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SEXUAL DIMORPHISM IN THE LACERTID LIZARD *Apathya cappadocica* (WERNER, 1902) (Reptilia: Lacertidae) FROM SOUTHEASTERN TÜRKİYE

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ABSTRACT. *Apathya cappadocica* is a medium-sized lizard species included in the family Lacertidae. The species is known from Türkiye, Northern Syria, Iraq, and Western Iran. Sexual dimorphism (SD), which is a phenomenon including phenotypic differences between males and females, has many effects on behaviour, shape and size characteristics. A total of 87 adult lizard specimens collected from south-eastern Anatolia were used in this study. The results of ANOVA showed that all morphometric features exhibited a pattern in which males have larger size than females. According to principal component analysis (PCA), the first three factors explain 81.553% of the total variance. Differences in head size between sexes have been well-documented in lizards and are associated with male-male aggression which results in mating success. This kind of pattern is supported by this study. Additionally, the results showed that males have more femoral pores, which is a signalling mechanism for sexual selection, than females. In conclusion, it can be accepted that the species in the genus *Apathya* has a similar pattern in accordance with the larger male theory.

1. INTRODUCTION

Apathya cappadocica (Werner, 1902), the Anatolian lizard, is a medium-sized lizard species included in the family Lacertidae. The species is known from Central, East, and South Anatolia, Northern Syria, Iraq, and Western Iran [1-3]. Although systematic, phylogenetic and ecological studies about the species group have been carried out, evolutionary evaluations including different aspects, such as sexual dimorphism are scarce [1,2,4-6]. Sexual dimorphism (SD) is a common phenomenon based on phenotypic differences between males and females of a species [7-9]. It consists of three main categories: (i) sexual size dimorphism (SSD), (ii) SD in body shape and (iii) SD in ornamentation [10-12]. Sexual size dimorphism (SSD), which was reported in lacertid lizards, is a widespread biological event in nature [5,13-16]. In most lizards, males have larger morphological features providing physical advantages than compared to

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females [17-19]. In the current study, we investigated SSD in *A. cappadocica* considering morphological characteristics for the first time.

2. MATERIALS AND METHODS

A total of 87 adult (38 males and 49 females) lizard specimens, which were collected during herpetological field surveys from south-eastern Anatolia between 2001 and 2006, were obtained from the Zoology Lab of the Department of Biology in the Faculty of Science, Dokuz Eylül University. The localities of the collected specimens are given in Table 1.

TABLE 1. Localities of samples used in this study.

No	Locality	Sample Number and Sex
1	Damlacık Village, Viranşehir, Şanlıurfa, Türkiye	3 males, 5 females
2	Keklikoluk Village, 20 km N of Göksun, Kahramanmaraş, Türkiye	1 male, 2 females
3	Çermik, Diyarbakır, Türkiye	1 male, 6 females
4	between Diyarbakır and Siverek 48. km, Diyarbakır, Türkiye	2 males, 2 females
5	between Şambayat and Besni 4. km, Adıyaman, Türkiye	3 males, 1 female
6	Tek tek Mountain, Şanlıurfa, Türkiye	1 male, 4 females
7	Halfeti, Şanlıurfa, Türkiye	3 males, 3 females
8	between Bitlis and Tatvan 13. km, Bitlis, Türkiye	1 male, 3 females
9	between Birecik and Halfeti 16. km, Şanlıurfa, Türkiye	1 male, 2 females
10	between Şanlıurfa and Viranşehir 32. km, Şanlıurfa, Türkiye	1 male, 4 females
11	Gerger, Adıyaman, Türkiye	3 males, 5 females
12	between Besni and Gölbaşı 5 km, Adıyaman, Türkiye	2 males
13	between Şanlıurfa and Bozova 33. km, Şanlıurfa, Türkiye	1 male
14	Hasankeyf, Batman, Türkiye	9 males, 3 females
15	Acar village, Kilis, Türkiye	1 male
16	between Batman and Hasankeyf 13. km, Batman, Türkiye	5 males, 5 females
17	Küçükalanlı village, Şanlıurfa, Türkiye	2 females
18	Küplüce village, Kilis, Türkiye	1 female
19	Ballık village, Yavuzeli, Gaziantep, Türkiye	1 female

Metric measurements were taken using a digital calliper with a sensitivity of 0.01 mm, and pholidosis characteristics were counted under a stereo microscope. Mensural and meristic data were recorded following the system of [20] and [21].

Eleven morphometric and sixteen meristic characters were examined for all adult specimens. The following metric measurements were taken: snout-vent length (SVL), tail length (TL), width of pileus (PW), length of pileus (PL), width of head (HW), length of head (HL), length of forelimb (FLL), length of hindlimb (HLL), length of parietal (PAL), width of occipital (OCW), width of internasal (INW). The meristic (pholidosis) characteristics are as follows: number of postnasals (PON), number of sublabial scales on the left side (SBLL), number of sublabial scales on the right side (SBLR), number of supraciliary scales on the left side (SPCL), number of supraciliary scales on the right side (SPCR), number of supraciliary granules on the left side (SCGL), number of supraciliary granules on the right side (SCGR), number of palpebral scales (PPL), dorsalia (DS), gularia (GU), ventralia longitudinal (VL), preanale (PAN), number of femoral pores on the left side (FPL), number of femoral pores on the right side (FPR), number of subdigital lamellae on the left side (SDLL), number of subdigital lamellae on the right side (SDLR).

All statistical analyses were conducted using Statistical Package for the Social Sciences SPSS v24. Means, standard error of the mean, minimum and maximum values for each variable were calculated. To determine the characteristics that contribute to the discrimination of sexes, analysis of variance (ANOVA) were performed since all variables exhibited normal distribution. Considering the results of ANOVA, one morphometric and six meristic characteristics were discarded because they were uninformative. Finally, principal component analysis (PCA) was performed to detect the size of variation between sexes at the multivariate level using the remaining informative variables (ten for both morphometric and meristic). The significance level for all statistical tests was set at 0.05.

3. RESULTS

The results of ANOVA showed that all morphometric features exhibited a pattern in which males had larger size than females (Table 2). Among these characteristics, SVL alone did not vary depending on sex considering the significance level (p=0.441, Table 4), while the other features appear to have significant differences (all p values are less than 0.05, Table 2). Similarly, males had larger values for many metric characteristics than females, except for PON, VL and SBLL. PON and VL in females were significantly larger than males and provided discrimination when considering sex-dependent variety (p=0.008 and F=7.344 for PON, p=0.000 and F=13.603 for VL, Tables 3 and 4).

TABLE 2. Results of the one-way ANOVA test for metric characteristics for both sexes. SEM: Standard. Error Mean, D of d: Direction of difference, Min: Minimum value; Max: Maximum value. All measurements are shown in millimetres.

SEX	♂ (n=38)				♀ (n=49)				D. of d.	F-value	P-value
	MEAN	SEM	MIN	MAX	MEAN	SEM	MIN	MAX			
TL	130.82	3.604	86.00	176.00	107.88	2.119	70.00	155.00	M>F	33.205	0.000
PW	7.48	0.18582	5.62	10.00	6.6645	0.09152	5.28	7.92	M>F	17.728	0.000
PL	17.2005	0.41791	13.16	22.22	14.9555	0.20583	11.88	17.70	M>F	26.562	0.000
HW	9.9347	0.27415	7.18	13.00	8.5371	0.14245	6.70	10.84	M>F	23.164	0.000
HL	18.8458	0.43243	14.54	24.02	16.44	0.20822	13.40	19.36	M>F	28.856	0.000
FLL	24.5763	0.42873	20.34	29.00	22.4078	0.27267	18.54	26.34	M>F	19.743	0.000
HLL	39.3395	0.82325	31.30	47.58	35.5155	0.41803	28.62	41.56	M>F	19.504	0.000
PAL	5.7784	0.16429	4.04	7.54	4.8682	0.08187	3.58	6.14	M>F	28.063	0.000
OCW	2.0374	0.07384	1.22	3.08	1.7306	0.04393	1.02	2.64	M>F	14.026	0.000
INW	2.9295	0.07757	2.14	4.04	2.7024	0.04728	1.92	3.36	M>F	6.835	0.011

TABLE 3. Results of one-way ANOVA test for meristic characteristics for both sexes. SEM: Standard. Error Mean, D of d: Direction of difference, Min: Minimum value; Max: Maximum value. All measurements are shown in millimetres.

SEX	♂ (n=38)				♀ (n=49)				D. of d.	F-value	P-value
	MEAN	SEM	MIN	MAX	MEAN	SEM	MIN	MAX			
PON	2.39	0.104	1	3	2.73	0.076	2	4	F>M	7.344	0.008
SPCL	6.61	0.167	5	9	6.22	0.089	5	8	M>F	4.578	0.035
PPL	5.84	0.179	4	8	5.33	0.128	4	9	M>F	5.769	0.018
GU	27.74	0.339	24	34	26.45	0.235	23	30	M>F	10.351	0.002
VL	25.61	0.201	24	28	26.45	0.127	25	28	F>M	13.603	0.000
PAN	5.63	0.157	4	8	5.08	0.108	4	7	M>F	8.801	0.004
FPL	22.24	0.228	18	25	20.61	0.204	17	23	M>F	28.161	0.000
FPR	22.37	0.240	18	26	20.69	0.217	17	23	M>F	26.673	0.000
SDLL	24.66	0.283	22	29	23.27	0.212	20	28	M>F	16.176	0.000
SDLR	24.79	0.318	22	30	23.27	0.214	21	28	M>F	16.914	0.000

TABLE 4. Results of one-way ANOVA test showed no significant in metric (**bold**) and meristic (no bold) characteristics for both sexes. SEM: Standard. Error Mean, D of d: Direction of difference, Min: Minimum; Max: Maximum.

SEX	♂ (n=38)				♀ (n=49)				D. of d.	F-value	P-value
	MEAN	SEM	MIN	MAX	MEAN	SEM	MIN	MAX			
SVL	68.8526	1.52251	53.60	85.86	67.4988	0.99041	51.72	82.36	M>F	0.599	0.441
SBLL	6.34	0.087	5	7	6.37	0.081	5	8	F>M	0.045	0.833
SBLR	6.53	0.098	6	8	6.47	0.078	6	8	M>F	0.213	0.646
SPCR	6.63	0.166	5	9	6.33	0.107	5	8	M>F	2.580	0.112
SCGL	13.84	0.363	7	19	13.39	0.247	11	19	M>F	1.143	0.288
SCGR	13.82	0.365	9	18	13.24	0.300	6	18	M>F	1.487	0.226
DS	62.58	0.485	58	69	61.92	0.416	56	68	M>F	1.074	0.303

PCA was performed to compare sexes at a multivariate level using all morphological variables which were standardized to obtain an unbiased statistical analysis (Figure 1). Considering the results of PCA, PON was not correlated with other characteristics, and SPCL, PPL and PAN which had less than 0.50 values of communalities and were discarded. According to PCA, the first three factors explained 81.553% of the total variance (Table 5). The most crucial contributors to the first component (PC1), which explained 54.043%, were determined to be PL, PW, HL, HW, FLL, HLL and PAL, while SDLL, SDLR, FPL, FPR and GU were the main contributors to the second component (PC2) which explained 20.684%. Also, 6.868% of variance was explained by PC3 that included VL, FPL and FPR, which play the most important roles (Table 5).

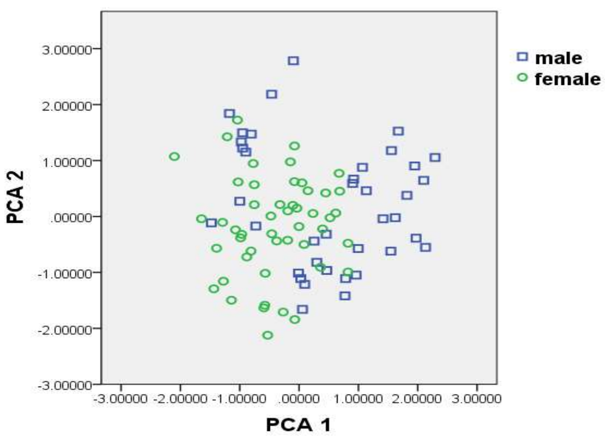

FIGURE 1. Ordination of individual males and females of *Apathya cappadocica* on the first two principal components.

TABLE 5. Loadings from principal component analysis of metric and meristic characteristics. Variables in bold represent strong loadings.

Variables	PC1	PC2	PC3
TL	**.718**	.296	-.055
PW	**.948**	-.036	.121
PL	**.986**	.039	.078
HW	**.972**	.023	.067
HL	**.985**	.042	.056
FLL	**.932**	.056	.030
HLL	**.969**	-.017	-.022
PAL	**.940**	.030	.050
OCW	**.753**	.098	.023
INW	**.888**	-.100	.142
GU	-.099	**.717**	.385
VL	**-.461**	.276	**.590**
FPL	.097	**.733**	**-.523**
FPR	.100	**.804**	**-.440**
SDLL	-.180	**.843**	.184
SDLR	-.156	**.841**	.196
Eigenvalues	8.647	3.309	1.092
% of Variance	54.043	20.684	6.826
Cumulative %	54.043	74.727	81.553

4. DISCUSSION

To compare SD in reptiles, scientists believe that body size should be used as a potential determinant and indicator of reproductive output [5,15,22,23]. Rensch's rule, which is a common perspective for SSD, stated there were two major issues: (i) females are prone to be larger than males in small species, whereas males are larger than females in large species and (ii) SSD increases with size when males are the larger sex and decreases with size when females are the larger sex [5,14,22,24-28]. In most lizards, males represent the larger body size, which is related to physical advantages that are critical for territorial defence and mating success [17-19]. Combat success between males is generally positively correlated with larger body size [15,29].

Considering morphometric characteristics which are closely related to body size, our results showed that males have larger size than females (Tables 2 and 3). Although a statistically significant difference could not be obtained, males were relatively larger than females in terms of SVL. Head size, another important size characteristic, showed that males were significantly larger than females (Table 2). Differences in head size between sexes were well-documented in lizards and associated with male-male aggression which results in mating success [30-33]. Males with larger heads may produce greater bite force and they can use this to provide a mating advantage by repelling other males [13,34,35]. This kind of pattern is also supported by our study considering HW, HL, PW and PL are larger in males than females (Table 2). Considering another lizard species in the same genus, *A. yassujica*, the species has a similar pattern based on the larger male theory [5].

As another important point of discrimination between sexes, femoral pores are also useful characteristics in lacertid lizards [15, 23]. Femoral pores are clear and large in males because of holocrine secretion which is a signalling mechanism for sexual selection during the reproductive period [36-38]. Our results showed that males (mean for left/right side: 22.24/22.37) have significantly more femoral pores than females (mean for left/right side: 20.61/20.69) (Table 3). Similar results were found for *A. yassujica* [5]. Based on these conditions, species in the genus *Apathya* exhibit the expected pattern for lacertids.

Author Contribution Statements KC- conceptualization, analysis, writing, review and editing EYC- validation, writing ÇI and YK- resources OSG-analysis.

Declaration of Competing Interests The authors declare no conflict of interest.

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