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Sexual dimorphism in *Carinatogecko heteropholis* (Minton, Anderson, and Anderson, 1970) (Sauria: Gekkonidae) from Ilam Province, western Iran

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***Abstract.*—Sexual dimorphism is a widespread phenomenon in animals, but so far undocumented in *Carinatogecko heteropholis*. In this study, 52 specimens were collected in Karezan, Ilam province, western Iran. The uni- and multivariate analyses performed on the morphological data revealed that females are larger than males. All of the sexual differences were female-biased, except for the infralabial scales.**

Key words. *Carinatogecko heteropholis*, sexual dimorphism, statistical analysis, morphology, Ilam Province, Iran

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Introduction

The genus *Carinatogecko* Golubev and Szczerbak, 1981 comprises three species, the Iranian keel-scaled gecko, the Iraqi keel-scaled gecko, and Anderson's keel-scaled gecko: all of them are found on the Iranian Plateau (Szczerbak and Golubev 1996; Anderson 1999; Torki 2011). The Iraqi keel-scaled gecko, *Carinatogecko heteropholis* (Minton, Anderson, and Anderson 1970) is a small species; its type locality in Iran is western Zagros foothills (Anderson 1999; Fathinia 2007; Rastegar-Pouyani et al. 2007). It is hypothesized that the genus *Carinatogecko* has a double Iranian-Mesopotamian origin (Fathinia 2007).

Sexual dimorphism (SD) is a common and widespread phenomenon in the animal world (Andersson 1994). Sexual size dimorphism (SSD) explains the status in which the males and females differ in measured values of certain morphological characteristics. Sexual size dimorphism (SSD) has been extensively described in reptiles (Andersson 1994; Kuo 2009). Sexual dimorphism in animals is revealed in three different aspects: behavior, size, and shape (Selander 1972). Numerous surveys have been carried out on sexual dimorphism in lizards (Stamps 1983; Rocha 1996; Carothers 1984; Trivers 1976; Molina-Borja 2003; Baird et al. 2003; Verrastro 2004; Bruner et al. 2005; Kaliontzopoulou et al. 2007).

Differences in the selective forces acting on male versus female body size are the main causes of sex differences in adult body size of animals (Cox 2006). Sexual dimorphism in lizards may result from differences in food resource partitioning and sexual differences in energy allocation to growth (Baird et al. 2003).

To our knowledge this is the first survey on the occurrence of sexual dimorphism in the genus *Carinatogecko*. Clarifying the sexually distinctive traits in *C. heteropholis* is of evolutionary and systematic importance; in this paper, we report results of such a study.

Material and methods

A total of 52 (28♂ and 24♀) adult specimens were collected during summer 2010. All of them were collected by hand with the aid of an electric torch at night on rocky mountain sides of the Zagros Mountains in Karezan, Shirvan-Chardavol, Ilam Province, western Iran (Fig. 1). Of these, 22 specimens were fixed in ethanol 75% and deposited in the RUZM (Razi University Zoological Museum) for future studies, and the rest (30 specimens) were released in their relevant habitat 24 hours after collecting and analyzing. The coordinates of the study site are 33º44´ N, 46º29´ E1325 m a.s.l. Eight metric and four meristic variables were chosen and measured by digital caliper and stereomicroscope to the nearest 0.01 mm (Table 1). Except for overall shape differences which can be used to distinguish males from females (Fig. 2), sex of specimens was mainly determined based on presence of two swellings at the base of tail just behind vent in males and their absence in females (Fig. 3).

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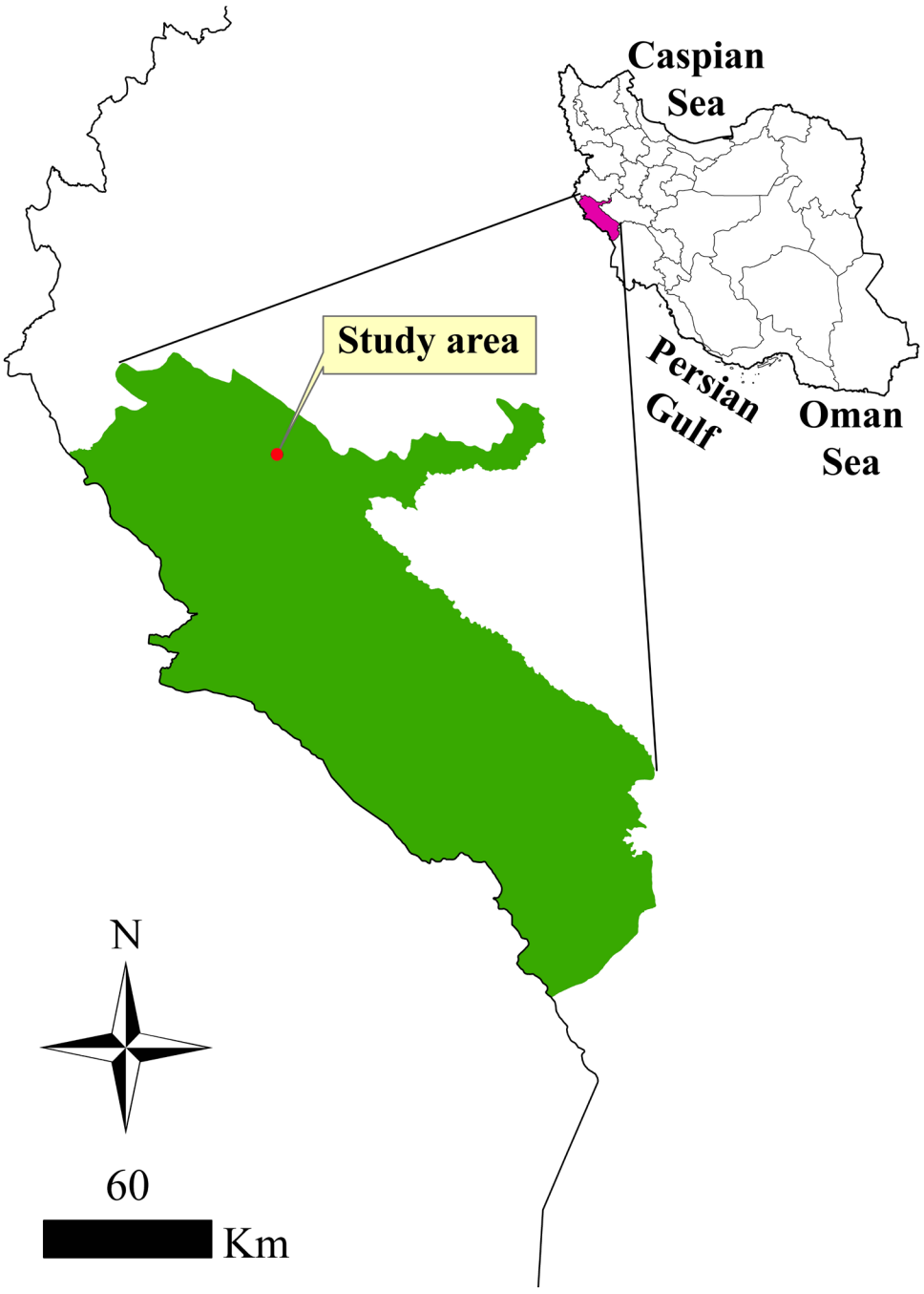

Figure 1. Map showing the coordinates of the study site in Karezan region at mountainsides of the Zagros.

To determine the significance of sexual dimorphism in *C. heteropholis*, the ANOVA Table as well as Principal Component Analysis (PCA: correlation matrix) were used. The SPSS statistical software (version 13) was used for carrying out the statistical analyses.

Results

Twelve morphological characters (eight metric and four meristic) were included in the analysis. The values for the metric and meristic characters as well as the direction of differences and the significant characters ($P < 0.05$) are summarized in Table 2.

ANOVA Table Analysis

Metric variables: obvious differences in the value of variables are observed between the sexes. Females have significantly greater values than the males for eight metric characters. In the case of body length and the distance

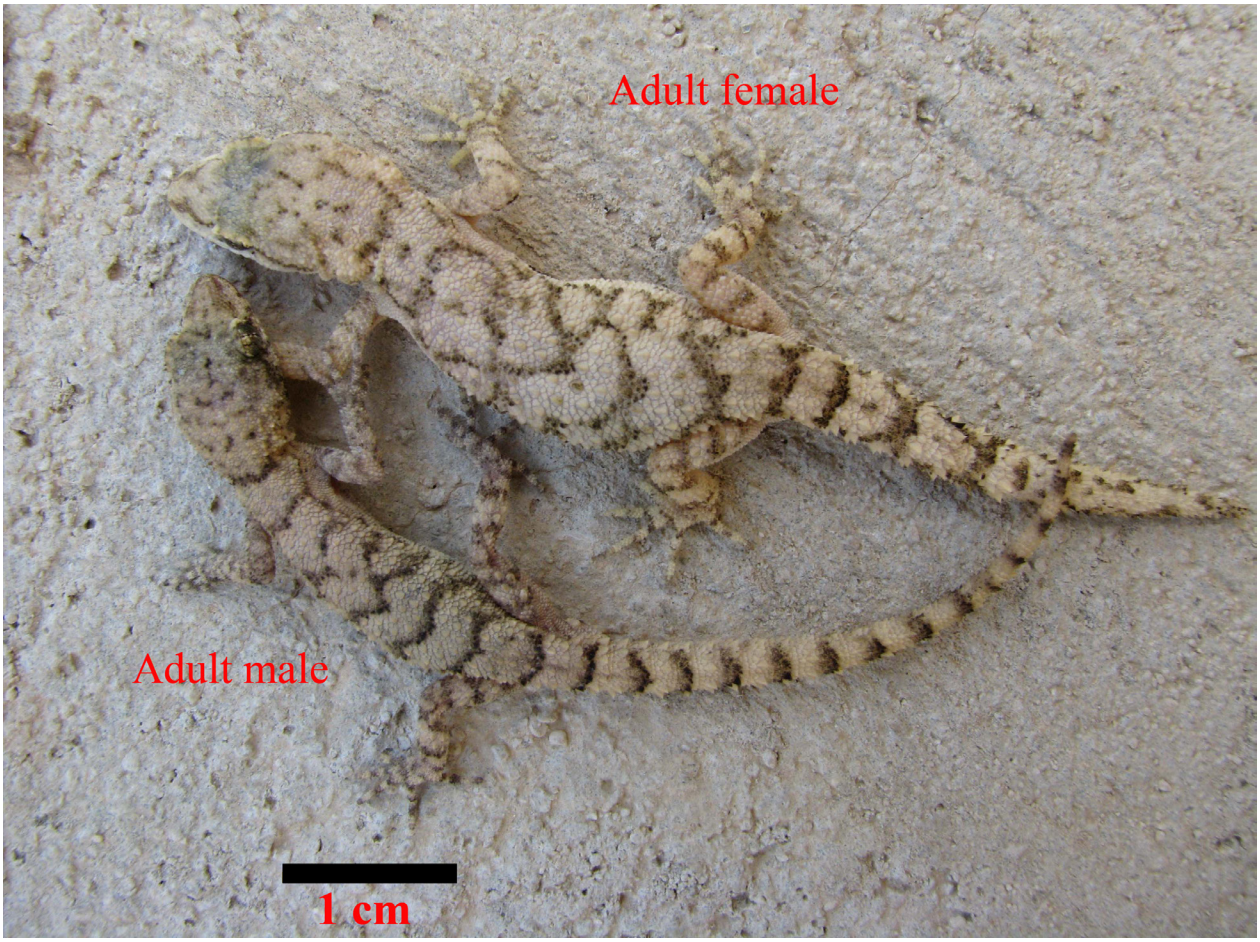

Figure 2. Dorsal view of male (left) and female (right) of *Carinatogecko heteropholis*.

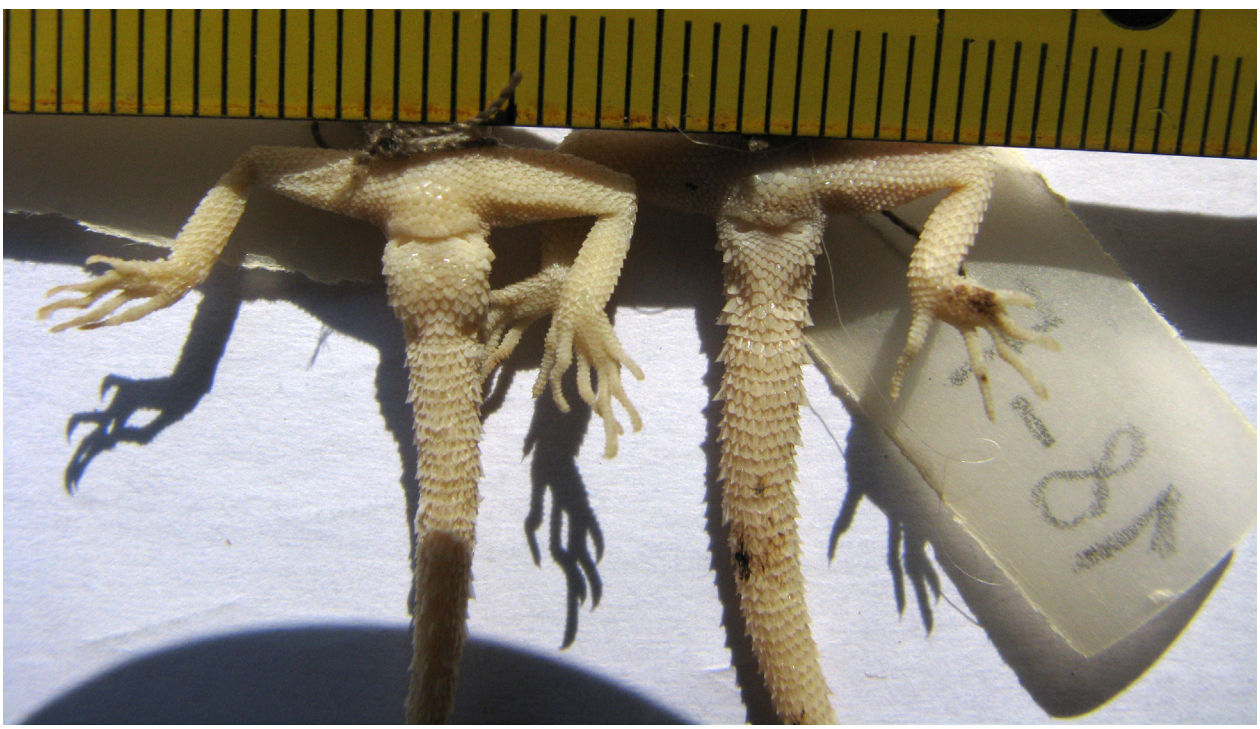

Figure 3. Presence of swelling in the male of *C. heteropholis* at base of the tail which accommodate hemipenes (left) and their absence in female (right).

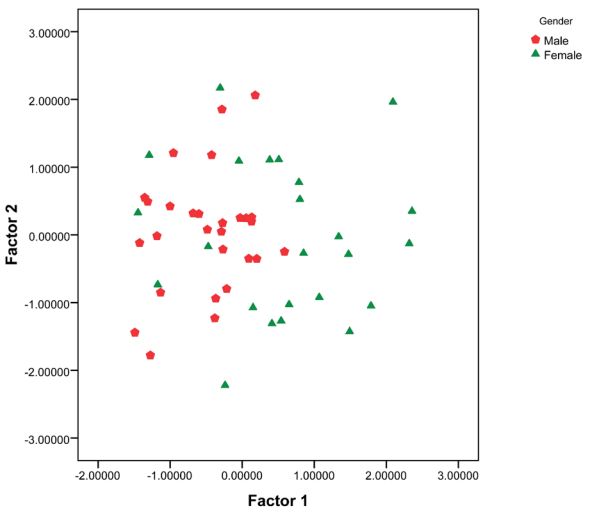

Figure 4. Ordination of the individual males and females of *Carinatogecko heteropholis* on the first two principal components. Note the relative degree of isolation between males and females, which is mainly attributed to SVL, TL, HL, HW, LFL, LHL, FHL, and VL in the PC1 and SL and IL in the PC2.

between forelimb – hindlimb (i.e., SVL and FHL, respectively) females had values of 36.34 ± 0.63 and 18.02 ± 0.41 and males had 32.53 ± 0.33 and 15.41 ± 0.20 ($P < 0.05$). Regarding the differences in extremities (forelimb, hindlimb, and tail) between females and males we observed that females had values of 12.96 ± 0.22, 17.46 ± 0.30, and 39.11 ± 0.80 and males had values of 11.86 ± 0.10, 15.95 ± 0.19, and 36.74 ± 0.68 for LFL, LHL, and TL respectively. Head dimensions also show significant differences between the sexes. Females had values of 8.94 ± 0.13 and 6.99 ± 0.10 and males had 8.51 ± 0.08 and 6.65 ± 0.07 for HL (head length) and HW (head width), respectively. Regarding the last metric character (i.e., VL or vent length), we realized that this character is significantly different between females and males, so that females have significantly greater values for VL (3.58 ± 0.10) than males (3.34 ± 0.04) ($P < 0.05$). All the metric variables are female biased. Reasons for presence of female biased sexual size dimorphism in the species are taken up in the discussion section.

Meristic variables: Significant differences were not observed in meristic variables, but SL (8.20 ± 0.12), CT (12.16 ± 0.24), and CD (7.45 ± 0.17) in females are larger than SL (8.07 ± 0.10), CT (11.96 ± 0.21), and CD (7.32 ± 0.14) in males. In other words, the three characters are not significantly female biased. Only one out of twelve variables (i.e., number of infralabials, IL) was male biased, which in turn was insignificant. The value of IL in males (6.85 ± 0.09) was insignificantly greater than that in females (6.79 ± 0.13) ($P < 0.05$).

Table 1. The metric and meristic characters used in this study.

	Characters	Definition
Metric	SVL	snout to vent length
	TL	length of tail
	HL	head length
	HW	head width
	LFL	length of forelimb
	LHL	length of hindlimb
	FHL	forelimb to hindlimb length
	VL	the greatest horizontal length of vent
Meristic	SL	number of supralabial scales
	IL	number of infralabial scales
	CT	number of crossbars on the tail
	CD	number of chevrons on dorsum

Principal Component Analysis

The PCA performed on the dataset yielded three axes, which collectively explained 73.38% of the total variation. The PC1 explains 50.788% of the total variation. Inspection of the loadings indicates that correlations with all morphological measurements have the same sign (positive) but not the same magnitude (Table 3). The first axis is a clear indicator of body size. All metric variables in the first axis have greater values than meristic ones, hence making a greater contribution in sexual discrimination. The scores of the females along this axis show an overlap with those for males, indicating that although sexual dimorphism occurs between males and females, the two sexes are not completely separated from each other regarding these characters (Fig. 4). The second axis, which contains 12.51% of the total variation is a meristic axis that records individuals at one end with large SL and IL and relatively small SVL compared with individuals with small SL and IL and relatively large SVL. The third axis contains only 10.08% of the total variation, being a meristic axis that records individuals with large CT and CD and relatively small VL at one end, compared with individuals at the other end with small CT and CD and relatively high values for VL.

Discussion

Carinatogecko heteropholis presented marked sexual dimorphism in general body size and several body parts, with females being significantly larger than males in eight out of 12 studied characters.

The evolutionary result of selection acting differently on body size and the rest of male and female traits is sexual size dimorphism (SSD) (Andersson 1994). Both the proximate (growth patterns) and ultimate (evolutionary payoffs) causes are responsible for sexual dimorphism (Stamps 1993; Cox et al. 2003; Kuo et al. 2009). Regarding size dimorphism, the proximate cause is an agent which creates intersexual differences in growth rate. Among these proximate causes, two are mention-

Table 2. Comparison of 12 morphological characters in males and females of *Carinatogecko heteropholis*. SE: standard error, D of d: Direction of difference. All measurements in millimeter (mm). Abbreviations: SVL (snout-vent length), TL (length of tail), HL (head length), HW (head width), LFL (length of forelimb), LHL (length of hindlimb), FHL (forelimb-hindlimb length), VL (the greatest horizontal length of vent), SL (number of supralabial scales), IL (number of infralabial scales), CT (number of crossbars on the tail), and CD (number of chevrons on dorsum).

SEX		SVL	TL	HL	HW	LFL	LHL	FHL	VL	SL	IL	CT	CD
	Mean	32.53	36.74	8.51	6.65	11.86	15.95	15.41	3.34	8.07	6.85	11.96	7.32
♂	**N**	28	21	28	28	28	28	28	28	28	28	28	28
	SEM	0.33	0.68	0.08	0.07	0.10	0.19	0.20	0.04	0.10	0.09	0.21	0.14
	Mean	36.34	39.11	8.94	6.99	12.96	17.46	18.02	3.58	8.20	6.79	12.16	7.45
♀	**N**	24	24	24	24	24	24	24	24	24	24	24	24
	SEM	0.63	0.80	0.13	0.10	0.22	0.30	0.41	0.10	0.12	0.13	0.24	0.17
	D. of d.	F>M	F>M	F>M	F>M	F>M	F>M	F>M	F>M	F>M	M>F	F>M	F>M
	***P*-value**	0.000	0.027	0.008	0.009	0.000	0.000	0.000	0.030	0.386	0.691	0.530	0.542

able: differences in growth hormone concentrations and trade-offs in allocating energy between growth and reproduction (John-Adler et al. 2007; Kuo et al. 2009). Presence of dimorphism between males and females are defined by three main forces including: sexual, fecundity, and natural selection (Olsson et al. 2002; Cox et al. 2003; Kaliontzopoulou et al. 2007).

Ectotherms grow continuously throughout life and they show a tendency to produce abundant, varying numbers of progeny, which results in a vigorous correlation between fecundity and body size of females, and probably that is why SSD in ectotherms is predominantly female-biased (Trivers 1972). The SVL (snout-vent length) and FHL (forelimb to hindlimb length) in females of *C. heteropholis* are greater than those in males. In other words, the two characters, SVL and FHL, are female-biased which can be the result of fecundity selection in the species. A larger abdominal volume is an ultimate cause which is selected in females because this feature enhances fecundity (Monnet and Cherry 2002, Tague 2005; Kuo et al. 2009).

Table 3. Loadings from a Principal Component Analysis of metric and meristic characters of *Carinatogecko heteropholis*. Variables loading strongly on each principal component are in bold. Abbreviations: SVL (snout-vent length), TL (length of tail), HL (head length), HW (head width), LFL (length of forelimb), LHL (length of hindlimb), FHL (forelimb-hindlimb length), VL (the greatest horizontal length of vent), SL (number of supralabial scales), IL (number of infralabial scales), CT (number of crossbars on the tail), and CD (number of chevrons on dorsum).

Variable	PC1	PC2	PC3
SVL	**0.958**	-0.133	-0.054
TL	**0.791**	0.061	0.003
HL	**0.884**	-0.057	-0.042
HW	**0.848**	-0.087	-0.032
LFL	**0.907**	-0.055	-0.031
LHL	**0.911**	-0.073	-0.028
FHL	**0.833**	-0.066	-0.007
VL	**0.756**	0.254	**-0.195**
SL	0.147	**0.784**	-0.064
IL	0.102	**0.851**	0.077
CT	0.286	-0.156	**0.748**
CD	0.140	0.174	**0.771**
Eigenvalue	6.095	1.502	1.210
% Variance	50.788	12.513	10.085
Cumulative	50.788	63.301	73.386

Head size in a variety of lizards is male-biased (e.g. Verrastro 2004; Smith and Nickel 2002; Vial and Stewart 1989; Anderson and Vitt 1990; Castilla and Bauwens 1991; Mouton and van Wyk 1993; Vitt and Colli 1994; Barbadillo et al. 1995; Hews 1996; Smith et al. 1997; Shine et al. 1998; Kratochvíl and Frynta 2002). In the cases of HL (head length) and HW (head width) in *C. heteropholis*, females have significantly greater values than males. As reported for other vertebrates, a phenomenon which can support niche divergence hypothesis is dimorphism in head size (Selander 1972; Shine 1989). Reproductive role hypothesis is a hypothesis that explains differences in head size. Females have a greater contribution in reproduction (Darwin 1871) and a larger head should maximize energy intake. This idea may explain the presence of larger heads in females of *C. heteropholis*.

Further, in *C. heteropholis*, the volumes of LFL (length of forelimb) and LHL (length of hindlimb) in females are significantly greater than in males. Sexually size-adapted dimorphism in traits such as head, limb, and tail measurements are assigned to an artifact of the acceptance of SVL for scaling to body size (Kratochvíl et. al. 2003). Moreover, we suggest that longer and stronger limbs are necessary to support greater distance between forelimb and hindlimb (i.e., greater FHL) either in females or in males.

Our results show that in the case of *C. heteropholis* the VL (vent length) in females is significantly greater than in males. During mating, females with a larger VL

are chosen by males. According to Andersson (1994), this character in geckos may be the result of selection for fecundity as well as selection for a larger female VL during evolution.

Additional studies are needed to determine which of these alternatives best explain the occurrence of sexual dimorphism in *C. heteropholis*.

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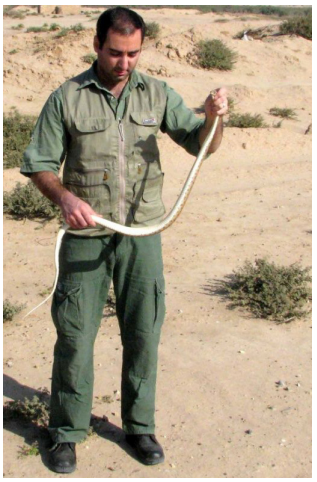

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