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Habitat Selection by Black-tailed Gulls on Hongdo Island, Korea

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Abstract.—Habitat selection in Black-tailed Gulls (*Larus crassirostris*) on Hongdo Island, Korea, was studied during the breeding period in 2002-2003. To compare topographical advantages and disadvantages on breeding, we examined two habitats on the island: rocky-cliffs (lower and edge) and grassy (upper and inside) for differences in breeding biology and feeding frequency. In rocky-cliff habitat, Black-tailed Gulls had higher clutch size, faster laying and hatching date, and higher hatching and fledging success. Topographically, rocky-cliff habitat had two advantages—it was closer to sea and difficult to access. Proximity to the sea allowed higher feeding frequency whereas difficult access restricted predators. Conversely, grassy habitat was farther from the sea and allowed easier access to predators, but a lot of grass covered nests to protect eggs and chicks. These disadvantages caused low feeding frequency and higher hatching failure. Egging by fisherman was also a disadvantage of grassy habitat because of easy access from landing places. Therefore, our results suggested that rocky-cliff habitat was more profitable habitat than grassy habitat and this profitability was related to topographical difference between habitats. *Received 6 August 2007, Accepted 3 March 2008.*

Key words.—Black-tailed Gulls, breeding biology, egging, habitat selection, *Larus crassirostris.*

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The selection of breeding habitat is important in that it can be related to breeding success in chicks and the survival of parents (Cody 1985; Danchin *et al.* 1998). Topographical differences among breeding habitats have been found to be directly or indirectly related to breeding success and individual survival (Partridge 1978). Gulls in preferred habitat having high breeding success occupy sites with topographical advantages such as easy access to foraging sites and difficult access by predators. Gulls occupying habitat leading to low breeding success exhibit disadvantages such as more difficult access to foraging sites and easier access by predators. In this way natural selection favours gulls choosing habitats that maximize survival and reproductive success (Krebs and Davies 1981; Pierotti 1982).

Black-tailed Gulls (*Larus crassirostris*) are one of the most abundant seabirds in Korea (Won 1981). Hongdo Island, one of the main breeding sites in Korea, accommodates the largest breeding colony of Black-tailed Gulls and is designated as a natural monument to conservation in Korea (Lee *et al.* 2005). In contrast with other islands, only one species, the Black-tailed Gull, breeds on Hongdo Island, so they compete only with each other to obtain sufficient food and occupy good habitats. Black-tailed Gulls occupied the lower elevation on Hongdo Island first when they arrived to breed (Paek and Yoo 1996). However, little is known about the ecological relation between habitat selection and breeding success.

Most gulls generally prefer rocky-cliff habitats for breeding (e.g., Herring Gulls (*Larus argentatus*), Pierotti 1982; Yellow-legged Gulls (*Larus michahellis*), Bosch and Sol 1998). In rocky-cliff habitat, gulls can reduce the threat of terrestrial or avian predators and also access marine foods more quickly. However, gulls in grassy habitats further from the sea do not possess these advantages but vegetation in grassy habitats provides greater shelter from some predators (Lee *et al.* 2006a). Lack (1933) and Cody (1985) suggested that the selection among alternative habitats could influence breeding success. The difference in breeding success because of topographical differences (i.e., rocky-cliff vs. grassy or near shore vs. inshore) is likely a primary mode of natural selection in these species. However, the mechanisms controlling habitat selection are often not clearly understood (Bergin 1992).

In previous studies, Lee *et al.* (2005, 2006a) showed the effect of vegetation cover on breeding success whereas Kwon *et al.*

(2006) described clutch size and other aspects of breeding ecology in Black-tailed Gulls. However the relationship between breeding success and habitat selection has not been described. The goal of this study was to compare advantages and disadvantages in breeding between rocky-cliff habitat and grassy habitat.

METHODS

Study Sites

Hongdo Island (34°31'87"N, 128°43'88"E) is located about 23 km from Geojedo, Southern Kyungsang Province, South Korea (Fig. 1). The highest point of the island is about 115 m.a.s.l. and the area is 98,380 m^2. Cliffs with a slope of over 45° surround the coastline. Vegetation consists mainly of a sedge (*Carex boottiana*), which covers the whole island except the cliffs (Cultural Properties Administration 2003). Two areas on the island were identified to address the question regarding the effect of topography on breeding biology in this species—rocky-cliff habitat and grassy habitat (Fig. 1). Rocky-cliff habitat occurred on the outside margin of the island and consisted of granitic cliff and soil. Grassy habitat on the island was away from the island edge and was covered by sedge. Grassy habitat was easy to access because of its flat ground and close proximity to the boat landing place, whereas rocky-cliff habitat was difficult to access because of a steep cliff.

Breeding Biology

In each habitat, laying date, clutch size, egg mass, and hatching date were measured during the breeding seasons (April to July) of 2002-2003. When nests were built, each nest was marked and was checked every day. In 2002 and 2003, 31 and 35 nests in rocky-cliff habitat and 33 and 26 nests in grassy habitat were sampled repeatedly. Due to egg loss and chick death samples were reduced to 29 and 30 nests in rocky-cliff habitat and 16 and 15 nests in grassy habitat. Egg mass was weighed to 0.5 g with a 100 g 'Pesola' spring-balance. Like Pierotti (1982) and Bosch (1998), this study selected the data (egg mass, laying date and hatching date) of the first-laid egg to compare between habitats. Hatching success is defined as the proportion of laid eggs that produced a hatched chick, and fledging success as the proportion of hatched chicks surviving 15 d after hatching. Causes of nest failure were carefully examined. During the incubating periods, only four causes of hatching failure were found: disappearance, rotten, predation, and died at hatching. After hatching, four causes of fledging failures were identified: disappearance, pecking, typhoon, and starvation. Each cause was defined in Table 1.

Figure 1. Map of Hongdo Island. Habitat A is rocky-cliff habitat (outside on the island). Habitat B is grassy habitat (inside on the island).

Feeding Frequency

Twenty focal nests were observed in each habitat for 4 h on 1, 3, 7, and 10 d after hatching using the scan-sampling method (Altmann 1974; Pierotti 1987) to determine feeding frequency. Using binoculars (Nikon 8×42) every nest was scanned and the number of feedings chicks received per hour was recorded. To compare the feeding frequency between habitats, the mean of measured data during 1, 3, 7, and 10 d was calculated.

Statistical Analysis

Unpaired t-tests were conducted to compare laying date, clutch size, egg mass, hatching and fledging success, the cause of hatching failure, and the feeding frequency between rocky-cliff habitat and grassy habitat. Mean clutch size, laying and hatching date, and hatching and fledging success were compared between years and habitats using the Two-Way ANOVA. Analyses were conducted using SPSS 11.5 (SPSS 2002). All means were represented with a standard error.

RESULTS

Breeding Biology

In 2002 and 2003, 61 and 78 eggs in rocky-cliff habitat and 61 and 44 eggs in grassy habitat were laid. Eleven (20.4%) of 54 and 9 (15.3%) of 59 chicks in rocky-cliff habitat and 15 (36.6%) of 41 and 11 (40.7%) of 27 chicks in grassy habitat failed to fledge. Clutches in rocky-cliff habitat in 2003 were significantly larger than in grassy habitat (Fig. 2). In 2002, clutch size in rocky-cliff habitat was not significantly larger. The difference of egg mass between habitats was not significant although egg mass in rocky-cliff habitat was larger (Fig. 2). Laying date in rocky-cliff habitat was significantly earlier than in grassy habitat, and hatching date in

Table 1. Definition of causes of hatching and fledging failure.

Causes	Definition
Disappearance	Egg or chick disappeared and the status was continued during 3 days.
Rotten	Egg cold and had a bad smell. Egg's condition checked no hatch over 30 days.
Predated	Yolk, broken egg shell, and blood at nest before hatching.
Died at hatching	Dead chick within egg.
Pecking	Signs of pecking on head or body of dead chicks.
Typhoon	After typhoon in 2003, wet dead chicks found with shed feathers.
Starvation	Dead chicks in nest without signs of pecking, underweight, hollow belly.

rocky-cliff habitat was also earlier (Fig. 2). Hatching success in rocky-cliff habitat in 2002 was significantly higher whereas hatching success in 2003 was similar between habitats (Fig. 2). Fledging success in rocky-cliff habitat in 2002 and 2003 was higher (Fig. 2). Clutch size, hatching success and fledging success were significantly different between habitats, but not between years, although clutch size contributed to the significant year × habitat interaction (Table 2).

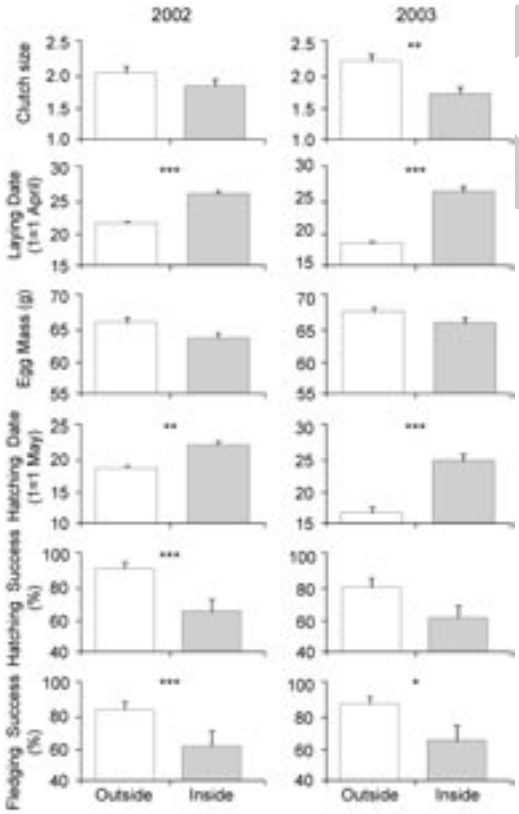

Figure 2. Comparisons in clutch size, laying date, egg mass, hatching date, hatching success and fledging success between rocky-cliff habitat (outside on the island) and grassy habitat (inside on the island) on Hongdo island during the breeding periods in 2002-2003 (*P < 0.05, **P < 0.01, ***P < 0.001); in unpaired t-tests: 1= 1st April in laying date, 1 = 1st May in hatching date.

Feeding Frequency

Mean feeding frequency of chicks was 0.74/h ± 0.07 in 2002 and 0.66/h ± 0.06 in 2003. The feeding frequency in rocky-cliff habitat in 2002 was higher than in grassy habitat. In 2003, however, it was not significant although the feeding frequency in rocky-cliff habitat was higher (Table 3).

Causes of Hatching and Fledging Failure

During the breeding seasons in 2002-2003, hatching failure of Black-tailed Gulls was 23.1% in 2002 and 30.4% in 2003. In both habitats, the highest cause of hatching failure was 'disappearance' and the second cause was 'rotten' (Fig. 3A). The third highest cause was; 'broken' in grassy habitat and 'died as hatching' in rocky-cliff habitat. Like hatching failure, fledging failure on the whole island was 28.7% in 2002 and 24.7% in 2003. Higher causes in both habitats were 'pecking' and 'disappearance' (Fig. 3B). However, 'starvation' cause was only observed in grassy habitat.

DISCUSSION

Selection of breeding habitat is strongly related to the survival of eggs and chicks (Danchin *et al.* 1998). Parents choose breeding habitats where they can more easily or quickly forage and conceal eggs and chicks from predators during feeding (Cody 1985;

Table 2. F values from two-way fixed-effect ANOVA with Year, Habitat, and their Interaction.

	Clutch Size	Hatching Success	Fledging Success
Year	0.277	1.273	0.325
Habitat	10.867**	11.758**	9.716**
Year × Habitat	4.398*	0.280	0.002

*P < 0.05, **P < 0.01.

Bried and Jouventin 2001). Hence, several studies of habitat selection discussed the effect of different feeding (Pierotti 1987) and predation on breeding between habitats (Burger and Gochfeld 1981; Good 2002).

Foraging

During the breeding period, Black-tailed Gulls foraged for foods such as anchovy (*Setipinna tenuifilis*) or squid (*Todar odes pacificus*) in shore around Hongdo Island (unpublished data). According to South Sea Fisheries Research Institute (2001), these species came near the island from April to June. Kwon (2004) suggested that Black-tailed Gulls' breeding timing was positively related with the timing of fish arrival. To forage on this abundant food, rocky-cliff habitat is possibly the best place on Hongdo Island because access to the food is quicker, allowing Black-tailed Gulls in rocky-cliff habitat to feed more frequently than gulls nesting in grassy habitat (Table 3).

Several researches (Pierotti 1982; Bosch and Sol 1998) showed rocky or cliff habitats were preferred as breeding habitat in gulls because of these topographical advantages, and also breeding success was better in rocky habitat than other habitats (Robertson *et al.* 2001). For instance, Herring Gulls (*Larus argentatus*) in Newfoundland had earlier laying date, larger clutch size, and higher breeding success in rocky habitat than in puffin (*Fratercula*) and meadow habitats (Pierotti 1982). Herring gulls in rocky habitat were able to more readily forage with the arrival of Capelin (*Mallotus villosus*) (Rodway and Regehr 1999). Our study also showed similar results that breeding performance in rocky-cliff habitat was better (Fig. 2). There was not the annual difference in breeding performance (Table 2) whereas clutch size in 2003 and hatching success in 2003 were not significantly different between habitats. Hipfner (1997) and Risch and Rohwer (2000) showed that high clutch size, earlier arriving and laying, and high breeding success were related with the body conditions of parents. For instance, the body condition of Yellow-legged Gulls (*Larus cachinnans*) was better in rocky habitat than in grassy habitat in that rocky habitat was occupied first and breeding success in the habitat was higher (Bosch *et al.* 2000). Similarly, our results showed that the selection for rocky-cliff habitat first (as evidenced by earlier laying date) was evidence itself of selection for rocky-cliff habitat ('preference') over grassy habitat. This situation supports the Fretwell-Lucas (1970) assumption that birds occupy the best habitat available to them and only utilize less suitable habitat when forced to because of competition from conspecifics, although we did not check the density between habitats. Because we could not capture adult gulls on Hongdo Island, we could not test whether the body condition of parents in rocky-cliff habitat was better. Based on a comparison of laying and hatching date

Table 3. Feeding rate (visit per hour) of brood provisioning in all habitats on Hongdo Island during the breeding periods in 2002-03. Number of nest in parentheses.

Year	Rocky-Cliff Habitat	Grassy Habitat	T-test
2002	0.73 ± 0.04 (20)	0.56 ± 0.05 (20)	P < 0.01
2003	0.64 ± 0.03 (20)	0.52 ± 0.06 (20)	P = 0.082

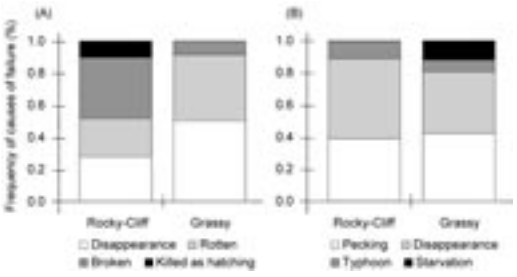

Figure 3. Frequency of causes of hatching failure (A) and fledging failure (B) in Black-tailed Gulls on Hongdo Island during the breeding periods in 2002-2003.

between habitats, we indirectly inferred that rocky-cliff habitat were preferred. Hence, we suggest that foraging differences relating to dissimilarity in topography likely brought about differences in breeding performance and habitat selection.

Predation and Disappearance

Predation could directly or indirectly influence breeding success and the selection of breeding habitat (Nisbet 1975; Rodgers 1987). In this study, hatching and fledging success in grassy habitat were lower and the major cause of the failures was predation (Figs. 2 and 3). 'Disappearance' and 'rotten' were major causes of hatching failure in grassy habitat. Unlike the hatching failures, however, causes of fledging failure aside from starvation (i.e., pecking, disappearance, and typhoon) were similar in both habitats. According to Paek and Yoo (1996), Kwon (2004), and Lee *et al.* (2006a), conspecific neighboring adults, Peregrine Falcons (*Falco peregrines*) and a cat (*Felis catus*) were the predators of Black-tailed Gulls on Hongdo Island. Lee *et al.* (2005) reported that broken eggs at nests and chicks killed by pecking were mostly the result of conspecific neighboring adults. On Hongdo Island, grassy habitats descend slowly toward the sea and are covered by sedge. Parents and chicks of Black-tailed Gulls in grassy habitat easily could move anywhere within the habitat and access other nests because of flat-ground. During the breeding period, like most gulls, Black-tailed Gulls are very sensitive to and aggressive against invaders and neighboring adults in their territory (Kwon 2004). At hatching, moreover, Black-tailed Gull chicks often moved away from the nest site (Won 1981). We observed aggressive interactions between neighboring nesting adults and chicks, which were killed by the pecking of adults. In contrast with grassy habitat, rocky-cliff habitat slopes steeply to the sea and is composed of rocks and hard soil. A steep slope could be difficult for chicks to return to the nest and also hard for parents to find missing eggs because of rolling down to lower areas. We often found missing eggs far away from nests and the distance in rocky-cliff habitat was longer than in grassy habitat (personal observation). Nevertheless, hatching and fledging success were higher in rocky-cliff habitat in that a crevice at rocky-cliff habitat could conceal eggs and chicks from predators. Moreover the spotted pattern of the eggshell and spots on feathers were similar in color and pattern to surroundings at rocky-cliff habitat (unpublished data).

Human Disturbance

Topographical differences between these two habitats caused differences in human disturbance (Parsons 1982). Hongdo Island is famous for being one of the best fishing sites on the southern coast of Korea and a major turning point of large schools of fish in south and east coasts (South Sea Fisheries Research Institute 2001). Year round, many fisheries take place around Hongdo Island. Further Hongdo Island is well known as 'Al-Sum' which means Egg Island. During the laying period (April-May), people living nearest Hongdo Island come to the island to obtain Black-tailed Gull eggs. They access mainly grassy habitat near a landing place whereas access to rocky-cliff habitat was difficult and dangerous. During this study, we often observed egging by fishermen. Egging mostly happened at the top of island in grassy habitat. We suggest that this egging on Hongdo Island was related to causes of hatching failure (e.g., 'disappearance') although we could not substantiate this hypothesis. Similarly, other authors have reported the effect of egging by human on

breeding success in the breeding colonies of gulls. For instance, low hatching success and clutch size in Glaucous-winged Gulls (*Larus glaucescens*) in Skidegate Inlet, B.C. was attributed to egging (Vermeer *et al.* 1991) and low breeding success in Yellow-footed Gulls (*Larus livens*) on Islas Coronado and La Ventana attributed to predation by man and Ravens (*Corvus corax*) (Spear and Anderson 1989).

Our results showed that topographical differences on Hongdo Island between rocky-cliff habitat and grassy habitat caused different hatching and fledgling success. In grassy habitat, Black-tailed Gulls suffered disadvantages such as longer foraging distances and frequent egging by human, whereas eggs and chicks in Black-tailed Gulls were protected by vegetation cover (Lee *et al.* 2006b, c). Unlike grassy habitat, rocky-cliff habitat had advantages for breeding such as quick foraging time and less disturbance by human, whereas a steep slope could be hard for parents to find missing eggs and be difficult for chicks to return to the nest. We suggest that rocky-cliff habitat was the preferred habitat over grassy habitat and the preference was related to topographical difference between habitats.

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