Long term reproduction data of Kentish Plover *Charadrius alexandrinus* along a Mediterranean coast

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Since the 1990s, the nest site preferences, breeding biology, population trend, habitat use and ecology of the Kentish Plover *Charadrius alexandrinus* have been studied along the sandy beaches of Latium, central Italy. Kentish Plovers breed there from the second week of March to the end of June. Until 2003, each female produced 0.64–0.79 fledged young per season and many second clutches were laid. But during 2007–2009 females only produced 0.31–0.59 fledged young per season and hardly any second clutches were laid. Moreover the number of pairs and the number of sites used halved. We attribute the decline in the population to increased human recreational use of the nesting beaches, especially the daily cleaning of sand using heavy mechanical equipment.

INTRODUCTION

Since the 1950s, the Kentish Plover *Charadrius alexandrinus* has been among the most rapidly decreasing waders in Europe, mainly due to the destruction of natural habitats and human disturbances mostly caused by tourism (Shulz & Stock 1993). This is well illustrated by the disappearance of the species from many areas in NW Europe such as the British Isles, Norway and Sweden and by declines in areas of Central and S Europe (Shulz & Stock 1993). The breeding biology of Kentish Plovers has been studied at some Mediterranean coast sites (Lessels 1984, Mainardi 1996, Massa 1977, Montalvo & Figuerola 2006, Pineau 1991, Szekely 1997, Valle *et al.* 1995). In Italy, however, long term data regarding habitat use and population trends are still sparse; moreover, existing knowledge is unequally distributed. Recently the first national workshop on the Kentish Plover (Biondi & Pietrelli 2011) highlighted the precarious situation of the species in Italy: about 80% of breeding pairs are located in just three large sites. This concentrated distribution means that the Italian breeding population is highly vulnerable. Human pressure on coastal environments is constantly increasing; therefore a detailed knowledge of the Kentish Plover's status and requirements is vital if conservation prescriptions are to be effective.

The beaches of Italy and much of Europe are at the centre of a conflict between the interests of recreation and conservation. This is well illustrated by the fact that the preservation of natural habitat and the management of the beaches are not included in the criteria for assessing the cleanliness and health of beaches for the Blue Flag eco-label (*www.blueflag.org/Menu/Criteria/Beaches*). This conflict cannot be completely resolved. However, experience in Italy is that the conservation of bird breeding habitat is compatible with limited human use of beaches (Pietrelli *et al.* 2001).

In this paper we present data on the breeding ecology and population of Kentish Plovers on the coast of the Italian region of Latium collected over the 19 years 1991–2009. During this period, the Latium coast has been the subject of extensive human development which has had a major impact on its Kentish Plover breeding population.

MATERIALS AND METHODS

Data on Kentish Plover breeding ecology were collected during 1991–2009 along the Latium coast (which is 299 km long, including 236 km of sandy and 63 km of rocky beaches). Although it has been subject to much human development, there is still a site that is largely inaccessible with primary dunes (Castelporziano Park) and a remarkable sandy salt marsh (Parco Nazionale del Circeo). Potential breeding areas were identified and plotted on detailed maps (1:5,000) using various sources of information about the suitability of available coastal habitats for Kentish Plovers (including Google Earth). Nest searches on foot were carried out on the breeding beaches every year; nests found were checked every 1–2 days during the laying period, and every 5–6 days during incubation, until their fates were known. Data collected included:

a. Egg laying and hatching times and dates were determined by direct observation (so it is likely that the error was <1 hour, but for nests found after clutch completion, laying dates were estimated using the egg-flotation method (Hays & Le Croy 1971).
b. Fledging success was determined as the ratio of fledged young to the total number of successfully hatched eggs.
c. Adult sex ratio at each site was determined as the male/female ratio of all adults present during egg incubation;
d. The presence of predators, major causes of disturbance, and feeding parameters were recorded during 30-minute observation periods (an aggregate of 52 hours over two years). These factors were compared between inaccessible and open-access beaches;
e. Distances (m) were measured of each nest from the sea, from freshwater, from the nearest active conspecific nest and from the nearest Little Ringed Plover *Charadrius dubius* nest. We also recorded the distance (cm) between each nest and the nearest object (defined as anything that was not vegetation and was >5 cm in any dimension). A laser rangefinder was used for all these measurements;
f. The % vegetation cover and vegetation characteristics were assessed for a radius of 2 m from each nest.

RESULTS

During the whole 1991–2009 study period, around half the Kentish Plover population of Latium occurred as solitary nests scattered among at least 23 different sites, some of which were used every year while others were only used temporarily. Almost half the sites (48%) had an area of suitable habitat of <5 ha. In 2009, only 12–14 breeding pairs were found at six sites, four of which were of >5 ha (Table 1). During the study period, the breeding density across all occupied sites varied from 0.03 to 1.67 pairs/ha with an annual average of 0.31 pairs/ha. The Latium population was stable during 1991–1998 at 30–38 pairs, but then declined and there were only 12–14 pairs in 2009 (Table 1). The maximum ratio of adult males to females recorded at a single site was 2.7, but the average annual value was 1.16 (Table 1).

Nest site preferences

Often, nesting territories were characterized by many scrapes (up to 15 in 25 m^2) made by the male during territory establishment and courtship. Among 234 clutches, five (2.1%) were in the same nest scrape that had already been used once in the same season. 73.2% of clutches were within 35 cm of an object, but objects were not in any specific compass direction from the nests.

The substrate of most nests was sand (>80 %) and plant cover in the 2 m radius from the nests was consistently <10% and mainly around 5cm high (Table 2). Plant species most commonly found close to the nest were *Cyperus capitatus*, *Daucus maritima*, *Pancratium maritimo*, *Inula viscosa*, *Ammophila littoralis* and seedlings of *Arundo donax*.

Plant cover in newly occupied nesting areas increased with date, as shown by a significant positive correlation between % plant cover within 2 m of each nest and successive 10-day periods in which the eggs were laid ($r = 0.31$, $n = 165$, $p < 0.001$). This trend is even stronger if the data for Castelporziano Park, a large site and the only one with no human access, are excluded ($r = 0.53$, $n = 124$, $p < 0.001$). Replacement and second clutches tended to be placed in a more vegetated area (cover >30%, h > 5 cm) than the first: an average increase of 37% cover. Replacement nests were constructed an average distance of 76 m (±SD = 19.5, range 0–110 m, n = 27) from the first nest.

Each year the average distance of nests from the sea (range 20–120 m) was invariably a lot less than their distance from freshwater (15–2,000 m, Table 2). Nests tended to be further from freshwater during 1991–1998 than during 2003–2009

Table 1. Percent frequency of sites with different numbers of pairs of Kentish Plovers breeding along the Latium coast of Italy during 1991–2009.

Year	Number of sites	% sites with:				Total pairs	Sex ratio male/female	Mean density pairs/ha (range)
		1 pair	2 pairs	3–4 pairs	>5 pairs			
1991	14	50	21	21	7	31–33	–	0.26 (0.05–1.25)
1992	15	47	13	27	13	35–36	1.26	0.29 (0.05–1.25)
1993	16	44	26	25	6	35–38	1.11	0.30 (0.03–1.25)
1994	16	44	25	25	6	36–37	1.34	0.37 (0.03–1.67)
1998	14	43	36	14	7	30–35	–	0.26 (0.03–1.25)
2003	13	39	31	23	8	24–25	1.15	0.27 (0.03–1.25)
2007	9	38	25	38	0	17	–	0.49 (0.07–1.67)
2008	9	44	22	22	11	19	1.00	0.23 (0.05–1.22)
2009	6	50	33	17	0	12–14	1.10	0.32 (0.05–1.25)

Table 2. Characteristics of the nest sites of Kentish Plovers breeding along the Latium coast of Italy during 1991–2009 (mean values). The data for distance to nearest conspecific nest and nearest Little Ringed Plover nest only relate to those sites where there were at least two Kentish Plover nests or at least one Little Ringed Plover nest respectively.

Characteristic	1991 n = 27	1992 n = 32	1993 n = 38	1994 n = 40	1998 n = 33	2003 n = 22	2007 n = 13	2008 n = 17	2009 n = 12
Distance to sea (m)	45.8	47.2	63.0	69.3	63.6	67.7	67.2	70.7	92.0
Distance to freshwater (m)	756.8	965.5	899.0	707.2	832.7	535.5	189.9	170.3	372.5
% plant cover within 2 m of nest	9.2	8.3	12.2	9.3	9.8	8.7	4.5	9.8	3.4
Height of plant cover:									
% 0–5 cm	?	63.3	60.5	70.0	65.4	73.1	67.4	69.7	67.5
% 6–30 cm	?	33.3	23.7	20.0	23.5	19.8	21.6	18.4	27.7
% 31–50 cm	?	3.4	13.2	7.5	9.8	7.1	8.0	8.3	3.4
% >50 cm	?	–	2.6	2.5	1.3	–	3.0	3.6	1.4
Substrate:									
% Sand	93.5	81.6	82.1	85.0	87.8	100	92.3	100	91.7
% Dry mud/soil	6.5	18.4	15.4	12.5	6.1	–	7.7	–	8.3
% Stones	–	–	2.6	2.5	6.1	–	–	–	–
Distance to nearest conspecific nest (m)	114.7	123.8	261.0	191.8	176.3	147.2	137.4	34.7	142.5
n	14	25	22	30	28	8	7	6	6
range	25–650	30–400	30–990	6–500	15–850	11–820	22–720	15–125	21–500
Distance to nearest Little Ringed Plover nest (m)	47.8	118.7	293.5	166.1	148.5	36.7	24.7	25.5	58.3
n	5	8	16	18	9	6	4	3	3
range	18–126	15–180	23–137	19–600	15–900	24–75	0–245	10–45	15–95

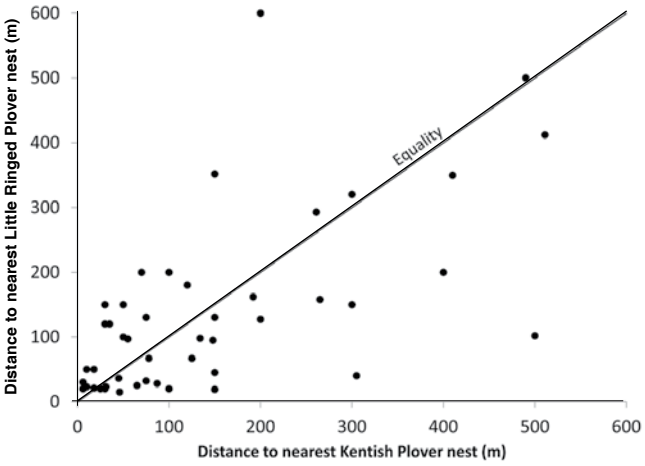

Fig. 1. Distance of 47 Kentish Plover nests on the Latium coast of Italy from the nearest Little Ringed Plover nest plotted against distance from the nearest conspecific nest (i.e. data limited to those sites where both species occur together). As there are similar numbers of observations on both sides of the equality line, there is no indication of a tendency for Kentish Plover nests to be closer to conspecific nests than Little Ringed Plover nests or vice versa.

(Table 2), but this is mainly due to the reduction in the number of nests at the largest breeding sites. The distance of nests from the sea was positively correlated with the decade (10-day period) in which the eggs were laid; and this correlation is stronger if data for the larger sites (>15 ha) are excluded (Table 3). The distance between Kentish Plover nests and the nearest conspecific nest was significantly greater in the larger sites (>15 ha) than in the smaller ones (337.6 m ±SD = 261.6 vs. 57.5 m ±27.2, t = 4.6, df = 56, $p < 0.01$). Similarly the distance between Kentish Plover nests and the nearest Little Ringed Plover nest was significantly greater in the larger sites than in the smaller ones (461.1 m ±SD = 333.9 vs. 92.9 m ±45.6, t = 6.24, df = 42, $p < 0.01$). For those sites where both species occur together there is no tendency for Kentish Plover nests to be closer to conspecific nests than Little Ringed Plover nests or vice versa (paired t-test: distance to conspecific nest minus distance to nearest Little Ringed Plover nest, mean = –5.9 m, 95% CIs –27.9 to +16.1, t = –0.54, p = 0.59, n = 47; Fig. 1).

Breeding biology

The egg laying period was from the second week of March to the first week of July, the earliest laying date recorded was 12 Mar 1994 (Fig. 2). The proportion of late clutches declined in the latter years of the study and in 2009 no new clutches were laid after May.

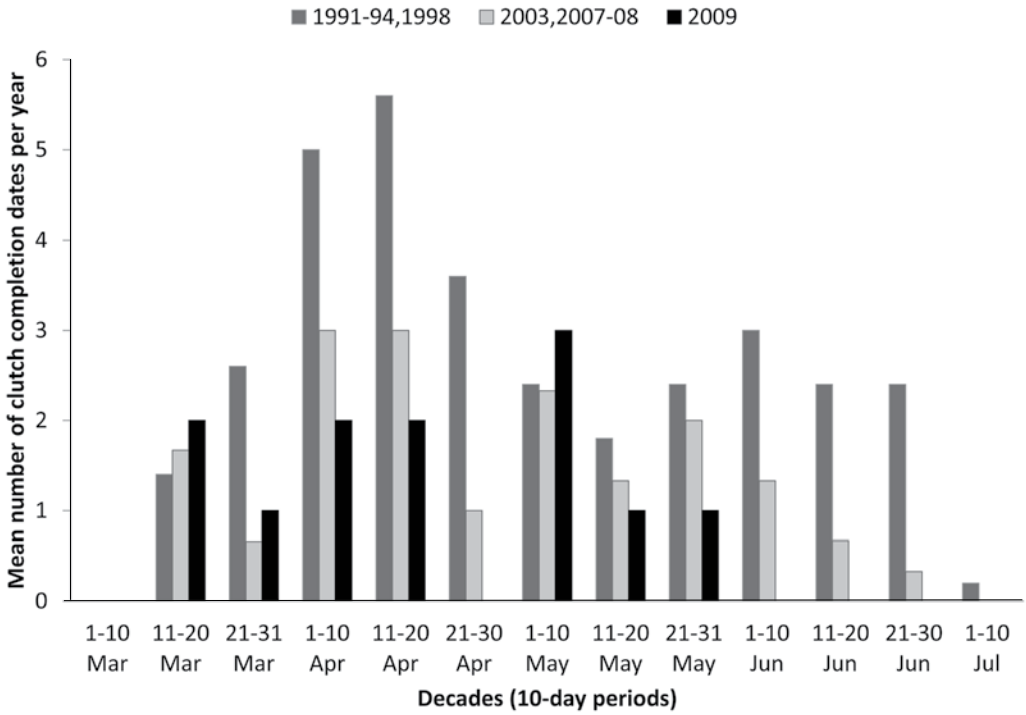

Fig. 2. Frequency distribution of clutch completion dates by decade (10-day periods) of Kentish Plovers breeding along the Latium coast of Italy between 1 Mar and 10 July during 1991–94 and 1998; during 2003 and 2007–08; and in 2009.

Table 3. Annual correlation coefficients (R) between laying decade (10-day period from 1 Mar) of Kentish Plovers breeding along the Latium coast of Italy during 1991–2009 and distance from the sea (* $p \leq 0.02$; ** $p \leq 0.001$).

	1992	1993	1994	1998	2003	2007	2008	2009
R (all sites)	0.424*	0.400*	0.735**	0.806*	0.902**	0.725*	0.714**	0.883**
n	32	38	40	33	22	13	17	12
R (sites <15 ha)	0.837**	0.500**	0.831**	0.884*	0.938**	0.768*	0.804**	0.900**
n	24	30	32	25	16	8	13	11

Average incubation period was 24.5 ±SD = 0.4 days (n = 38) while the mean interval between the laying of each egg was 33.2 ±4.7 hours (n = 9). When clutches were lost in the early stages of the breeding season, replacement clutches were laid; and on average females started laying replacement clutches 10.5 ±0.8 days after clutch failure (n = 8). At two sites females deserted their first brood 8.2 ±0.3 days after hatching (n = 6) and the male cared for the chicks alone. Chicks fledged on average 31.0 ±2.6 days (n = 6) after hatching.

Average clutch size varied annually between 2.41 and 2.92, though differences in clutch size between years were not significant (Kruskal–Wallis Test, H = 0.68, p = 0.88; Table 4). The modal clutch size was three (79.4% of nests); 15.1% of clutches were of two eggs and 5.5% of one egg (n = 126). However, no one-egg clutch was incubated, suggesting that they were nests that had been deserted before the clutch was complete. Clutch size decreased with laying-date: 63 % and 74% of clutches containing respectively one and two eggs were laid after 20 April.

When data for all years are combined, 42% of eggs hatched, 23% of eggs produced a fledged young, and of the eggs that hatched 55% produced a fledged young (Table 4).

Predators were responsible for more than half of nest losses the cause of which could be determined, and human activities were responsible for about a third (Table 5).

DISCUSSION

During 1991–1998, the years of population stability, the willingness of Kentish Plovers to nest as solitary pairs in small isolated sites in Latium and to use places that appeared to afford less-than-optimal habitat suggests that they have the capability of surviving in sub-optimal conditions. But since 1998, the number of breeding pairs has declined by almost two thirds and it is clear that the population is no longer sustaining itself. Undoubtedly the main factor responsible for the decline has been the increase in human use of beaches for recreation. This is reflected in the reduction in the number of occupied sites from 11–15 during 1993–1998 to only four in 2009, the tendency for birds to use less suitable habitat (more vegetated and further from the sea) as the season progressed and a cessation of late breeding attempts.

The fact that six females deserted their broods around eight days after hatching suggests a system of sequential polyandry as reported for the very similar Snowy Plover *Ch. nivosus* by Warriner *et al.* (1986) who suggest that it could be a facultative response to a male-biased sex-ratio arising from differential adult survival. Sandercock *et al.* (2005) found similar male-biased sex-ratios in Kentish Plovers breeding in Turkey, but the explanation was not related to adult survival but to differential survival of juveniles and by higher encounter rates among adult males than females. We have no idea why the proportion of males found in 2008–2009 was reduced compared with earlier years (Table 1), but it seems possible that this change may have limited the opportunities for females to rear additional broods. Therefore this might have contributed to the population decline.

Kentish Plovers, like other ground-nesting birds, lay nest material around their eggs to reduce the amplitude of temperature fluctuation and to provide camouflage against visually searching egg predators though camouflage is thought to be the more important reason (Solis & de Lope 1995, Szentirmei & Szekely 2004). In much the same way the tendency for later nests to be located in areas of greater vegetation cover and at a greater distance from the sea (Table 3) might be interpreted as a strategic withdrawal to a habitat that is safer in view of the predation and disturbance threats but is otherwise

Table 4. Reproductive parameters of Kentish Plovers breeding along the Latium coast of Italy during 1991–2009.

Year	No. of sites	No. of pairs	Eggs laid	Eggs per clutch	Eggs hatched (% of eggs laid)	Fledged young (% of eggs laid)	Fledged young as % of eggs that hatched
1991	9	22	36	–	–	–	–
1992	10	28	75	2.68	37 (49%)	22 (29%)	59%
1993	12	36	101	2.81	54 (53%)	23 (23%)	43%
1994	15	31	88	2.84	37 (42%)	23 (26%)	62%
1998	11	33	91	2.76	35 (43%)	21 (23%)	60%
2003	10	22	53	2.41	22 (42%)	15 (28%)	68%
2007	6	13	32	2.46	9 (28%)	4 (12%)	44%
2008	8	17	44	2.59	11 (25%)	10 (23%)	91%
2009	4	12	35	2.92	8 (23%)	4 (11%)	50%
Total		**192**	**555**		**156 (42%)**	**86 (23%)**	**55%**

Table 5. Causes of clutch loss of Kentish Plovers breeding along the Latium coast of Italy during 1991–2009.

Cause	1992	1993	1994	1998	2003	2007	2008	2009	Total
Stormy sea	–	1	–	–	1	4	2	–	8
Corvids	1	5	1	2	3	1	2	4	19
Gulls	–	1	–	2	–	–	–	–	3
Foxes	1	4	1	2	–	–	1	–	9
Mustelids	–	1	1	–	–	–	–	–	2
Domestic dogs	–	5	2	–	–	–	1	–	8
Human activity	1	3	2	3	4	3	6	2	24
Desertion, cause unknown	–	3	1	–	–	–	–	–	4
Unknown	3	2	4	1	1	1	–	–	12
Total	**6**	**25**	**12**	**10**	**9**	**9**	**12**	**6**	**89**

suboptimal. The tendency for nests to be located further form the sea in more vegetated areas is particularly evident if one of the largest sites, Castelporziano Park, is excluded. That is the only site without human access, so the birds are not constrained to move up-beach to avoid human disturbance. Nevertheless we noted a tendency for birds at Castelporziano Park that had lost their first clutch to make their second nest in a more camouflaged site (e.g. under driftwood or close to an object on the beach). On average replacement nests in our relatively small sites were only 76 m (range 1–110 m) from the first nest which is much less than that found by Fraga & Amat (1996) at a large site in Spain (mean 467 m, range 0–3.29 m). Therefore the small size of the Latium sites represents a significant constraint on the birds' ability to choose a safer site for re-nesting.

Spacing between Kentish Plover nests (where at least two were present at a site) was similar between years (Table 2) but the mean distance (>100 m in most years) was high compared with other similar size breeding populations (Norte & Ramos 2004, Valle & Scarton 1999). Other studies suggest that a good strategy for birds that are unable to defend their nests against visually-searching predators is to site them widely dispersed from each other (Gottfriield 1978). Therefore it seems that Latium Kentish Plovers employ this strategy within the constraints set by the small size of the sites.

The phenology of egg-laying we recorded on the Latium coast is similar to that found in other Mediterranean sites (Cherubini & Panzarin 1994, Mainardi 1996, Mascia & Grussu 2011, Massa 1977, Oltra & Gomez 1994, Pineau 1991) and the Arabian Peninsula (Kosztolanyi *et al.* 2009). However, it is about a month earlier than on the Atlantic coast of Europe (Debout 2009, Norte & Ramos 2004) and in Asian populations (SoonBok & Higashi 2008). Quantitative analysis of entomofauna along the coast of the Tyrrhenian Sea shows that the breeding season starts when arthropod food resources reach their peak (Fallaci *et al.* 1994).

The interval between the laying of eggs was similar to that at other Mediterranean sites (Szekely *et al.* 1999) but less than half the time reported for a site in N France (Debout 2009). The period we recorded between clutch-loss and laying a replacement clutch appears to be about the minimum required for egg formation (Szekely *et al.* 1993). Mean clutch size was similar to other Mediterranean areas (Fraga & Amat 1996, Oltra & Gomes 1994).

The distribution of clutch completion dates (Fig. 2) shows two peaks, the second relating to replacement and second clutches. Similar curves were reported by Debout (2009) and SoonBok & Higashi (2008). However, the difference between the first and last laying dates shows a sharp reduction in the breeding season on the Latium coast over the period of our study. During 1991–1998, clutches were laid over 89–103 days with the last in July, but over only 64 days in 2009 with the last in May, a reduction in the laying period of about a third. Similarly in two areas with low human disturbance in Spain, clutches were laid over 100–105 days and 88–110 days compared with 70–75 days where human disturbance was high (Fraga & Amat 1996, Oltra & Gomez 1994). The shorter laying period in disturbed areas reflects the fact that replacement clutches are laid when the first is lost, but there are few if any second clutches following successful first clutches (Fig. 2). Consistent with this is the fact that from 2008 we found that many birds departed from the Latium breeding sites earlier than in previous years.

The decline in the Latium Kentish Plover population since 2007 is reflected not only in the reduction in the number of sites occupied, the number of pairs and the number of eggs laid, but most importantly in the proportion of eggs that hatched; 42–53% hatched during 1992–2003, but only 23–28% during 2007–2009 (Table 4). In contrast fledging rates have remained fairly stable. Therefore it is the incubation phase that has been the most affected by increased human use of the beaches (which in recent years has included daily mechanical beach-cleaning).

During the 1991–2003, female Kentish Plovers on the Latium coast produced 21–23 fledged young per year (Table 4) which corresponds to 0.64–0.79 per female. Page *et al.* (1983) considered that 0.80 fledged young per year per breeding female were required for Snowy Plovers to maintain a stable population. Therefore, even during 1991–2003 productivity was probably insufficient to maintain the population without immigration. Subsequently productivity dropped to 0.31, 0.59 and 0.33 fledged young per female in 2007, 2008 and 2009 respectively indicating that reproduction is far below sustainable levels. A factor that has clearly exacerbated this situation is the recent failure even for the birds to attempt second broods. Juvenile survival in Kentish and Snowy Plovers is low (Boyd 1962, Fraga & Amat 1996, Stenzel *et al.* 2007); therefore it is likely that in recent years very few Latium-reared birds will have survived long enough to augment the adult population.

Although many clutches are lost to natural predators, particularly crows (Table 5), we have no reason to believe that the impact of predation has increased over the two decades of our study or changes during the course of a single breeding season. On the other hand not only has human disturbance increased over the years but it also increases strongly during March to July and has become the single most important factor affecting the Kentish Plover population on the Latium coast. Human disturbance causes the birds to spend time and energy avoiding humans and this means that they have less time in which to forage and look after their eggs or chicks (Burger 1993). Thus, whether the Kentish Plovers' eggs hatch or the chicks survive has come to depend on spring weather, not because the weather affects the birds but because good weather brings many people on to the beaches. All too many clutches have disappeared after a sunny weekend. This is consistent with the finding that less human activity, particularly during weekends, leads to increases in bird density (Cornelius *et al.* 2001, authors' unpubl. data). Broadly, our assessment of the impact of predators and human disturbance is consistent with that found in Normandy by Sagat (1994) and in the NW Adriatic by Cherubini & Panzarin (1994).

As Little Ringed Plovers show a preference for fresh water (Cramp & Simmons 1983), Kentish Plovers which prefer saline sites should have little contact with them. However, on the Latium coast the two species come together around river-mouths and where there are freshwater ponds within or behind the sand dunes. The adults of the two species tend to forage in different places, Kentish Plovers forage mainly in the intertidal or supratidal zones, whereas Little Ringed Plovers forage around freshwater rivers, channels or ponds (Cramp & Simmons 1983). However, they might come into conflict through nest site selection, in particular within the boundaries of the some of the smaller sites. There is no tendency for Kentish Plover nests to be further from Little Ringed Plover nests than from other Kentish Plover nests (Fig. 1). Therefore, although the two species clearly tolerate one another, there is potential for conflict if they both want to nest in the same place. This sort of conflict might have been behind the surprising case of a nest containing a mixture of the two species' eggs found in 2007 at Torre Flavia, near Rome (Biondi & Pietrelli 2009).

The situation for Kentish Plovers at Castelporziano Park is very different from that of the smaller sites. It is an area that has a high number of predators (red foxes *Vulpes vulpes*, crows *Corvus* spp., gulls *Larus* spp., etc.), but there is a complete absence of the humans and no Little Ringed Plovers. Without human activity, the length of the breeding season at Castelporziano Park is longer (>90 days) than it is now at the other sites, the eggs appear to be bigger (authors' unpublished data) and when they are away from the nest the adults devote nearly 75% of their time to foraging and 25% to avoiding predators, and no time to avoiding humans (based on 26 hours of diurnal observation). In contrast, at other Latium sites the adults spend a considerable proportion of their time mobbing humans in much the same way that they mob predators.

In an effort to reduce clutch-loss to predators at Castelporziano Park, wire mesh exclosures (6 × 6 cm mesh, 1.5 m diameter) have been installed over some nests. This has resulted in much higher clutch survival (69% of eggs hatched) (Pietrelli *et al.* 2001). Possibly this approach could be tried on other beaches, though exclosures might attract the unwanted attention of people.

As we have shown, the main problem for Kentish Plovers on the coast of Latium has been the huge increase in human recreation, particularly the daily cleaning of beaches by raking and sieving the sand using heavy mechanical equipment. Until this conflict is addressed, the prospects for the species are bleak.

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