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Physical characteristics and age structure of Mongolian racerunner (*Eremias argus*; Larcertidae; Reptilia)

Ja-Kyoung Kim[1], Jae-Young Song[2], Jung-Hyun Lee[1] and Daesik Park[3,*]

[1]Department of Biological Science, Kangwon National University, Chuncheon 200-701, Korea
[2]Korea National Park Research Institute, Korea National Park Service, Seoul 121-717, Korea
[3]Division of Science Education, Kangwon National University, Chuncheon 200-701, Korea

In this study, we have evaluated the physical characteristics of neonate, female, and male Mongolian racerunners (*Eremias argus*) and determined the age structure of a population of the species in a field located in Taean-gun, Chungnam, South Korea. The physical parameters of females and males, including snout-vent length (SVL), head length, head width, and body mass were found to be significantly interrelated. Male Mongolian racerunners exhibited significantly longer heads than the females, but other physical parameters, such as SVL, head width, and body mass did not differ between the female and male specimens. In the study population, the females ranged in age from two to eleven years old and the males ranged between two to eight years of age. The number of females and males, when separated into different age classes, did not differ within each age class. Male Mongolian racerunners evidenced greater SVL growth coefficients than the females, but asymptotic SVL did not differ between the females and males.

Key words: age structure, endangered species, *Eremias argus*, lizard, morphology

INTRODUCTION

Like many other species, reptile species are declining throughout the world, and some of them are endangered (Gibbons et al. 2000). Based on the 2009 annual Red List report compiled by the International Union for Conservation of Nature and Natural Resources (IUCN), more than 470 reptile species are currently classified as endangered (IUCN 2009). In Korea, many reptile species are also in decline, although few results have been published in this regard (Song 2007). In order to successfully conserve or restore a particular species, knowledge of its life history and basic ecology, including physical characteristics of individuals and age structures of natural populations, is a matter of critical importance (Germano 1992, Andreone et al. 2005). Nevertheless, very few studies concerning reptile species have been conducted (Anderson and Vitt

1990, Shine and Charnov 1992); this is particularly true of reptile species in Korea.

The Mongolian racerunner (*Eremias argus*) is a small lizard species belonging to family Lacertidae, Reptilia, and has been designated as an endangered species (category II) by the Korean Ministry of Environment since 2005. The range of the Mongolian racerunner encompasses the Korean peninsula, Mongolia, and certain areas of Russia and China (Zhao et al. 1999). Mongolian racerunners primarily inhabit grasslands near mountains, sand dunes formed along coastlines, or riparian areas along major Korean rivers, including the Nakdong and Han rivers (Kang and Yoon 1975). The total body length of adult Mongolian racerunners is approximately 150-200 mm (Kang and Yoon 1975). The dorsal surface of

the body is grayish or brown-gray, and that of the ventral surface is whitish or light brown (Kang and Yoon 1975). In China, this species has been studied to a certain extent, including studies of temperature effects on hatching rates and foraging behavior and differences in the activity levels of lizards reared under various temperature regimes (Hao et al. 2006, Luo et al. 2006, Wu et al. 2006, Zhao et al. 2008). However, no studies of this species have been conducted in Korea, despite the lizard's status as an endangered species.

Skeletochronology has been used to determine the ages of many different amphibian and reptile species (Castanet and Baez 1988, 1991, Cheong et al. 2007, Lee and Park 2009, Lee et al. 2009) based on the number of lines of arrested growth appearing in cross-sectioned phalanges. Lines of arrested growth are formed as the result of different growth rates of phalange bones in active growing seasons relative to those in resting winter seasons (Patnaik 1994, Esteban et al. 2004). In lizards, it has been previously reported that ages estimated by skeletochronology deviate by one or two years from ages calculated via the mark-recapture method (Smirina and Tsellarius 1996). Nevertheless, skeletochronology has been frequently employed in reptile studies to determine age at sexual maturity, individual growth coefficients, and age structures of natural populations (Castanet and Baez 1988, Halliday and Verrell 1988, Roitberg and Smirina 2006). This method is rather attractive because several years are required to obtain adequate data via the mark-recapture method.

In this study, we evaluated the physical characteristics of neonate, female, and male Mongolia racerunners collected from a population located in Taean-gun, Chungcheongnam-do, South Korea, and determined the age structure of the population.

MATERIALS AND METHODS

On July 10, 2008 and June 11, 2009, we collected 67 female and 50 male Mongolian racerunners by hand or with an insect net in a natural population located in Baramare Beach (N 36°24′34.9″, E 126°23′01.4″), Taean-gun, Chungcheongnam-do, South Korea. The Baramare population is located on a small sand dune island (23 m long × 17 m wide) approximately 50 m from the coastline. Magellan wheatgrass (*Elymus mollis*) and Smooth crabgrass (*Ischaemum anthephoroides*) are the predominant plants on the island. During ebb tides, the island is frequently connected by land to another pine-dominated island.
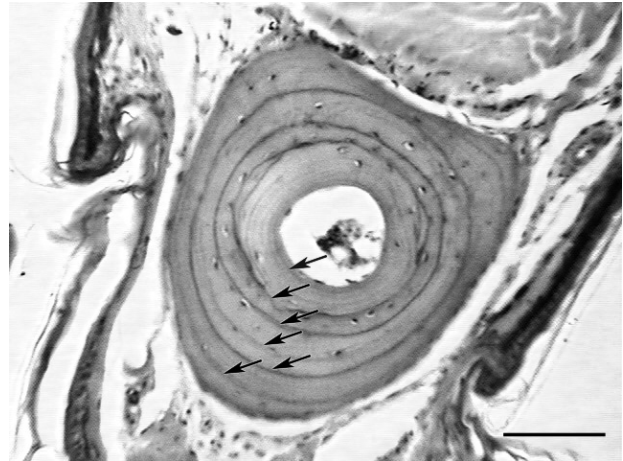

Fig. 1. Phalangeal cross-section of a six-year-old male *Eremias argus* from the Baramare population. Each black arrow indicates a line of arrested growth (scale bar = 15 μm).

Whenever we captured a lizard, we first determined the sex of the lizard based on the presence of a hemipenis (male) or bite marks on the abdomen (female). After sex determination, we measured the snout-vent length (SVL), head length, head width, and body mass of each lizard with a digital vernier caliper (M500-181; Mitutoyo, Tokyo, Japan) and a digital field balance (TMB 120-1; Kern, Wildeck, Germany) to the nearest 0.1 mm and 0.1 g, respectively. In order to determine the ages of individuals by skeletochronology, we clipped the outermost two segments of the central toe from the right hindlimb and individually preserved each in 10% neutral-buffered formalin.

Skeletochronology was conducted according to the methods developed by Cheong et al. (2007) and Lee and Park (2009). First, we washed the clipped toes for 24 h in running tap water to clean them. We then softened the toe bone by submerging it for 4 h in 5% nitric acid. Subsequently, the dehydrated toes were paraffin-embedded and sectioned at a thickness of 15 μm using a rotary microtome (Erma, Tokyo, Japan). The collected sections were then stained with Harris' hematoxylin & eosin and observed under a microscope. Growth zones and lines of arrested growth (LAGs) were clearly visible in the cross-sections of the phalanges (Fig. 1). The number of LAGs was determined independently by two authors based on the methods developed by Cheong et al. (2007) and Lee and Park (2009). The two age estimates were compared to derive a consensus value for the age of each individual.

To obtain SVL data for neonates, which was necessary to estimate the growth curves of the female and male Mongolian racerunners, we collected 10 pregnant

females from the Baramare field population on May 12, 2009 and brought them into the laboratory. We housed them in two plastic boxes (48 cm long × 27 cm wide × 30 cm deep) containing sand with a depth of 5-7 cm, wet paper towels that provided hiding places for the lizards, and a ceramic water container (5 cm diameter, 5 cm deep). Approximately 10 days after housing, the females began to oviposit eggs inside the sand. We successfully collected a total of 38 eggs. We placed the eggs in an incubator (35 cm long × 20 cm wide × 7 cm deep, PX-20R; Auto Elex Co., Ltd, Seoul, Korea) containing wet vermiculite at a depth of approximately 5 cm. The air temperature and relative humidity within the incubator were maintained at 27.5-29°C and 80-90%, respectively, throughout the incubation period. After approximately 50 days of incubation, most of the eggs had successfully hatched. We measured the SVL, head length, head width, and body mass of 25 neonates using a digital vernier caliper and a digital balance five days after hatching.

Growth curves of the female and male Mongolian racerunners were estimated by applying the growth curve model of von Bertalanffy (1938) to the SVL data for females and males recorded in the field and for neonates hatched in the laboratory. The von Bertalanffy model equation is $S_t = S_m - (S_m - S_o) e^{-k (t - to)}$, where S_t = average SVL of females or males at age t, S_m = asymptotic SVL of females or males, S_0 = average SVL of neonates, t = age of each individual, t_0 = age at which offspring hatch, and K = growth coefficient of female or male SVL (average growth rate of SVL per year). For the S_o value, we used 26.6 mm (calculated from 25 neonates); for t_o, we used 0.15 because the egg incubation period was approximately 50 days in this species. The von Bertalanffy growth model was fitted to the average growth curves using dynamic fitting in SigmaPlot ver. 10.0 (Systat Software Inc., Houn-slow, UK).

Among the physical parameter data, only the SVL data passed the normality test after square root data transformation (Kolmogorov-Smirnov, $P > 0.05$). As the majority of physical parameter data did not pass the normality test (Kolmogorov-Smirnov, $P < 0.05$), we analyzed the relationships among parameters via Spearman's correlation test. In order to determine whether the physical parameters differed between females and males, we employed an independent sample t-test for the SVL data and the analysis of covariance (ANCOVA) for other physical parameters. In the ANCOVA of each physical parameter, the rest parameters were employed as covariates. In analyzing the age data, differences in the number of females and males based on different age classes were tested via chi-square tests. Differences between males and females in growth coefficients and asymptotic size were determined via independent sample t-tests using means and standard deviations estimated from the growth curves. All statistical analyses were conducted using SPSS ver. 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The SVLs of neonates, females, and males were approximately 26.6 mm, 49.2 mm, and 48.8 mm, respectively. Interestingly, the head lengths of the males were significantly greater than those of females (ANCOVA, $F = 20.28$, df = 1, $P < 0.01$), but SVL ($t = 0.16$, df = 115, $P = 0.87$), head width (ANCOVA, $F = 1.69$, df = 1, $P = 0.20$), and body mass (ANCOVA, $F = 0.94$, df = 1, $P = 0.33$) did not differ between the females and males (Table 1). In both females and males, relationships among the physical parameters SVL, head length, head width, and body mass were sig-

Table 1. Comparison of physical parameters of neonate, female, and male *Eremias argus*

Physical parameters	Neonate (N = 25)	Female (N = 67)	Male (N = 50)
SVL (mm)	26.6 ± 1.3 (24.4-29.8)	49.2 ± 1.2 (30.9-65.8)	48.8 ± 1.2 (32.3-63.7)
Head width (mm)	5.0 ± 0.7 (4.5-7.9)	7.0 ± 0.1 (5.0-9.9)	7.4 ± 0.2 (5.4-14.2)
Head length (mm)	7.7 ± 0.6 (5.3-8.4)	10.8 ± 0.2 (6.0-14.6)	12.0 ± 0.3 (8.8-19.0)
Body mass (g)	0.7 ± 0.1 (0.4-1.1)	2.9 ± 0.2 (0.7 - 6.8)	3.1 ± 0.2 (0.9-7.0)

Data are expressed as means ± standard error (range).
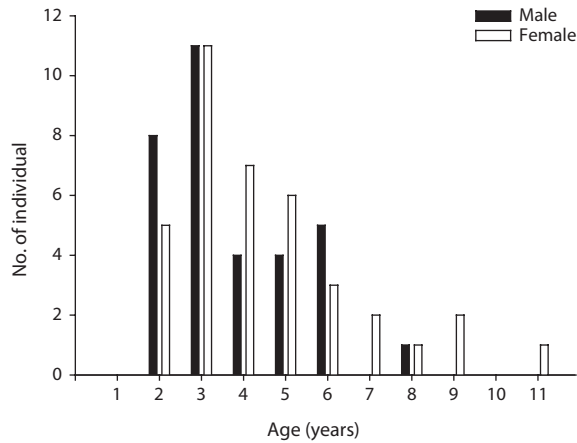SVL, snout-vent length.

Fig. 2. Age distribution of female and male *Eremias argus* in the Baramare population.
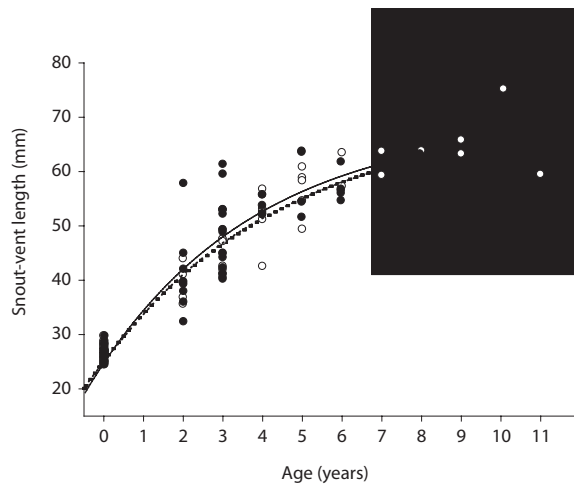

Fig. 3. Growth patterns of female and male *Eremias argus* in the Baramare population fitted to von Bertalanffy's equation (1938). The dashed line indicates males; the dotted line indicates females. $S_t = S_m - (S_m - 26.6) e^{-k(t-0.15)}$.

nificant in all comparisons made (Spearman correlation test, $P < 0.01$ for all cases) (Table 2). In the neonates, relationships between SVL and head width and between SVL and body mass were significant (Spearman correlation test, $P < 0.01$), whereas other comparisons were not significant (Spearman correlation test, $P > 0.05$).

We successfully determined the ages of 38 females and 33 males among a total of 117 lizards, but were unable to determine the ages of 46 lizards due to a loss of sections during the skeletochronology process or incomplete staining of sections. The ages of the females ranged from two to eleven years (mean ± SE = 4.5 ± 0.4, $N = 38$), whereas those of males ranged from two to eight years (mean ± SE = 3.7 ± 0.3, $N = 33$) (Fig. 2). In both females and males, three-year-old lizards were the most abundant (Fig. 2). Although females over seven years of age were slightly more frequent than males of the same age, the number of females and males did not differ significantly within any age class (chi-square test, $P > 0.05$). In the growth curve analysis, the growth coefficient of males (0.26 ± 0.08) was higher than that of females (0.22 ± 0.04, $t = 13.19$, df = 69, $P < 0.01$), but asymptotic SVL did not differ significantly between females (70.1 ± 3.9 mm) and males (67.8 ± 7.4 mm) ($t = 0.97$, df = 69, $P > 0.05$) (Fig. 3).

DISCUSSION

In this study, we evaluated the physical characteristics of female and male Mongolian racerunners and determined the age structure of a natural population. The heads of the male lizards were significantly longer than those of the females, but no other physical parameters differed between the females and males. The ages of

Table 2. Relationships among physical parameters of neonate, female, and male *Eremias argus*

Physical parameters compared	Spearman correlation coefficient (r)		
	Neonate ($N = 25$)	Female ($N = 67$)	Male ($N = 50$)
SVL × Head width	0.491[*]	0.872[**]	0.916[**]
SVL × Head length	0.312	0.843[**]	0.921[**]
SVL × Body mass	0.568[**]	0.975[**]	0.962[**]
Head width × Head length	0.262	0.706[**]	0.937[**]
Head width × Body mass	0.338	0.857[**]	0.952[**]
Head length × Body mass	0.235	0.856[**]	0.934[**]

[*]$P < 0.05$, [**]$P < 0.01$.
SVL, snout-vent length.

the natural population of Mongolian racerunners tested herein ranged between two to eleven years, and the numbers of females and males did not differ within the different age classes. Although asymptotic SVL did not differ between females and males, the males evidenced a higher growth coefficient than the females.

In lizards, sexual dimorphism is generally promoted by sexual selection and scarcely by natural selection such as food competition (Shine 1989, Vincent and Herrel 2007). Because the larger heads (usually both longer and wider) of male lizards may be a mechanism of relative advantage in male-male mating competitions and in subduing potential mates during mating (Olsson et al. 2002), the males of several species, including the Multiocellated racerunner (*Eremias multiocellata*), the Grass lizard (*Takydromus septentrionalis*), and the Common lizard (*Zootoca vivipara*) (Ji et al. 1998, Gvoždík and van Damme 2003, Li et al. 2006,) all generally have larger heads than the females of their respective species (Vitt 1983). For example, during mating, male *E. multiocellata* and *T. septentrionalis* often control the female by biting the female's tail or abdomen with their large mouth, which is seated in a relatively large head (Li et al. 2006, Du and Yao 2007). Although the mating behavior of the Mongolian racerunners has not been previously studied, male lizards may bite females' abdomens during mating. We frequently observed bite marks on the abdomens of female lizards. However, a recent study of the dietary habits of this species demonstrated that the volume of food consumption did not differ between females and males, and also that the food consumption volume was unrelated to SVL and head width (Jeong and Song 2010). These results indicate that the large head size of male Mongolian racerunners might be a crucial factor in successful mating, and was probably promoted by sexual selection. On the other hand, unlike the results seen in other lizards (Gvoždík and van Damme 2003, Li et al. 2006, Du and Yao 2007), the head widths of male Mongolian racerunners did not differ from those of the females. It is possible that the sand-burrowing behavior of this species might constrain the growth of head widths in both females and males, although we are currently unaware of any studies having been conducted in this regard. Thus, further study is clearly warranted to elucidate in detail which factors are responsible for these results.

In contrast to other lizard species in which females evidence longer SVL than males (Haenel and John-Alder 2002, Liu et al. 2008), our finding that SVL did not differ between female and male Mongolian racerunners implies that female body size may not constitute a reliable indicator of female fecundity. Similar results have been recently reported in studies of *E. multiocellata* (Li et al. 2006). In that species, females' SVLs were not correlated with litter size, and explained only 19% of the variability in litter mass, thereby suggesting that selective pressure on large female SVL for high fecundity through sexual selection is quite low. Such low selective pressure on female SVL should not be sufficient to induce differences in SVL between females and males (Li et al. 2006). By way of contrast, in lizards such as the eastern fence lizard (*Sceloporus undulatus*) and the Viviparous lizard (*Lacerta vivipara*), female SVL is correlated strongly with clutch mass and clutch size, and females have longer SVLs than males (Haenel and John-Alder 2002, Liu et al. 2008). These results indicate that the fecundity of female Mongolian racerunners may be dependent on other factors, rather than on female SVL. Additional studies will be necessary to elucidate which factors are important determinants of female fecundity in this species.

Based on our skeletochronological findings, the lifespan of Mongolian racerunners is approximately 10 years. This lifespan is greater than that of *L. vivipara* and *S. undulatus* (five years) but slightly shorter than that of *L. agilis* (12 years) (Tinkle and Ballinger 1972, Pilorge and Castanet 1981, Arnold 2002). Unfortunately, the longevity of other species in the genus *Eremias,* to the best of our knowledge, has yet to be determined. The age at sexual maturity of *L. vivipara, L. agilis,* and *S. undulatus* has been reported as three years, two years, and one year, respectively (Tinkle et al. 1970, Tinkle and Ballinger 1972). Considering that the age structure of our Mongolian racerunner population was quite similar to that of previously studied populations of *L. agilis*, it appears that some Mongolian racerunners might reach sexual maturity at two years of age. Additionally, our observations of many two- to four-year-old lizards in the tested population reveal that this population is demographically stable, and also show that the recruitment of new individuals is ongoing.

The higher SVL growth coefficient of male Mongolian racerunners as determined in our study may explain, at least in part, the finding of greater head length in males relative to females. The results of previous studies have shown that male *Eremias brenchleyi* and *T. septentrionalis* have longer heads than females of the respective species. In these species, the heads of males grew in length more rapidly than the heads of females (Zhang and Ji 2000, Xu and Ji 2003). Considering that SVL is generally positively correlated with head length in lizards (Ekner et al. 2008), the greater SVL growth coefficient of males

should be responsible for their greater head length, particularly if asymptotic SVL does not differ between females and males. Since the SVL of Mongolian racerunner females and males was not found to be different in this study, the greater SVL growth coefficient of male Mongolian racerunners might influence physical characteristics other than SVL, such as head length, which might be the result of selection for successful mating.

ACKNOWLEDGMENTS

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