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Habitat Use, Home Range, and Hibernaculum of the Mongolian Racerunner, *Eremias argus* (Lacertidae, Reptilia) in a Coastal Sand Dune in South Korea

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Abstract Information on habitat use is critical in sizing protected areas for endangered reptile species. To investigate habitat use, home range, and hibernaculum of the endangered Mongolian Racerunner (*Eremias argus*), we radio-tracked 40 specimens in a coastal sand dune in South Korea. Of the 163 locations recorded during the breeding season, 150 (92.0%) were in grass sand dunes, and the rest (8.0%), all associated with the same lizard, were in shrub sand dunes. All of the 123 locations recorded during the non-breeding season were in grass sand dunes. No lizards were found in the grasslands abutting the dunes. The four lizards with identifiable hibernation sites were found under an average of 17.8 cm of sand and were all located in grass sand dunes. The lizards moved approximately 5 m daily and used 162 m^2 of home range (computed by minimum convex polygon, MCP) during the breeding season, and they moved approximately 2 m and used 68 m^2 of home range during the non-breeding season. However, the mean daily moved distances and MCP home ranges were not statistically significantly different between the seasons or between males and females. Our results suggest that in coastal sand dunes, *E. argus* uses grass sand dunes as its main habitat throughout the year. This finding could be used to determine the appropriate habitat size and to designate for the conservation of this endangered species.

Keywords coastal sand dune, spatial ecology, *Eremias argus*, lizard, radio-telemetry

1. Introduction

Similar to other animal populations, reptile populations are declining worldwide due to the loss or fragmentation of available habitat, increased introduction of invasive species, increased spread of disease following climate change, and continued overexploitation of reptiles for domestic and medical uses (Mullin and Seigel, 2009; Reading *et al.*, 2010; Todd *et al.*, 2010). According to the 2011 IUCN Red List (IUCN, 2011), 664 reptile species, which represent approximately 20% of all reptile species in the world, are critically endangered, endangered, or vulnerable, and the number of endangered species is increasing (Reading *et al.*, 2010). The determination of habitat types is essential to the conservation of endangered reptile species because habitat types inform the sizing of protected areas dedicated to conservation (Cooke, 1991; Armstrong and Seddon, 2007; Lee and Park, 2011). For example, after major habitats used by Sand Lizards (*Lacerta agilis*) in Britain were identified, projects to protect the habitats were established as a part of the efforts to conserve the field populations of the species (Moulton and Corbett, 1999; Edgar and Bird, 2005). Habitat studies of Asian endangered lizard species, however, are very limited (Kim *et al*., 2011).

The Mongolian Racerunner (*Eremias argus*) is a diurnal small Lacertid lizard. The species has been found in Eastern and Central Mongolia, northeastern China, Russia, and Korea (Kang and Yoon, 1975; Zhao *et al.*, 1999). In South Korea, most populations are located in sand dunes on the west coast, though several populations inhabit river sand dunes or mountain areas (Kim, 2010). The lizards leave their hibernacula in early April, mate between early April and late May, and lay eggs in two clutches between late April and middle July (Kim *et al.*, 2010). The sexual dimorphism, population age structure, and diet of the lizards have been previously

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studied (Jeong and Song, 2010; Kim *et al.*, 2010). Recently, a preliminary determination of the home range of four individual lizards was reported using a mark-recapture technique (Song *et al.*, 2010). *Eremias argus* was listed as endangered by the Korean Ministry of Environment in 2005 due to its limited distribution and decreased population sizes (Kim, 2010). The Ministry of Environment urges that this endangered species be conserved and allowed to recover, but the lack of information about its spatial ecology prevents effective determination of the appropriate location and size of its protected areas.

The aim of the present work is to investigate the spatial ecology of the Mongolian Racerunner in a western coastal sand dune in South Korea during the breeding season (June – August), non-breeding season (October), and late autumn (October – November), immediately before hibernation.

2. Materials and Methods

2.1 Study area The study was conducted in a sand dune (36° 39′ N, 126° 17′ E) on the west coast of South Korea, located in Taean-gun, Chungcheongnam-do Province. The study site is a long, narrow sand dune (Figure 3 A). Small shrub sand dunes populated by black locusts (*Robinia pseudoacacia*) are located in the north and south of the study site. East of the site is a windbreak forest of Japanese black pine (*Pinus thunbergii*), located 5–25 m from the shoreline. East of the forest are wastelands and dried crop fields. Several old concrete walls, the remains of houses, are present in the area. The dominant plant species at the site, in order of abundance, are American dune grass (*Elymus mollis*), fragrant evening primrose (*Oenothera odorata*), shore bindweed (*Calystegia soldanella*), and several plant species of the family Cyperaceae. The overall vegetation cover is approximately 70%. In this study, we classify areas with shrubs or trees, including the black locust shrub and windbreak forest areas, as shrub sand dune. Areas with grass are considered grass sand dune. The remaining areas nearby are considered grasslands because the ground-surface substrate is soil, not sand. At the site, Kim (2010) found an average of 13 *E. argus* individuals during five-minute visual encounter surveys, and also insects belonging to 15 families, and plants to 17 species.

2.2 Radio-telemetry The radio-telemetry study was conducted between 24 June and 6 August during the breeding season, between 3 and 20 October during the non-breeding season, and between 23 October and 12 November in late autumn immediately prior to hibernation.

We captured lizards opportunistically by hand, determining the sex of each by gently pressing on the abdomen and observing the presence of a hemipenis. We measured the snout-vent length (SVL) of each lizard to an accuracy of 0.1 mm using a vernier caliper (Digital caliper, Mitutoyo Korea, Seoul, Korea) and its body mass to an accuracy of 0.1 g using a field balance (ELT4001, Sartorius Korea, Seoul, Korea). Due to the weight of the transmitters, we selected heavy lizards. This preference resulted in the selection of more females (24) than males (16) in the study because females are heavier than males (Kim, 2010). Although we searched for the lizards in both grass and shrub sand dunes and grasslands, we only found the lizards in the grass sand dunes so that all subject lizards were caught from the grass sand dunes. Nevertheless, we have considered that the lizards might use shrub sand dunes and/or grasslands as habitats during any particular time of a year during either breeding, non-breeding, or late autumn study period.

We transported the lizards to a field station located approximately 5 km from the study site and attached the transmitters (Pip4 AG337, Lotek Wireless Inc., Dorset, UK) using a modification of the method described by Warner *et al.* (2006) (Figure 1). We glued the transmitter to an X-shaped piece of fabric using epoxy (Axia EP-04, Korea Axia, Seoul, Korea) and attached it to the dorsal plate of the lizard using skin-bond (Smith and Nephew Korea, Seoul, Korea). We tied the fabric around the lizard's chest and placed small amounts of skin-bond on the knot. The transmitter packages weighed an average of 0.32 g (range = 0.31–0.33 g, n = 8), and the ratio of the transmitter mass to the lizard's body mass averaged 8.8% (range = 6.5%–10.0%, n = 26). Each lizard with an attached transmitter was kept in an individual box (50 cm long × 40 cm wide × 40 cm high) overnight. The bottoms of the boxes were covered with 3 cm of sand. We placed several paper towels inside the boxes for shelter but provided no food. The next morning, if the transmitter was attached satisfactorily, we released each lizard where it had been caught.

Using a Sika radio-tracking receiver and a flexible Yagi antenna (Biotrack, Ltd., Dorset, BH, UK), we radio-located the lizards once each day between 08:00 and 18:00 in a random order selected by drawing lots. If we could not directly observe a lizard because it was within dry vegetation or underground, we determined its location to a point within 10 cm by triangulation, as in our previous study (Ra *et al.*, 2008). The location of each lizard was marked with a 1.3-m pole for one day. We first recorded the type of habitat (grass sand dune, shrub sand dune, or grassland), and then measured the vegetation cover in 10% increments within a 30-cm-radius area centered on the lizard's location (Ra *et al.*, 2010). We selected 30 cm because most of the American dune grass at the study site occupied areas of approximately 30 cm in diameter. We also determined the daily activity patterns of the lizard, which we classified as underground, on the surface under shelter, or on open ground, based on Wone and Beauchamp (2003). The "underground" designation was used when we detected a signal from under the ground. A lizard was classified as being located "on the surface under shelter" when we could not initially observe the lizard but detected the lizard as it ran away from shelter (e. g., dried plants) or when we observed the lizard within the plants. A lizard was classified as "on open ground" when we observed it directly on open ground. Next, we measured the shortest distance between two subsequent daily locations of the lizard in 0.1-m increments using a 50-m tape measure (hereafter referred to as the minimum linear "daily moved distance"). Finally, we determined the X and Y coordinates of the location from known GPS points (Vista CX, Garmin Korea, Seoul, Korea) in 0.1-m increments using the tape measure. To obtain the coordinate data, we designated four different landmarks, one near each corner of the study site and placed tape lines radiating from the landmarks at 10-m intervals throughout the study site, approximately 1 m above the ground.

During the late autumn, radio-location was performed once per day or twice per week, with the aim of determining the hibernacula of the lizards. We did not perform any statistical comparison of these data with data collected during the breeding or non-breeding seasons. We assumed a lizard was in hibernation if the lizard did not move for over 10 days (Wone and Beauchamp, 2003). When a hibernation site was identified, we recorded the surface habitat type and the vegetation cover, classifying them as described above. We also measured the shortest distance between the site and the nearest plant having a height greater than 10 cm to determine whether the lizards select hibernation sites near plant roots. The majority of plants in the study site were over 10 cm in height. We dug out the lizard and measured the depth at which it was found to the nearest 0.1 cm. Finally, we replaced the lizard at the same depth and buried it with a mixture of sand and soft, and dry plants.

The mean daily air temperature and humidity data were collected using a HOBO pendant temperature data logger

Figure 1 A male Mongolian Racerunner (*E. argus*) with an attached transmitter package on it's back.

(Onset Computer Co., Cape Cod, MA, USA) at the study site during the study period.

2.3 Data analyses We plotted the location of each lizard on a 1:5000 digital map of the study site in ArcView (v. 3.2, Environmental Systems Research Institute Inc., Redlands, CA, USA) using the X and Y coordinates of the locations obtained in the field based on known GPS points. We excluded the first day's location data from the analysis because we had kept the lizards at the field station overnight.

The home range of each lizard during both the breeding and non-breeding seasons was estimated by the minimum convex polygon (MCP) method (Haenel *et al.*, 2003) implemented in the 'animal movement' extension in ArcView GIS. We selected the MCP home range because MCP does not make any a priori assumptions about the lizards' pattern of space use, and it is easy to calculate based on real observations of lizards (Haenel *et al.*, 2003). We determined the minimum number of locations that represented an adequate sample size to estimate the MCP home range size by plotting the number of locations against cumulative home range size, which was converted to percentage of maximum home range size (Rose, 1982; Kenward, 2001). Approximately 13 locations described 80% of the asymptotic MCP home range ($y = 57.2 \ln x - 69.1$). In the breeding and non-breeding season analyses, we used data from 17 of the 31 radio-tracked lizards that fulfilled this requirement. In the late autumn analysis, to describe the characteristics of hibernacula, we used data from four of the nine radio-tracked lizards for which hibernacula were determined.

In this study, we did not estimate the kernel home range, which could hypothetically provide information about core habitats (Worton, 1989), for two reasons. First, the habitat structures where we relocated the lizards were simple, without any particular microhabitat structures. Second, the MCP home ranges of some lizards were too small to determine which specific areas within the home range were more frequently used. For these reasons, we believe that further home range analysis would not yield substantial additional habitat use information.

The movement rate of a lizard was calculated by dividing the number of movements by the number of relocations. The mean daily moved distance for a particular lizard was the mean value of the daily moved distances during the radio-tracking period. We restricted our analysis of the daily activity pattern to data collected on sunny days to control for weather. The number of sunny days during the breeding and non-breeding study periods was each 119 days (73.0%) out of total 163 days and 96 days (78.0%) out of total 123 days, respectively. The number of cloudy days was too few to analyze the daily activity pattern during each study period. To draw a graph detailing the daily activity pattern, the data were grouped into two-hour blocks (Lee *et al.*, 2011). The mean air temperature measurement represents the mean air temperature recorded at each time of the day during the study periods in the breeding and non-breeding seasons. In this study, we did not analyze the overlap between individual home ranges (Kerr *et al.*, 2004) because we attempted to keep radio-tracked lizards far approximately 10 m apart to minimize disturbance by researchers, and often encountered other non-subject lizards during radio-tracking subject lizards.

2.4 Statistical analyses We applied the Mann-Whitney U test to compare the SVL, body mass, and movement rate of the lizards, and vegetation cover of individual locations between males and females as well as between the breeding and non-breeding seasons.

Because body mass was not normally distributed (Kolmogorov-Smirnov, $P < 0.05$), we used the Spearman's rank correlation test to determine the relationships between the lizards' SVL and body mass, vegetation cover, movement rate, daily mean air temperature, daily mean humidity, mean daily moved distance, and home range during the breeding and non-breeding seasons.

To compare the mean daily moved distance and the MCP home range to the sex (male and female) and the season (breeding and non-breeding), the home ranges were first log-transformed to produce normally distributed data (Kolmogorov-Smirnov, $P > 0.05$). We then applied a univariate analysis of variance with the SVL and body mass of the lizards as covariates.

All statistical analyses were performed in SPSS (v. 17.0, SPSS Inc., Chicago, IL, USA). For all tests, a P-value of < 0.05 was regarded as statistically significant. The data are reported as the means ± standard error throughout the text.

3. Results

During the breeding season, 17 lizards were located an average of 16.3 times ± 0.7 times per individual and directly observed in 89 out of 163 (54.6%) cases; during the non-breeding season, they were located an average of 17.6 times ± 0.4 times per individual and directly observed in 46 out of 123 (37.6%) cases. During the breeding season, 150 out of 163 locations (92%) were in the grass sand dune, and the remaining 13 (8.0%), all associated with the same lizard, were in the shrub sand dune (Figure 3 A). No lizards were located in the grassland. During the non-breeding season, all of the 123 locations of the lizards were in the grass sand dune (Figure 3 A). We detected the lizards in areas of higher vegetation cover during the breeding season (58%) than during the non-breeding season (49%) (z = -2.15, P = 0.033).

The lizards showed different daily activity patterns during the breeding and non-breeding seasons. During the breeding season, observations on open ground were most frequent in the early morning, gradually declined until 15:00, and increased slightly after 16:00 (Figure 2). During the non-breeding season, the lizards were more frequently observed on open ground in midday and generally located underground in the morning and late afternoon (Figure 2).

Mean daily moved distance during the breeding season and the body mass of the lizards during the non-breeding season showed a positive and negative correlation with the MCP home range size (R = 0.927, $P < 0.001$; R = -0.821, P = 0.023, respectively). Other correlations were not significant ($P > 0.05$ for all cases).

The lizards made more frequent movements during the breeding season (92.4% ± 3.0%) than during the non-breeding season (84.6% ± 0.1%; z = 2.79, P = 0.005). During the breeding season, the lizards moved 4.9 ± 0.8 m daily (range = 1.6–10.5 m) and used 161.6 ± 47.3 m^2 (range = 17.1–432.2 m^2) MCP home range (Figure 3 B, Table 1); during the non-breeding season, they moved 1.9 m ± 0.5 m daily (range = 1.1–4.7 m) and used 67.5 ± 26.3 m^2 (10.2–210.4 m^2) MCP home range (Figure 3 C, Table 1). The differences in the mean daily moved distance and MCP home range size between the seasons and between

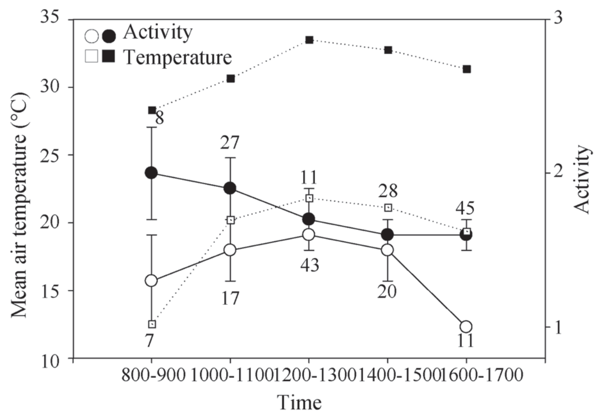

Figure 2 Pattern of the mean air temperature (quadrangles) during the breeding (filled) and non-breeding (open) study periods and activity level (circles) of radio-tracked Mongolian Racerunners (*E. argus*) on sunny days during the study periods. Activity codes: 1: Underground; 2: On the surface under shelter; 3: On open ground. The numbers on the lines indicate the sample size.

males and females were not significant ($P > 0.05$ for all cases).

During the late autumn, we located nine lizards an average of 10 ± 0.7 times (range = 6–13 times) over an average of 16.4 ± 1.5 days (range = 8–20 days). Four lizards (two males and two females) moved into hibernacula on 26 or 30 October or on 2 November. The hibernacula of the four lizards were all located in the open grass sand dune where they were found during both the breeding and non-breeding seasons, 17.8 ± 5.3 cm (range = 12–24 cm) beneath the surface, with 17.5% ± 2.5% vegetation cover (range = 10%–20%) (Figure 3 A). The hibernacula were located 23.3 ± 8.6 cm (range = 7–43 cm) away from the nearest plant.

4. Discussion

The Mongolian Racerunner spent both the breeding and the non-breeding periods in grass sand dunes. In this study, approximately 96% of the lizard locations were in grass sand dunes during these periods. In addition, the hibernacula of the lizards were all located within grass sand dunes. These results suggest that the Mongolian Racerunner lives in grass sand dunes throughout the year. On one hand, our results might be caused by the reason that all subject lizards were caught in the grass sand dunes, not in the shrub sand dunes or grasslands. However, the factor could not be a major explanation. That we only detected one lizard in the shrub sand dunes

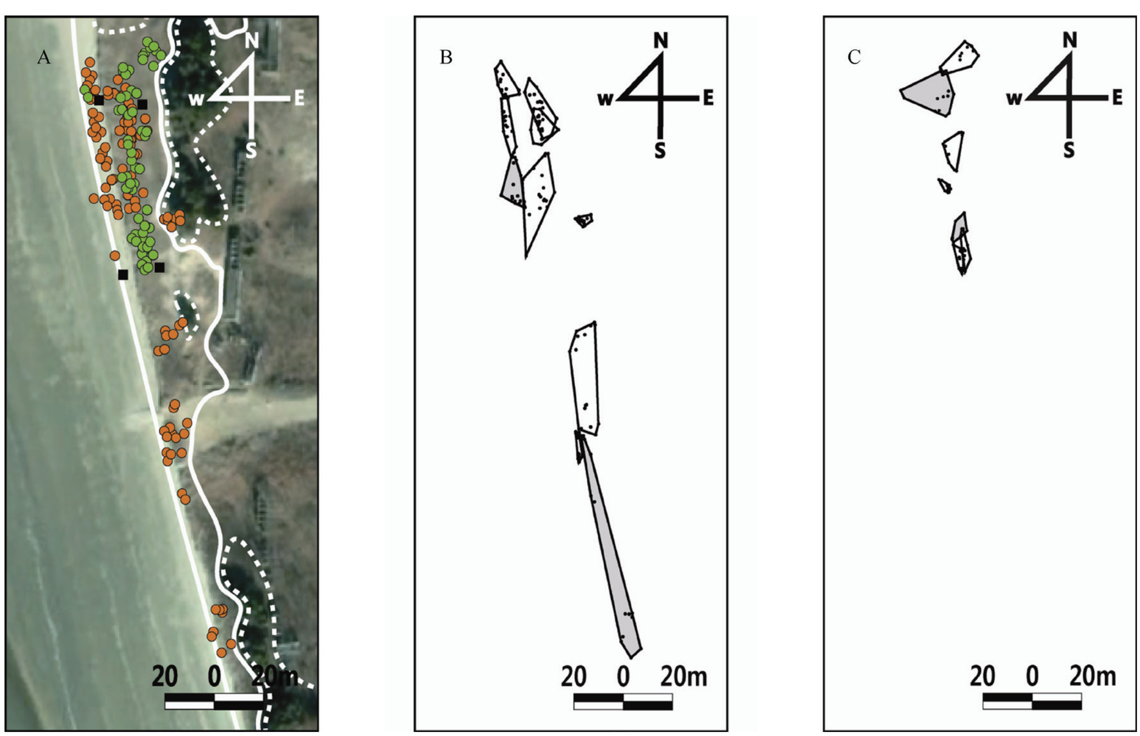

Figure 3 A satellite image of the study site and the locations of the Mongolian Racerunner (*E. argus*), as confirmed by radio-tracking (A). Individual locations during the breeding and non-breeding seasons are indicated by brown and green circles, respectively. Hibernacula are indicated by black quadrangles. Grass sand dunes within the study site are indicated by white lines, and shrub sand dunes are indicated by white dotted lines. The remaining areas, including waste lands and dried crop fields east of the study site, are considered grasslands. Minimum convex polygon (MCP) estimates of male (shaded polygons) and female (open polygons) home ranges during the breeding season (B) and non-breeding season (C).

Table 1 Characteristics of individuals and summary of radio-tracking data for the Mongolian Racerunner (*E. argus*).

Season	Ind no.	Sex (m, f)	SVL (mm)	Body mass (g)	No. of relocations	Plant cover (%)	Movement rate (%)	Moved distance (m)	MCP home range (m^2)
Breeding	b7	m	53.7	3.5	13	57.9	100	10.5 ± 4.0	432.2
	b13	m	55	3.7	18	54.2	94.4	5.2 ± 1.2	107.3
	b3	f	56.2	3.5	18	56.8	83.3	2.9 ± 0.6	71.1
	b5	f	65	5.4	18	69.5	88.9	6.7 ± 1.6	287.5
	b9	f	53.2	3.8	18	56.8	77.8	1.6 ± 0.3	18.1
	b11	f	54.8	3.5	14	59.3	100	3.4 ± 0.6	70.3
	b17	f	54.6	3.6	19	47	100	4.2 ± 0.6	95.7
	b19	f	59.7	3.6	14	64.7	100	2.1 ± 0.5	17.1
	b22	f	59.6	3.8	16	51.2	75	6.8 ± 2.4	138.8
	b23	f	55.5	4.4	15	64.4	100	5.8 ± 2.0	378
Mean ± SE			56.7 ± 1.2	3.9 ± 0.2	16.3 ± 0.7	58.2 ± 2.1	91.9 ± 3.2	4.9 ± 0.8	161.6 ± 47.3
Non-breeding	nb3	m	56.1	5.0	15	54.4	60	1.4 ± 0.6	36.9
	nb5	m	57.8	5.0	18	58.9	77.8	4.7 ± 1.4	210.4
	nb7	f	57.1	4.7	18	40	77.8	1.1 ± 0.7	97.6
	nb9	f	61.4	5.2	18	38.9	66.7	1.5 ± 0.5	64.4
	nb12	f	61.7	6.2	18	53.2	61.1	1.7 ± 0.6	30.8
	nb13	f	64.3	6.5	18	44.2	77.8	1.5 ± 0.3	22.0
	nb18	f	66.5	5.6	18	52.1	83.3	1.1 ± 0.3	10.2
Mean ± SE			60.7 ± 1.5	5.5 ± 0.3	17.6 ± 0.4	48.8 ± 2.9	72.1 ± 3.5	1.9 ± 0.5	67.5 ± 26.3
Total mean ± SE					16.8 ± 0.5	54.3 ± 2.0	83.8 ± 3.5	3.7 ± 0.6	122.8 ± 31.3
Statistical analyses between the seasons			$z = -2.15$ $P = 0.033$	$z = -3.04$ $P = 0.001$	$z = -0.25$ $P = 0.315$	$z = -2.15$ $P = 0.033$	$z = -2.79$ $P = 0.005$	$F = 3.26$ $P = 0.094$	$F = 1.54$ $P = 0.236$

and no lizards in the grasslands implies that the shrub sand dunes and grasslands in the study areas might not be proper habitats for the Mongolian Racerunner. If the shrub sand dunes and grasslands are appropriate habitats for the Mongolian Racerunner, we should detect some of the subject lizards in the shrub sand dunes and grasslands during either breeding, non-breeding, or hibernation study period. On the other hand, it is highly possible that the Mongolian Racerunner used the grass sand dunes as a major habitat because the grass sand dunes at our study sites could provide all of the essential ecological factors required by the Mongolian Racerunner. It has been well known that many lizard species prefer a specific habitat type. For example, the Iberian Wall Lizard (*Podarcis hispanica*; Diego-Rasilla and Pérez-Mellado, 2003) prefers rocky areas, and the Spotted Sand Lizard (*Pedioplanis lineoocellata;* Wasiolka *et al.*, 2009) prefers grass and shrub areas in the African savanna. Although these preferred habitat types differ, both habitats provide essential areas for foraging, hiding, hibernation, egg-laying, and mating. In a previous study of the Sand Lizard (*L. agilis*), Nicholson and Spellerberg (1989) suggested that coastal sand dunes could provide a variety of insects for foraging, many open slopes for basking, and open sand areas for egg-laying and hibernation.

The hibernacula of the Mongolian Racerunner were located in the open grass sand dunes, the habitats same used during the breeding and non-breeding seasons. The lizards began their hibernation under the sand at a depth of approximately 17.8 cm. Some lizard species migrate to hibernacula outside of their breeding habitats, whereas other species do not. For example, the Granite Spiny Lizard (*Sceloporus orcutti*) migrates to rocky areas for hibernation and returns to its breeding habitat in the spring (Weintraub, 1968). In contrast, the European Common Lizard (*L. vivipara*; Bauwens, 1981) and the Six-lined Racerunner [*Aspidoscelis* (= *Cnemidophorus*) *sexlineatus*; Etheridge *et al.*, 1983] remain in their breeding habitats to hibernate if the habitats are safe for hibernation. These previous results and our finding that the Mongolian Racerunner remained in the grass sand dunes to hibernate indicate that grass sand dunes in coastal areas provide appropriate hibernacula for *E. argus*, similar to that for Sand Lizards (*L. agilis*; Nicholson and Spellerberg, 1989).

Thermal conditions might explain the different daily activity patterns of the Mongolian Racerunner in the breeding and non-breeding seasons. Between late June and early August, we observed more individuals on the open ground in the morning, but observations on the open ground were less frequent at midday, perhaps because the lizards retreated into shelters to avoid the intense midday heat. In October, we observed more individuals on the open ground at midday, probably basking under the midday sun. This pattern has been reported for several lizards (Diego-Rasilla and Pérez-Mellado, 2000; Wone and Beauchamp, 2003; Pal *et al.*, 2010). It is physiologically advantageous for the lizards to escape extreme surface temperatures during the summer but to take the opportunity to bask in proper thermoregulation temperatures in the autumn (Avery *et al.*, 1982).

In our study, during the non-breeding season, the lizards with greater body masses had smaller home ranges. This result might indicate that the heavy lizards had accumulated enough additional mass for hibernation, resulting in reduced use of their home ranges. Considering that four lizards moved into hibernacula between 26 October and 2 November in this study, some lizards could have already gained additional body mass for hibernation in October, when our non-breeding season study was conducted.

The mean daily moved distance of the Mongolian Racerunner was small. The distances moved daily by different lizard species vary with body size and habitat conditions. For example, the Spotted Sand Lizard (*P. lineoocellata*), an inhabitant of savanna areas with an SVL of approximately 50 mm, was found to travel a mean distance of 27.4 m per day, whereas the Western Green Lizard (*L. bilineata*), which inhabits the slopes along the Rhine River and has an SVL of 130 mm, moved 10.4 m daily (Sound and Veith, 2000; Wasiolka *et al.*, 2009). Two factors may explain the short distance moved daily by the Mongolian Racerunner. First, its small body size might be responsible; the moved distances of lizards are generally correlated with body size (Turner *et al.*, 1969), and the SVL of *E. argus* is relatively small (approximately 57 mm). Second, the restriction of their activity within the grass sand dunes might be responsible for the short moved distances. Because coastal grass sand dunes provide the lizards with abundant insect food and favorable hiding places (Jeong and Song, 2010; Kim, 2010), the relatively short movements of the Mongolian Racerunner may be sufficient to meet its ecological requirements.

The home range of the Mongolian Racerunner found in the present study was relatively small, and its MCP home range was approximately 123 m^2. Moreover, the MCP home range estimated from a one-year mark-recapture study of four *E. argus* lizards was even smaller, averaging 31.5 m^2 (Song *et al.*, 2010). Similar to the distance moved daily, the home range of lizards varies with body size and habitat conditions. For example, the summer MCP home range of the Iberian Wall Lizard (*P. hispanica*) (with an SVL of approximately 60 mm), which lives in rocky areas, was approximately 460 m^2 (Diego-Rasilla and Pérez-Mellado, 2003). The MCP home range of the Sand Lizard (*L. agilis*) (with an SVL of approximately 70 mm), which lives in coastal sand dunes, was 648 m^2 for males and 398 m^2 for females (Nicholson and Spellerberg, 1989). The small home range size of the Mongolian Racerunner found in our study has three possible explanations. First, the relatively short radio-tracking periods might be responsible. This explanation is unlikely because we selected data from which we could adequately infer home range size in this population. Moreover, a one year study of the same species also showed small home range values (Song *et al*., 2010). Second, the small study areas might be responsible. This factor may be involved in the result in part but cannot be a major factor because most lizards in this study had very small home ranges, which occupied only small portion of the our study area. Third, small grass sand dunes might be sufficiently large to satisfy the lizards' ecological requirements for foraging, mating, and cover. The third explanation appears to be the most probable, and it is consistent with a previous finding that Sand Lizards (*L. agilis*) in coastal sand dunes had smaller home ranges than other lizards in mixed habitats (Nicholson and Spellerberg, 1989).

5. Conclusion

Our study shows that most Mongolian Racerunners remain within small grass sand dunes throughout the breeding and non-breeding seasons, and hibernate within the dunes, suggesting that lizards use the grass sand dunes as a major habitat throughout the year. This preference may explain the relatively small daily moved distance and small MCP home range of the species. Given that at least 11 Mongolian Racerunner populations are located along the west coast of South Korea (Kim, 2010), our results can be useful in selecting and sizing the appropriate protected areas for the conservation of this endangered lizard species in coastal sand dunes.

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