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Nesting Site Preference and Hatching Success of the Kentish Plover (*Charadrius alexandrinus*) in the Nakdong Estuary, Busan, Republic of Korea

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ABSTRACT: This study was conducted to determine clutch size and habitat usage of Kentish plovers (*Charadrius alexandrinus*) breeding on Sinja-do Islet in the Nakdong Estuary from 22 April to 12 July in 1995 and from 21 April to 20 June in 1996. The Kentish plover preferred grasslands and damp sands to dry dunes as nesting sites. The difference in hatching success among these microhabitats was attributed to high tides, which washed away many nests on damp sands, and strong winds, which frequently shifted the sand to bury eggs on dry dunes. The main mortality factor in grasslands was predation by magpies *Pica pica.* Each clutch contained one to four eggs, with a mode of three eggs. Hatching success was highest in two-egg clutches and lowest in one- and four-egg clutches. The mean interval for egg laying was 1.8 days between the first and second eggs and 2.1 days between the second and third eggs. The average incubation period was about 24.2 days.

Key words: *Charadrius alexandrinus*, Hatching success, Kentish plover, Nakdong Estuary, Nesting site preference

INTRODUCTION

The Kentish plover (*Charadrius alexandrinus*) is a cosmopolitan bird species, breeding on coasts and in saline inland wetlands (Johnsgard 1981, Cramp and Simmons 1983, Székely 1990). In general, shorebirds nesting on the ground are exposed to many abiotic mortality factors such as high waves, high tides, strong winds, and heavy rains (Morris 1979, Clancy 1987), and their choice of microhabitats for breeding is the most critical factor affecting their breeding success (Morris 1979, Holloway 1993). In addition to abiotic factors, shorebirds are exposed to predatory birds, mammals, and reptiles (Morris 1979, Page et al. 1983, Székely 1992, Holloway 1993). Some shorebird species form large colonies in which birds show communal defense against predators (Lark 1954, Götmark 1982). However, many shorebirds species, including plovers, depend more on subterfuge and camouflage than aggressive anti-predator behaviors, although they sometimes mingle into colonies of other shorebirds to breed under their protective umbrella (Powell 2001).

The Nakdong Estuary, in Busan, Republic of Korea, is one of the most important staging and wintering areas for birds that migrate along the East Asian route (Post 1983). Accordingly, most previous studies in the Nakdong Esturary have focused on surveys of the avifauna (Won 1974, 1988, Post 1983, Scott 1989, Hong 1997, 2003, 2004a, 2004b, 2005) except for studies of the breeding ecology of little terns (*Sterna albifrons*; Hong 1997, Hong et al. 1998).

A total of 133 avian species (29 families, 12 orders) have been recorded so far in the Nakdong Estuary. The Kentish plover is one of the dominant species (Hong et al. 1998). Kentish plovers primarily inhabit small islets dominated by colonies of little terns, which show communal anti-predator defense (Davies 1981). These islets are often flooded at high tide but are occasionally connected to each other or the mainland at low tide, allowing mammalian predators access to the islets. In this study, we observed the breeding behavior of the Kentish Plover on an islet in the Nakdong Estuary, with special reference to the effects of habitat usage, clutch size, and egg laying order on their breeding success. Our study was conducted to obtain information about Kentish plover breeding ecology to inform conservation and management plans for the Nakdong Estuary.

METHODS

Kentish plovers nested in the following three types of habitat on Shinja-Do Islet: dry bare sand (habitat type A); grasslands dominated by short grasses (habitat type B); and damp bare sand on

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relatively low land (habitat type C; Fig. 1). Habitat types A, B, and C occupied 20.5 ha, 10 ha, and 3.5 ha of the 125-ha Shinja-Do Islet, respectively (Table 1). The other 91 ha of the islet were covered by reeds or wet habitats that were not inhabited by Kentish plovers. We conducted observations of the habitat preferences of Kentish plovers on Shinja-Do Islet. From 1978 to 1992, the mean monthly air temperature in Busan ranged from 2.8℃ (January) to 25.7℃ (August), and the mean monthly precipitation ranged from 35.6 mm (January) to 269.2 mm (July), with mean annual precipitation of 1,516 mm (Kim 1993). Statistical analysis were performed using *t*-tests (clutch size), ANOVA (mean egg size), and Duncan's posterior analysis (egg-laying order).

Census of Nest Distribution, Clutch Size, and Egg Mortality in 1995

In 1995, we conducted nest censuses by walking around the whole of Shinja-Do Islet almost daily. When a new nest was found, the type of habitat (A, B, or C) was recorded and the nest was marked using an approximately 40-cm-long bamboo stick placed about 1 m from the nest. This bamboo stick was numbered and tagged with a pink ribbon on which the date of discovery and the number of eggs were described with indelible ink. Thereafter, the phenology of the nest was followed for about 30 days until all eggs hatched, and the clutch size, number of surviving eggs, and factors leading to egg mortality were recorded. The following causes of egg mortality were identified: predation by brown rats (*Rattus norvegicus*) or humans (predators were identified by their footprints); wind (shifting sands to cover eggs); waves (washing away the eggs, especially on the southernmost beach on the islet); and flooding due to high tides (washing away the eggs, especially on the northernmost beach on the islet). Egg-laying order was also recorded for 23 three-egg clutches. The eggs were numbered with red indelible ink according to the order of laying. The length (L) and breadth (B) of each egg were measured to the nearest 0.1 mm using Vernier calipers, and egg volume (V) and shape index (SI) were calculated as follows: $V = 0.457 \times L \times B^2 / 1000$ (Hoyt 1979); $SI = B \times 100 / L$ (Coulson 1963). The constant 0.457 was used by Galbraith (1988b) for the lapwing (*Vanellus vanellus*), which belongs to the same family (Charadriidae) as the Kentish plover. The incubation period was recorded as the number of days from the start of incubation to the hatching of all fertilized eggs. The Kentish plover starts incubation soon after all eggs are laid. Hatching success was calculated as $100 \times H / T$ where T is the total number of eggs and H is the number of eggs that hatched.

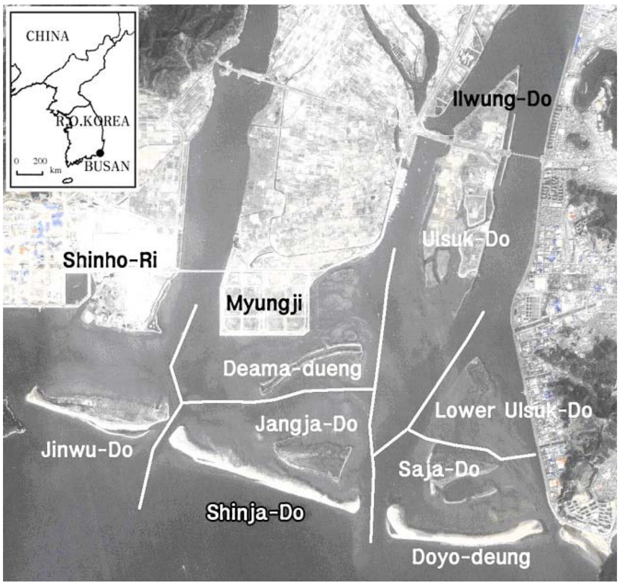

Fig. 1. Location of the study site (Shinja-Do) in the Nakdong Estuary, Busan, Republic of Korea.

Table 1. The area of each type of breeding habitat for the Kentish plover on Shinja-Do Islet

Site	Type	ha
A	Dry bare sand	20.5
B	Grassland	10
C	Damp bare sand	3.5

Additional Surveys in 1996

In 1996, a total of 64 nests were chosen for observation. In three-egg clutches, the length and breadth of each egg were measured to the nearest 0.01 mm using digital Vernier calipers. Calculations of egg volume, shape index, incubation period, and hatching success were as described above. In addition, the eggs were weighed to the nearest ± 0.1 g using a digital pan balance. The main predators of Kentish plovers in this year were a pair of magpies *Pica pica* that constructed their nest on a weeping willow (*Salix* spp.) on a nearby islet (Jangja-Do) and often visited Shinja-Do Islet in the daytime.

RESULTS

Nesting Site Preferences

A total of 237 nests were constructed on Shinja-Do Islet in 1995. About 84% of nests were constructed by mid-May, with another peak in nest-building from late May to early June (Fig. 2). Most of the nests built during the second peak were probably made by birds that had lost their first nests.

Of the 237 nests recorded, 105 were located in habitat type A,

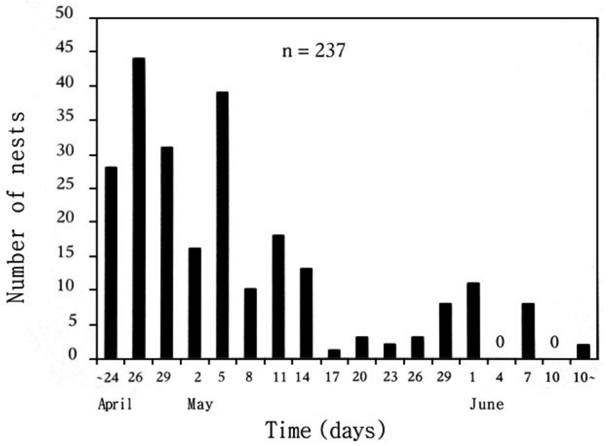

Fig. 2. Number of nests found on each day in 1995.

99 in habitat type B and 33 in habitat type C. In April, habitat B was not yet covered by grasses, and the Kentish plovers preferred habitat type C for their nesting sites over other two habitat types (Fig. 3), with nest density in habitat C reaching its maximum of 9.1 nests/ha on 5 May. However, large areas of this lowland habitat were flooded on 15 May, after which the nest density decreased to 2.3 nests/ha. Habitat type B was rapidly covered by grasses in May and the nest density gradually increased to its maximum of 5.1 nests/ha on 7 June. Habitat type A was the most abundant, covering about 16% (20.5 / 125 ha) of Shinja-Do Islet. However, Kentish plovers did not favor this habitat, which was mainly distributed on higher ground in areas that were frequently blown by strong winds. Eggs successfully hatched in 83 of the 237 nests observed: 35 in habitat type A, 40 in habitat type B and 8 in habitat type C. Thus, the hatching success per nest was 33% (35/105 nests) in habitat type A, 40% (40/99) in habitat type B and 24% (8/33) in habitat type C. Analysis by ANOVA detected significant differences in hatching success among the three types of habitat ($F_{2,234} = 12.30$, $p < 0.001$).

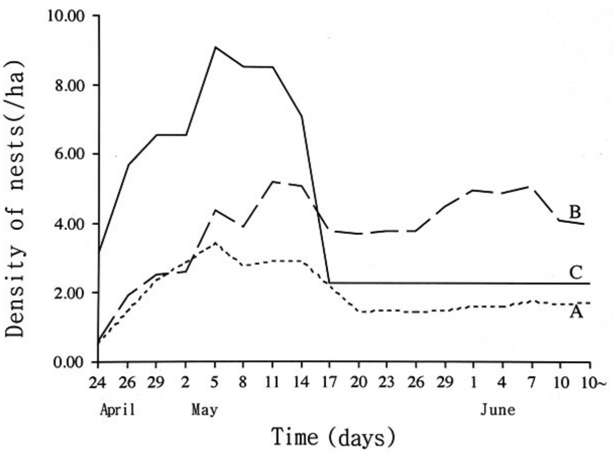

Fig. 3. Seasonal fluctuations in nest density in habitat types A, B, and C.

Clutch Size and Egg Size

The egg-laying period was from early April to late June. Clutch size was determined for 237 nests in 1995 and for 64 nests in 1996. The mean (± S.D.) clutch size was 2.73 ± 0.61 eggs in 1995 and 2.36 ± 0.86 eggs in 1996 (Table 2). Mean clutch size was significantly higher in 1995 than in 1996 ($t = 3.27$, $p < 0.001$). In 1995, the mean clutch size declined significantly during the breeding season from 2.77 ± 0.56 eggs ($n = 199$ nests) from mid-April to mid-May to 2.55 ± 0.83 eggs ($n = 38$ nests) from mid-May to June (Fig. 2; $t_{235} = 2.01$, $p < 0.05$). Most eggs laid in mid-to-late May and June appeared to be produced by birds that had failed in earlier breeding attempts. Variation in egg size was affected by the egg-laying order (Table 3). In three-egg clutches, one-way ANOVA showed that the difference among the first-laid, second-laid, and third-laid eggs was statistically significant for the shape index ($F_{2,105} = 5.55$, $p < 0.005$) in 1996. Analysis by two-way ANOVA with year and order of laying as factors indicated that egg breadth significantly different between two years ($F_{1,173} = 5.28$, $p < 0.05$), egg shape index significantly varied among first-laid, second-laid, and third-laid eggs ($F_{2,173} = 6.82$, $p < 0.001$), and egg volume significantly differed between two years ($F_{1,173} = 6.38$, $p < 0.02$). Results for all other variables and factors were not significant.

Egg-laying Interval and Incubation Period

In three-egg clutches, the egg-laying interval ranged from 1 to 5 days, with an average of 1.76 ± 0.63 days in 1995 ($n = 38$) and 1.81 ± 0.67 days in 1996 ($n = 36$) between the first and second eggs and 2.11 ± 0.76 days in 1995 and 2.00 ± 0.59 days in 1996 between the second and third eggs. There was a significant difference bet

Table 2. Clutch size of the Kentish plover in 1995 (n=237) and in 1996 (n=64)

Clutch size	1995		1996	
	No	%	No	%
1 egg	18	8	15	23
2 eggs	30	13	12	19
3 eggs	186	78	36	56
4 eggs	3	1	1	2
Mean clutch size	2.73		2.36	
s.d.	0.61		0.86	
t-test	$p < 0.001$			

Table 3. Mean egg size (±S.D.) of Kentish plovers by egg-laying order in three-egg clutches in 1995 ($n = 23$) and 1996 ($n = 36$)

	1995				1996			
	Three-egg clutch ($n = 23$)				Three-egg clutch ($n = 36$)			
Laying order	First egg	Second egg	Third egg	p^*	First egg	Second egg	Third egg	p^*
Mean length (mm)	33.04±1.17	33.03±1.28	33.36±1.32	n.s.	32.75±1.05	32.74±0.83	33.16±0.79	n.s.
Mean breadth (mm)	23.58±0.62	23.63±0.69	23.38±0.45	n.s.	23.39±0.52	23.40±0.38	23.26±0.43	n.s.
Mean volume (cc)	8.41±0.58	8.44±0.70	8.34±0.52	n.s.	8.20±0.51	8.20±0.37	8.20±0.43	n.s.
Shape index	71.44±2.79	71.61±2.73	70.17±2.75	n.s.	71.49±2.33	71.52±1.95	70.16±1.58	< 0.005
Mean weight (g)					9.26±0.56	9.24±0.40	9.25±0.44	n.s.

*: ANOVA

ween the egg-laying intervals for first and second eggs and second and third eggs (Duncan's posterior analysis) but there was not a significant effect of year.

A clutch of eggs was incubated for 23 to 26 days, with the mean (± S.D.) incubation period of 24.20 ± 0.86 days in 1995 ($n = 15$) and 24.28 ± 0.84 days in 1996 ($n = 25$). The hatching period, i.e., number of days from the laying to the hatching of each egg, ranged from 23 to 29 days, with an average of 27.73 ± 0.46 days in 1995 and 28.24 ± 0.83 days in 1996 for first eggs and 26.00 ± 0.65 days in 1995 and 26.32 ± 0.85 days in 1996 for second eggs.

Hatching Success in Relation to Clutch Size and Egg-laying Order

Effects of clutch size on egg mortality was analyzed for 225 nests in 1995 (Table 4): 8 one-egg clutches, 28 two-egg clutches, 186 three-egg clutches and 3 four-egg clutches. Hatching success was 0% for one-egg clutches, 43% for two-egg clutches, 38% for three-egg clutches, and 0% for four-egg clutches. The overall mean hatching success was 36%. The main mortality factors for eggs were predators, flooding, waves, and wind. In three-egg clutches ($n = 36$), the egg-laying order did not affect the hatching success.

Table 4. Relationship between clutch size and mortality of the Kentish plover in 1995

Clutch size	1995				
	One-egg[1]	Two-egg[2]	Three-egg	Four-egg	Total
Observed	8	28	186	3	225
Mortality (%)	100	57.1	61.8	100	63.1
Predators	37.5	17.9	20.4		20.4
Wind	50.0	10.7	15.6	33.3	16.4
Waves	12.5	7.1	7.5	33.3	8.0
Floods		17.9	18.3	33.3	17.8
Other		3.6			0.4

[1] Ten out of 18 eggs (cf. Table 2) died by age four days.
[2] Two out of 30 eggs (cf. Table 2) died by age five days.

DISCUSSION

Nest site selection refers to the precise location of nests within a colony (Burger and Shisler 1980). Many previous studies of ground-nesting birds have suggested that reproductive success is affected by habitat conditions (Burger and Shisler 1980) and predators (Göransson et al. 1975, Lessells 1984, Galbraith 1988a, Baines 1990, Berg et al. 1992, Székely et al. 1994b, Blomqvist and Johansson 1995). In this study, Kentish plovers preferred grasslands and damp sand to inland dry dunes as nesting sites, probably because the former two habitats were close to the tidal zone and therefore provided better access to food for the chicks (Page et al. 1983). Galbraith (1988a) and Székely (1992) have shown that chicks from nests nearer to foraging areas tend to have lower mortality rates than those reared farther from food sources.

In many precocial bird species, including the Kentish plover, the primary mortality factor for eggs is predation by crows, magpies, and gulls (Page et al. 1983, 1985, Székely 1990, 1992, Yogev et al. 1996). Precocial species do not display communal anti-predator defense, so their chicks can only try to hide to escape from predators (Page et al. 1983). This suggests that habitat choice may have a strong effect on the breeding success of precocial species. However, the intensity of predation and the productivity of the birds both fluctuate from year to year (Page et al. 1983). Major predators can also differ from year to year, as shown in this study site where magpies were the main predator in 1996 but not in 1995. Nest desertion by females, wherein a female deserts her eggs and mate for unknown reasons and attempts to breed a second time with a different mate, was occasionally observed on the study islet (Hong, unpublished data). Amat et al. (1999) suggested that polygamous breeding may be an important breeding strategy in the long-lived Kentish plover.

Crowell and Rothstein (1981) have suggested that the clutch sizes of some birds vary geographically. In this study, the mean clutch size was 2.55, which is smaller than the mean clutch size of 2.9 reported from Hungary (Székely 1992); however, mean egg size (33.01 mm length, 23.44 mm breadth, 9.25 g mass) in Korea was markedly larger than that reported from Hungary (31.9 mm length, 23.1 mm breadth, 8.7 g mass). Greig-Smith et al. (1988) noted that larger clutches tended to have smaller eggs. The mean incubation period of the Kentish plover in this study was 24.20 days in 1995 and 24.28 days in 1996, whereas Székely et al. (1994b) has reported a mean incubation period in this species of 21.6 days in Hungary. This may be because the definition of "incubation periods" employed differed among authors (Coulson and White 1958b, Cramp and Simmons 1983, Galbraith 1988a, Pietiäinen 1988, Kim 1995, Yogev et al. 1996). Székely et al (1994b) counted the incubation period from the first day when the clutch was continuously incubated and when at least one egg in the clutch sank under water with the apex of the egg not rising up by more than 45 degrees. Kentish plovers start incubating a clutch one or two days after the last egg is laid, and it takes about half a day for eggs are under water to rise (Lessells 1984). Thus, the difference of about 2.6 days in reported incubation periods between this study and that of Székely (1994b) can be explained by different definitions of the incubation period.

In 1995 and 1996, Sinja-do was main breeding site of Kentish Plovers in the Nakdong Estuary. However, more recently, many Kentish plovers in the Nakdong Estuary have been observed breeding at Doyo-deung.

Kentish plovers preferred dry bare sands and grassland dominated by short grasses as breeding sites. If reeds aggressively invade bare sands and grasslands in the Nakdong Estuary, the area used for breeding by Kentish plovers will contract. Therefore, management plans should include control of the spread of reeds in these habitat types.

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