Amphibian and Reptile Conservation 5(1):75-87.

Analysis of sexual dimorphism in the Persian long-tailed desert lizard, *Mesalina watsonana* (Stoliczka, 1872; Sauria: Lacertidae)

[1]HAMZEH ORAIE, [1]AZAR KHOSRAVANI, [1,3]NASRULLAH RASTEGAR-POUYANI, AND [2]SAYED KAMRAN GHOREISHI

[1]*Department of Biology, Faculty of Science, Razi University, Kermanshah, IRAN* [2]*Department of Statistics, Faculty of Science, Razi University, Kermanshah, IRAN*

Abstract.—Mesalina watsonana **is one of the most widely distributed lacertid lizards of Iran. To investigate patterns of sexual dimorphism in this taxon, 206 (99 female, 107 male) adult specimens collected either from various regions of the Iranian Plateau during 2005-2008 or examined from museum collections were studied based on 19 morphometric and nine meristic characters. The results suggest that in *Mesalina watsonana*, body size could be the product of sexual and natural selection modified by ecological factors. Further, in all the studied populations, head size parameter has a more pronounced effect on the degree of sexual dimorphism than the length factors.**

Key words. Lacertidae, *Mesalina watsonana*, sexual dimorphism, Iranian Plateau, head size, statistical analysis

Citation: Oraie H, Khosravani A, Rastegar-Pouyani N, Ghoreishi SK. 2011. Analysis of sexual dimorphism in the Persian long-tailed desert lizard, *Mesalina watsonana* (Stoliczka, 1872; Sauria: Lacertidae). *Amphibian and Reptile Conservation* 5(1):75-87(e35).

Introduction

Between-sex differences in body size, coloration and morphology, so-called sexual dimorphism (SD), are widespread among reptiles (Schoener 1977; Berry and Shine 1980; Fitch 1981; Stamps 1983; Gibbons and Lovich 1990; Shine 1991). Several hypotheses attempt to explain the evolution of sexual dimorphism. Shine (1989) reviewed the literature and recognized two alternative explanations for sexual dimorphism: "sexual selection" and "intraspecific niche divergence."

Sexual dimorphism is a much-studied topic in the lacertid lizard literature (Brana 1996; Fitch 1981; Gvozdik and Boukal 1998; Molina-Borja 2003; Molina-Borja and Rodriguez-Dominguez 2004; Herrel et al. 2002; Kaliontzopoulou et al. 2007, 2010a, 2010b; Roitberg 2007). Sexual head size dimorphism is common in lacertid lizards, where an increased male head size may simultaneously be important in intersexual interactions (e.g., male-male combat, territorial contests; Trivers 1976; Fitch 1981; Anderson and Vitt 1990; Mouton and Van Wijk 1993; Bull and Pamula 1996; Censky 1995), intersexual interactions (copulatory bites, Herrel et al. 1996), and resource partitioning (e.g., males being able to eat larger prey than female conspecifics; Schoener 1967 and 1977; Stamps 1977; Best and Pfaffenberger 1987; Preest 1994).

Mesalina, a monophyletic group with 14 species, is a widespread lacertid occurring throughout the Saharo-Sindian region from North Africa to Pakistan (Kapli et al. 2008). Based on recent literature, *M. watsonana* is one of the two species of *Mesalina* whose occurrence has been confirmed in Iran. *Mesalina watsonana* is distributed widely on the Iranian Plateau and extends as far north as southern Turkmenistan and occurs in Afghanistan at elevations below 2500 m. This lizard is abundant on hard soils of plains and alluvial fans throughout much of Iran and is found on hillsides, valleys, and along stream courses. It is absent only in high mountains, along the Caspian coast and in the Azerbaijans as well as Kurdistan and Kermanshah provinces (Anderson 1999; Rastegar-Pouyani et al. 2007).

Little information is available on inter-population variation and habitat of *Mesalina watsonana* in Iran except that vegetation in areas where it occurs is usually scanty desert or steppe shrub, or areas stripped bare of perennial vegetation. To date no detailed information has been reported on morphometric and pholidotic differences between males and females in Iranian populations of *Mesalina watsonana*.

In this study, different aspects of sexual dimorphism in *Mesalina watsonana* are analyzed and discussed.

Correspondence. *Email:* [3]*nasrullah.r@gmail.com*

Table 1. The morphological (19 morphometric and nine meristic) characters examined in both sexes of *Mesalina watsonana*.

Characters	Definition
SVL	Snout-vent length (from tip of snout to anterior edge of cloaca)
TL	Tail length (from posterior edge of cloaca to tip of tail)
LHF	Trunk length (distance between hindlimb and forlimb)
HL	Head length (from tip of snout to the posterior edge of tympanum)
HH	Head height (maximum distance between upper head and lower jaw)
HW	Head width (distance between posterior eye corners)
LFL	Length of forelimb (from top of shoulder joint to tip of 4th finger)
LHL	Length of hindlimb (from hip joint to tip of 4th toe)
LFO	Length of femur (from hip joint to top of knee)
LA	Length of tibia (from top of knee to beneath wrist)
EL	Length of eye (distance from anterior corner to posterior corner to its posterior)
RED	Snout length (from tip of nostril to anterior corner of eye)
EED	Distance between posterior edge of eye and tympanum
NL	Length of neck (distance between posterior edge of tympanum and shoulder joint)
TD	Tympanum diameter (largest size)
IOR	Interorbital distance (largest size)
LV	Length of cloaca crevice (largest size)
LBT	Length of widest part of tail base
LWB	Length of widest part of belly
NSL	Number of labial scales anterior to the center of eye on the right side of head
NIL	Number of scales on the right lower labial region
NGS	Number of gular scales in a straight median series
NCS	Number of collar scales
NEE	Number of scales between posterior edge of eye and tympanum
NVS	Number of transverse series of ventral scales counted in straight median series between collar and the row of scales separating the series of femoral pores
NDS	Number of dorsal scales across midbody
SDLT	Number of subdigital lamellae along underside of 4th toe (defined by their width, the one touching the claw included), counted bilaterally
NFP	Number of femoral pores, counted bilaterally

Methods and materials

Source of material

We examined more than 250 specimens of *M. watsonana* from its range on the Iranian Plateau (see Appendix). Of these, 207 undamaged and fully-grown adults (107 males and 99 females) were selected for the analyses. The specimens were obtained from two sources: 1) our own material collected in various parts of the Iranian Plateau during field work in 2006-2008. The collected materials are deposited at the Razi University Zoological Museum (RUZM). 2) Museum material borrowed from various museum collections throughout Iran, such as Iran National Natural History Museum (MMTT), Razi University Zoological Museum (RUZM), Zoological Museum of Tarbiat Moallem University of Sabzevar (SUZM), and Tehran University Zoological Museum (ZUTC).

Statistical analysis

All the specimens were examined for 19 morphometric and nine meristic characters (Table 1). Metric characters were evaluated using vernier calipers with measurements taken to the nearest 0.1 millimeter. During the sampling time some females were gravid and apparently had broader abdomens, thus width of body was not used in analysis. Data analysis was performed using parametric analyses after the assumptions of this analysis were checked and found to be met. Statistical analyses were performed using the SPSS (16) and S-Plus (8) for Windows.

All specimens used for the study of between-population variability in sexual dimorphism come from a limited geographic area, thus belonging to the same pop-

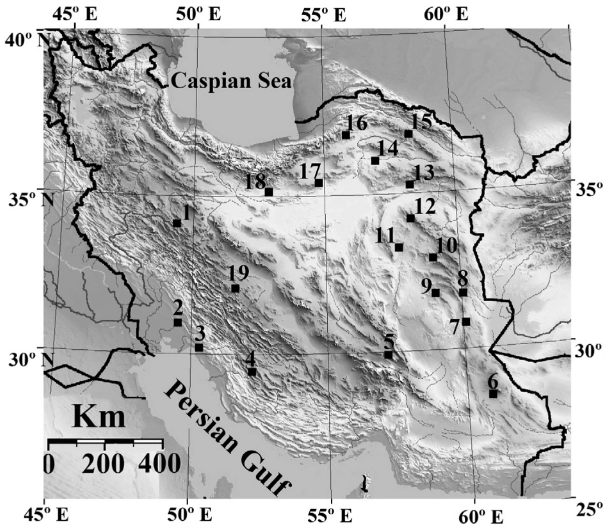

Figure 1. Geographic distribution of 19 Operational Taxonomic Units (OTU) of *Mesalina watsonana* used in this study.

Table 2. The localities of 19 OTUs of the *Mesalina watsonana* complex used in this study.

OTUs	Locality	Sample size	
		Female	Male
1	Arak, Markazi Province	2	4
2	Izeeh, Khuzestan Province	8	7
3	Dehdasht, Kohkiloye and Boyer Ahmad Province	7	6
4	Shiraz, Fars Province	6	3
5	Kerman, Kerman Province	5	10
6	Khash, Sistan- Balochestan Province	4	3
7	Nehbandan, Southern Khorasan Province	4	4
8	Sarbishee, Southern Khorasan Province	7	7
9	Birjand, Southern Khorasan Province	10	5
10	Ghaen, Southern Khorasan Province	3	2
11	Ferdoos, Southern Khorasan Province	4	3
12	Gonabad, Khorasan Razavi Province	13	4
13	Kashmar, Khorasan Razavi Province	6	1
14	Sabzevar, Khorasan Razavi Province	3	5
15	Ghochan, Khorasan Razavi Province	2	3
16	Jajarm, Northern Khorasan Province	4	3
17	Khartooran, Semnan Province	7	8
18	Semnan, Semnan Province	7	7
19	Unknown region in Central Zagros	5	14
Total		107	99

ulation of animals (analysis of sexual dimorphism was carried out in three separate geographic regions of Iran; Fig. 1 and Table 2).

1. Eastern populations (OTUs: 6, 7, 8, 9, 10, 11, 12, 13)
2. Northeastern populations (OTUs: 14, 15, 16, 17, 18)
3. Zagros populations (OTUs: 1, 2, 3, 4, 5, 19)

To reveal dispersion patterns among morphological characters of both sexes, descriptive statistical parameters, including minimum, maximum, mean, and standard error were employed separately for each region.

The Analysis of Variance (ANOVA) was used to carry out pair-wise comparisons of the characters between males and females and significant characters were plotted using the error bars.

Principal Components Analysis (PCA) was used based on a correlation matrix of 17 characters for each region separately. In order to show the contribution of morphological characters to sexual dimorphism, all individuals of each region were subjected to a Principal Components Analysis.

Discriminant Function Analysis (DFA) was also used as a tool to determine which variable discriminates between males and females. To investigate the importance of various parameters in sexual dimorphism, we calculated the two components of head and length factors in each population and then ran the DFA for each population separately based on the following formula:

Head size parameter = (0.902 × HL) + (0.904 × HH) + (0.890 × HW) + (0.763 × NL) + (0.790 × IOR) + (0.863 × EED) + (0.806 × RED)

Length size parameter = (0.896 × SVL) + (0.818 × LHF) + (0.900 × LFL) + (0.831 × LA) + (0.884 × LHL) + (0.905 × LFO)

The weight of each character was gained from the PCA.

Results

Descriptive Analysis

Descriptive parameters of morphometric and meristic characters are presented for males and females separately in each region. The comparison of characters between male and female individuals is presented in Table 3.

Univariate Analysis

The results of Analysis of Variance (ANOVA) carried out for intra-sexual comparison of meristic and morphometric characters are presented in Table 4.

Analysis of Variance revealed significant differences in 13 morphometric (HL, HH, HW, LFL, LA, LHL, LFO,

Table 3. Descriptive parameters of some morphological characters including minimum, maximum, mean, and standard error in *Mesalina watsonana*.

Characters		Eastern Populations (Female = 28, Male = 45)		Northeastern Populations (Female = 27, Male = 29)		Zagros Populations (Female = 44, Male = 33)	
		Mean ± std. error	Minimum-Maximum	Mean ± std. error	Minimum-Maximum	Mean ± std. error	Minimum-Maximum
HL	**Female**	9.4971 ± 0.33823	7.42-16.58	9.6222 ± 0.16429	8.13-11.26	10.5677 ± 0.15922	8.83-13.54
	Male	10.5913 ± 0.20579	7.58-13.90	10.6545 ± 0.18343	9.00-12.78	11.6036 ± 0.21712	8.17-13.74
HH	**Female**	3.8500 ± 0.12321	2.82-5.19	4.0000 ± 0.11171	2.70-4.91	4.4725 ± .09356	3.15-6.55
	Male	4.4184 ± 0.10492	3.05-5.80	4.6672 ± 0.07675	4.06-5.72	4.7864 ± 0.11501	3.53-5.69
HW	**Female**	5.6618 ± 0.15458	4.00-6.94	5.9596 ± 0.13134	4.39-7.16	6.3482 ± 0.09748	5.17-7.78
	Male	6.3942 ± 0.12450	4.76-7.91	6.5686 ± 0.09957	5.18-7.93	7.0758 ± 0.13050	5.32-8.32
LFL	**Female**	13.4314 ± 0.34455	10.10-17.12	14.3822 ± 0.24598	12.25-17.00	15.4589 ± 0.23607	12.93-20.51
	Male	14.8482 ± 0.29742	10.95-18.87	15.8286 ± 0.31250	12.80-19.28	16.9803 ± 0.33027	11.84-19.98
LHL	**Female**	24.0686 ± 0.67549	16.98-31.07	25.3215 ± 0.43876	19.92-29.34	28.6845 ± 0.35742	22.91-34.15
	Male	26.9444 ± 0.49379	20.17-32.86	28.3431 ± 0.59926	21.58-35.00	31.4548 ± 0.49111	23.80-35.63
LFO	**Female**	6.9643 ± 0.22032	4.77-9.40	8.0878 ± 0.19763	6.15-9.97	9.1268 ± 0.18047	6.72-11.11
	Male	8.1504 ± 0.17475	5.95-10.41	9.0341 ± 0.17226	7.48-11.49	10.3670 ± 0.22624	7.86-13.49
IOR	**Female**	4.1086 ± 0.10835	3.00-5.08	4.1374 ± 0.08482	3.14-5.10	4.4623 ± 0.06698	3.79-5.54
	Male	4.4638 ± 0.08422	3.24-5.83	4.5410 ± 0.07131	3.94-5.26	4.6742 ± 0.07675	3.87-5.46
EED	**Female**	3.3736 ± 0.10541	2.23-4.80	3.5007 ± 0.09999	2.45-4.51	4.0720 ± 0.07063	3.15-4.92
	Male	3.9462 ± 0.11887	2.81-7.15	4.2107 ± 0.08289	3.32-5.11	4.4452 ± 0.08917	3.20-5.11
RED	**Female**	3.9486 ± 0.11848	2.60-5.42	4.5967 ± 0.10457	3.63-5.93	4.8602 ± 0.09168	3.53-6.18
	Male	4.5304 ± 0.10906	2.92-5.83	5.0383 ± 0.07962	4.00-6.17	5.3382 ± 0.12157	3.54-6.29
LV	**Female**	3.3446 ± 0.11795	2.24-4.61	3.3730 ± 0.10538	2.56-4.89	3.8791 ± 0.10236	2.75-5.89
	Male	3.9807 ± 0.09483	2.89-5.22	4.5814 ± 0.13158	3.52-6.25	4.7927 ± 0.15846	3.09-7.27
LBT	**Female**	3.9611 ± 0.12691	2.67-5.28	4.2741 ± 0.11800	3.15-5.52	4.5425 ± 0.09579	3.65-6.85
	Male	4.8444 ± 0.13169	3.36-6.90	5.4131 ± 0.13380	3.88-6.89	5.8264 ± 0.20259	3.70-7.68
NVS	**Female**	29.7143 ± 0.32472	27.00-34.00	30.3704 ± 0.38913	27.00-35.00	29.3864 ± 0.29480	25.00-35.00
	Male	28.9333 ± 0.21415	26.00-33.00	29.1724 ± 0.35466	25.00-33.00	28.5152 ± 0.27566	26.00-33.00

Table 4. The ANOVA based intra-sexual comparison of meristic and morphometric characters in three different groups of populations of *Mesalina watsonana*.

	Eastern					Northeastern					Zagros				
	Sum of squares	df	Mean square	F	Sig.	Sum of squares	df	Mean square	F	Sig.	Sum of squares	df	Mean square	F	Sig.
SVL	285.448	1	285.448	8.806	0.004	45.877	1	45.877	3.179	0.081	23.934	1	23.934	0.894	0.347
HL	22.909	1	22.909	9.446	0.003	7.470	1	7.470	12.600	0.001	20.236	1	20.236	15.527	0.000
HH	5.537	1	5.537	11.950	0.001	4.942	1	4.942	19.750	0.000	1.858	1	1.858	4.563	0.036
HW	9.652	1	9.652	13.847	0.000	3.025	1	3.025	9.073	0.004	9.982	1	9.982	20.819	0.000
LFL	2.989	1	2.989	0.202	0.654	3.840	1	3.840	0.453	0.504	43.650	1	43.650	14.839	0.000
LHL	170.396	1	170.396	12.918	0.001	70.025	1	70.025	11.695	0.001	13.433	1	13.433	1.365	0.246
LFO	28.408	1	28.408	17.970	0.000	7.613	1	7.613	9.089	0.004	29.002	1	29.002	18.804	0.000
IOR	2.438	1	2.438	7.812	0.007	1.802	1	1.802	10.004	0.003	0.847	1	0.847	4.320	0.041
LV	8.779	1	8.779	18.005	0.000	16.725	1	16.725	47.084	0.000	15.741	1	15.741	25.476	0.000
LBT	15.852	1	15.852	20.376	0.000	13.075	1	13.075	37.487	0.000	31.082	1	31.082	38.404	0.000
NVS	13.949	1	13.949	4.345	0.040	25.274	1	25.274	6.510	0.014	14.313	1	14.313	4.387	0.040
RED	7.230	1	7.230	13.384	0.000	1.311	1	1.311	6.193	0.016	4.308	1	4.308	10.254	0.002
EED	7.069	1	7.069	13.727	0.000	5.282	1	5.282	22.693	0.000	2.625	1	2.625	11.039	0.001
TD	0.727	1	0.727	5.314	0.024	1.063	1	1.063	5.089	0.029	0.275	1	0.275	2.487	0.119
LA	3.585	1	3.585	4.417	0.039	2.808	1	2.808	2.910	0.094	6.305	1	6.305	7.063	0.010
NL	6.603	1	6.603	4.873	0.030	2.304	1	2.304	2.751	0.104	5.103	1	5.103	4.197	0.044
NCS	0.563	1	0.563	0.262	0.610	1.206	1	1.206	.673	0.416	8.766	1	8.766	4.007	0.049
NDS	0.008	1	0.008	0.001	0.976	34.268	1	34.268	3.394	0.072	0.848	1	0.848	0.078	0.780
NEE	0.872	1	0.872	0.736	0.394	6.376	1	6.376	4.384	0.042	3.040	1	3.040	1.419	0.237
SDLT	0.010	1	0.010	0.004	0.947	5.180	1	5.180	1.712	0.197	29.464	1	29.464	7.819	0.007
NFP	6.154	1	6.154	6.083	0.016	1.133	1	1.133	.680	0.414	7.456	1	7.456	7.912	0.006

Table 5. Factor loadings on the first three principal components, extracted from the separated correlation matrix of morphological characters, for males and females of *Mesalina watsonana*.

	Northeastern			Eastern			Zagros		
Characters	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
Zscore (SVL)	0.813	0.070	0.176	0.927	0.059	-0.048	-	-	-
Zscore (HL)	0.882	0.040	-0.048	0.883	0.209	-0.039	0.936	0.029	0.048
Zscore (HH)	0.866	-0.110	-0.091	0.917	0.190	0.072	0.848	-0.168	-0.090
Zscore (HW)	0.890	-0.177	0.027	0.915	0.029	0.055	0.808	0.081	-0.133
Zscore (LFL)	0.774	0.276	0.226	0.920	-0.044	-0.102	0.795	0.060	0.244
Zscore (LA)	-	-	-	0.822	-0.049	0.252	0.678	-0.317	0.460
Zscore (LHL)	0.803	0.310	0.060	0.922	0.090	-0.101	0.842	0.112	-0.029
Zscore (LFO)	0.812	0.035	0.004	0.940	0.030	0.002	0.763	-0.007	0.366
Zscore (TD)	0.630	-0.481	0.276	0.699	0.011	0.339	-	-	-
Zscore (NL)	-	-	-	0.761	-0.128	-0.046	0.633	-0.388	0.009
Zscore (IOR)	0.818	-0.109	0.279	0.846	0.036	0.084	0.558	-0.374	-0.370
Zscore (EED)	0.811	-0.015	-0.190	0.816	-0.016	-0.147	0.836	-0.076	-0.016
Zscore (RED)	0.754	0.098	0.014	0.765	-0.229	-0.053	0.869	0.082	0.231
Zscore (LV)	0.814	-0.142	-0.290	0.855	-0.190	0.007	0.794	0.059	-0.253
Zscore (LBT)	0.858	0.135	-0.114	0.885	-0.162	-0.070	0.872	0.089	-0.191
Zscore (NDS)	-0.059	0.700	-0.439	-0.005	0.850	0.470	-	-	-
Zscore (NVS)	-0.331	0.377	0.758	-0.153	-0.566	0.749	-0.273	0.207	0.613
Zscore (NCS)	-	-	-	-	-	-	0.383	0.690	-0.227
Zscore (NEE)	0.282	0.588	0.099	-	-	-	-	-	-
Zscore (SDLT)	-	-	-	-	-	-	0.284	0.849	0.045
Eigenvalues	8.77	1.49	1.16	11.14	1.27	1.03	8.49	1.70	1.16
Accumulated percent of trace	54.80	64.14	71.39	65.54	73.00	79.10	53.10	63.74	70.96

NL, IOR, EED, RED, LV, and LBT) and four meristic characters (NFP, SDLT, NCS, and NVS) between the two sexes at the level of 95% ($p < 0.05$) in the Zagros populations.

In the eastern populations, the ANOVA showed significant differences in 15 morphometric (SVL, HL, HH, HW, LFL, LA, LHL, LFO, NL, TD, IOR, EED, RED, LV, and LBT) and two meristic characters (NVS and NDL) between the two sexes at the level of 95% ($p < 0.05$), and in the northeastern populations, the ANOVA revealed significant differences in 13 morphometric (SVL, HL, HH, HW, LFL, LHL, LFO, TD, IOR, EED, RED, LV, and LBT) and three meristic characters (NVS, NEE, and NDS) between the two sexes at the level of 95% ($p < 0.05$).

Some characters (HL, HH, HW, LFL, LHL, LFO, IOR, LV, LBT, NVS, RED, and EED) show significant differences ($p < 0.05$) between the two sexes. Most of these characters (HL, HH, HW, IOR, RED, and EED) are related to head size, so that males have greater absolute head size than the females in all the three studied populations (Figure 2A-D). Also, males have proportionately longer limbs (LFL, LHL, and LFO) than females.

Multivariate Analysis

Comparing the two sexes at multivariate level, the PCA was used plotting individual males and females from each of the three separated populations to explore the patterns of sexual dimorphism in each region.

For the entire three geographic regions most of characters loaded heavily on the first three components. The first component (PC1) is interpretable as a general body size factor providing a good measure of overall size. In almost all the OTUs, males tend to be larger than females in general body size and often have higher scale counts in various parts of body except NVS (number of transverse series of ventral scales, counted in strait median series between collar and the row of scales separating the series of femoral pores) which is lower in males. The first component (PC1) addresses 53-65% of the total variation within all three populations. In the case of the Zagros populations, the PC1 explains 53.1%, and the first three principal components address 70.9% of the total variation (Table 5). The magnitude and sign of the loadings on PC1 and PC2 show a consistent pattern between samples and the high degree of sexual dimorphism is easy to interpret (Figure 3A).

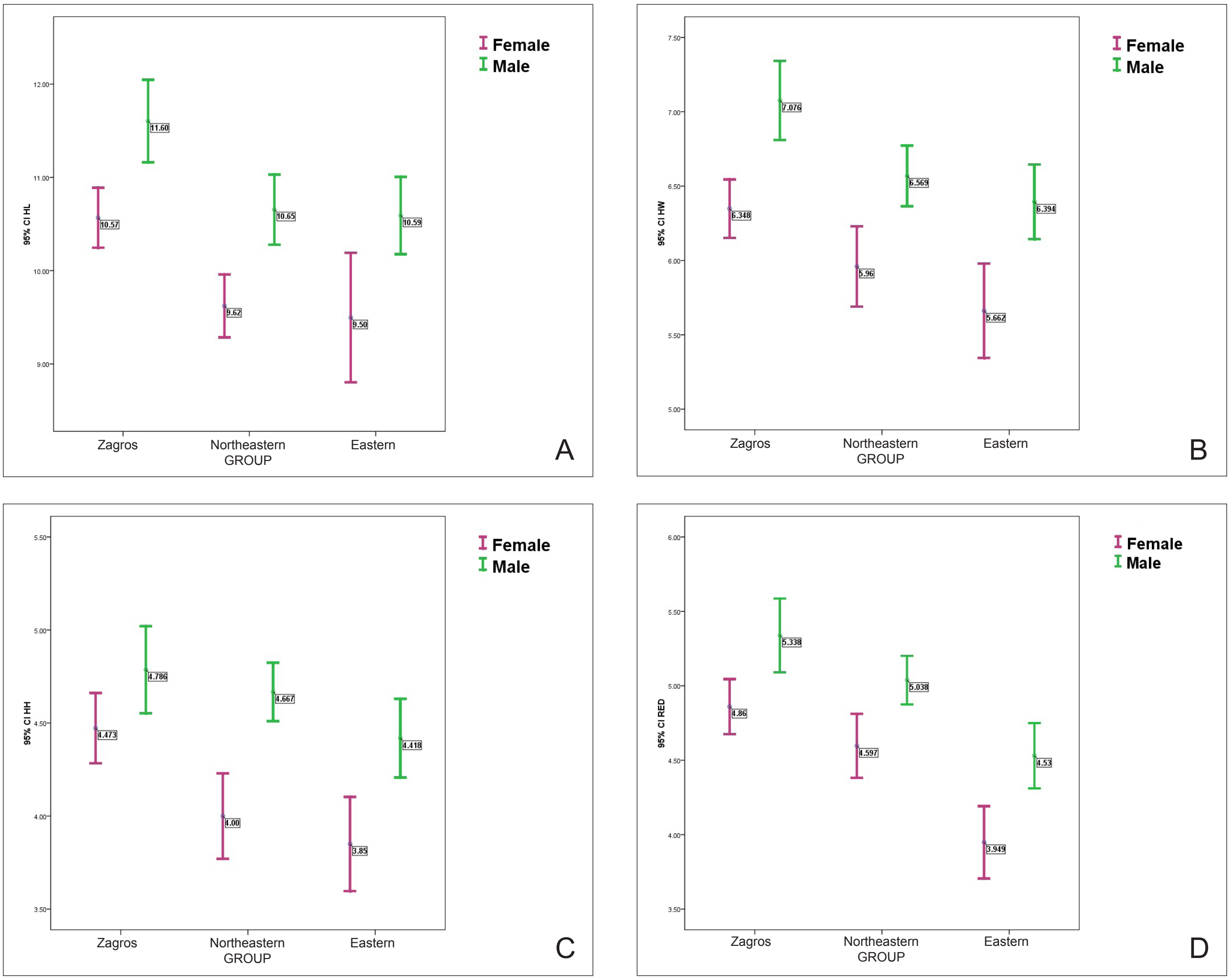

Figure 2. The mean and standard error (bars) for significantly different head size characters between males and females of *Mesalina watsonana*, revealed from the analysis of variance (ANOVA). Head length (A), head width (B), head height (C), and snout length (D).

In the northeastern populations, PC1 explains 54.1%, and the first three principal components address 71.4% of the total variation (Table 5). The magnitude and sign of the loadings on PC1 and PC2 show a consistent pattern between samples and the high degree of sexual dimorphism is easy to interpret (Figure 3B).

In the eastern populations, the PC1 explains 65.5%, and the first three principal components address 79% of the total variation (Table 5). The magnitude and sign of the loadings on PC1 and PC2 show no consistent pattern between samples and are difficult to interpret. In some instances PC3 does have a little contribution in discrimination between males and females (Figure 3C).

Discriminant Function Analysis (DFA)

Based on this analysis, head size parameter has more effect on sexual dimorphism than the length size parameter in all populations. Based on the Discriminant Function Analysis, the head size parameter could classify the original grouped cases almost correctly, so that 70.1% of the Zagros populations, 73.2% of the northeastern populations, and 67.1% of the eastern populations were correctly classified into their relevant groups. As well, based on this analysis, the length size parameter classified the original grouped cases almost correctly: 62.3% of the Zagros populations, 64.3% of the northeastern populations, and 64.4% of the eastern populations were correctly classified into their relevant groups. Although, the head size parameter separates the males and females better than the length size parameter, its effect is obviously related to environmental conditions. So that the head size in the eastern populations has less effect in separation in relation to the other populations. Interestingly in the eastern populations, the length size parameter also has a weak effect in separation of the groups.

Scatterplots of head length (HL) against the snout-vent length (SVL) for each population is shown in Figure 4A-C.

In the northeastern and Zagros populations, in an individual male and female with the same SVL, obviously

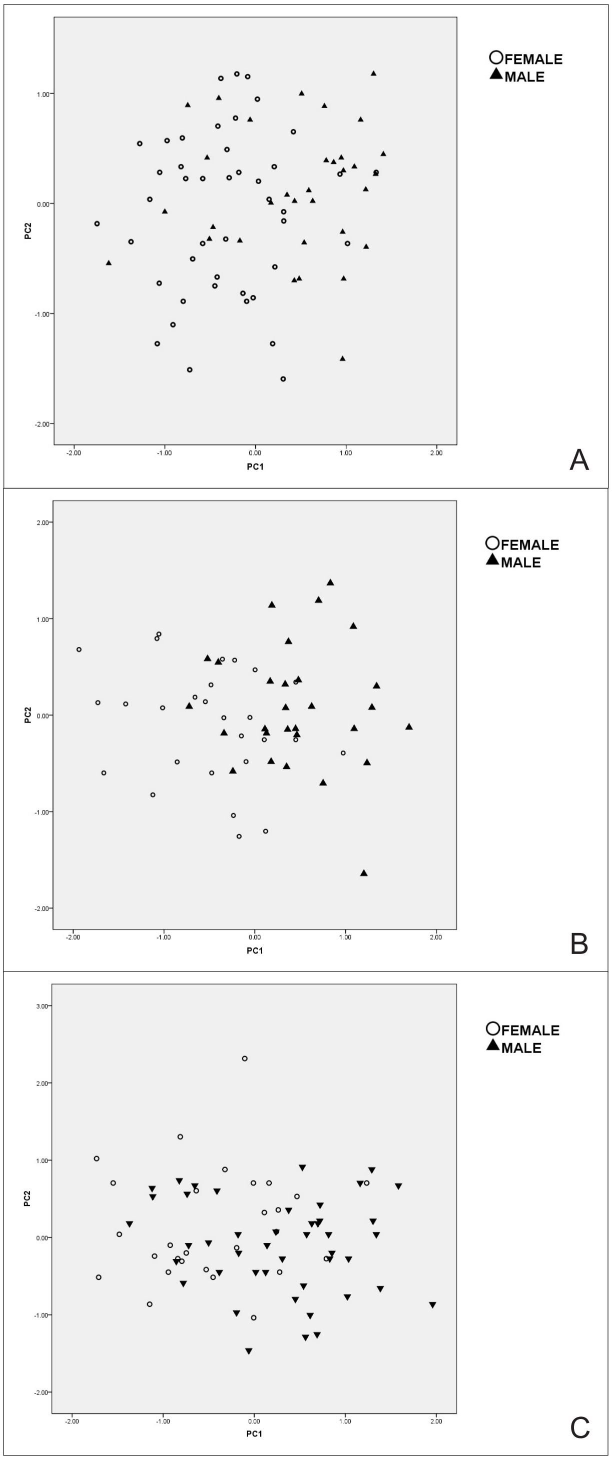

Figure 3. Ordination of individual male (▲) and female (○) specimens of the Zagros populations (A) Northeastern populations (B) Eastern populations (C) on the first two principal components.

the males having larger heads (HL) than the females, but in the eastern populations the head size of both sexes is nearly the same. This pattern is repeated in the other head size characters (HW, HH, IOR, RED, and EED) but with different influences. Finally we may conclude that the rate of head size growth relative to the SVL growth, though not significantly different ($p > 0.05$) in all populations, was faster in males than in females (Fig. 4).

Discussion

Body size variation (e.g., SVL) among populations of lizards is a common phenomenon. Variation in body size has even been observed among individuals living in different habitats in the same population (Smith 1996 and 1998).

Variation in sexual dimorphism among populations is less well investigated; however, it is apparent that it does occur (McCoy et al. 1994; Molina-Borja et al. 1997). In *Mesalina watsonana*, interestingly in each group of populations we found a distinct pattern of sexual dimorphism (Table 4). Some characters (HL, HH, HW, LFL, LHL, LFO, IOR, LV, LBT, NVS, RED, and EED) show significant differences ($p < 0.05$) between the two sexes in all populations. Most of these characters (HL, HH, HW, IOR, RED, and EED) are related to head size.

Sexual differences in head size are common within the clade of lacertid lizards (e.g., Castilla et al. 1989; Brana 1996; Molina-Borja et al. 1997; Gvozdik and Boukal 1998; Huang 1998) with obvious implications. It is likely that sexual dimorphism in head size was present in a common ancestor of lacertids. We propose that sexual dimorphism in head size did not evolve *de novo* in *M. watsonana* but as a result of phylogenetic history. However, as demonstrated here, the actual extent of the dimorphism may be maintained through competition over mates (sexual selection) and environmental conditions (ecology). Environmental conditions (ecology, competition, and so on) affected the pattern of head size sexual dimorphism in different populations of *M. watsonana* in various regions of Iran. Our results illustrate that unlike other cases (Shine 1990; Stamps 1993; Gvozdik and Damme 2003), proximate environmental factors can be important determinants of sexual dimorphism in head size and other characters (ecological conditions having different effects on sexual dimorphism in different populations of *M. watsonana*).

Our results suggest that decreased sexual dimorphism in *M. watsonana* from the Zagros populations to the eastern and northeastern populations was understandable and this pattern may be due to environmental changes and hence changes in sexual selection in different habitats. On the other hand, individuals of the Zagros populations have larger heads than the other populations. It may be related to differences in environmental conditions in each region. Ecological causes have been used to explain sexual dimorphism in some lizards (Shine 1989; Schoener 1977). Butler and Losos (2002) explained the relationship between habitat use and extent of sexual dimorphism by two hypotheses:

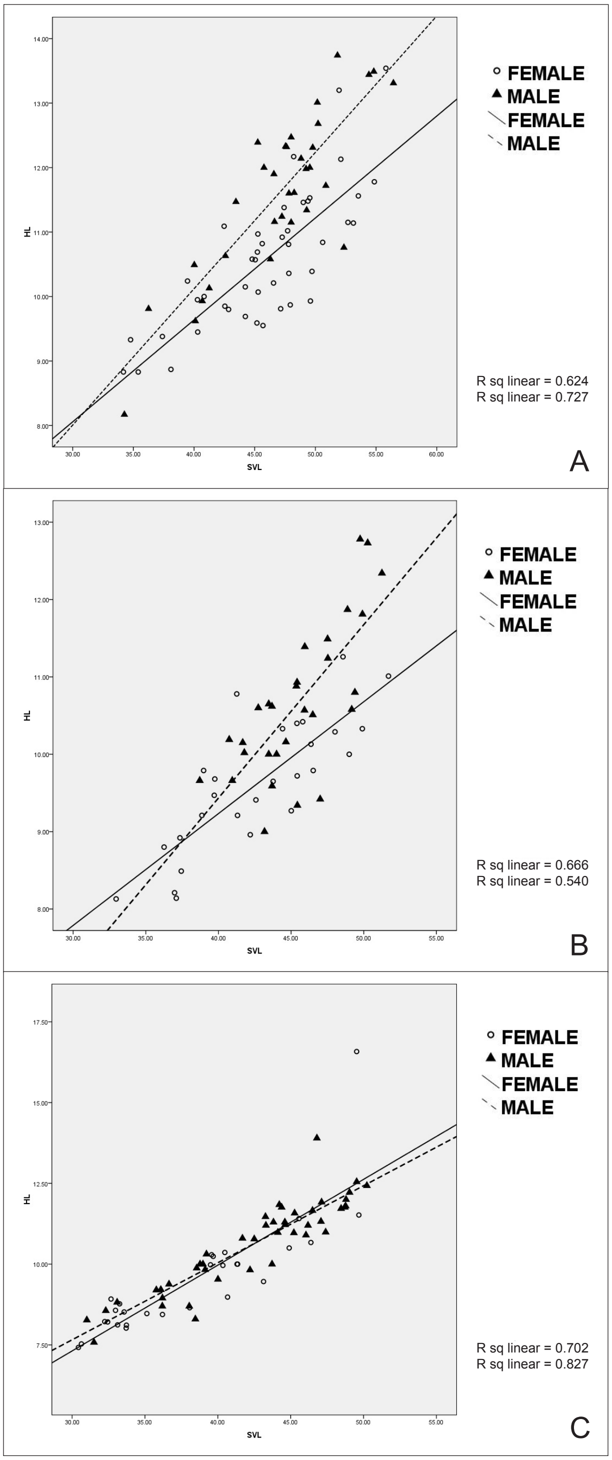

Figure 4. Scatter plots of the head length (HL) against the snout-vent length (SVL) for the Zagros populations (A) North-eastern populations (B) Eastern populations (C) Male = (▲) and Female = (○). Regression lines are shown whenever the slopes are significantly different from zero.

1) Males and females may interact in different ways with the environment, thus leading to a quantitative sex difference in the relationship between morphology and habitat use. This implies that sexes may or may not differ in habitat use, but regardless, the relationship between morphology and ecology will differ between the sexes.

2) The relationship between morphology and habitat use does not differ between the sexes, but the sexes differ in microhabitat use more in some habitats than in others. The amount of ecological difference between the sexes may differ qualitatively among habitats, leading to greater morphological difference in habitats where sexes are more ecologically distinct.

Further, differences in sexual dimorphism between populations of *Mesalina watsonana* may be due to differences in the level of competition experienced by these populations. Sexual dimorphism may be due to other reasons, such as higher survival rates of one sex compared to the other (Vitt 1983), or the differential allocation of energy to reproduction after sexual maturity in males versus females (Cooper and Vitt 1989; Vial and Stewart 1989). It seems that *Mesalina watsonana* feeds on spiders, crickets, beetles, ants and ant larvae and other small insects (Anderson 1999).

The authors in this paper have attempted to explore several aspects of sexual dimorphism patterns in *Mesalina watsonana* in Iran. Key to further understanding entails further field work and behavioral observation especially during the breeding season and the integration of comparative, demographic, and experimental techniques designed to simultaneously address both the ultimate evolutionary causes and proximate developmental mechanisms for sexual dimorphism and unknown aspects of this phenomenon.

Acknowledgments.—We thank the Razi University authorities for financial support during field work in various parts of Iran. We would also like to thank the curators of zoological collections in the Tehran University (Hasan Salehi) and Iran National Natural history Museum (Alireza Motesharei) for borrowing material. We appreciate Eskandar Rastegar-Pouyani and Soheila Shafiei for providing some material for our study. We thank Ali Gomar, Hamid Reza Oraie, and Hamid Reza Yazdani for their help and cooperation in material examination and statistical analysis. An anonymous reviewer provided critical information and comments on an initial draft of the manuscript.

Appendix

Material examined (*Mesalina watsonana*)

RUZM, LM 10 / 25-36 (*n* = 11, around Nehbandan, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 37-45 (*n* = 9, Darmian, Asad-Abad, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 46-53 (*n* = 8, around Sarbishe, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 54-59 (*n* = 6, Birjand, Khorashad Village, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 60-65 (*n* = 6, around Khosf, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 66-76 (*n* = 11, Gonabad, Khezri Village, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 77-82 (*n* = 6, around Ferdoos, South Khorasan Province, eastern Iran)
RUZM, LM10 / 83-90 (*n* = 8, Ghaen, Haji-abad Village, South Khorasan Province, eastern Iran)
RUZM, LM 10 / 91-92 (*n* = 2, Khash, Nook-abad, Sistan-Baloochestan Province, southeastern Iran)
RUZM, LM 10 / 93-94 (*n* = 2, Darab, Fars Province, southern Iran)
RUZM, LM 10 / 95-100 (*n* = 6, Fasa, Jellian Village, Fars Province, Southern Iran)
RUZM, LM 10 / 1-24 (*n* = 24, central Iran)
RUZM, LM 10 / 101 (*n* = 1, Masjed Solyman, Golgir Village, Khuzestan Province, southwestern Iran)
ZUTC, REP 1026 (*n* = 10, Biarjmand, Semnan Province, Northern Iran)
ZUTC, REP 1023 (*n* = 1, Khartoran, Kalate Taleb, Semnan Province, northern Iran)
ZUTC, REP 1024 (*n* = 2, around Damghan, Semnan Province, northern Iran)
ZUTC, REP 1025 (*n* = 1, Khartoran, Belbar, Semnan Province, northern Iran)
ZUTC, REP 1027 (*n* = 1, Khartoran, Delbar, Khosh-Chah Village, Semnan Province, northern Iran)
ZUTC, REP 1028 (*n* = 1, Khartoran, Kal e Datjerd Village, Semnan Province, northern Iran)
ZUTC, REP 1079 (*n* = 1, Shiraz, Fars Province, southern Iran)
ZUTC, REP 1332 (*n* = 1, Arak, Delijan, Markazi Province, eastern Iran)
ZUTC, REP 1117 (*n* = 3, Dehdasht,Koh- bord Village, Kohkiloye and Boyer Ahmad Province, southwstern Iran)
ZUTC, REP 1118 (*n* = 3, Arond Dehbasht, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1119 (*n* = 1, Dehdasht, Ab-Kaseh Village, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1120 (*n* = 1, Dehdasht, Likak, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1121(*n* = 3, Dehdasht, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1122 (*n* = 1, Dehdast, Sogh Village, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1123 (*n* = 1, Dehdasht, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1124 (*n* = 1, Dehdasht, Ghal e Madrese Village, Kohkiloye and Boyer Ahmad Province, southwestern Iran)
ZUTC, REP 1175 (*n* = 1, Ghom, Ghom Province, central Iran)
ZUTC, REP 1180 (*n* = 1, Shahr E Babak, Kerman Province, southern Iran)
ZUTC, REP I260 (*n* = 4, Garmsar, Semnan Province, northern Iran)
ZUTC, REP 1334 (*n* = 2, Gheshm Island, Hormozgan Province, southern Iran)
MMTT 1111-1119 (*n* = 9, Bidokht, South Khorasan Province, eastern Iran)
MMTT 1210-1211 (*n* = 2, Soltan Abad, Northern Khorasan Province, northeastern Iran)
MMTT 860-861 (*n* = 2, Khash, Sistan-Baloochestan Province, southeastern Iran)
MMTT 712 (*n* = 1, Khash, Sistan-Baloochestan Province, southeastern Iran)
MMTT 856 (*n* = 1, Khash, Sistan-Baloochestan Province, southeastern Iran)
MMTT 98 (*n* = 1, Khash, Sistan-Baloochestan Province, southeastern Iran)
MMTT 623-624 (*n* = 2, Kerman, Hosein Abad, Kerman Province, central Iran)
MMTT 230 (*n* = 2, Bardesir, Kerman Province, central Iran)
MMTT 1586-1587 (*n* = 2, Kerman, Kerman Province, central Iran)
MMTT 224-226 (*n* = 3, Izeh, Pole Jeh-Jeh, Khuzestan Province, southwestern Iran)
MMTT 1745 (*n* = 1, Izeh, Pole Jeh-Jeh, Khuzestan Province, southwestern Iran)
MMTT 1725-1728 (*n* = 4, Izeh, Mordeh Fill, Khuzestan Province southwestern Iran)
MMTT 2111-2112 (*n* = 2, Izeh, Mordeh Fill, Khuzestan Province, southwestern Iran)
MMTT 2115 (*n* = 1, Izeh, Mordeh Fill, Khuzestan Province, southwestern Iran)
MMTT 1703 (*n* = 1, Izeh, Morde Fill, Khuzestan Province, southwestern Iran)
MMTT 1675 (*n* = 1, Izeh, Morde Fill, Khuzestan Province, southwestern Iran)
MMTT 1716 (*n* = 1, Izeh, Morde Fill, Khuzestan Province, southwestern Iran)
MMTT 251-254 (*n* = 4, Shahrod, Semnan Province, northern Iran)
MMTT 258-262 (*n* = 5, Shahrod, Semnan Province, northern Iran)
MMTT 735-738 (*n* = 4, Sirjan, Kerman Province, southern Iran)
MMTT 785-787 (*n* = 3, Sirjan, Kerman Province, southern Iran)

MMTT 967-969 (*n* = 3, Kashan, Isfahan Provine, central Iran)
MMTT 721 (*n* = 1, Kashan, Isfahan Provine, central Iran)
SUZM 87 (*n* = 1, around Eshghabad, 70 km on the road to Tabas, eastern Iran)
SUZM 116, SUZM 122 (*n* = 2, Deyhook, 5 km on the road to Ferdows, southern Khorasan Province, eastern Iran)
SUZM 252 (*n* = 1, around Mayamai, 60 km E Shahrood, Semnan Province, northeastern Iran)
SMP 200-203 (*n* = 3, Jorbat Village, 35 km E Jajarm, northen Khorasan, northeastern Iran)
SUZM 612, SUZM 614 (*n* = 2, Golgir Village, Khuzestan Province, southwestern Iran)
SUZM 1-2, SUZM 5 (*n* = 3, 25 km E Bardaskan, Khorasan Province, Northeastern Iran)
SUZM 18 (*n* =1, 70 km E Bardaskan, Khorasan Province, northeastern Iran)
SUZM 51, SUZM 53, SUZM 55 (*n* = 3, around Birjand, 10 km on the Sarbisheh, Khorasan Province, eastern Iran)
SUZM 118-119 (*n* = 2, 35 km SW Bam on the road to Jiroft, Kerman Province, southern Iran)
SUZM 69, SUZM 77, RFK 76, RFK 75 (*n* = 4, 20 km E Jajarm, northen Khorasan Province, northeastern Iran)
SUZM 131, SUZM 136 (*n* = 2, 25 km NW Sabzevar, Beed Village, northen Khorasan Province, northeastern Iran)
SUZM 148, SUZM 151 (*n* = 2, 10 km S Sabzevar, Mehrshahi Village, northen Khorasan Province, northeastern Iran)
SUZM 92-93 (*n* = 2, 50 km W Sabzevar, Yosefabad Village, northen Khorasan Province, northeastern Iran)
SUZM 100-101 (*n* = 2, 80 km NW Sabzevar, Kahaneh Village, northen Khorasan Province, northeastern Iran)
SUZM 132 (*n* = 1, 90 km W Sabzevar, around Abasabad, northen Khorasan Province, northeastern Iran)
SUZM 324, SUZM 339 (*n* = 2, around Sabzevar, northen Khorasan Province, northeastern Iran)

Literature cited

Anderson SC. 1999. *The Lizards of Iran*. Society for the Study of Amphibians and Reptiles. Oxford, Ohio. 442 p.

Anderson RA, Vitt LJ. 1990. Sexual selection versus alternative causes of sexual dimorphism in Teiid lizards. *Oecologia* 84(2):145-157.

Berry JF, Shine R. 1980. Sexual size dimorphism and sexual selection in turtles (Order: Chelonia). *Oecologia* 44(2):185-191.

Best TL, Pfaffenberger GS. 1987. Age and sexual variation in diet of collared lizards (*Crotophytus collaris*). *Southwestern Naturalist* 32(4):415-426.

Brana F. 1996. Sexual dimorphism in lacertid lizards: Male head increase vs female abdomen increase? *Oikos* 75(3):511-523.

Bull CM, Pamula Y. 1996. Sexually dimorphic head size and reproductive success in the sleepy lizard *Tiliqua rugosa*. *Journal of Zoology* (London) 240(3):511-521.

Butler MA, Losos JB. 2002. Multivariate sexual dimorphism, sexual selection, and adaptation in greater Antillean anolis lizards. *Ecological Monographs* 72(4):541-559.

Castilla AM, Bauwens D, Van damme R, Verheyen R. 1989. Notes on the biology of the high altitude lizard *Lacerta bedriagae*. *Herpetological Journal* 1:400-403.

Censky EJ. 1995. Mating strategy and reproductive success in the teiid lizard, *Ameiva plei*. *Behaviour* 132(7-8):529-557.

Cooper WE Jr, Vitt LJ. 1989. Sexual dimorphism of head and body size in an Iguanid lizard: Paradoxical results. *The American Naturalist* 133(5):729-735.

Gibbons WJ, Lovich JE. 1990. Sexual dimorphism in turtles with emphasis on the slider turtle (*Trachemys scripta*). *Herpetological Monographs* 4:1-29.

Gvozdik L, Boukal M. 1998. Sexual dimorphism and intersexual food niche overlap in the sand lizard, *Lacerta agilis* Squamata, Lacertidae. *Folia Zoologica* 47(3):189-195.

Gvozdik L, Damme RV. 2003. Evolutionary maintenance of sexual dimorphism in head size in the lizard *Zootoca vivipara*: A test of two hypotheses. *Journal of Zoology* (London) 259(1):7-13.

Herrel A, Van Damme R, De Vree F. 1996. Sexual dimorphism of head size in *Podarcis hispanica atrata*: Testing the dietary divergence hypothesis by bite force analysis. *Netherlands Journal of Zoology* 46(3-4):253-262.

Herrel A, Spithoven R, Van Damme R, de Vree F. 2002. Sexual dimorphism of head size in *Gallotia galloti*: Testing the niche divergence hypothesis by functional analyses. *Functional Ecology* 13(3):289-297.

Huang WS. 1998. Sexual size dimorphism and microhabitat use of two sympatric lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis*, from the central highlands of Taiwan. *Zoological Studies* 37(4):302-308.

Kaliontzopoulou A, Carretero MA, Llorente GA. 2007. Multivariate and geometric morphometrics in the analysis of sexual dimorphism variation in *Podarcis* lizards. *Journal of Morphology* 268(2):152-165.

Kaliontzopoulou A, Carretero MA, Llorente GA. 2010. Sexual dimorphism in traits related to locomotion: Ontogenetic patterns of variation in *Podarcis* wall lizards. *Biological Journal of the Linnean Society* 99(3):530-543.

Kaliontzopoulou A, Carretero MA, Llorente GA. 2010. Intraspecific ecomorphological variation: Linear and geometric morphometrics reveal habitat-related patterns within *Podarcis bocagei* wall lizards. *Journal of Evolutionary Biology* 23(6):1234-1244.

Kapli P, Lymberakis P, Poulakakis N, Mantziou G, Parmakelis A, Mylonas M. 2008. Molecular phylogeny of three *Mesalina* (Reptilia: Lacertidae) species (*M. guttulata*, *M. brevirostris* and *M. bahaeldini*) from North Africa and the Middle East: Another case of paraphyly? *Molecular Phylogenetics and Evolution* 49(1):102-110.

Mccoy JK, Fox SE, Baird TA. 1994. Geographic variation in sexual dimorphism in the collared lizard, *Crotaphytus collaris* (Sauria: Crotaphytidae). *The Southwestern Naturalist* 39(4):328-335.

Molina-Borja M. 2003. Sexual dimorphism of *Gallotia atlantica atlantica* and *Gallotia atlantica mahoratae* (Lacertidae) from the eastern Canary Islands. *Journal of Herpetology* 37(4):769-772.

Molina-Borja M, Rodriguez-Dominguez MA. 2004. Evolution of biometric and life-history traits in lizards *Gallotia* from the Canary Islands. *Journal of Zoological Systematics and Evolutionary Research* 42:44-53.

Molina-Borja M, Padron-Fumero M, Al-Fonso-Martin MT. 1997. Intrapopulation variability in morphology, coloration, and body size in two races of the lacertid lizard, *Gallotia galloti*. *Journal of Herpetology* 31(4):499-507.

Molina-Borja M, Padron-Fumero M, Al-Fonso-Martin MT. 1998. Morphological and behavioural traits affecting the intensity and outcome of male contests in *Gallotia galloti galloti* (Family Lacertidae). *Ethology* 104(4):314-322.

Mouton FN, Van Wijk JH. 1993. Sexual dimorphism in cordylid lizards: A case study of the Drakensberg crag lizard, *Pseudocordylus melanotus*. *Canadian Journal of Zoology* 71(9):1715-1723.

Preest MR. 1994. Sexual size dimorphism and feeding energetics in *Anolis carolinensis*: Why do females take smaller prey than males? *Journal of Herpetology* 28(3):292-298.

Rastegar-Pouyani, N, Johari, M, and Rastegar-Pouyani, E. 2007. *Field Guide to the Reptiles of Iran. Volume 1: Lizards*. Second edition. Razi University Publishing, Iran. 296 p. (In Persian).

Roitberg ES. 2007. Variation in sexual size dimorphism within a widespread lizard species. In: *Sex, Size, and Gender Roles: Evolutionary Studies of Sexual Size Dimorphism*. Editors, Fairbrain DL, Blackenhorn WU, Székely T. Oxford University Press, New York, New York. 280 p. 143-217.

Schoener TW. 1966. The ecological significance of sexual dimorphism in size in the lizard *Arcolis conspersus*. *Science* 155:474-477.

Schoener TW. 1977. Competition and the niche. In: *Biology of the Reptilia, Volume 7: Ecology and Behaviour A*. Editors, Gans C, Tinkle DW. Academic Press, London, UK. 727 p. 35-136.

Shine R. 1988. The evolution of large body size in females: A critique of Darwin's "fecundity advantage" model. *The American Naturalist* 131(1):124-131.

Shine R. 1989. Ecological causes for the evolution of sexual dimorphism: A review of the evidence. *Quarterly Review of Biology* 64(4):419-461.

Shine R. 1990. Proximate determinants of sexual differences in adult body size. *The American Naturalist* 135(2):278-283.

Shine R. 1991. Intersexual dietary divergence and the evolution of sexual dimorphism in snakes. *The American Naturalist* 138(1):103-122.

Smith GR. 1996. Habitat use and its effect on body size distribution in a population of the tree lizard, *Urosaurus ornatus*. *Journal of Herpetology* 30(4):528-530.

Smith GR. 1998. Habitat-associated life history variation within a population of the striped plateau lizard, *Sceloporus virgatus*. *Acta Oecologica* 19(2):167-173.

Stamps JA. 1977. The relationship between resource competition, risk and aggression in a tropical territorial lizard. *Ecology* 58(2):349-358.

Stamps JA. 1983. Sexual selection, sexual dimorphism and territoriality. In: *Lizard Ecology: Studies of a Model Organism*. Editors, Huey RB, Pianka ER, Schoener TW. Harvard University Press, Cambridge, Massachusetts. 512 p. 169-204.

Stamps JA. 1993. Sexual size dimorphism in species with asymptotic growth after maturity. *Biological Journal of the Linnean Society* 50(2):123-145.

Stoliczka F. 1872. Notes on reptiles, collected by Surgeon F. Day in Sind. *Proceedings of the Asiatic Society of Bengal* 1872(May):85-92.

Trivers RL. 1976. Sexual selection and resource accruing abilities in *Anolis garmani*. *Evolution* 30(2):253-269.

Vial JL, Stewart JR. 1989. The manifestation and significance of sexual dimorphism in Anguid lizards: A case study of *Barisia monticola*. *Canadian Journal of Zoology* 67(1):68-72.

Vitt LJ. 1983. Reproduction and sexual dimorphism in the tropical Teiid lizard *Cnemidophorus ocellifer*. *Copeia* 1983(2):359-366.

Manuscript received: 17 January 2011
Accepted: 10 September 2011
Published: 29 December 2011

HAMZEH ORAIE is a Ph.D. student in the Department of Zoology at University of Tehran. He received his B.S. in biological sciences from the University of Razi, Kermanshah. He obtained his M.S. in animal biosystematics from the University of Razi, Kermanshah, where he researched the geographic variation of *Cyrtopodion scabrum* (Sauria: Gekkonidae) in Iran. His current research interests include molecular systematics and phylogeography of *Ophisops elegans* (Sauria: Lacertidae) in Iran.

AZAR KHOSRAVANI earned her B.S. in biological sciences from the University of Zabol. She received her M.S. in animal biosystematics from the University of Razi, Kermanshah, where she researched the geographic variation of *Mesalina watsonana* (Sauria: Lacertidae) in Iran. Currently she is a Ph.D. student in the Department of Biology at the University of Razi, Kermanshah. Her current research interests include molecular systematics and phylogeography of Lacertid lizards in Iran.

NASRULLAH RASTEGAR-POUYANI earned his B.S. in zoology from Razi University Kermanshah, Iran in 1986 and his M.S. in zoology from Tehran University, Tehran, Iran in 1991, where he studied herpetology with the agamids as the central object. He started his Ph.D. in Gothenburg University, Sweden in 1994 under the advisement of Professor Göran Nilson and graduated in 1999, working on taxonomy and biogeography of Iranian Plateau agamids with *Trapelus* as the main objective. His research interests include taxonomy and biogeography of the Iranian Plateau, the Middle East and central Asian herpetofauna.

SAYED KAMRAN GHOREISHI obtained B.Sc., M.Sc., and Ph.D. degrees in statistics from the University of Shahid Beheshti in Tehran, Iran. His main research interests are experimental design, multivariate analysis, and categorical data analysis and he has supervised several graduate students working in related areas of statistics and biostatistics. Ghoreishi has consulted and collaborated with various companies and organizations in Tehran, and has given a number of talks at international statistical conferences on association models in contingency tables. Presently, Ghoreishi is chairman of the Statistics Department at Qom University. He has twice received (consecutively) the university's award for top researcher.