Journal of Wildlife and Biodiversity 3(1): 40-51 (2019)

by Arak University, Iran (http://jwb.araku.ac.ir/)

DOI: 10.22120/jwb.2018.98610.1042

Research Article

Intraspecific variation within *Meriones persicus* (Rodentia: Gerbillinae) populations in the south central of Iran

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Received: 29 November 2018 / Revised: 17 December 2018 / Accepted: 21 December 2018 / Published online: 11 January 2019. Ministry of Sciences, Research and Technology, Arak University, Iran.

Abstract

In the present study intraspecific differences of the *Meriones persicus* populations were investigated based on traditional morphometry using the external and cranial characters in the south central of Iran. Totally 89 specimens of *M. persicus* were collected in three regions of the area (Geno protected area, Minab county, and Anjerk prohibited hunting area). Five external and 15 cranial characters were measured. In order to represent the significant differences in sizes observed among the three populations, the one-way ANOVA was applied. Our results demonstrated that nine out of 20 measured morphological characters of the populations in the study areas are significantly different ($P<0.05$). The results of MANOVA showed statistically significant differences among the populations of the three regions based on the morphometric characters ($F=15.968$, $P<0.001$; Wilk's $\Lambda = 0.039$, partial $\eta^2 = 0.802$). The principal component analysis (PCA) on the cranial parameters showed that two first components can justify 54.3% and 23.1% of total variance respectively. For the external parameters, the first two principal component axes (PC1 and PC2) explained 83.6% (55.2% and 28.4%, respectively) of the variation in size among the populations. Discriminant function analysis correctly classified the populations to regions with a high degree of reliability (97.8%). This study confirms the possibility of the presence of intraspecific variations among the populations of the three regions.

Keywords: geographic variation, MANOVA, morphometric, Persian jird.

Introduction

Phenotypic change trend along with a geographic range is known as a common phenomenon among some organisms (Monteiro *et al*. 2003, Ashrafzadeh *et al*. 2010, Tabatabaei Yazdi and Adriaens 2011). Ecological factors play vital roles during the speciation process because evolutionary lineages often occur in different environmental conditions (Martínez and Di Cola 2011). Therefore, the adaptation to the different subsets of the environmental factors drives evolutionary divergence (Wiens 2004). Totally, identification and description of the various patterns of the phenotypic characteristics within wildlife populations is essential.

The genus *Meriones* Illiger, 1811 can be regarded as one the most interesting taxon for exploring such phenotypic variations, adaptations and speciation mechanisms (Darvish 2009, Tabatabaei Yazdi and Adriaens 2011). The genus is widely distributed throughout the desert and semi-desert regions in North Africa, Middle East and Asia Minor (Chevret and Dobigny 2005, Musser and

Carleton 2005). Up to now, 17 species have been identified (Wilson and Reader 2005) from which eight species are distributed in Iran (Darvish 2009). The Persian jird (*Meriones persicus* Blanford 1875) was described based on its small suprameatal triangle and tympanic bulla which is smaller than the other *Meriones* members. The zygomatic plates in this species are less projected forwards and the external bony auditory meatus does not meet the posterior root of the zygoma (Darvish 2011, Yigit and Colak 1999).

Meriones persicus is found on the slopes of the mountain areas, talus and rocky outcrops (Darvish 2009, Shirani Bidabadi *et al*. 2009, Tabatabaei Yazdi and Adriaens 2011). This species is distributed throughout Iran, Transcaucasia, Turkey, Iraq, Turkmenistan, Afghanistan and Pakistan, in the altitudes as high as 3250 m.a.s.l. (Etemad 1978, YiĞit and Çolak 1999, Molur *et al*. 2005, Darvish *et al*. 2006, Karami *et al*. 2008) (Figure 1A). The Persian jird is distributed in almost all parts of the country (Darvish 2009), with the exception of the Hyrcanian forests along the southern shores of the Caspian Sea and the border of the Persian Gulf (Dianat *et al*. 2016). The type locality of the species is Kouhroud, 115 Km toward the north of Isfahan, Iran (Musser and Carleton 2005). The species is listed as Least Concern (LC) by IUCN (2016) (www.iucnredlist.org). In general, there are no major threats to this species, except some populations might be threatened by prolonged periods of drought (Molur *et al*. 2005).

An ideal description of the intraspecific variability is that it can play a crucial role in the systematic or taxonomic revisions (Bohoussou *et al.* 2014). The response of the intraspecific variation to the environmental conditions is vital for many processes driving at micro- and macroevolutionary scales (Kostikova *et al.* 2016). For example, cryptic speciation of the phylogenetically young clades depends on the genetic and phenotypic divergence which is present in a population (Evans *et al*. 2009). Furthermore, the intraspecific variation may influence the processes of interspecific competition, community composition, and the adaptation of species to novel environments (Urbanski *et al.* 2012; Kostikova *et al.* 2016). Several studies have been carried out focusing on the morphology and morphometry of the Persian jird in Iran (Darvish 2009, Darvish 2011, Tabatabaei Yazdi and Adriaens 2011, Tabatabaei Yazdi and Adriaens 2013, Dianat *et al*. 2016, Dianat *et al*. 2017). However, little is known about the morphometric peculiarities of the species in south central of Iran. The aim of this research was to study and compare the external and cranial characters of *M. persicus* within the range of three sites in the south central of Iran (Geno protected area, Minab county, and Anjerk prohibited hunting area).

Materials and methods

Study area

The present research was conducted throughout the three regions of the south central Iran including the Geno protected area, Minab county and the Anjerk prohibited hunting area (Figure 1B). The Geno protected area (GPA) covers an area of 42356 ha. The mean annual rainfall is 370mm for the elevations above 1550m and 257.5mm for the elevations below it. The mean annual temperature is 26.8˚c up to latitude of 2000m. The second region, Minab County (MC) is located along Oman Sea coastline. The elevations vary as high as 2000m above sea level. The maximum annual temperature is around 33.2˚c while the minimum stands at 20.5˚c. The mean annual rainfall is estimated at about 253mm. Anjerk prohibited hunting area (APHA) covers almost 23000 ha and its highest point is at 2809 m.a.s.l. The mean annual temperature and rainfall is 14.2˚c and 257- 281mm respectively.

Sampling

In total 89 specimens were collected using live trapping method from the study areas (33, 49 and 7 specimens from GPA, APHA and MC respectively). Collected specimens were

identified using Abu Baker and Amr (2003), Harrison and Bates (1991) and Corbet (1978) identification keys. Specimens were classified to the mature and immature age groups based on their dental and external sexual characteristics, and merely the mature ones were entered in the statistical analysis (Momenzadeh *et al*. 2001, Moradi and Kivanc 2003, Mirshamsi *et al*. 2007).

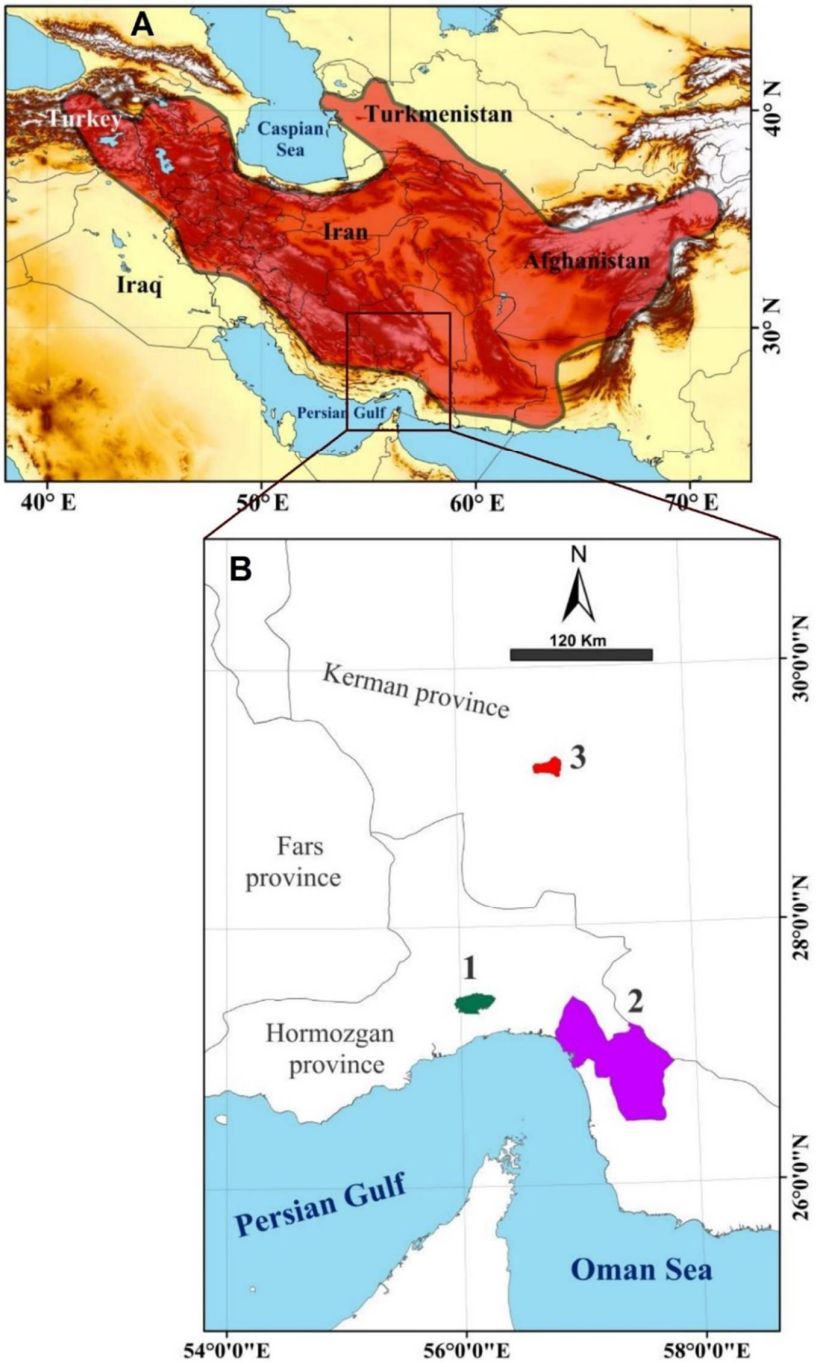

Figure 1. A: The approximate current (dark shade) distribution of the species throughout the world (IUCN 2016); B: Geographical distribution of the sampling sites including 1) Geno protected area, 2) Minab county, and 3) Anjerk prohibited hunting area.

External and cranial measurements

External characteristics: Head and body length (HBL), Tail length (TL), Ear length (EL), Hind foot length (HFL), Weight (gr).

Cranial characteristics: Occipito-nasal length (OL), Condylobasal length (CL), Zygomatic width (ZW), Lacrimal width (LW), Cranial width (CW), Length of Nasal (LN), Length of Diastema (LD), Length of Palate Front (LPF), Length of tympanic bullae (LTB), Width of tympanic bullae (WTB), Maxillary toothrow height (UCH), Mandibular toothrow height (LCH), Height of skull (HS), Width of rostrum (WR), Length of Mandible (LM) (Moradi and Kivanc 2003, Ashrafzadeh *et al*. 2007, Mirshamsi *et al*. 2007, Khaje and Meshkani 2010, Ghadirian *et al*. 2011).

Statistical analysis

Kolmogorov-Smirnov and Levene's test was used to assess data distribution normality and their homogeneity of variances respectively. The descriptive statistics were also obtained for all the external and cranial characters. We used One-Way Analysis of Variance (ANOVA) to determine significant differences among the groups. Morphometric characters were investigated for geographic variation in size among three regions using multivariate analysis of variance (MANOVA, Wilks's likelihood ratio method—Baker *et al*. 1978). Principle component analysis (PCA) was applied in order to visualize the overall differences using the external and cranial characters. Additionally, the Discriminant Function Analysis (DFA) was performed to confirm separation of populations and reliability of the provided classification values based on the cranial characters. All the analyses of this research were performed using SPSS 24 software.

Results

The Persian Jird was active throughout the year in GPA and was sampled throughout the year. A decrease in collected specimens in late winter (considering the same sampling activity throughout the year) may demonstrate the lower density of the species in this season. In GPA, the species was only sampled in the mountainous habitats from the latitude of 1000 to 2300 m where was usually could be found in the valleys, rocky areas, stone fences and around mountainous residential areas. In MC, it was sampled in rocky habitats and valleys as high as 1000m and as low as 150m and in APHA from 2159m to 2334m. Figure 2 shows two Persian Jirds from MC. The descriptive statistics of the measurements resulted from *M. persicus* populations living in three mentioned regions are represented in Table (1). The HBL, EL, OL, ZW, LW, CW, LN and WTB are in average greater in the specimens collected from GPA than the other regions. The TL, HFL, CL, LPF, UCH, LCH and LM characters are in average greater in the specimens collected from APHA than the two other areas. Mean weight is greater in MC specimens than specimens from GPA. The LD, LTB, HS and WR characters are also in average greater in MC specimens than the two other areas. The results of One- Way ANOVA demonstrated that there are significant differences between HBL, TL and EL of three populations ($p<0.01$) (Figure 3). But considering HFL, no significant difference was recognized among the populations ($p>0.05$). According to Duncan's test, populations of GPA and APHA show significant differences in HBL ($p<0.01$). In this respect, MC specimens are not significantly different from any of other two areas ($p>0.05$), but TL is significantly smaller in comparison to other two areas ($p<0.05$). The GPA and MC specimens are significantly different in EL ($p<0.05$); but the APHA specimens are not significantly different from the other two regions ($p>0.05$).

Table 1. The descriptive statistics of 20 measured characters (mm) in the mature individuals of *M. persicus* from the south central parts of Iran. (APHA: Anjerk prohibited hunting area; GPA: Geno protected area; MC: Minab county)

	GPA					APHA					MC				
cha	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
HBL	33	140.15	7.760	127.3	157.8	49	122.73	10.502	100	147	7	136.02	8.035	126.4	148.5
TL	33	162.27	7.097	148.2	176.1	49	166.04	13.686	129	195	7	146.54	6.939	135.7	153.4
HFL	33	36.80	0.392	36.3	37.6	49	38.58	1.763	35	42	7	34.76	1.276	33.2	36.6
EL	33	21.39	0.677	20.1	22.4	49	20.65	1.771	17	24	7	20.34	1.992	18.3	23.4
W(gr)	33	80.21	13.290	56.52	103.82	-	-	-	-	-	7	96.84	8.032	87.64	106.36
OL	33	39.43	1.272	37.2	41.7	42	38.96	2.365	31.94	47.52	6	37.88	0.301	37.55	38.14
CL	33	35.51	1.306	33.2	38.3	42	36.40	1.652	32.27	39	6	35.16	0.735	34.42	35.89
ZW	33	20.30	0.970	18.5	21.9	42	19.75	0.931	18.37	21.67	6	20.20	0.327	19.94	20.57
LW	33	6.61	0.315	6.1	7.2	42	6.44	0.384	5.26	7.26	6	6.26	0.462	5.75	6.65
CW	33	17.76	0.807	16	18.9	42	16.92	0.468	15.96	18.14	6	15.85	1.126	14.55	16.5
LN	33	17.26	0.304	16.5	17.8	42	15.64	0.921	14.28	17.32	6	15.60	1.317	14.8	17.12
LD	33	10.28	0.145	10	10.6	42	10.38	0.507	9.37	11.45	6	10.74	1.240	9.52	12
LPF	33	7.34	0.573	6.5	8.4	42	7.39	0.654	5.67	9.06	6	6.76	0.521	6.26	7.3
LTB	33	14.01	0.613	12.3	14.7	42	12.68	1.317	11.23	19.84	6	14.71	1.140	13.4	15.44
WTB	33	10.74	0.466	12.3	11.5	42	9.55	0.580	8.19	11.53	6	9.83	0.562	9.38	10.46
UCH	33	5.48	0.213	5.1	5.8	42	5.58	0.353	4.97	6.8	6	5.37	0.266	5.09	5.62
LCH	33	5.26	0.214	4.8	5.7	42	5.42	0.408	4.58	6.06	6	5.20	0.100	5.1	5.3
HS	33	14.77	0.364	14.1	15.6	42	14.45	0.889	13.51	19.37	6	15.59	1.327	14.12	16.7
WR	33	4.18	0.208	3.70	4.6	42	4.52	0.342	3.70	5.07	6	4.84	0.316	4.60	5.2
LM	33	19.40	0.910	17.7	20.7	42	20.31	0.877	18.45	21.95	6	19.86	0.465	19.4	20.33

Figure 2. Persian Jirds from Minab county, Iran.

The results of the One-Way ANOVA demonstrated that among the cranial measurements, the CW, HS, LN, LTB, WTB, and WR are significantly different among the populations (p<0.01) (Figure 4). Accordingly, the OL, CL, LCH, LD, LM, LPF, LW, UCH, and ZW are not significantly different (p >0.05). The result of Duncan's test showed that CW and WR are significantly different in the three regions (p <0.01). Our results indicated that the specimens collected from MC are significantly greater in HS than those of two other areas (p<0.05). The GPA specimens are significantly greater in LN than the others (p<0.01). Duncan's test, indicate that the specimens from APHA are significantly smaller than the others with regard to the LTB parameter (p<0.01) while the GPA specimens are significantly greater in WTB than the others (p<0.01).

The results of MANOVA also confirmed statistically significant difference among the populations (F=15.968, p<0.001; Wilk's Λ = 0.039, partial η^2 = 0.802). The principal component analysis (PCA) of cranial indicated that the first principal component accounts for 54.3% of total variance and the second component accounts for 23.1% variance (Figure 5). The Occipito-nasal length has 55%

and 3.9% influences on the components 1 and 2 respectively. The Zygomatic width has 53% and 11% influence on the components 1 and 2 and the 49 and 19 percent for Condylobasal length. Based on the PCA of external data, the first principal component accounts for 55.2% of total variance and the second component accounts for 28.4% variance (Figure 6). The tail length has 71% influences on component 1 and 6.9% on component 2. The head and body length has 67.4% influence on component 1 and 7.1% on component 2. The separation of populations was approved by the discriminant function analysis (DFA) gaining a high degree of validity (97.8 %) (Table 2, Figure 7).

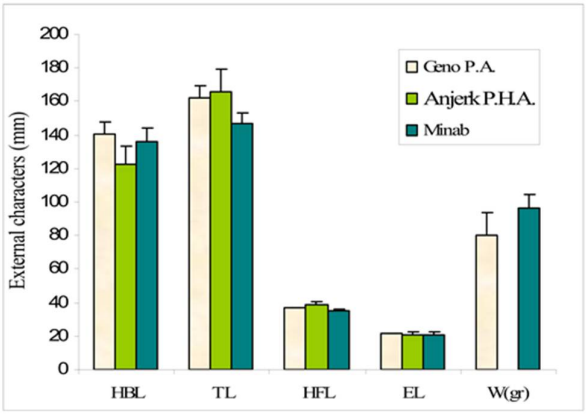

Figure 3. External characters comparison among the three populations of the *M. persicus* from the south central areas of Iran.

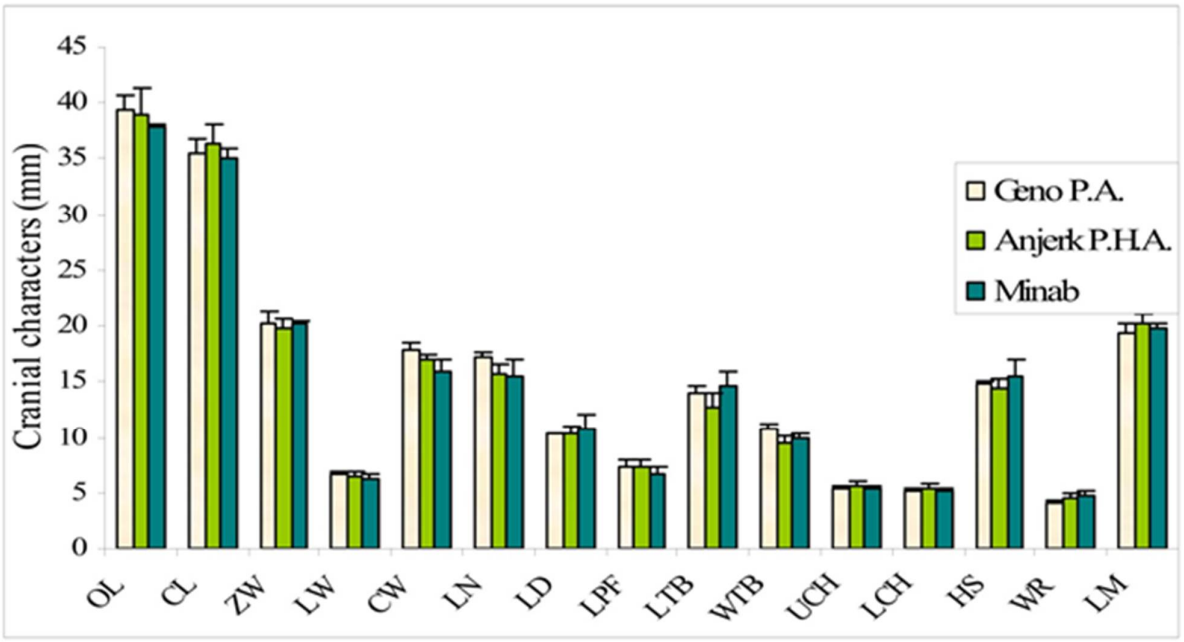

Figure 4. Comparison of the cranial characters among the *M. persicus* populations from the southern central of Iran.

Table 2. Self-classification rates from the discriminant analysis of the morphological data. Our results indicate percent of individuals correctly classified is on the diagonal. Our results showed that 97.8% of original grouped cases has been correctly classified. (APHA: Anjerk prohibited hunting area; GPA: Geno protected area; MC: Minab county)

Population	Predicted Group Membership		
	APHA	GPA	MC
APHA	97.4	.0	2.6
GPA	.0	100.0	.0
MC	.0	.0	100.0

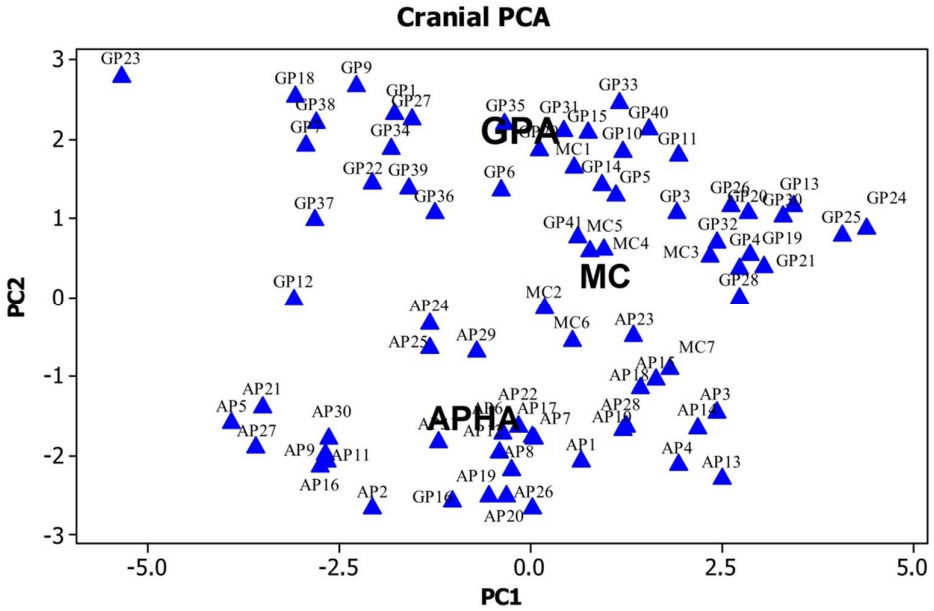

Figure 5. Principal component analysis of cranial size related variables. Acronymes are: (GPA) and (GP): Geno protected area; (APHA) and (AP): Anjerk prohibited hunting area, (MC): Minab county.

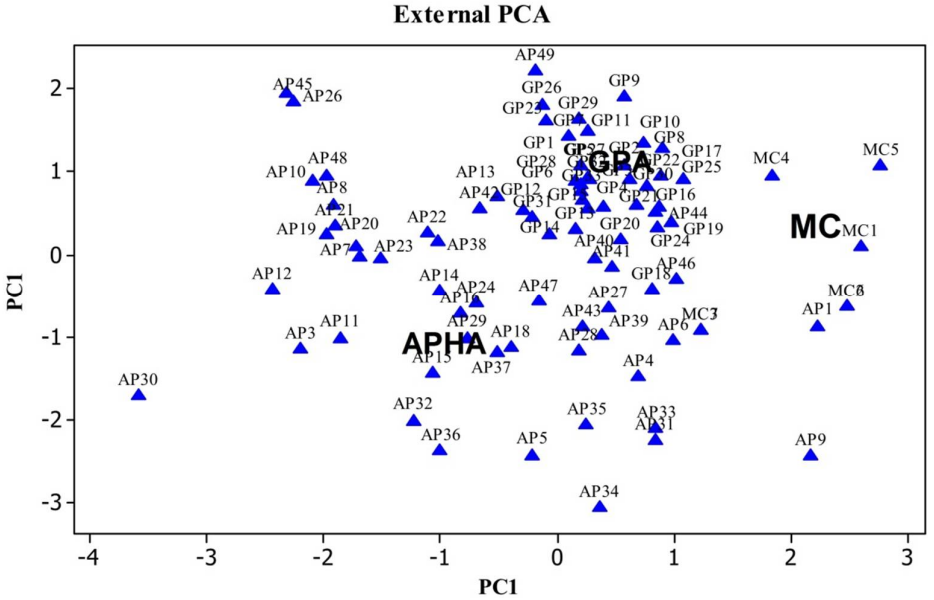

Figure 6. Principal component analysis of external size variables. Acronymes are (GPA) and (GP): Geno protected area; (APHA) and (AP): Anjerk prohibited hunting area, (MC): Minab county.

Discussion

The Persian Jird is a terrestrial, nocturnal, gregarious and almost omnivorous rodent that usually lives in dry rocky mountainous regions and the rock fences between the high agricultural fields where constitute their favourite habitat (Molur *et al*. 2005). According to Brohi and Fakhri (2006), Molur *et al*. (2005), Shenbrot *et al*. (2002) and YiĞit and Colak (1999), this species prefers dry, rocky and mountainous habitats. At Geno protected area (GPA), it was only captured in the mountainous habitats as high as 1000m and according to Lay (1967), it coexists with *Calomyscus bailwardi*; but in Minab county (MC) it was also found as low as 150m. We could not find *M. lybicus* throughout the *M.*

persicus habitats in GPA, but they shared the same habitat in Anjerk prohibited hunting area (APHA). However, in APHA, *M. lybicus* was mostly captured in the flat and low lands and farmlands as well while *M. persicus* was mostly captured in the higher mountainous habitats.

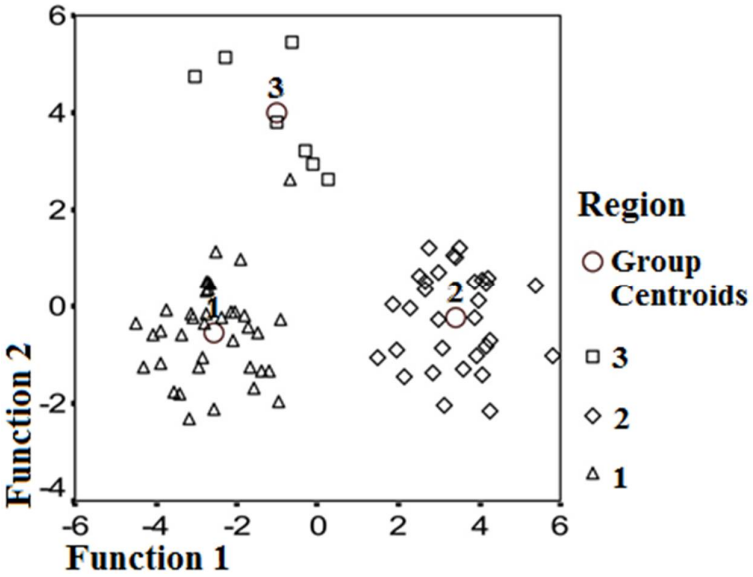

Figure 7. Ordination of the three populations of the species based on the discriminant functions1 and 2. The most part of the variances were justified by two first PCs (1= Anjerk prohibited hunting area; 2= Geno protected area; 3= Minab county).

The Persian Jird lives in different geoclimatical conditions and disclose the particular patterns of morphological characteristics related to its environmental conditions of their local habitat (Tabatabaei Yazdi and Adriaens 2011). For example, Tabatabaei Yazdi and Adriaens (2011) showed the individuals from higher and colder areas (e.g. Zagros Mountains, Iran) have a relatively broader zygomatic plate and a more convex zygomatic arch. Variations of the cranial and external characters in the Persian Jird reflect the different environmental conditions spread over the range of this species (Tabatabaei Yazdi and Adriaens 2011).

The identification of geographic variation of body and skull sizes is important for studies on systematics and taxonomy of small mammals (Quintela *et al*. 2016). The external and cranial characters can be regarded having fundamental importance in determination and classification of the Jirds (Darvish 2009). Based on the conducted researches, in comparison to the specimens captured in Turkey (YiĞit and Çolak 1999), the mean measurements of *M. persicus* in these three regions were mostly smaller. Also, the calculated mean measurements of all these three regions were mostly equal to or smaller than the specimens collected from Deh-Sorkh region in Isfahan province, Central Iran (Shirani Bidabadi *et al*. 2009). But, the mean length of tympanic in specimens of the three studied regions were greater (about 13.80 mm) than this measurement in the specimens examined from Turkey (12.66 mm) (Yigit and Çolak 1999) and Deh-Sorkh (11.44mm). The inflated tympanic bulla is among the most convergent desert adaptive structures in mammals (Ojeda *et al*. 1999, Francescoli *et al*. 2012, Alhajeri 2014). It seems the bulla hypertrophy increases the auditory sensitivity and is probably useful for desert species against predation, particularly in open habitats (Liao *et al*. 2007, Tabatabaei Yazdi and Adriaens 2011). This pattern has previously been reported by other authors (e.g. Vaughan *et al*. 2000, Monteiro *et al*. 2003,

Darvish *et al*. 2009, Darvish *et al*. 2011, Francescoli *et al*. 2012). Tabatabaei Yazdi and Adriaens (2011) observed the existence of relatively larger tympanic in the populations of the Persian Jird from areas with lower rainfall than north western localities. Previous studies (Momtazi *et al*. 2008, Tabatabaei Yazdi and Adriaens 2011), in agreement with our results, showed the specimens from the Geno protected area (GPA) have the most bulla inflation in comparison with the other studied populations from northern areas.

The mean weight of specimens from Deh-Sorkh (135gr) (Shirani Bidabadi *et al*. 2009) and Turkey (107gr) (YiĞit and Çolak 1999) are bigger than the mean weight of the specimens examined from GPA (80.211gr) and MC (96.84gr). The mean tail length and mean length of head and body is 136mm and 168mm respectively for specimens collected from Deh-Sorkh, while these measurements are respectively 162.27mm and 140.155mm for specimens collected from GPA, 166.04mm and 122.735mm for specimens from APHA specimens and 146.54mm and 136.02mm for specimens from MC. Based on Shirani Bidabadi *et al*. (2009), the mean tail length (TL) is lesser than the mean head and body length (HBL); but in these three studied regions, the results are exactly reverse. Just the same as the present study, for specimens collected from Turkey (YiĞit and Çolak 1999), the mean tail length (169.66mm) is more than the mean head and body length (159mm). According to Etemad (1978), the mean tail length is more than the mean head and body length of this species. But it should be mentioned that some studied showed that Persian Jirds from Isfahan and Qom provinces, Central Iran, had the tail length smaller than or equal to the head and body length (Etemad 1978).

Conclusion

Findings of the present study (MANOVA, PCA, and DFA) confirm the presence of significant morphological differences among the populations of different investigated regions. Statistical analysis of this study indicated that the external and cranial characters HBL, TL, EL, CW, HS, LN, LTB, WTB, and WR are significantly different in the three populations ($p<0.01$). A considerable observation is that the mean length of head and body (LBH) in specimens from GPA ($p<0.01$) and specimens from MC ($p>0.05$) are more than the specimens from APHA, while the TL is longer in specimens from APHA than the specimens collected from MC ($p<0.05$) and GPA ($p>0.05$). The results of discriminant function analysis demonstrated that with regard to the cranial data, it is possible to discriminate among the studied populations.

Acknowledgements

This research was supported by Vice Chancellor for Research of Shahrekord University (Shahrekord, Iran) and Shahid Bahonar University of Kerman (Kerman, Iran), which is greatly appreciated.

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