Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi

Afyon Kocatepe University Journal of Science and Engineering

AKÜ FEMÜBİD **20** (2020) 041001 (551-557) AKU J. Sci. Eng. **20** (2020) 041001 (551-557)

DOI: 10.35414/ akufemubid.714889

Araştırma Makalesi / Research Article

Sexual Dimorphism In Spiny - tailed Lizard, *Darevskia rudis* (Bedriaga, 1886) (Sauria: Lacertidae), from Northeastern Anatolia, Turkey

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Geliş Tarihi: 05.04.2020 Kabul Tarihi: 20.07.2020

Abstract

Detailed investigations carried out on *Darevskia rudis* (Bedriaga, 1886) populations from Northeastern Anatolia, Turkey to identify sexual dimorphism. 11 morphometric and 30 meristic features of 317 specimens were analyzed. Seven meristic (Ventral width, Dorsals attached ventrals at mid-trunk, Femoral pores, Subdigital lamellae left, Tibial scales, Dorsalia). and four metric (Pileus length, Pileus width, Head length, Head width) characters were significant in sexual dimorphism pattern (p<0.05). Males have relatively longer head sizes, and related to this snout-vent length than females. Furthermore, it was found that the number of femoral pores are also higher in males than females because signaling compounds might be released in breeding seasons.

Keywords
Sexual dimorphism; *Darevskia rudis*; metric; meristic; statistical analysis; Turkey.

Kuzeydoğu Anadolu'daki Trabzon Kertenkelesi, *Darevskia rudis* (Bedriaga, 1886) (Sauria: Lacertidae) Türünde Eşeysel Dimorfizm

Öz

Eşeysel dimorfizmi belirlemek için Kuzeydoğu Anadolu'dan *Darevskia rudis* (Bedriaga, 1886) populasyonları üzerinde detaylı yapılan araştırmada 317 örneğin 11 morfometrik ve 30 meristik özelliği analiz edilmiştir. Yedi meristik (Ventral genişlik, gövdedeki ventrale bağlanan dorsalia sayısı, Femoral porlar, Sol subdijital lamel, Tibial plaklar, Dorsalia). ve dört metrik (Pileus uzunluğu, Pileus genişliği, Kafa uzunluğu, Kafa genişliği) karakterleri eşeysel dimorfizm açısından anlamlı bulunmuştur (p <0.05). Erkeklerin kafa boyutları nispeten daha uzundur ve bunla ilgili olarak Baş+Gövde uzunlukları da dişilerden daha fazladır. Ayrıca eşeysel çağrı bileşikleri de üreme dönemlerinde salındıklarından dolayı femoral por sayılarının erkeklerde dişilerden daha fazla olduğu bulunmuştur.

Anahtar kelimeler
Eşeysel dimorfizm; *Darevskia rudis*; metrik; meristik; istatistiksel analiz; Türkiye

1. Introduction

The spiny tailed lizard, *Darevskia rudis* (Bedriaga, 1886), is distributed central and northern coastal region of Anatolia, Turkey, Georgia, Armenia, Russia and Azerbaijan, therefore it is one of the representative faunal elements of the Black Sea region of Anatolian Peninsula (Arribas et al. 2013). Due to its relatively wide range distribution, it can be a good model for different aspects of evolutionary studies, such as sexual dimorphism. The sexual dimorphism phenomenon has been relatively well studied in lacertid lizards especially for the last two decades (Herrel et al. 1999; Heidari et al. 2012; Oraie et al. 2013; Karamiani et al. 2015). This phenomenon in lizards is thought to have serious effects on behavior, size and shape characteristics (Carothers 1984). According to Rensch's rule, males display higher phenotypic plasticity in body size than females (Fairbairn 1997). In addition to that, males generally have larger head size and longer tail lengths in lizards (Verwaijen et al. 2002). Therefore, in present study, we would like to investigate whether *D. rudis* displays sexual dimorphism in different characters, that has not been studied before for this species.

2. Materials and methods

Field surveys were carried out in the Black Sea region of Anatolian Peninsula between 2000 and 2003. A total of 317 specimens (166 ♂♂ and 151 ♀♀) were collected and they were deposited in the Fauna and Flora Research and Application Centre of Dokuz Eylül University (Buca-İzmir). The specimens were examined based on 11 morphometric and 30 meristic characters. The presence/absence of a hemipenis retracted in the hemipenial sack at the base of the tail were used to assess specimen's sex (Başoğlu and Baran. 1977). Morphometric characters are as follows: Pileus length (PL), Pileus width (PW), Head length (The following metric dimensions were taken using dial calipers with accuracy to the nearest 0.01 mm: Snout-vent length (SVL): from tip of snout to anal cleft. Tail length (TL): from anal cleft to tip of tail. Pileus width (PW): at widest point between parietal plates. Pileus length (PL): tip of snout to posterior margins of parietals. Head width (HW): at widest point of head. Head length (HL): tip of snout to posterior margin of ear opening. Furthermore, morphometric ratios and indexes were calculated, Snout-vent/Tail length (SVL/Ta), Tail length/Total length (Ta/T), Pileus index (PI) [(PL / PW)] and Head index (HI) [(HL / HW)].

Meristic scalation characters considered here consisted of the following counts: Supraciliar granules (left-right) (ScgL-ScgR), Supraciliar plates (left-right) (ScL-ScR), Supralabial plates (left-right) (SuplL-SupR), Sublabial plates (left-right) (SublL-SublR), transversal series of gular scales between inframaxillar symphysis and collar (MG), Collaria (C), Supratemporal scales (ST), temporal scales 1 (transversal rows of temporal scales between masseteric and tympanic) (left-right) (MaTyL-MaTyL), temporal scales 2 (longitudinal rows of temporal scales between supratemporal and masseteric) (left-right) (MasSupL-MasSupL), Postemporal plates (left-right) (PostTL-PostTR), Ventral plates (transversal and longitudinal) (VenLeng and VenWid), dorsals attached ventrals at mid-trunk (VenattDor), Preanals 1 (number of preanals located anterior of anal plate) (Pra1), Preanals 2 (number of preanals surrounding anal plate) (Pra2), Femoral pores (left-right) (FPL-FPR), longitudinal rows of scales on ventral surface of thigh between the femoral pores and the outer row of enlarged scales (left-right) (FPopL-FPopR), Subdigital lamellae in the 4th toe (left-right) (SDLL-SDLR), Tibial scales (scales lying on dorsal surface of ankle between the large scales (TS) and transversal series of dorsal scales at the midtrunk (Dor). Meristic characters were counted under a stereomicroscope.

Statistical analyses were performed using R Software version 3.6.1 (R. Core Team 2019). The significance level for all statistical tests was set at $p < 0.05$. In the first part of analysis, the whole raw data was examined in Kolmogorov-Smirnov test and it was found that morphological characters were not normally distributed. After that, these characters were logarithmically transformed. To uncover dispersal patterns among all characters, descriptive statistical parameters including minimum, maximum, mean, standard deviation, ANOVA were established for each sex separately in Table 1. Moreover, the homogeneity of variances was also tested to filter the best reflected parameters in sexual dimorphism, as the threshold level is 0.1 (Table 1). Finally, we performed a principal component analysis (PCA) to evaluate the contribution of statistically significant characters in the patterns of sexual dimorphism (Table 2).

Table 1. Descriptive analysis including minimum, maximum, mean, standard deviation, Test of Homogeneity of Variances (Test of HV[a]) and ANOVA (A[b]) of each metric and meristic characters. ANOVA and Test of Homogeneity of Variances based intra-sexual comparisons in *Darevskia rudis* (Male N= 166, Female N=151). p values are printed in **bold**.

	Male			Female			Statistics	
	Mean	SD	Range	Mean	SD	Range	Test of HV [a] (Sig.)	A [b] (Sig.)
ScgR	10.5	2.09	4-14	10.6	1.93	5-15	0.555	0.631
ScgL	10.4	2.02	4-14	10.7	2.12	2-15	0.991	0.242
ScR	6.26	0.76	4-9	6.15	0.69	4-8	0.093	0.198
ScL	6.18	0.70	4-8	6.11	0.66	4-8	0.406	0.337
SuplR	4.04	0.32	3-5	4.02	0.27	3-5	0.06	0.403
SuplL	4.07	0.34	3-5	4.02	0.25	3-5	0.003	0.181
SublR	6.14	0.53	5-8	6.13	0.42	5-7	0.143	0.824
SublL	6.13	0.48	5-8	6.04	0.39	5-7	0	0.066
MG	27.58	2.66	21-35	27.04	2.62	19-34	0.513	0.071
C	9.50	0.99	6-12	9.50	1.08	6-13	0.196	0.982
ST	2.93	0.42	1-4	2.86	0.50	1-4	0.009	0.132
Ma TyR	2.27	0.69	1-4	2.15	0.63	1-4	0.031	0.118
Ma TyL	2.26	0.73	1-5	2.16	0.63	1-4	0.03	0.208
Post TR	3.80	0.81	2-6	3.90	0.77	2-6	0.322	0.297
Post TL	3.80	0.79	2-6	3.88	0.81	2-6	0.927	0.375
Ven Leng	6	0	6	6	0	6	.	.
Ven Wid	23.31	1.23	20-27	25.47	1.14	21-28	0.912	***0***
Ven att Dor	26.12	3.42	20-33	24.86	3.34	20-30	0.776	***0.001***
Pra1*	1.20	0.44	1-3	1.37	0.56	1-3	0	**0.003**
Pra2*	6.99	1.03	5-10	7.33	1.05	5-10	0.057	**0.004**
FPR	19.64	1.79	15-26	18.75	1.67	15-24	0.318	***0***
FPL	19.54	1.78	15-26	18.66	1.74	10-24	0.492	***0***
FP opR*	5.32	0.57	4-6	5.06	0.60	4-6	0.011	**0**
FP opL*	5.32	0.57	4-6	5.06	0.60	4-6	0.011	**0**
SDLR	26.30	1.88	23-32	25.98	1.75	22-30	0.21	0.11
SDLL	26.42	1.87	23-32	25.97	1.69	22-30	0.113	***0.027***
Mas SupR	1.72	0.61	1-3	1.79	0.71	1-3	0.056	0.373
Mas SupL	1.69	0.61	1-3	1.77	0.69	1-3	0.197	0.296
TS	14.86	1.93	10-19	14.18	1.99	10-19	0.531	***0.002***
Dor	49.71	6.40	38-64	47.11	5.60	38-61	0.115	***0***
PL	16.36	1.98	11.3-21.6	14.41	1.51	11.7-18.6	0.397	***0***
PW	8.61	1.03	6.2-11.3	7.61	1.70	6-9.94	0.443	***0***
HW	10.42	1.44	7.1-14.6	9.00	7.42	6.5-12.4	0.963	***0***

	Male			Female			Statistics	
HL	17.75	2.20	12.1-23.2	15.54	13.79	12.6-20.1	0.487	***0***
SVL	68.18	7.87	45.4-88.5	67.23	21.17	50.9-89.2	0.944	0.293
TaL ***	131.7	16.23	94-176	121.53	2.27	84-149	0.891	**0.002**
TL***	205.4	23.89	151.2-264.5	191.87	2.83	134.9-226.6	0.995	**0.007**
PI	52.56	2.06	47.8-59.5	52.86	0.03	46.4-61.7	0.933	0.504
HI**	58.78	2.49	51.9-65.4	58.08	0.03	49.02-64.1	0.106	**0.006**
SVL/Ta ***	0.53	0.03	0.46-0.62	0.55	0.01	0.49-0.63	0.308	**0.002**
Ta/T***	0.65	0.02	0.62-0.69	0.65		0.61-0.67	0.279	**0.004**

*: not selected because its test of homogeneity of variance value is lower than threshold (0.1)

**: not selected because HI is derived from HL and HW, which have already been in analysis

***: not selected because many specimens did not have tails

3. Results and discussion

Differences between males and females were found in seven meristic (transverse series of ventral plates, dorsal scales attached ventral plates at mid-trunk, Femoral pores, Subdigital lamellae left, Tibial scales, and Dorsal scales). and four metric (Pileus length, Pileus width, Head length, Head width) characters as identified by PCA. The PCA showed that the first three principal components explained 85.6% of variation between genders. Of this, 57.45% explained by PC1 in which TS and Dor are mainly responsible for this variation; 19.81% is explained by PC2 in which VenWid, FPR, FPL, SDLL, PL, PW, HL and HW are responsible for the variation; and finally 8.37% is explained by PC3 in which VenattDor is mainly responsible for this variation (Figure 1).

Table 2. Factors loadings on the first five principal components analysis of metric and meristic characters in *Darevskia rudis*. Strong loadings on each principal component are shown in **bold**.

	PC1	PC2	PC3	PC4	PC5
VenWid	0.043201	**-0.25277**	-0.0069	-0.09833	0.001746
VenattDor	-0.3577	0.247178	**-0.85206**	0.227636	-0.06671
FPR	-0.01162	**0.259356**	-0.01515	-0.62048	-0.20686
FPL	-0.01337	**0.282081**	-0.05728	-0.57877	-0.20792
SDLL	-0.03435	**0.219593**	-0.14193	-0.28248	0.70369
TS	**-0.19561**	-0.11165	-0.02582	-0.0177	-0.61987
Dor	**-0.90381**	0.003038	0.389045	-0.01594	0.12433
PL	0.060558	**0.468694**	0.183447	0.212296	-0.05777
PW	0.040609	**0.239261**	0.095179	0.127022	-0.04264
HW	0.055793	**0.334547**	0.125968	0.156788	-0.07606
HL	0.071616	**0.527864**	0.199217	0.228888	-0.06092
Eigenvalues	12.3251	4.2859	1.7993	1.1351	0.7457
Standard deviation	6.7275	3.951	2.5678	2.03344	1.65389
Proportion of Variance	**0.5745**	**0.1981**	**0.0837**	0.05249	0.03472
Cumulative Proportion	**0.5745**	**0.7726**	**0.8563**	0.90884	0.94356

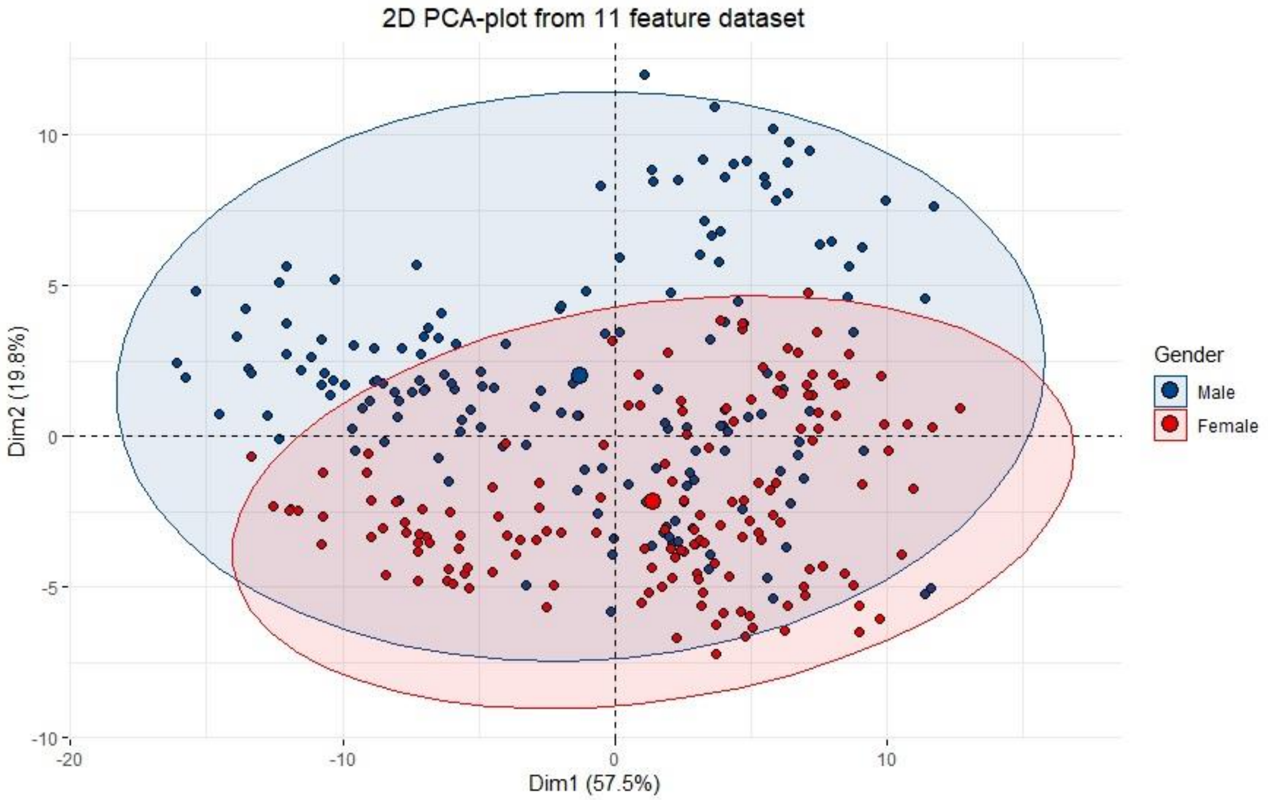

Figure 1. Ordination of the individual males and females of *Darevskia rudis* in the first two principle components.

Comparative studies on sexual dimorphism (SD) should generally include body size as a potential determinant (Fairbairn et al. 2007) and reproductive output is related with morphological features in reptiles (Heidari et al. 2012; Dehghani et al. 2014; Karamiani et al. 2015). Especially combat success is generally positively correlated with larger body size (Olsson 1992; Heidari et al. 2012). According to Rensch's rule, sexual size dimorphism (SSD) characteristically increase with size when males are the larger sex (Cox et al. 2003; Fairbairn et al. 2007; Karamiani et al. 2013).

According to our data, it was obvious that males of *Darevskia rudis,* showed longer SVL and TL than females even in relatively less individual comparisons. Besides, it is universal that male lacertids have a relatively larger head size than females (HL, HW, PL and PW) (Huang 1998; Molina-Borja et al. 2010; Dehghani et al. 2014; Karamiani et al. 2015). Males with larger heads could produce greater bite force as ammunition in combat (Lappin and Husak 2005). Furthermore, due to noteworthy reproductive success, males tend to have more spacious and better space. That's why females have a tendency to prefer larger sized males (Chang and Oh 2012). This pattern is well observed in our data with HW, HL, PW and PL are higher in *D. rudis* males than females (Table 1.).

On the other hand, femoral pores and ventral scales are also useful characters to distinguish males and females in lacertids (Heidari et al. 2012; Dehghani et al. 2014). Males have femoral pores with holocrine secretion that is abundant only in the reproductive period, that play an important role in sexual selection because of their contribution to signaling mechanisms (Martín and López 2006; Gabirot et al. 2008; Iraeta et al. 2011). Here, our results supported this process as males (mean=19.59) have more femoral pores in both legs than females (mean=18.70), and this suggested that males are endeavoring to discharge signaling compounds to find an appropriate mate.

According to an overall evaluation of all these results, we may conclude that *D. rudis* shows the classic pattern of lacertid sexual dimorphism.

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