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Sexual size dimorphism in *Darevskia raddei* (Sauria: Lacertidae) from northwestern Iran

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We examined sexual size dimorphism of the rock-dwelling lizard *Darevskia raddei* (Boettger, 1892) with the help of 30 specimens that were provided from various sources. Eleven metric and seven meristic features were examined. Seven characters (gulars, length of basal tail, femoral pores, length of head, width of head, length of fore limb and length of hind limb) were identified as dimorphic between the two sexes. Some of these characters have important roles in copulation for males, especially the hind limb and the tail base. The number of femoral pores is important in the release of signal components because females release these components to attract males during the mating season. The length of the hind limb as locomotor performance plays an important role during mating, so that the male can grasp the female and adopt the correct position during copulation.

Key words: Lacertidae, *Darevskia raddei*, sexual size dimorphism, Iran.

Introduction

Several studies that have been carried out on lizards to determine sexual size dimorphism have reached the conclusion that differences in body sizes between males and females in lizards are not consistent; in some species males are larger than females and vice versa (Fitch, 1981; Perry, 1996; Adriana, Helga, & Guarino, 2005; Antigoni, Carretero, & Gustavo, 2007; Chi-Yun, Yu-The, & Yao-Sung, 2009). We examined sexual dimorphism in the rock-dwelling lizard *Darevskia raddei* (Boettger, 1892), which can be found in Armenia, northwestern Iran including the Lake Sevan basin, and Azerbaijan (Anderson, 1999).

Material and Methods

We examined morphometric and meristic characters in 30 specimens (16 males and 14 females). The material was obtained during fieldwork between 2011 and 2013 from five localities in the northwestern part of the Iranian Plateau and some additional samples were obtained from museum voucher specimens from Razi University Zoological Museum (RUZM). Collection sites are: (1) Varzaqan (38°36'N, 46°42'E, 2100 m a.s.l.): 5♂, 3♀. – (2) Kharvana (38°64'N, 46°56'E, 1460 m a.s.l.): 3♂, 4♀. – (3) Ahar (38°22'N, 47°10'E, 1540 m a.s.l.): 2♂, 2♀. – (4) Kalibar (38°80'N, 47°15'E, 1773 m a.s.l.): 3♂, 3♀. – (5) Tabriz (37°41'N, 46°23'E, 1630 m a.s.l.): 3♂, 2♀.

Eleven morphometric and seven meristic characters were used in this study: LBT: length of widest part of tail base; EL: ear length (distance from top to bottom of the ear opening); LFT: length of fourth toe (distance from the base of toe to the tip); SVL: snout-vent length (from tip of

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Table 1. Descriptive table including minimum, maximum, mean and standard error in 18 morphometric characters and ANOVA of all morphometric characters in *Darevskia raddei* (male: N=16; female: N=14). Significant values ($p < 0.05$) are shown in bold.

	Sex	Mean± STD	Range	p	Mean of squares	F
LBT: length of widest part of tail base	♂	6.14 ± 0.088	5.15-6.72	**0.008**	0.981	8.241
	♀	5.78 ± 0.089	5.21-6.21			
EL: ear length	♂	2.29 ± 0.048	2.02-2.67	0.972	0.000	0.001
	♀	2.28 ± 0.026	2.13-2.44			
LFT: length of 4th toe	♂	11.65 ± 0.127	10.93-12.46	0.378	0.169	0.801
	♀	11.80 ± 0.105	10.94-12.56			
SVL: snout-vent length	♂	62.82 ± 0.153	61.98-63.87	0.797	0.022	0.067
	♀	62.87 ± 0.139	62.04-63.59			
HL: head length	♂	14.62 ± 0.199	13.01-15.23	**0.005**	3.598	9.495
	♀	13.92 ± 0.076	13.34-14.24			
LHF: trunk length	♂	3.39 ± 0.290	31.18-35.22	0.538	0.633	0.388
	♀	33.66 ± 0.372	31.16-35.34			
HH: head height	♂	3.26 ± 0.039	3.01-3.50	0.942	0.000	0.005
	♀	3.26 ± 0.039	3.06-3.45			
HW: head width	♂	9.18 ± 0.048	8.78-9.50	**0.019**	0.385	6.214
	♀	8.95 ± 0.080	8.32-9.34			
LFL: length of fore limb	♂	2.05 ± 0.202	19.12-21.83	**0.022**	3.351	5.860
	♀	19.89 ± 0.184	19.02-21.70			
LHL: length of hind limb	♂	30.98 ± 0.105	30.23-31.65	**0.020**	1.327	6.100
	♀	30.56 ± 0.136	30.03-31.73			
LE: length of eye	♂	3.38 ± 0.055	2.98-3.72	0.402	0.044	0.723
	♀	3.31 ± 0.073	2.86-3.70			
NSL: no. of supralabials	♂	6.81 ± 0.101	6.00-7.00	0.754	0.015	0.1
	♀	6.85 ± 0.097	6.00-7.00			
NIL: no. of infralabials	♂	6.12 ± 0.085	6.00-7.00	0.891	0.002	0.019
	♀	6.14 ± 0.097	6.00-7.00			
NGS: no. of gular scales	♂	29.50 ± 0.242	27.00-31.00	**0.001**	21.943	13.254
	♀	27.78 ± 0.421	25.00-30.00			
NCS: no. of collar scales	♂	13.50 ± 0.183	12.00-15.00	0.230	0.952	1.505
	♀	13.85 ± 0.231	12.00-15.00			
NVS: no. of transverse series of ventral scales	♂	26.94 ± 0.143	26.00-28.00	0.478	0.172	0.518
	♀	26.78 ± 0.154	26.00-28.00			
NFP: no. of femoral pores	♂	17.50 ± 0.274	16.00-19.00	**0.025**	5.486	5.644
	♀	16.64 ± 0.225	15.00-18.00			
NSBF: no. of scales betw. femoral pores	♂	2.31 ± 0.120	2.00-3.00	0.878	0.005	0.024
	♀	2.28 ± 0.125	2.00-3.00			

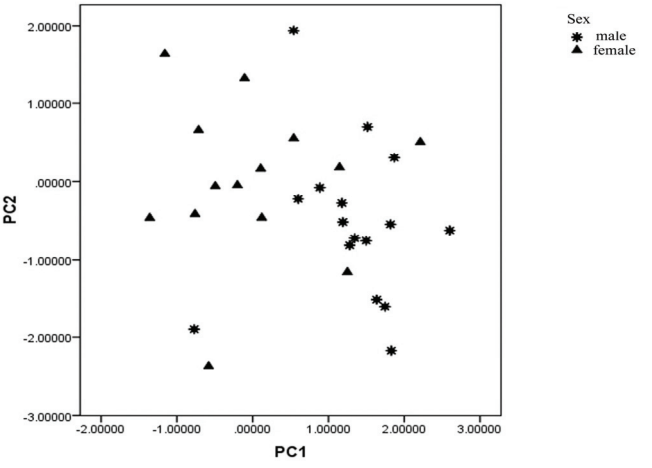

Figure 1. Ordination of PCA between male (*) and female (▲) specimens of *Darevskia raddei* for the first two principal components.

snout to anterior edge of cloaca); HL: head length (from tip of snout to the posterior edge of tympanum); LHF: trunk length (distance between hind limb and fore limb); HH: head height (maximum distance between upper head and lower jaw); HW: head width (distance between posterior eye corners); LFL: length of fore limb (from top of shoulder joint to tip of fourth toe); LHL: length of hind limb (from hip joint to tip of fourth toe); LE: length of eye (distance from anterior corner to its posterior corner); NSL: number of supralabials (number of labial scales anterior to the centre of eye on the right side of head); NIL: number of infralabials (number of scales on the lower labial region); NGS: number of gular scales in a straight median series; NCS: number of collar scales; NVS: number of transverse series of ventral scales; NFP: femoral pores (total number of femoral pores); NSBF: number of scales between the two series of femoral pores.

Statistical analyses were carried out by SPSS 16.0 for Windows. The significance value was set as $p \leq 0.05$ for all characters. Descriptive statistics was performed for all characters to avoid biases between sexes and minimum, maximum, mean and standard deviations were established for each sex separately (Table 1). An ANOVA was used to identify significant characters between males and females and after that all meaningful variables were identified using a Principal Component Analysis (PCA). The PCA showed the differences between two groups (male and female) with metric and meristic characters in a single plot.

Results

Differences between males and females were found in two meristic and five metric characters as identified by the PCA. These seven characters (gulars, length of basal tail, femoral pores, length of head, width of head, length of fore limb, and length of hind limb) were significantly different between males and females. The descriptive statistics including minimum, maximum, mean and standard deviation and ANOVA for each sex are shown in Table 1.

The PCA showed that the first three principal components (HL, LHL, and NFP; evaluation by the varimax method) explained 72.1% of variation between males and females, while PC1 explained 28.4% (Figure 1). According to the first three components that were obtained from the PCA, femoral pores (with 0.808), width of head (with 0.656) and width of basal tail (with 0.612) are the most important characters in verifying the two sexes with component 1. Other components and the most important characters are listed in Table 2.

Table 2. Factor loadings on the first three principal components elicited from a correlation matrix of seven morphological characters in 30 specimens of *Darevskia raddei* that were used in the present study (important values for each component are marked as bold).

Character	PC1	PC2	PC3
LBT	**0.612**	**-0.569**	0.270
NGS	-0.499	0.195	0.302
NFP	**0.808**	0.308	0.336
HL	0.096	-0.423	**0.797**
HW	**0.656**	-0.016	**-0.478**
LFL	0.510	**0.676**	-0.005
LHL	-0.117	**0.817**	**0.397**
Eigen values	1.989	1.760	1.300
Cumulative	28.415	53.553	72.121

Discussion

Sexual dimorphism in *Darevskia raddei* has a clear pattern resulting from seven characters, of which five are metric and two meristic. As previously shown, sexual differences in head size are common in lacertid lizards (Brana, 1996; Castilla, Bauwens, van Dam, & Verheyen, 1989; Gvozdik & Boukal, 1998; Huang, 1998; Molina-Borja, Padron-Fumero, & Al-Fonso-Martin, 1997). In this study we found similar results. The head size (head width as well as head length) of *D. raddei* differs between the sexes, with males having larger head sizes than females. Arribas (1996) reported that the snout-vent length (SVL) is the most important distinguishing character between males and females in the family Lacertidae (tribe Lacertini), since it reflects the body size differentials in sexual dimorphism. However, in *Darevskia raddei* SVL was not significantly different between males and females, whereas LHL was significantly different in our study (Table 1).

Sexual dimorphism is a result of sexual selection, which is an evolutionary process that leads to sexual dimorphism due to different selective pressures on males versus females. For example, longer hind limbs in male of lacertids are due to intrasexual selection, where males fight with other males to gain reproductive access to females (Anderson & Vitt, 1990). Males with longer hind limbs have a higher chance to win these fights and increase their reproductive success (Hosseinian Yousefkhani & Arab, 2012). Head size, especially in males, also plays a role in holding females during copulation and males with the deepest and widest heads are the most successful in copulation (Anderson & Vitt, 1990; Iraeta, Monasterio, Salvador, & Díaz, 2011).

In meristic characters, NGS and NFP differ significantly between males and females (Table 1): males have gular scales because they have larger heads. The number of femoral pores (NFP) is another meristic character that significantly differs between the sexes. Females have more femoral pores than males because of signalling in sexual selection (Alberts, 1991; Martín & López, 2006; Gabirot et al., 2008; Iraeta et al., 2011).

The two metric characters that were found to be different in males and females have a role in intrasexual selection. Head length is important for covering the female during the mating process, and hind limb length as locomotor performance during mating is important for grasping the female (Iraeta, Salvador, Monasterio, & Díaz, 2010; Iraeta et al., 2011). On the other hand, the number of femoral pores is more important for signalling by females during the mating season, and their number is high in females because they are attempting to release sufficient signalling compounds to find an appropriate male for mating (Gabirot et al., 2008).

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