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Migration and Habitat Use of Breeding Blue Rock Thrushes on Hongdo Island, Korea

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The Blue Rock Thrush (*Monticola solitarius*) is distributed along the Korean coast, but its migratory and breeding habits are poorly known. To determine migratory patterns and habitat use of the Korean population, bird ringing, daily counts, and territory mapping were conducted on Hongdo Island, Korea from 2005 to 2009. Significant monthly changes in daily occurrence along with an international ring recovery suggested the presence of migratory habits, but ringed birds showed weak site fidelity to the study area. Breeding densities and mean territory size were of 7.7-9.2 pairs/km^2 and 2.87±1.01ha (range: 1.73-4.54ha) in the study area. Breeding pairs did not select habitats randomly on regional and territorial scales. Among the seven habitat types assessed, sea surface areas were avoided, and rocky cliffs without vegetation and with hard substrates were preferred. No other significant differences in habitat preference were detected. Considering this habitat preference, we suggest that the coastal distribution of *M. solitarius* in Korea may be related to landscape traits limiting the occurrence of precipitous cliffs in inland areas rather than related to a preference for coastal habitat types, such as intertidal areas. Further studies, including three-dimensional space use, foraging behavior and diet are needed to refine our knowledge of habitat preference and distribution in the Blue Rock Thrush.

key words: distribution, habitat preference, migratory habits, *Monticola solitarius*, territory size

Introduction

The Blue Rock Thrush (*Monticola solitarius*) is a member of the Turdidae, and is widely distributed in southern Palearctic, northern Afrotropic, and Oriental regions (Vaurie 1959, del Hoyo *et al.* 2005). It commonly breeds on precipitous cliffs in steep rocky valleys and defiles, as well as on crags, sea cliffs, and in rocky coastal areas, and has been observed breeding in quarries and on isolated stone buildings in rural environments (Clement and Hathway 2000; del Hoyo *et al.* 2005).

Currently five subspecies have been recognized (Clement and Hathway 2000; del Hoyo *et al.* 2005) with two subspecies present in Korea: *M. s. pandoo* and *M. s. philippensis* (Park and Seo 2008). The Himalayan and central Chinese race *M. s. pandoo* is a scarce vagrant (Park and Seo 2008) with few records of its presence in Korea. The northeast Asian race *M. s. philippensis* is commonly regarded as

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a resident of Korea, especially in coastal areas (Yamashina 1941; Won 1981; Park 1998; Lee *et al.* 2000; Park and Seo 2008). The Japanese population of *M. s. philippensis* is also commonly considered sedentary or partially migratory, and has been observed in rocky coastal areas throughout its range in Japan (Yamashina 1941; Brazil 1991; OSJ 2000). However, there is controversy about the movements of *M. s. philippensis* in Korea, because some authors, based on different occurrence by season, have reported it as a summer visitor to the Korean Peninsula rather than as resident (Austin 1948; Vaurie 1959; Won 1993). Unfortunately, there is no clear evidence of migration and no quantitative information on temporal changes in occurrence of the Korean population.

In general, *Monticola solitarius* prefers arid and open regions from boulder-strewn coasts at sea-level to high montane areas at up to 4200m above sea-level (Clement and Hathway 2000; del Hoyo *et al.* 2005). However, *M. s. philippensis* is highly distinctive in plumage and to some extent in ecology, as it appears to prefer coastal areas more than other subspecies (del Hoyo *et al.* 2005). For example, *M. s. philippensis* in Japan is exclusively a coastal species that does not breed in mountain habitats (Brazil 1991). On that basis, separation of *M. s. philippensis* from other Blue Rock Thrushes as a full species (i.e., Red-bellied Rock Thrush, *Monticola philippensis*) has been suggested by several authors (McCarthy 2006; Brazil 2009). Although small numbers of *M. s. philippensis* have been observed in inland rocky mountainous areas in Korea (Won 1981), there are no confirmed records of *M. s. philippensis* breeding in montane habitats in Korea. Moreover, there are no reports on habitat preferences of this population. Thus, dominant factors which have limited its distribution along the Korean coast are poorly known.

Within those contexts, this study was carried out to determine the migratory and breeding habits of *M. s. philippensis* on a remote island near the southwest tip of the Korean Peninsula. More specifically, we focused on their seasonal occurrence and breeding habits in terms of territory size and habitat preference. The distribution and migration characteristics of the Korean population are also discussed based on the results.

Methods

Study area This study was carried out within the Hongdo 1-gu district (N 34° 41' 10", E 125° 11' 30") of Hongdo Island, Shinan-gun, Jeonnam Province, Korea (Fig. 1). Hongdo Island is a small ($6.74km^2$), remote island 120km from mainland Korea. The Hongdo 1-gu district is a main residential area including port facilities, inns, and markets. Near the village, there are many scattered crop fields surrounded by warm-temperate evergreen forests. Steep rocky cliff areas are common along the coast line as a result of strong geological activities. Most of the intertidal areas are composed of gravels.

Migration From August 2005 to September 2008, two or three mist nets (2.5m×12m, mesh size: 38mm) were used to capture Blue Rock Thrushes in the study area with the permission of the local governments. Biometric variables (wing, tail, tarsus, bill, head, and total lengths) of the captured Blue Rock Thrushes were measured, and the birds were ringed with a metal-alloy ring and UV-resistant plastic color rings on their tarsi. Each metal ring bore a distinct serial number. Unique combinations of

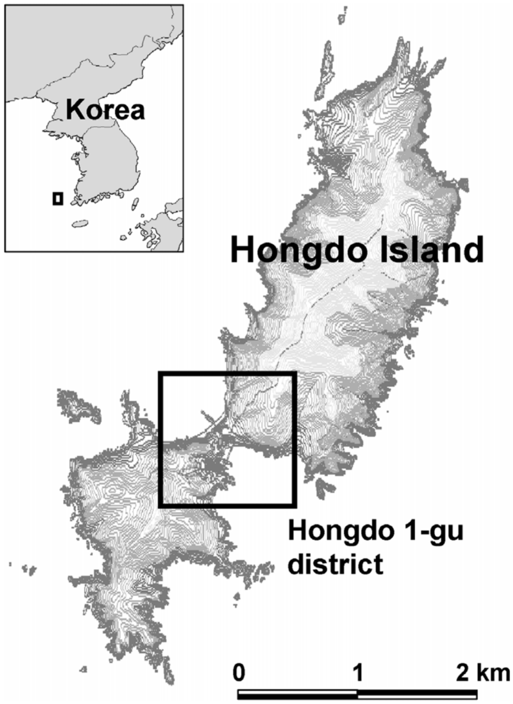

Fig. 1. Location of the study area (Hongdo 1-gu district) and Hongdo Island, Shinan-gun, Jeonnam Province, Korea

plastic rings in different colors enabled field identification of individuals.

In conjunction with the ringing survey, researchers monitored the study area and counted the number of Blue Rock Thrushes to determine changes in seasonal occurrence. For occurrence monitoring, the line transect method (Bibby *et al.* 1992) was used everyday from January 2007 to June 2009. Daily transect counts were grouped and analyzed by months to determine monthly changes in numbers of observed Blue Rock Thrushes per day. We used PROC UNIVARIATE for normality tests and PROC NPAR1WAY for non-parametric tests with the Bonferroni adjustment in SAS 9.1 Software (SAS 2003).

Territory size Territory mapping is time consuming, but can be effective for determining distribution during the breeding season when many species are territorial (Bibby *et al.* 1992; Sutherland 1996). Territory mapping was used to estimate breeding density and territory size of breeding Blue Rock Thrushes in the study area. From April to July, in 2007 and 2009, locations of territorial adults observed during daily transect counts were plotted on 1:1,000 maps. Regardless of subsequent movement of the observed Blue Rock Thrushes, only the initial position where the individual was first detected (or first landed if observed in flight) was used to determine their territory boundaries and habitat use.

Territories were estimated from 100% Minimum Convex Polygons (MCPs) (Mohr 1947; White and Garrott 1990; Kenward 2001) calculated from locations plotted using ArcView 3.2 GIS software (ESRI 1999) and the Animal Movement Extension (Hooge and Eichenlaub 1997). Fixed kernel territories

(Worton 1989; Seaman and Powell 1996; Kenward 2001) were estimated based on utilization densities (UD) of 95%, 75% and 50%. Least squares cross validation (LSCV) was used to calculate the smoothing parameter h (Worton 1989; Seaman and Powell 1996; Kenward 2001).

According to the theoretical assumption that territory size approaches an asymptote when an adequate sample size is reached (McLoughlin and Ferguson 2000), incremental analysis is commonly used to determine the sample size required for unbiased estimates (Kenward 2001; Börger *et al.* 2006). Incremental analysis was undertaken using Ranges 7 software (South *et al.* 2008) to determine whether adequate sample sizes or sampling saturation have been achieved (Kenward 2001).

Because all territory estimates passed normality and equal variance tests, we used t-tests to determine difference in territory sizes between study years with SAS 9.1 PROC TTEST (SAS2003). All territory size values are given as means and standard deviations and referred to as mean±SD hereafter.

Habitat preference Habitats in the study areas were grouped into seven types: sea surface (SS), intertidal areas (IT), rocky cliffs (RC), man-made buildings and roads (BR), forested areas (FA), grasslands and croplands (GC), and bare lands (BL). Table 1 shows additional characteristic details on each habitat.

Habitat preference of breeding Blue Rock Thrush pairs was determined by compositional analysis assuming that habitat use was not random, that habitats may be ranked according to relative use, and that significant between-rank differences can be detected (Aebischer *et al.* 1993). Prior to compositional analysis, randomization tests of goodness-of-fit were conducted using PROC FREQ with the Monte Carlo estimate option to test randomness of habitat use at two spatial scales: regional (MCP territories vs total study area) and territorial (location points vs MCP territories). When a particular habitat type is available but not included within MCPs on a regional scale or not used by rock thrushes on a territorial scale, we excluded the habitat type for randomization tests.

If habitat selection by the observed rock thrushes was non-random at the two scales, we compared the

Table 1. Seven habitat type categories and details on their physical features

Habitat	Description	Substrate	Vegetation	Type
Sea surface (SS)	Sea surface	water	None	Natural
Intertidal areas (IT)	Rocky seashores in intertidal areas	Hard substrate	None	Natural
Rocky cliffs (RC)	Rocky cliffs, outcrops, and headlands above sea level	Hard substrate	None	Natural
Buildings and roads (BR)	Buildings, roads, piers, electronic piles, and other man-made structures	Hard substrate	None	Artificial
Forested areas (FA)	Forests and vegetated areas with tall trees and bushes	Soft substrate	Tall vegetations	Natural
Croplands and grasslands (CG)	Vegetated areas with short grasses and commercial plants	Soft substrate	Low vegetations	Artificial & Natural
Bare lands (BL)	Bare soil and grounds without vegetation covers	Soft substrate	None	Natural

used habitats with available habitats within the pairs' territories. These criteria were met for six pairs in 2007 and five pairs in 2009 with territories estimated by 100% MCPs. If a pair's proportional habitat use of the seven habitat types is described by x_{u1}, x_{u2},…, x_{u7}, and if the proportions of available habitat are x_{a1}, x_{a2}, …, x_{a7}, then the differences $d_{ij} = \ln(x_{ui}/x_{uj}) - \ln(x_{ai}/x_{aj}) = \ln(x_{ui}) - \ln(x_{uj}) - \ln(x_{ai}) + \ln(x_{aj}) = \ln(x_{ui}/x_{ai}) - \ln(x_{uj}/x_{aj})$ can be calculated to rank habitat *i* and *j* for each pair (Aebischer *et al.* 1993; Millspaugh and Marzluff 2001). During the d_{ij} calculation, missing values (0%) were replaced by 0.0001% to permit log transformations. The mean of the calculated d_{ij} from the 11 pairs was then compared to the value 0 by a one-sample t-test (SAS 9.1 PROC TTEST; SAS 2003) to create pair-wise comparisons of habitat types (Aebischer *et al.* 1993; Millspaugh and Marzluff 2001). We then constructed a ranking matrix using means and SDs of differences in log ratios (d_{ij}) of used habitat versus available habitat. To make a simplified ranking matrix, the matrix elements were replaced by signs indicating relative preference and statistical significance (Aebischer *et al.* 1993; Millspaugh and Marzluff 2001).

Results

Daily counts and ringing study The daily count data indicated significant differences in the monthly occurrence of Blue Rock Thrushes in the study areas ($H_{11} = 439.99$, $p < 0.001$) (Fig. 2). The data show an increase in rock thrush counts in April and a decrease in September and early October (Fig. 2). The number of observed Blue Rock Thrushes was relatively high from April through September, and, on average, less than one bird was observed during the winter period (Nov-Mar) suggesting a seasonal movement patterns.

During the ringing study from August 2005 to September 2008, 27 Blue Rock Thrushes (including 23 one-calendar-year birds) were trapped and ringed. Two individuals were recaptured at the same site (N

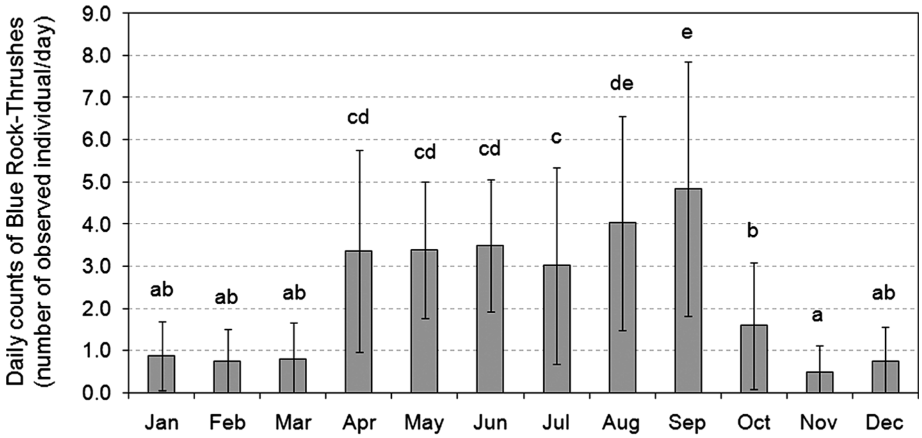

Fig. 2. Monthly changes in mean daily counts of Blue Rock Thrushes (*Monticola solitarius*) observed by line transect census on Hongdo Island from January 2007 to June 2009. Bars indicate mean values, and vertical lines represent SD (standard deviation); different letters above bars indicate significant differences between bars ($p < 0.05$).

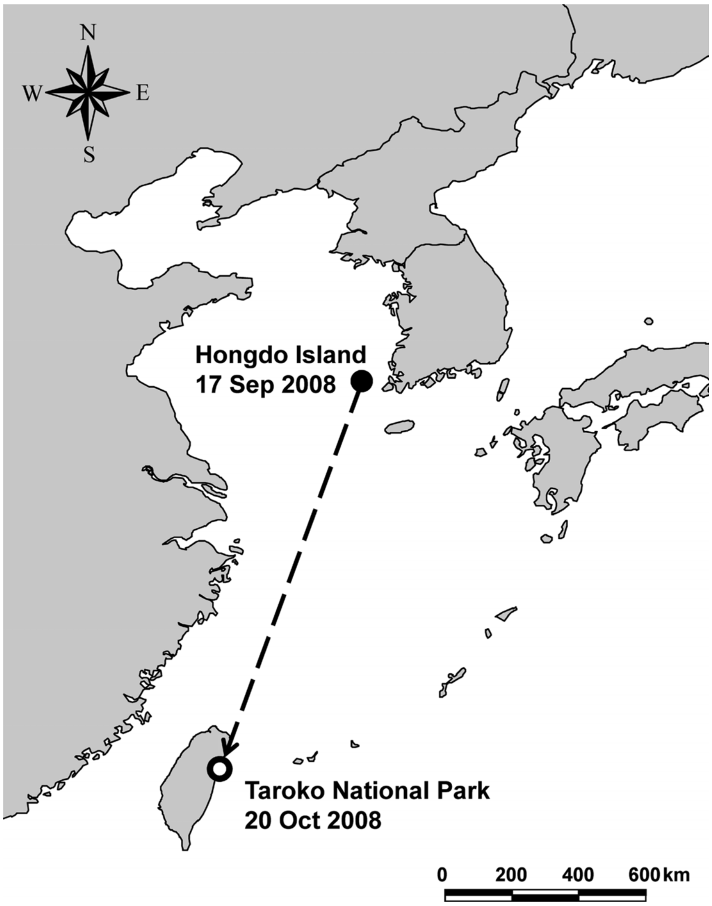

Fig. 3. Recovery record of a juvenile Blue Rock Thrush ringed in the study area. The female migrated from Korea to Taiwan, over 1215km, over a period of up to 33 days

34° 41' 10", E 125° 11' 30") in Hongdo within three months, but none of the ringed rock thrushes returned to the study area in subsequent years. One young female was recovered on 20 October 2008 at the visitor center of the Taroko National Park, Taiwan (N 24° 09' 26", E 121° 37' 20") following minor concussion from a window strike. Because the young bird was ringed in the study area on 17 September 2008, the Blue Rock Thrush migrated 1,215km over 33 days (Fig. 3).

Territory size From April to July, six breeding pairs of the Blue Rock Thrush in 2007 and five breeding pairs in 2009 were observed in the $0.65km^2$ study area (7.7-9.2 breeding pairs/km^2). In 2007, juveniles were fledged from five nesting pairs, but one pair failed to breed successfully due to unknown causes. However, all five pairs successfully produced fledglings in 2009. All 11 nests were located on rocky cliffs or in cracks in buildings (nine in rocky cliffs and two in buildings).

Table 2, Fig. 4 and Fig. 5 present summaries of the territory analyses. Over two breeding seasons, 867 locations (460 points in 2007 and 407 in 2009) were mapped. There were no significant differences between estimates of territory sizes in 2007 and 2009 (100% MCP: $t_9 = 0.481$, $n = 11$, $p = 0.642$, 95% kernel: $t_4 = -0.0882$, $n = 6$, $p = 0.934$, 75% kernel: $t_4 = -0.549$, $n = 6$, $p = 0.612$, 50% kernel: $t_4 = 0.172$, $n = 6$, $p = 0.612$). Thus, we pooled the two years of data for further analysis. Mean territory size estimated by 100% MCPs was 2.87±1.01ha for all 11 pairs, but was 2.98±0.98ha for the 10 pairs that bred successfully. Six pairs with more than 80 location points each were used to estimate Kernel territory sizes. In those pairs, the mean territory size was 2.16±1.09ha at 95% UD, 0.63±0.55ha at 75% UD, and 0.21±0.12ha at 50% UD. The territory of BR2007F, which failed to breed successfully, was smallest (1.73ha by 100% MCP; Table 2), and most of its territory was occupied by the nearest male of pair BR2007E soon after breeding failure (Fig. 4).

Incremental analysis indicated that observations of all pairs bred in 2007 achieved sample sizes adequate to determine unbiased estimates of territory sizes (Fig. 6A). In 2009, however, two pairs (BR2009C and BR2009E) did not show clear asymptotes in their plot estimates of territory size against the number of locations (Fig. 6B).

Habitat preference Habitats within MCP determined territories of observed Blue Rock Thrushes were different in composition from overall habitat availability within the study area (randomization tests with 10,000 replicates; $p < 0.001$ in 2007, $p < 0.001$ in 2009) suggesting that, on a regional scale, breeding

Table 2. Territory sizes of six breeding pairs of Blue Rock Thrushes (*Monticola solitarius*) in 2007 and five breeding pairs in 2009 on Hongdo Island, Korea

Pair ID	Breeding	Number of locations	100% MCP (ha)	Kernel (ha)		
				95%	75%	50%
BR2007A	Successful	40	3.68	-	-	-
BR2007B	Successful	80	2.06	1.80	0.31	0.11
BR2007C	Successful	89	3.86	3.63	1.70	0.41
BR2007D	Successful	55	2.20	-	-	-
BR2007E	Successful	138	2.86	1.18	0.27	0.09
BR2007F	Failed	58	1.73	-	-	-
BR2009A	Successful	81	2.23	0.81	0.28	0.16
BR2009B	Successful	86	4.12	3.01	0.68	0.30
BR2009C	Successful	35	1.78	-	-	-
BR2009D	Successful	140	4.54	2.52	0.52	0.21
BR2009E	Successful	65	2.51	-	-	-
All breeding pairs						
No. of pairs			11	6	6	6
Territory size (ha)			2.87±1.01	2.16±1.09	0.63±0.55	0.21±0.12
Successful pairs						
No. of pairs			10	6	6	6
Territory size (ha)			2.98±0.98	2.16±1.09	0.63±0.55	0.21±0.12

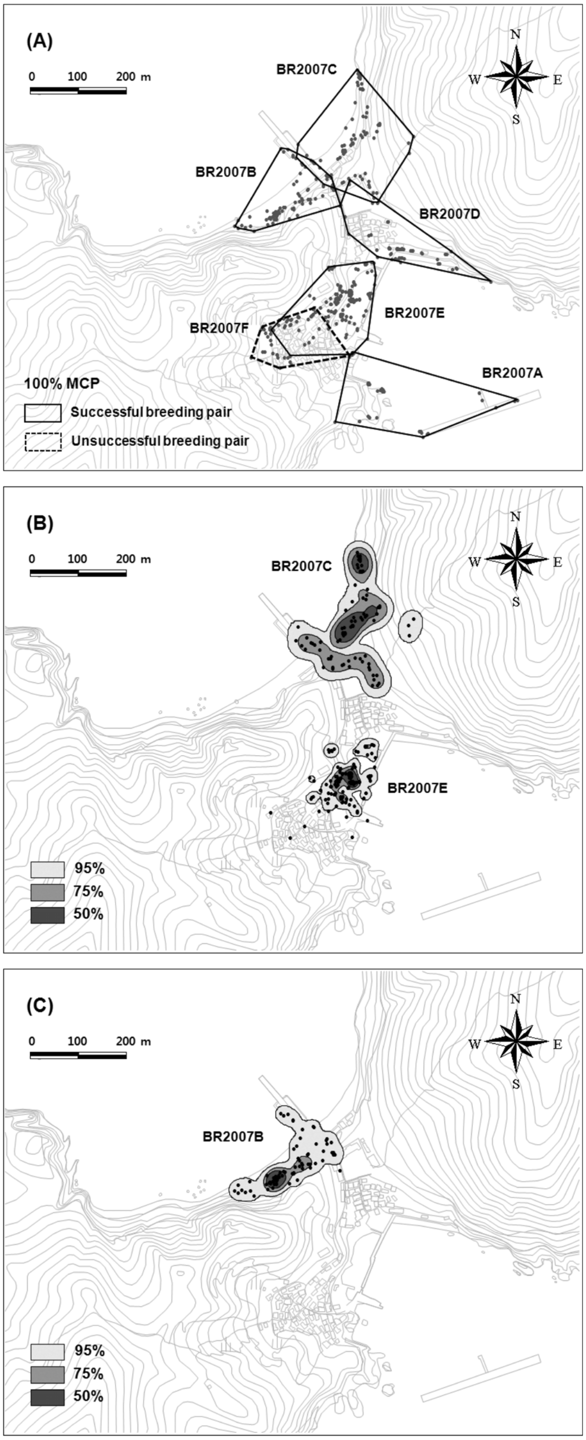

Fig. 4. Territories of six breeding pairs of the Blue Rock Thrush (*Monticola solitarius*) in 2007 on Hongdo Island, Korea. (A) 100% MCPs (minimum convex polygons) were used to estimate territory sizes of all six pairs. Kernel territories of two (B) and one (C) successful breeding pairs

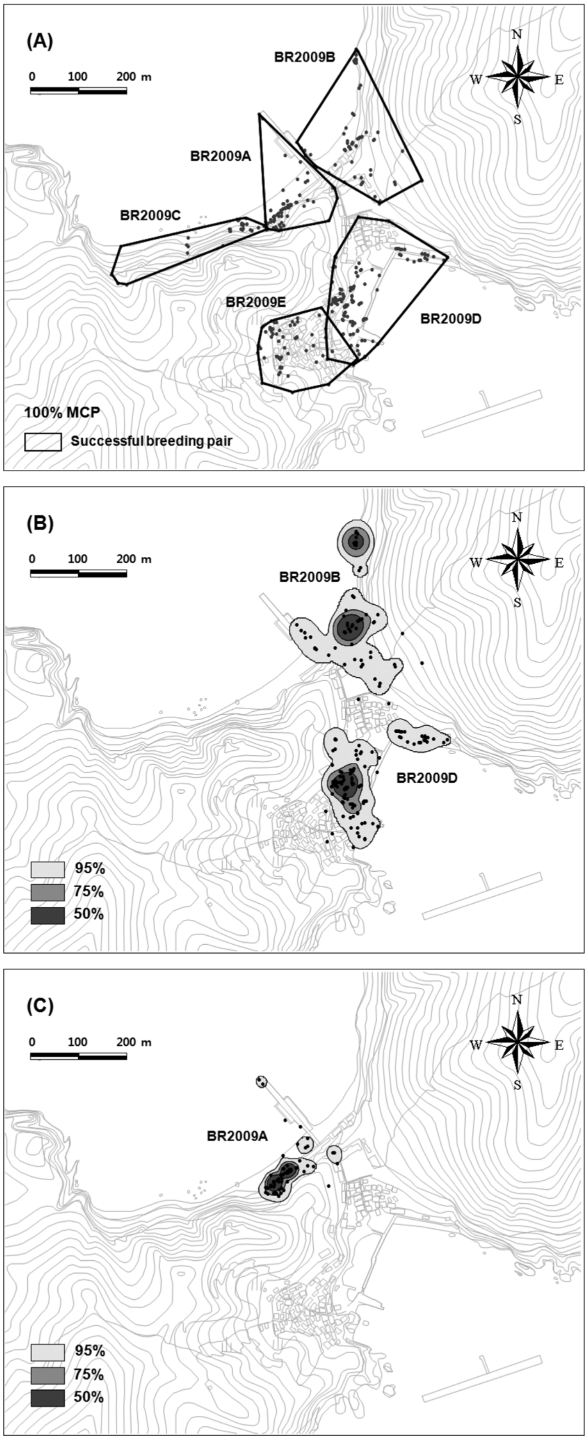

Fig. 5. Territories of five breeding pairs of the Blue Rock Thrush (*Monticola solitarius*) in 2009 on Hongdo Island, Korea. (A) 100% MCPs (minimum convex polygons) were used to estimate territory sizes of all five pairs. Kernel territories of two (B) and one (C) successful breeding pairs

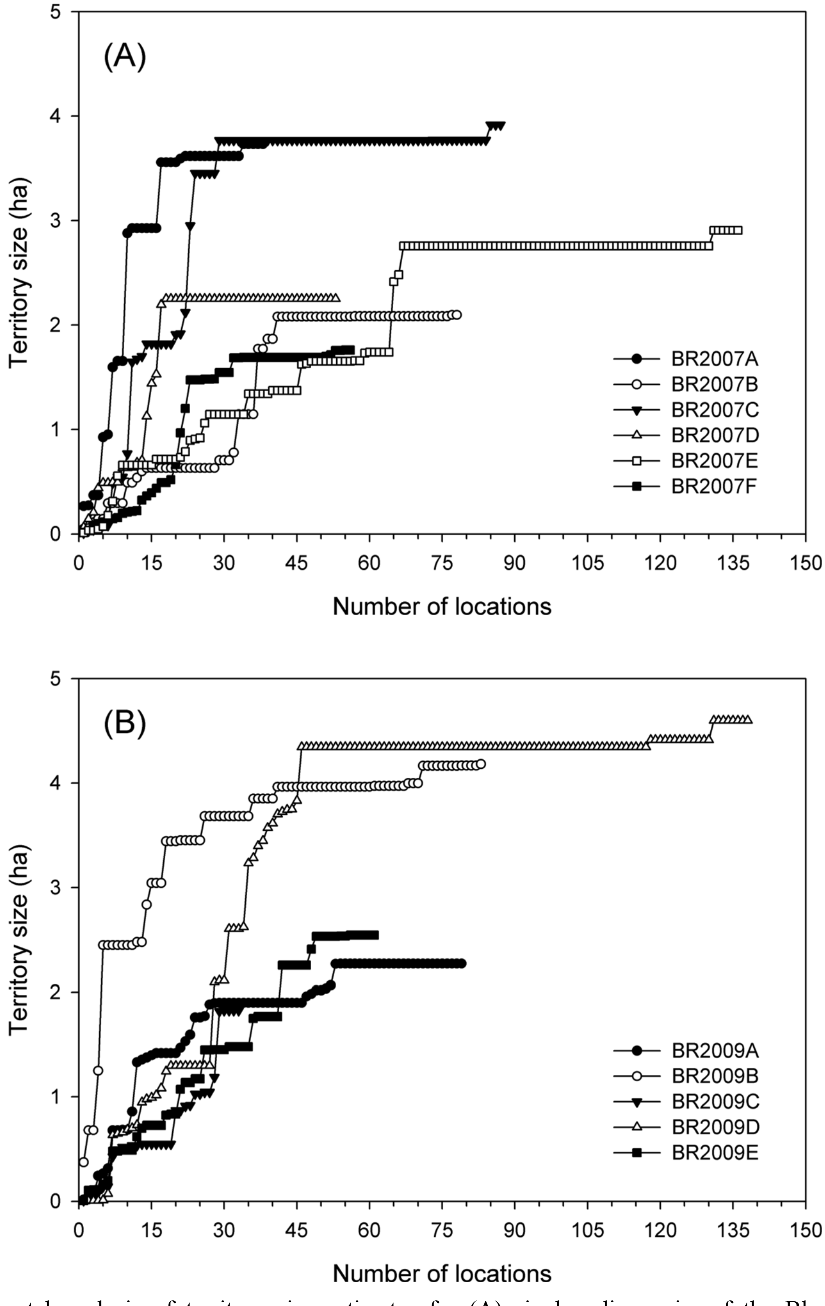

Fig. 6. Incremental analysis of territory size estimates for (A) six breeding pairs of the Blue Rock Thrush (*Monticola solitarius*) in 2007 and (B) five breeding pairs in 2009

pairs do not select habitats randomly. Similarly, on a territorial scale, sea surface area was excluded from habitat types due to absence of location data, and the habitat use of all pairs within the territories was not random (randomization tests with 10,000 replicates; $p < 0.001$ in 2007, $p < 0.001$ in 2009).

Table 3. Percentage habitat composition within each pair's 100% MCP (minimum convex polygon) territory and percentage habitat use by each breeding pair of Blue Rock Thrush (*Monticola solitarius*) on Hongdo Island, Korea

Pair ID	% MCP range[1] (Percentage of available habitats)							% Locations[1] (Percentage of used habitats)						
	SS[2]	IT	RC	BR	FA	GC	BL	SS	IT	RC	BR	FA	GC	BL
BR2007A	66.20	6.94	7.87	7.41	11.57	>0.01	>0.01	>0.01	7.50	55.00	32.50	5.00	>0.01	>0.01
BR2007B	32.43	31.53	7.21	9.91	2.70	16.22	>0.01	>0.01	11.25	37.50	38.75	7.50	5.00	>0.01
BR2007C	24.32	13.51	4.96	16.67	4.05	32.43	4.05	>0.01	8.99	46.07	40.45	>0.01	3.37	1.12
BR2007D	4.03	2.42	4.03	50.81	17.74	8.87	12.10	>0.01	5.45	34.55	58.18	1.82	>0.01	>0.01
BR2007E	12.77	10.94	6.69	52.89	9.12	7.29	0.30	>0.01	12.32	29.71	52.17	2.90	2.17	0.72
BR2007F	>0.01	>0.01	2.59	77.72	9.33	8.29	2.07	>0.01	>0.01	3.45	86.21	6.90	3.45	>0.01
BR2009A	35.85	19.50	8.80	11.32	4.40	20.13	>0.01	>0.01	7.41	34.57	35.80	8.64	13.58	>0.01
BR2009B	31.01	14.98	6.27	10.45	3.14	33.45	0.70	>0.01	10.59	35.29	45.88	1.18	7.06	>0.01
BR2009C	14.17	12.50	31.67	>0.01	41.67	>0.01	>0.01	>0.01	17.14	57.14	>0.01	25.71	>0.01	>0.01
BR2009D	40.33	7.24	3.45	41.71	6.20	1.03	0.03	>0.01	20.00	27.14	41.43	4.29	4.29	2.86
BR2009E	>0.01	>0.01	>0.01	64.69	13.76	21.34	0.21	>0.01	>0.01	>0.01	80.95	9.52	9.52	>0.01

[1]All zero values were replaced by 0.0001 (represented as '>0.01') to permit log transformations during compositional analysis.

[2]SS: sea surface, IT: intertidal areas, RC: rocky cliffs, BR: buildings and roads, FA: forested areas, GC: grasslands and croplands, BL: bare lands

Percentages of available habitat types within each pair's MCP, and the proportion of the habitat types used by each breeding pair are shown in Table 3. Breeding pairs of rock thrushes seldom visited bare lands (BL), and in particular, none were observed over sea surface (SS) areas (Table 3).

An antisymmetric difference matrix was created based on the calculated dijs from 11 breeding pairs (Table 4A), and a simplified ranking matrix was then derived (Table 4B). Rocky cliffs (RC) had six positive values in their difference matrix rows, while sea surface (SS) areas did not have any positive value. Excluding those two preferred and avoiding habitats, there were no other significant differences detected in relative use of the other habitats, though the rock thrushes showed greater use of buildings and roads (BR) than croplands and grasslands (CG). Consequently, a simplified habitat-use matrix for breeding Blue Rock Thrushes resulted in the seven habitat types ranked in the following order: rocky cliffs (RC) >> buildings and roads (BR) > intertidal areas (IT) > forested areas (FA) > croplands and grasslands (GC) > bare lands (BL) >> sea surface (SS) (where >> denotes a significant difference in habitat use).

Table 4. Ranking matrices for 11 breeding pairs of Blue Rock Thrush (*Monticola solitarius*) on Hongdo Island based on results of compositional analysis. (A) Means and standard deviations of differences in log ratios (d_{ij}) in a comparison of the proportions of habitats used by each pair with the proportions of habitats available within the pair's 100% MCP (minimum convex polygon) territory. (B) Simplified ranking matrix composed of sign-replaced elements

Habitat types	Habitat types							No. of positive	Rank
	SS	IT	RC	BR	FA	GC	BL		
(A) *Means±SD*									
Sea surface (SS)		−10.1±5.0	−11.5±5.7	−10.7±5.4	−8.7±5.6	−8.5±6.0	−7.8±9.4		
Intertidal areas (IT)	10.1±5.0		−1.4±1.0	−0.6±1.2	1.4±3.2	1.6±3.6	2.2±5.2		
Rocky cliffs (RC)	11.5±5.7	1.4±1.0		0.8±0.8	2.8±3.6	3.0±3.7	3.7±4.9		
Buildings and roads (BR)	10.7±5.4	0.6±1.2	−0.8±0.8		2.0±3.3	2.2±3.4	2.9±4.9		
Forested areas (FA)	8.7±5.6	−1.4±3.2	−2.8±3.6	−2.0±3.3		0.2±4.0	0.8±5.9		
Croplands and grasslands (GC)	8.5±6.0	−1.6±3.6	−3.0±3.7	−2.2±3.4	−0.2±4.0		0.6±3.8		
Bare lands (BL)	7.8±9.4	−2.2±5.2	−3.7±4.9	−2.9±4.9	−0.8±5.9	−0.6±3.8			
(B) *Simplified ranking matrix*[1,2]									
Sea surface (SS)		− − −	− − −	− − −	− − −	− − −	− −	0	7
Intertidal areas (IT)	+ + +		− − −	−	+	+	+	4	3
Rocky cliffs (RC)	+ + +	+ + +		+ + +	+ +	+ +	+ +	6	1
Buildings and roads (BR)	+ + +	+	− − −		+	+ +	+	5	2
Forested areas (FA)	+ + +	−	− −	−		+	+	3	4
Croplands and grasslands (GC)	+ + +	−	− −	− −	−		+	2	5
Bare lands (BL)	+ +	−	− −	−	−	−		1	6

[1]Positive signs represent relative preference and negative signs indicate relative avoidance
[2]A triple sign indicates a significant deviation from random at $p<0.01$, a double sign represents $p<0.05$, and a single sign denotes relative preference without statistical significance. One-sample t-tests were used to compare the mean of the differences ($d_{ij}s$) between % use and % availability to the value 0.

Discussion

Migration In spite of controversy on movements and seasonal occurrences of the Korea population of *M. s. philippensis*, there have been no quantitative studies on this population. In this study, a significant seasonal change in the mean daily occurrence of *M. s. philippensis* on an island off the southwest coast of the Korean Peninsula was detected. The numbers of Blue Rock Thrush as indicated by mean daily counts were higher during the spring and autumn migratory periods and during the spring-summer breeding season. The low numbers during late autumn and winter suggest that few Blue Rock Thrush winters on Hongdo Island. The number of observed Blue Rock Thrush was highest in September, possibly a result of the arrival of migratory groups from mainland Korea. Although the Blue Rock Thrush in Korea has been widely regarded as a sedentary bird (Yamashina 1941; Won 1981; Park 1998; Lee *et al.* 2000; Park and Seo 2008), the pattern of changes in seasonal occurrence detected here suggests the presence of migratory behaviors within the Korean population. This suggestion is concordant with previous descriptions of possible seasonal differences in occurrence suggested by other authors (Austin 1948; Vaurie 1959; Won 1993). The presence of migratory behavior within Korean *M. s. philippensis* was confirmed by the recovery of a ringed juvenile from Taiwan. This is the first report of long-distance migration in *M. s. philippensis* confirmed by international ring recovery in Asia to our knowledge. Considering the seasonal change in occurrence together, this movement of the young bird over long distances seems to be a true migration rather than a natal dispersal. Consequently, we suggest that the Blue Rock Thrush in Korea is a migratory summer visitor rather than a sedentary bird. Although a few individuals have been observed in winter along the Korean coast, they are possibly northern populations that have moved to the south for wintering.

Territory size Breeding Blue Rock Thrush pairs on Hongdo occupied 2.87±1.01ha (100% MCP, range: 1.73-4.54ha) or 2.16±1.09ha (95% Kernel, range: 0.81-3.63ha) breeding territories at a breeding density of 7.7-9.2 pairs/km^2. There is no previous information on territory size in breeding Blue Rock Thrush, but the breeding density in this study is similar to a previously reported density (8 pairs/km^2) on Tokara Islands, southern Japan (Seki 2001).

Though this study could not confirm a direct linkage between the smallest territory size of the BR2007F pair and its breeding failure, it is possible that the pair's small territory may have limited the quantity and availability of its preferred foods and habitats.

Habitat preference The observed breeding Blue Rock Thrush pairs on Hongdo strongly preferred rocky cliffs in their territories, and apparently avoided sea surface areas. Man-made structures and intertidal areas were more frequently used than vegetated areas, but there were little differences in use of forested areas, grasslands and croplands. Interestingly, intertidal areas and sea surface, which are representative characteristics of coastal environments, were not preferred habitat types for breeding Blue Rock Thrush.

Based on physical characteristics of the top-ranked habitats, as a territorial bird, Blue Rock Thrush tended to be observed more often in open grounds with hard substrates and without vegetation cover. This agrees with previous reports that the Blue Rock Thrush is not a forest-dependent species in Japan (Hitoshi 2007) and that its distribution is associated with areas dominated by rocks and bare soil without vegetation cover (Coreau and Martin 2007; Hitoshi 2007). Conversely, Coreau and Martin (2007) and Hitoshi (2007) noted a preference for bare soil areas. However, because they primarily defined habitat areas based on presence of vegetation, they did not distinguish bare soil and bare rock areas. Nevertheless, the preference for bareland in this study may be underestimated, because this type of habitat, i.e., no vegetation on soft soil, only occurred in a small portion of a public schoolyard in the study area.

Furthermore, disturbance related to persistent human presence in the schoolyard may have affected our estimate of bare land use.

Distribution in Korea We propose two possible hypotheses to explain the association of *M. s. philippensis* with coastal habitats in Korea; 1) the Korean population relies on specific features of coastal areas, or 2) suitable habitats for breeding are not common in inland areas.

The Republic of Korea is comprised of 71.16% mountainous forests with tall vegetation; 20.21% paddy fields and crop lands, 5.60% urban areas, 1.17% grasslands, 0.87% wetlands, and 0.44% waterbody; exposed rocks and bare soils (categorized as barrens) are only 0.55% of total area (Jeong *et al.* 2006). Moreover, steep slopes (>80%) are only found in 1.53% of the Republic of Korea (WAMIS 2009). The low proportion of steep, rocky landscape features in Korea imply that the presence of rocky cliffs with low amounts of vegetation cover and steep slope angles, which are the preferred breeding habitats of the Blue Rock Thrush, is limited in inland areas. Furthermore, preferred habitat patches with exposed rocks and bare soils are also small in size, and those areas are scattered, fragmented, and embedded within larger habitat area such as forests (Jeong *et al.* 2006).

The results from the habitat preference analysis do not support the former hypothesis that Blue Rock Thrush prefers distinctly coastal area features, such as sea surface and intertidal areas. On the other hand, the proportions of crags, headlands, quarries, and outcrops are very confined in inland montane areas, and most of those features are surrounded and isolated by vegetation or soft soil, whereas precipitous cliffs are common in coastal areas. Thus, our results support the hypothesis that suitable breeding habitats are not common in inland areas, thereby affecting Blue Rock Thrush distribution in Korea.

In spite of similarities in the spatial distribution of breeding territories in 2007 and 2009, no ringed birds returned to the study area during consistent banding efforts after 2004 on Hongdo Island. This implies that the distribution of preferred nesting habitats, rather than breeding site fidelity, may determine the location of breeding territories of Blue Rock Thrush. Consequently, we suggest that the limited availability of preferred breeding habitats in inland and montane areas of Korea is the dominant factor in determining the spatial distribution of *M. s. philippensis* in Korea.

Further studies Members of the genus *Monticola* are typically alert, but patient and sedate birds exhibiting a watch-and-wait foraging technique; they unhurriedly survey the ground below a high perch from which they make sudden dashes when a diet item is detected; or they may hop and walk on the ground to chase invertebrates (Clement and Hathway 2000; del Hoyo *et al.* 2005). During our observations, they exhibited typical foraging behaviors and rarely moved soil or litter to obtain hidden food items. It is unclear whether such foraging habits define their preference for rocky, hard substrates, or vice versa. However, there was no evidence of preference or dependence on coastal invertebrate species, because the observed birds fed on a variety of territorial insects and other invertebrates as well as on some fruits (e.g., *Elaeagnus macrophylla*) from forest edges as Yamashina (1941) noted. In future studies, relationships among habitat use, diet items, and foraging habits of Blue Rock Thrush should be examined to further elucidate the apparent coastal reliance of *M. s. philippensis* on the Korean Peninsula.

In this study, we used two-dimension horizontal mapping to locate subject bird positions and to estimate territory sizes, but animal movements are not typically confined to two dimensions (Meserve 1977). Considering that Blue Rock Thrushes show marked vertical movements within their cliff-based territories, the areas used by and territory sizes of Blue Rock Thrush may be significantly underestimated when using two-dimensional analysis. To remove this source of bias, further research that accounts for vertical movement through the use of three-dimensional terrain maps is needed. Furthermore, although the observed rock thrushes typically remained on exposed branches or canopy areas rather than on the forest floor, habitat use in forested areas may have been slightly underestimated because of lower vision-based detectability in the forested portions of the study area. Location detection in forest areas using radio transmitters may be useful for evaluating bias in habitat use estimates derived through visual observation.

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홍도에서 번식하는 바다직박구리의 이동과 서식지 이용

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바다직박구리(*Monticola solitarius*)는 주로 우리나라의 해안에 분포하는 텃새로 알려져 있으나, 이동 및 서식지 이용에 대한 정보는 빈약한 실정이다. 국내에서 번식하는 개체군의 이동 경향과 서식지 이용을 파악하기 위하여, 2005년부터 2009년까지 전남 홍도에서 가락지 부착 조사, 일일 관찰 조사, 세력권 도시법 등을 실시하였다. 대만에서의 가락지 회수 기록과 일일 출현 양상이 월별로 차이를 보이는 점 등을 고려할 때, 바다직박구리는 계절에 따른 이동성을 보였으나 서식지 충실도는 낮은 것으로 나타났다. 조사지역에서의 번식 밀도와 평균 세력권의 크기는 각각 7.7-9.2쌍/km^2 및 2.87±1.01ha (범위: 1.73-4.54ha)였으며, 지역 및 세력권 수준의 공간 규모에서 서식지를 선택적으로 이용하였다. 조사한 총 7개의 서식지 유형 중에서 해수면을 회피하는 반면 식생이 없고 기반이 단단한 암벽을 선호하는 것으로 나타났으며, 기타 서식지 유형에 대해서는 뚜렷한 선호도가 확인되지 않았다. 이런 서식지 선호도를 감안할 때 바다직박구리가 주로 해안에 분포하는 주요 원인은 조간대와 같이 해안에 발달한 서식지 유형에 유인되는 것이 아니라 선호하는 서식지의 유형이 내륙에서 잘 발달되지 않은 경관적 특성에 기인한 것으로 판단된다. 바다직박구리의 서식지 선호도와 분포에 대한 상세한 정보를 분석하기 위해 향후 3차원적인 공간 이용과 섭식 행동, 먹이 등에 대한 연구가 요구된다.

주요어: 바다직박구리(*Monticola solitarius*), 분포, 서식지 선호도, 세력권, 이동

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