberto 1990, Calvo 1994, Calvo & Furness 1995, Goutner 1997, Tajuelo & Manez 2003, Galván 2005, Vincent-Martin 2007, Kayser *et al.* 2008). These studies have underlined that although some traditional agricultural activities, such as traditional grazing regimes, were beneficial for this species, the intensive transformation of natural marshes and grasslands into modern agricultural lands constitutes a serious threat to the breeding population.

In North Africa, Collared Pratincoles nest regularly in localized areas along the Atlantic and Mediterranean coasts, and at some inland wetland sites (Cramp & Simmons 1983). In Morocco breeding of this species has been recorded in a variety of habitats – lagoons and marshes, river margins and estuaries – along the Atlantic coast (Beaubrun 1981, Barreau & Bergier 2001, Thévenot *et al.* 2003, Rihane & Aouinty 2006). However, the ecology and breeding success of this species in these areas remain poorly known, despite the importance of such information for understanding the long-term dynamics of this species at different spatial scales (from within Morocco to the scale of the entire Mediterranean basin).

Here we describe data collected during a two-year monitoring programme of Collared Pratincole nests in an Atlantic coastal area in northwest Morocco and describe important aspects of its breeding ecology. We

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use the results to check how breeding parameters vary between habitats, and also to compare the breeding performance of these Moroccan colonies with those nesting along the northern border of the Mediterranean. In so doing we provide new data on this species from one rarely explored area situated at the margin of its geographic range.

METHODS

Study area

Study sites were on the Atlantic coast of Rabat-Bouznika in northwest Morocco, between the Bou-Regreg estuary (34°03′N–6°50′W) in the north and the Bouznika beach (33°50′N–7°10′W) in the south (Fig. 1). The study area is dominated by rocky intertidal flats, locally interrupted by estuaries (Cherrate and Yquem rivers) and sandy beaches. Two main habitat types were distinguished: rocky platforms and sandy habitats.

Data collection

Data were collected in 2003 and 2004 at three nesting sites: Petit Val d'Or beach (sandy habitat), Skhirate shoreline (rocky habitat) and Cherrate river estuary (sandy habitat) (Fig. 1). We searched extensively for nest sites from the second half of March until the first half of August. All discovered nests were monitored by means of regular visits. Visits were carried out early in the morning, at five-day intervals from the beginning of incubation and then daily near the predicted hatching date.

For each monitored nest, we noted the laying date and clutch size. Laying date was determined either by knowing the date the first egg was laid or by backdating

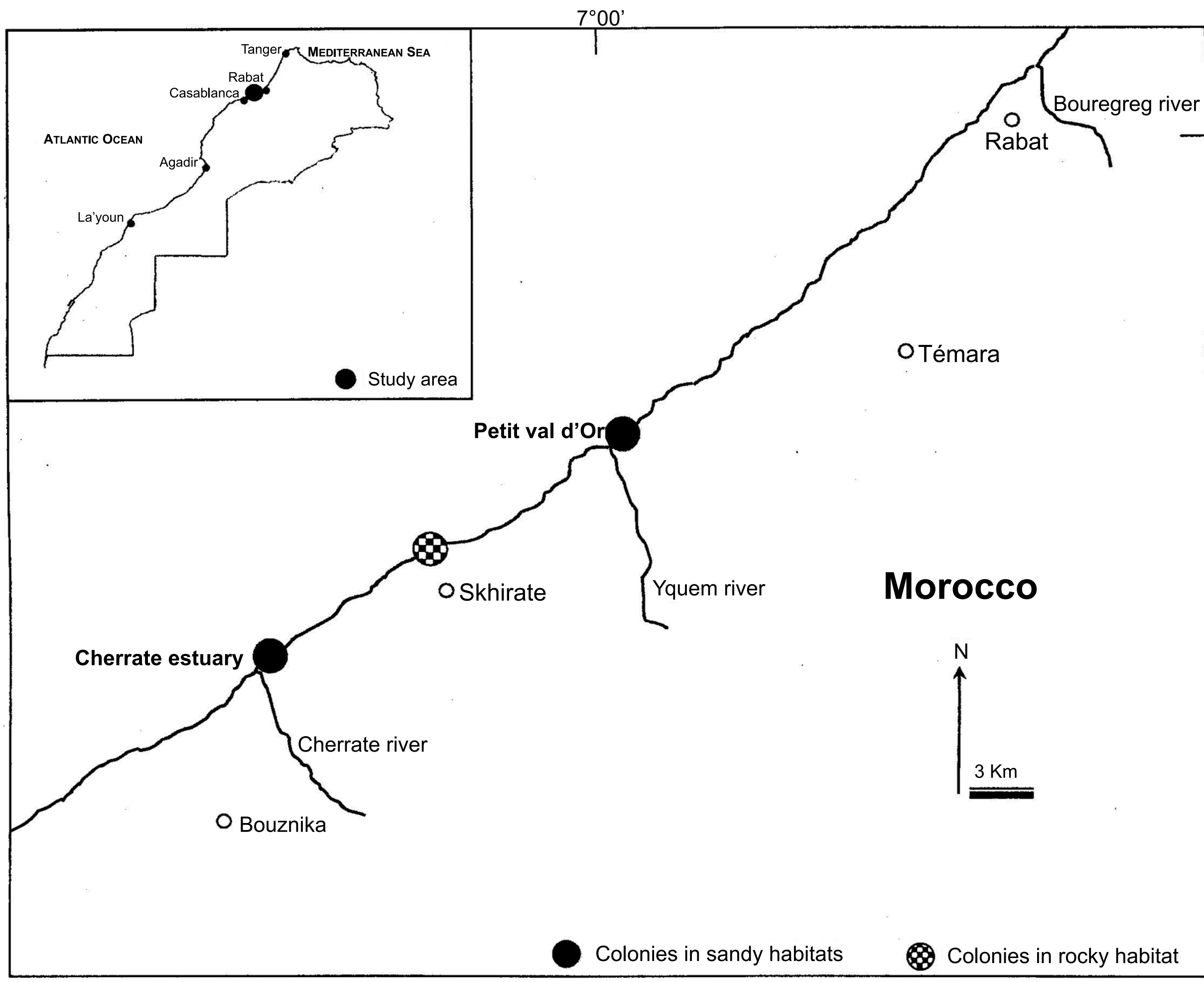

Figure 1. Map showing the location of study sites on the north Moroccan Atlantic coast.

from the known hatching date, assuming incubation is 18 days (Cramp & Simmons 1983). Clutch size was determined for complete clutches only. Nests were considered successful if at least one egg hatched, otherwise the nests were considered to have failed. In such cases, we tried to identify the cause of nest failure by examining the nest and its surroundings. When eggs disappeared before the expected hatching date, they were considered as either depredated or collected by people. In the former case, the nest was generally damaged and fresh animal tracks, as well as eggshell fragments, were found in its vicinity. However, when egg disappearance was because of egg-gathering by people, the nest was generally intact and fresh human footprints were found in its vicinity. Furthermore, when eggs were found in the nest but were totally damaged and there were human footprints on the nest and in its surroundings, we considered the nest to be trampled by walkers. Finally, a nest was considered as flooded when its bottom was wet and/or eggs were totally or partially submerged.

For clutches laid in 2003, we measured egg length and width with a vernier caliper to the nearest 0.1 mm. The data obtained were then used to calculate egg volume (V_e) and egg Shape Index (SI) using the following formulas: V_e (cm^3) = $K \times L \times B^2$ and SI = $(B/L) \times 100$ (Coulson 1963), where $K = 0.482$ (Calvo 1994, Bertolero & Martinez-Vilalta 1999), L = egg length (cm) and B = egg width (cm). In 2004, the spatial distribution of nests was assessed by measuring the distance to the next active nest from each nest.

Data analyses

Data on breeding phenology, nest spacing, egg dimensions, clutch size and breeding success were subject to statistical analyses to investigate the possible effects of habitat type (rocky versus sandy) and year (2003 versus 2004) on these breeding parameters. We used parametric tests and ANOVA when the normality assumption was met, and non-parametric tests when the data lacked normality.

With regard to nest survival, we used the modelling approach developed by Shaffer (2004) to estimate daily nest survival rates and to investigate whether they varied between habitats (rocky versus sandy) and according to laying date (Julian date). This approach takes into account possible differences in the exposure period among the monitored nests (Mayfield 1975) and allows accounting for the effects of possible covariates when estimating daily nest survival rates (Shaffer 2004). Exposure days were measured in relation to the outcome of the nests. Nest exposure was equal to the number of days since nest discovery until the halfway point between the last day the nest was known to be active and the day that the clutch was observed to have disappeared. Nests with unknown outcomes had an exposure equal to the number of days since their discovery until their last known active day (Manolis *et al.* 2000). We used the GENMOD procedure in SAS (SAS Institute 1999) to fit logistic exposure models with a binomial error distribution and a logit-link function. We constructed five candidate models which included each variable by itself, the two variables without interaction, the two variables with their interaction and a constant model (i.e. without any explanatory variable). The candidate models were then ranked according to their AIC_c scores (Burnham & Anderson 2002). The best model (lowest AIC_c score) was then used to derive the estimates for the effects of the predictor variables. We also examined the best model graphically by plotting the predicted daily nest survival rates as a function of the predictor variables using values spanning our sample range.

RESULTS

Colony size and breeding phenology

Our monitoring work shows that in Petit Val d'Or beach (sandy habitat) and Skhirate shoreline (rocky habitat), the Collared Pratincole populations increased in size during the two years of the study. In Petit Val d'Or beach, the number of breeding pairs was 16 in 2003 and 42 in 2004, while in Skhirate shoreline there were 32 breeding pairs in 2003 and 44 in 2004. In the third study area, the Cherrate river estuary (sandy habitat), the reproduction of Collared Pratincoles was only recorded in 2004, with a colony size of seven breeding pairs.

The first recorded arrival date was 8 March in 2003 and 10 March in 2004. However, egg-laying started in the first half of April (7 April in 2003 and 16 April in 2004). For both years, the peak of laying activity was noted during the first half of May (2003: 68.3%, $n = 63$ and 2004: 52.7%, $n = 112$) (Fig. 2). The average laying period (calculated using data from both years of study) was 53 days (se = ± 4.5). Hatching started in May (11 May in 2003 and 25 May in 2004), whereas the peak was recorded during the last ten days of May in 2003 and during the first ten days of June in 2004 (Fig. 3). The mean hatching period was 45 days (se = ± 3.00). Departure from the colonies started in mid-July and continued until the end of that month.

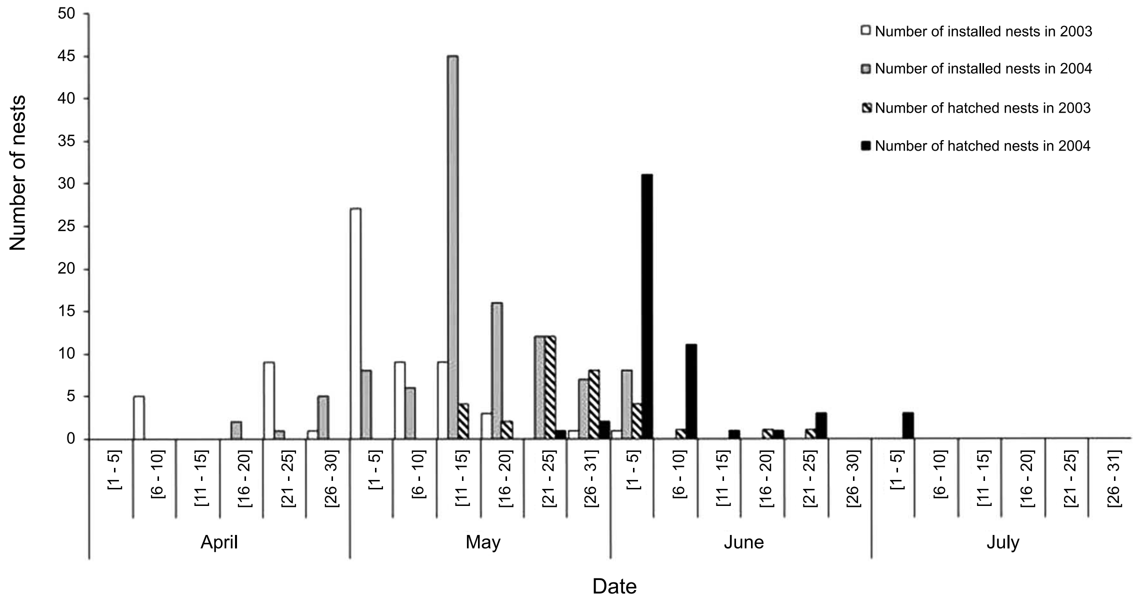

Figure 2. Phenology of nest initiation and hatching in 2003 (n = 63) and in 2004 (n = 112).

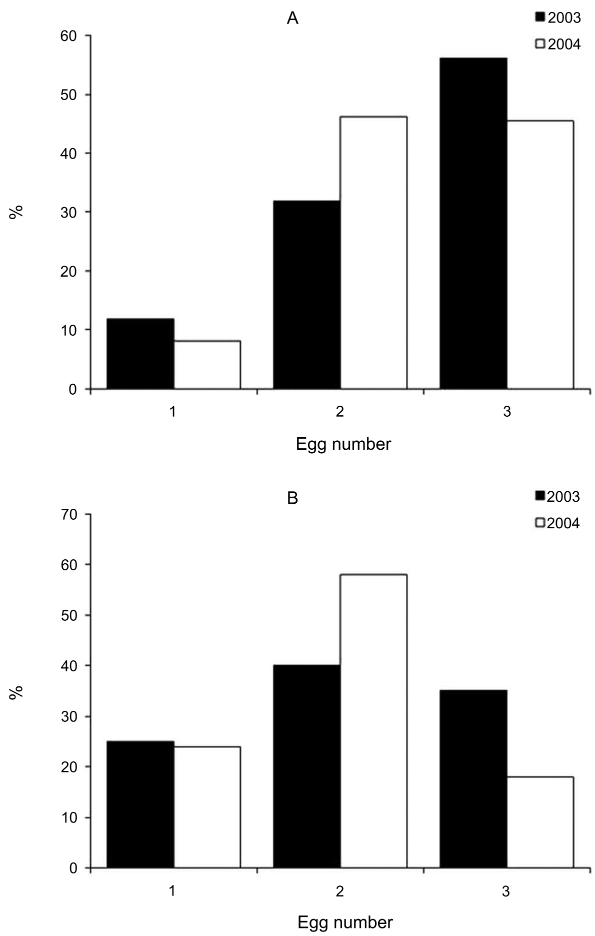

Figure 3. Frequency distribution of clutch size in sandy (A) and rocky (B) habitats during the two years of study.

Nest spacing

Using data collected in 2004, we found that the average distance to the nearest active nest (± se) was 6.26 ± 0.27 m (n = 112). Nests built in rocky habitats (mean spacing = 5.65 ± 0.28 m, n = 55) were significantly closer to each other than those in sandy habitats (mean spacing = 6.84 ± 0.45 m, n = 57) ($F_{1,110}$ = 4.82, P = 0.03). In the rocky habitat, Collared Pratincole pairs shared available nesting sites with Kentish Plovers *Charadrius alexandrinus* and Little Terns *Sternula albifrons*. However, in sandy habitats, there were also some nests of Stone Curlews *Burhinus oedicnemus* and Crested Larks *Galerida cristata* in addition to the aforementioned species. In these areas Collared Pratincoles primarily deposited eggs under tufts of *Sporobollus pungens* (58.8%, n = 68), *Zygophyllum fontanesii* (20.6%) and *Sueda vera* (16.2%).

Clutch size and egg dimensions

Clutch size varied from one to three in both years of the study (Fig. 3). Average clutch size was not significantly different between years (mean = 2.28 ± 0.11 se in 2003 and 2.14 ± 0.07 se in 2004; $F_{1,130}$ = 1.16, P = 0.28), but varied significantly with habitat type ($F_{1,130}$ = 12.7, P = 0.001). Indeed, clutch size was significantly higher in rocky habitats (mean = 2.4 ± 0.07 se) than in sandy ones (mean = 1.98 ± 0.08 se). This is likely to be because of the higher frequency of three-egg clutches

Table 1. Biometrics of Collared Pratincole *Glareola pratincola* eggs in sandy and rocky habitats in the north Moroccan Atlantic coast.

Measurement	Sandy habitat (n = 32)	Rocky habitat (n = 49)	F	P
Mean length (mm) ± se	30.3 ± 0.15	31.4 ± 0.17	10.27	0.02
Mean width (mm) ± se	23.6 ± 0.09	23.5 ± 0.12	0.62	0.92
Mean volume (cm^3) ± se	8.1 ± 0.07	8.3 ± 0.09	0.15	0.69
Mean shape index ± se	77.9 ± 0.51	75.0 ± 0.67	33.1	0.00

in rocky habitats compared to sandy ones, where the modal clutch size was two eggs (Fig. 3). The average length and shape index of eggs differed significantly between sandy and rocky habitats. However, there was no significant difference in egg breadth and volume (Table 1).

Nest survival rates and breeding success

Among the 175 monitored clutches, 86 produced chicks, corresponding to a hatching rate (proportion of hatched nests among the monitored nest sample) of 49%. The main factors affecting nest success were clutch desertion (26.9%) and egg-gathering by humans (23.6%). Effects of predation and flooding by high tides also contributed to nest failure (respectively 16.9% and 14.6%). Flooding and egg-gathering had an important impact in rocky habitats, while nest desertion and predation were mainly observed in sandy habitats (Table 2). In summary, 85% of the nest losses were because of biotic factors, whereas 15% of the losses were because of abiotic factors.

When the effects of habitat type and laying date were not controlled for (constant model), the estimated daily nest survival rate was 0.96 (95% CI: 0.95–0.97), which corresponds to an overall estimated hatching rate of 48%, assuming that incubation lasts for 18 days. Among the five candidate models used to explain variation in daily survival rates of the monitored nests (see Methods), the model including laying date and habitat type ranked the highest (Δ AIC$_c$ = 0). The Akaike weight of evidence (w_i = 0.58) indicated that there was a 58% chance that this model was actually the true or best model to explain observed variation in daily survival rates (Table 3). Predicted estimates derived from this model showed that daily survival rates increased throughout the season and were higher overall in the rocky habitat compared with the sandy one (Table 4, Fig. 4).

Using data on all successful nests, we found that the mean number of chicks hatched per successful nest was 1.95 ± 0.07 se. The number of chicks produced by successful nests did not vary among years (Mann–Whitney U-test, U = 847, P = 0.864), but was significantly higher in rocky areas (mean = 2.08 ± 0.08 se) than in sandy ones (mean = 1.67 ± 0.61 se) (Mann–Whitney U-test, U = 549, P = 0.006).

Table 2. Number and causes of failed nests of Collared Pratincoles *Glareola pratincola* in sandy and rocky habitats.

Failure cause	Sandy habitat n	Sandy habitat %	Rocky habitat n	Rocky habitat %
Desertion	19	36.54	5	13.51
Egg-gathering	10	19.23	11	29.73
Predation	13	25	2	5.41
Flooding	0	0	13	35.13
Trampling	4	7.69	2	5.41
Unknown	6	11.54	4	10.81
Total	52	100	37	100

DISCUSSION

The aim of our study was to investigate the breeding ecology of Collared Pratincoles in two different natural coastal habitat types in Morocco. Our results suggest

Table 3. Comparison of models used to determine factors affecting daily nest survival rate of Collared Pratincoles *Glareola pratincola*.

Model	K	AIC$_c$	Δ AIC$_c$	w_i
Julian date + Habitat	3	502.292	0	0.57866
Julian date + Habitat + Julian date × Habitat	4	503.258	0.9658	0.35704
Habitat	2	506.688	4.3957	0.06426
Julian date	2	521.520	19.2279	0.00004
Constant	1	529.444	27.1521	0

K, number of model parameters; AIC$_c$, model AIC corrected for small sample size; w_i, model weight.

Table 4. Parameter estimates derived from the best logistic exposure model (laying date + habitat) of daily nest survival rate of Collared Pratincoles *Glareola pratincola*.

Parameter	Estimate (± se)	95% CI Lower	95% CI Upper	χ^2	P
Intercept	−2.925 (± 1.266)	−5.405	−0.444	5.34	0.0208
Date	0.045 (± 0.010)	0.025	0.064	20.74	<0.0001
Rocky habitat	0.594 (± 0.236)	0.131	1.057	6.31	0.0120
Sandy habitat	0.000 (± 0.000)	0.000	0.000	–	–

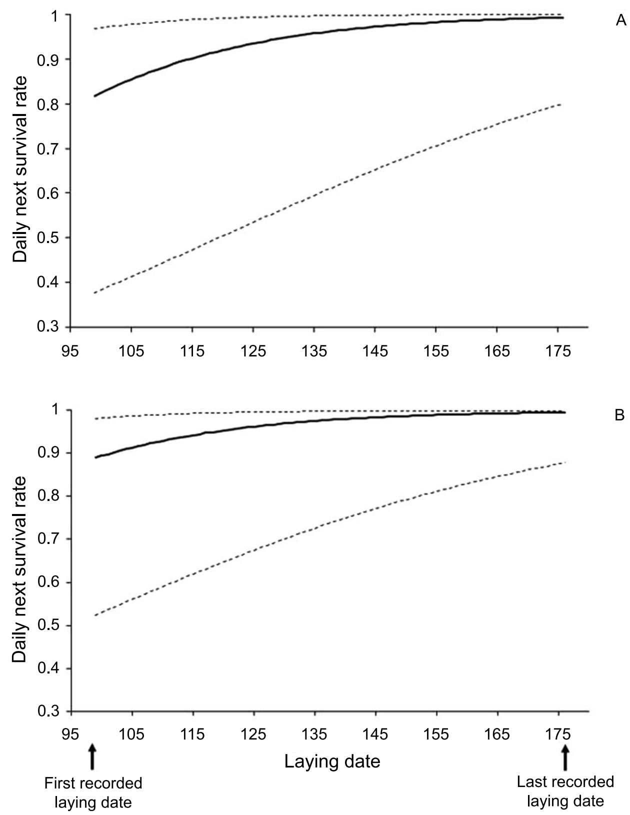

Figure 4. Variation of daily nest survival rate as a function of date in sandy (A) and rocky (B) habitats. Estimates were calculated from the model (laying date + habitat); dashed lines represent the lower and upper limits of 95% CI of the estimates.

that these birds return to breed along the northern Atlantic coast of Morocco at an earlier date (first half of March) than other Mediterranean breeding populations, such as those in Spain (end of March and beginning of April; Bertolero & Martinez-Vilalta 1999) and France (first half of April; Vincent-Martin 2007). This temporal shift was also observed for egg-laying between Morocco (first half of April) and France (first half of May; Vincent-Martin 2007), but did not correspond directly for Spain (second half of May; Bertolero & Martinez-Vilalta 1999). Furthermore, we found that in the studied colonies, nest spacing was closer than that noted in southwestern Spain (Calvo 1994, Calvo & Furness 1995). It should be noted that there is no evidence that this difference in nest aggregation is because of a limited number of available nesting sites, since suitable potential nesting sites in both sandy and rocky habitats were widely available in our study area. However, it could be interpreted as a response of nesting birds to increase nest protection against predators as suggested for some related colonial birds (Oro 1996, Hernandez-Matias *et al.* 2003, Lengyel 2006). Our field observations showed that the main nest predators of Collared Pratincoles were Yellow-legged Gulls *Larus michahellis* and Norway Rats *Rattus norvegicus*. We also observed that when a predator was approaching the colony, incubating birds left their nests and attempted to face the intruder collectively, by flying in congregated flocks above the colony and by emitting intense alarm calls.

With regard to clutch size, our results suggest that, in our study area, Collared Pratincoles produce relatively smaller clutches (mean = 2.3 ± 0.71 se) than those breeding in more northern areas, such as in Spain (Bertolero & Martinez-Vilalta 1999) and France (Vincent-Martin 2007). This geographic variation in clutch size is consistent with the widely recognized pattern of latitudinal changes in avian clutch sizes (Ashmole 1963, Baker 1995, Rubolini and Fasola 2008). However, our results suggest that even at the small scale of our study area, there was significant variation in clutch size according to habitat type. Overall, clutch size was higher in rocky areas compared with sandy ones. Similarly, the number of chicks produced per successful nest was higher in the rocky habitat compared with the sandy one, suggesting that rocky platforms may confer better nesting conditions than sandy beaches.

In our study area, the hatching success of Collared Pratincole nests did not exceed the threshold of 50%, which is similar to that reported in the Ebre Delta in Spain (Bertolero & Martinez-Vilalta 1999), but lower than that recorded at the Guadalquivir marshes in Spain (Calvo 1994), in Valence and in the Camargue area in France (Dolz *et al.* 1989, Vincent-Martin 2007). In all these areas, human-related causes (mainly egg-gathering in our study area and nest destruction by domestic animals in the European areas) contributed significantly to nest loss, which shows the great vulnerability of Collared Pratincoles to human disturbance. Moreover, we found that in the Moroccan populations studied, nest survival rate varied according to nesting habitat type. Higher nest survival rates were found in rocky areas compared with sandy ones. This may be explained by the relatively lower human disturbance in rocky areas compared with sandy ones. Indeed, sandy beaches are more intensely used as recreational areas. The high spring and summer frequentation of beaches by walkers and their animals (especially dogs) constitute a serious threat to Collared Pratincole nests. This underlines the high vulnerability of Collared Pratincoles to human disturbance. However, in the rocky platforms, Collared Pratincole nests were more threatened by flooding. These platforms are generally located near the infratidal zone, and are thus more frequently subject to flooding by high tides. Nest survival rates were also found to increase over the breeding period in the two nesting habitats studied, suggesting that in both habitats nest failure was more frequent at the beginning of the breeding season. Nonetheless, the underlying processes seem to be different from one habitat to another. For example, in the rocky habitat, nest flooding decreased as the breeding season progressed because the seas are stormier in spring than at the beginning of summer. However, on sandy beaches the increase in nest failure over time seemed to be related to the change in the activity and behaviour of nest predators, especially Norway Rats. Unfortunately, we did not monitor these nest predators or collect data on their activities and behaviours, but some field observations that we made led us to believe that Norway Rats are less abundant during the summer months than in the spring. More detailed studies of seasonal variation in predator activities should tell us more about this issue.

Overall, the results of our work show that, along the Atlantic coast of Morocco, Collared Pratincoles face comparable threats to those known along the northern border of the Mediterranean. Our results also show that in this coastal area, rocky platforms seem to confer better nesting conditions than do sandy beaches. The latter habitat is subject to relatively high human disturbance, decreasing nest survival and breeding success. However, further, more detailed studies on the effects of human disturbance and predators on the survival of Collared Pratincole nests are needed for more firm conclusions about this issue.

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