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Investigation of climatic effects on the shape and volume of tympanic bulla of *Meriones libycus* and *M. persicus* (Muridae: Rodentia) from Northeastern Iran: An evolutionary approach

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The jirds, *Meriones persicus* and *M. libycus* are two widespread species in Iran. *Meriones libycus* can be found in low lands of deserts and semi desert areas, but *Meriones persicus* in high rocky regions of Khorasan. In this research 190 skulls belonging to *Meriones persicus* and *Meriones libycus* of northeast of Iran were at first identified on the basis of morphologic characters, and then were divided regarding wearing quantity of molar teeth surfaces into four age classes in which 20 quantitative cranial and dentary characters were measured. The results show that five characters including Infraorbital thickness, mastoid length, zygomatic width, first mandibular molar length (M/1), and lower cheek teeth length from alveole in different age classes are not significantly different, and can be applied in identification of specimens relating to each of the two species in all age classes. This study also shows that the ratio of bullar length to the skull length in these two species is basically different and in *M. libycus* is closely related to environmental conditions like humidity and population density. This character can be used as intraspecific population density coefficient about desert and semi desert species and it is important for basic studies relating to adaptation, field studies, and harmful rodents controls.

Key words: *M. libycus*, *M. persicus*, tympanic bulla, climatic effects

INTRODUCTION

Jirds are very widespread in desert and semi desert areas of North Africa, Middle East, and Central Asia. Dispersal range of *Meriones persicus* is Iran Plateau, beyond Caucasia, and Iraq (Vinogradov and Argyropulo, 1941), and dispersal range of *Meriones libycus* is North Africa, North Arabia, Iraq, Iran, Afghanistan, and Central Asia(Corbet, 1978). These two jirds are among widely dispersed species in whole parts of Iran, and Khorasan. *M. libycus* can be found in low land desert and semi desert areas, between 700 to 1500 meters and *M. persicus* in high and rocky elevations up to 3500 meters, like in the protected area of Tandooreh. Besides these two species, other species of this genus are locally distributed in Khorasan with very low population density. For example, *Meriones meridianus* is found

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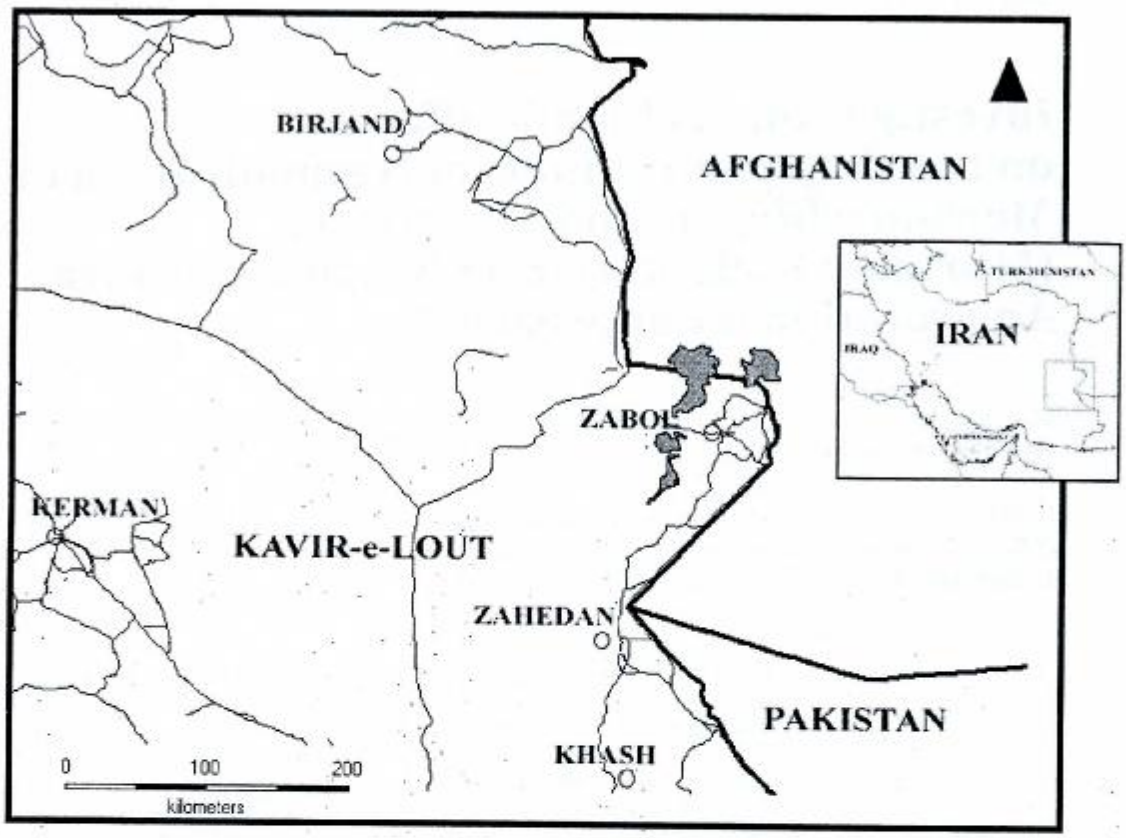

FIG.1. - Collection localities at northeast and eastern parts of Iran.

in Sarakhs and southeastern Sabzevar deserts, and *M. crassus* in low lands and very hot deserts of western Bajestan.

In the genus *Meriones* ears are middle- sized, the tympanic bulla is large, and its mastoid part is much hypertrophied, the suprameatal triangle is big and distinct in posterior part of the skull (Ellerman, 1941). The upper incisor teeth have one median groove, and the molars are hypsodont. *Meriones persicus* of northern Khorasan have been studied by Goodwin (1939), Lay (1967), Khosravi (1996), and *M. libycus* of this area by Heptner (1975), Goodwin (1939), Lay (1967), Khosravi (1996). But jirds of center and south of Khorasan have not been studied biosystematically, and it's the same about the relationship between age and morphologic variations of dental characters and cranial dimensions. These two species are different from each other from the point of view of topography. Although in mammals the length of tympanic bulla is usually less than nearly 30 percent of the skull length (Petter, 1968), in some rodents like jirds the bullar volume increases considerably between 30 to 60 percent (Vinogradov and Argyropulo, 1964; Roberts, 1997; Petter, 1961), and the bullar volume can be applied as environmental dryness coefficient (Chetboun and Tchernov, 1983). The results showed there is a basic difference between the two species from the point of view of bullar shape and volume. In this research besides studying *M. persicus* and *M. libycus*, adaptive significance of their characters, and the effects of ecological factors on the tympanic bulla sizes are considered.

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MATERIAL AND METHODS

In this study, a total of 190 skulls belongs to the rodents collection of Zoological Museum of Ferdowsi University of Mashhad (ZMFUM), were studied (see fig.1 for details of sampling locality). For morphometric studies 20 cranial and dentary characters were measured and presented in table 1 (see Fig.s 2 and 3 for details);

For age determination molar teeth studying were carried out under Nikon stereomicroscope equipped with a camera lucida. Quantitative statistical analysis of the data was done by SPSS software. The minimum, the maximum, and the variance of the studied characters like bullar volume in adult specimens of *M. libycus* were measured by ANOVA statistical method (table 3).

For investigating about relationship between bullar volume and environmental conditions and population density, bullar volume was measured using fallowing formula (Chaworth-Musters and Ellerman, 1947) (Fig. 4):

$$\text{Bullar volume} = \frac{\text{Length} \times \text{width} \times \text{height} \times 10^{-3}}{6}$$

The measurements were carried out using pointed calipers with a 0.05 millimeter precision.

RESULTS

Regarding wearing quantity of teeth surfaces and appearing of the third molars of upper and lower jaws, the specimens were divided into four age classes of new born, juvenile, adult, and old(Fig. 5) (Yigit *et al*, 1999).

The new born age class with approximate age of 30 days can be identified through the absence of the third mandibular and maxillary molars and the lateral grooves of mandibular and maxillary molars run into the gums. In the second age class with approximate age of 45 to 50 days, the third mandibular and maxillary molars appears out from alveolar foramen and crown and enameled surface of the molars are completely distinct, and the lateral grooves of the molars extends downwards about half of crown length. In the third age class, adults with approximate age of 6 to 16 months, cutting surface of the teeth were widened, and the lateral grooves of mandibular and maxillary molars are about half length of crown length of the teeth.

In the fourth age class, with the age of more than 16 months wearing or cutting surface of the teeth have been widened and approximately without enamel, and the lateral grooves of upper and lower molars are very short about the edges of the teeth. The study shows that as age increases in jirds, crown length decreases. In table 2 the means and standard errors for invesugated characters are presented.

The results of analysis of variance show that just five characters out of 20 studied characters between the two species *M. persicus* and *M. libycus* were significantly different. Fig. 6 shows that as examples, From incisor alveolar distance to the point between articular and angular processes(V), increase with age, while two characters(Fig. 7), Zygomatic width (ZW) (a diagram), and Infraorbital thickness (IOT) diameter mean (b diagram) are constant when age increases.

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TABLE 1.- description of measured cranial and dentary characters in *M. libycus* and *M. persicus*

Row	Variable	Abbriviations
1	Bullar length	BL
2	Upper cheek teeth row length from alveoli	CRA
3	Bullar height	BH
4	Bullar width (from meatus to paraoccipital process)	BWT 1
5	Apophyse length	AL
6	Base of suprameatal triangle of tympanic bulla	LTS
7	Length of anterior part of the first molar tooth to the deepest part between articular and angular	MAL
8	Mental foramen to the deepest part between articular and angular	MEAL
9	Mental-angular length	MAnL
10	Bullar width (from meatus to basioccipital process)	BWT 2
11	Mastoid length	MASL
12	Distance from incisor alveolar distance to the point between articular and angular processes	V
13	The first mandibular molar length	M/1 L
14	Height of suprameatal triangle of tympanic bulla	HRS
15	Intraorbital thickness	IOT
16	Zygomatic width	ZW
17	Mandibular length	ML
18	Lower cheek teeth row length from alveole	LCA
19	Upper cheek teeth row length from crown	CRC
20	Interorbital width	IOW

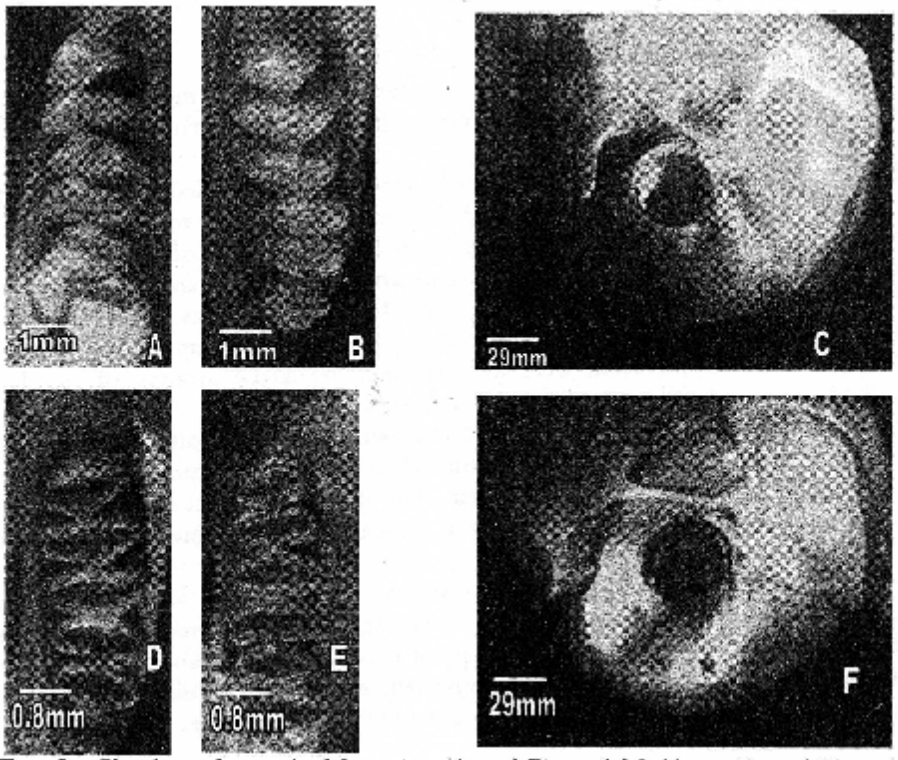

FIG. 2.- Cheek teeth row in *M. persicus* (A and B), and *M. libycus* (D and E) and tympanic bullas of *M. persicus* (C), and *M. libycus* (F)

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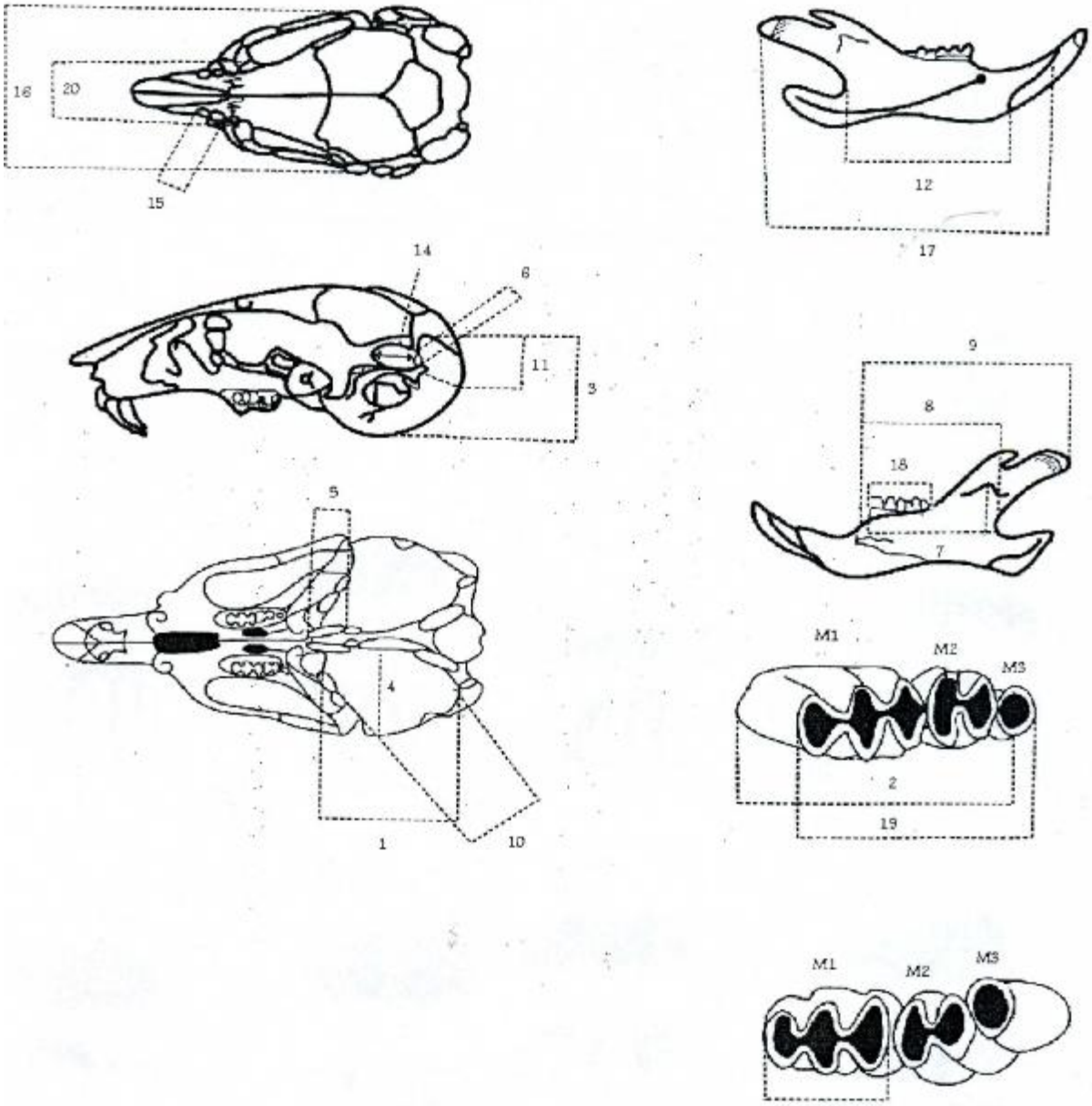

FIG. 3.- Measured parameters on the cranium and molars of *Meriones* (Characters shown by numbers were described in materials and methods).

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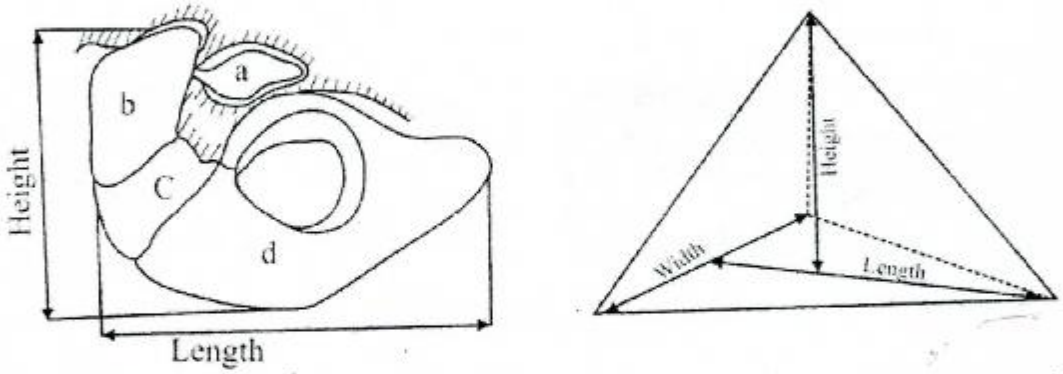

FIG. 4.- (Left): Tympanic bulla shape, a: suprameatal triangle (Petter, 1968) or mastoid anterior part (Lay, 1972), b and c: upper and lower posterior mastoid (Lay, 1972), d: sympatic (Lay, 1972) (Right): how to measure characters of tympanic bulla in *M. libycus*

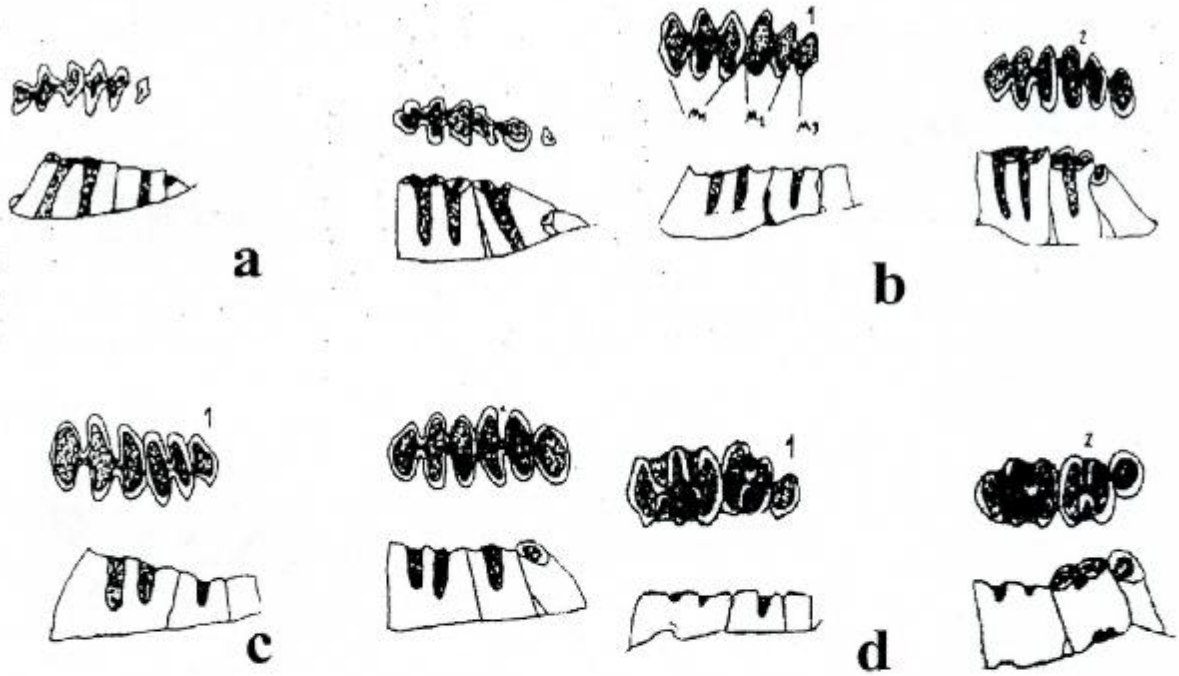

FIG. 5.- Age class determination of the studied Jirds on the basis of wearing quantity of molar teeth in four groups of a) new born, b) juvenile, c) adult, and d) old specimens.

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TABLE 2.- means and standard errors of 20 measured cranial characters in *M. libycus* and *M. persicus*

Characters	*Meriones libycus*			*Meriones persicus*		
	N	mean	Standard error	N	mean	Standard error
BL	130	15.04	1.12	33	14.02	1.09
CRA	130	6.30	0.55	34	6.84	0.5
BH	123	12.71	1.07	33	11.96	1.32
BWP(1)	117	10.27	1.15	32	9.065	0.58
AL	126	6.77	0.66	34	7.49	0.83
UTS	123	2.81	0.41	33	3.12	0.47
MAL	132	9.07	0.80	34	9.88	0.96
MEAL	132	9.82	0.85	34	10.43	0.85
MAnL	129	13.15	1.29	34	14.12	1.58
BWP(2)	126	11.53	1.09	33	9.79	1.01
MASL	125	6.17	0.52	33	5.76	0.51
V	132	11.68	0.97	34	12.95	2.05
M/L	132	2.54	0.27	34	2.77	0.23
IIRS	123	4.64	0.53	33	5.45	0.69
IOT	128	2.09	0.30	34	2.29	0.38
ZW	123	17.66	1.73	31	17.15	2.11
ML	131	19.04	1.60	34	20.16	1.63
LCA	131	6.55	0.78	34	7.14	1.13
CRC	129	4.68	0.44	34	4.99	0.39
IOW	126	6.84	0.47	33	6.43	0.42

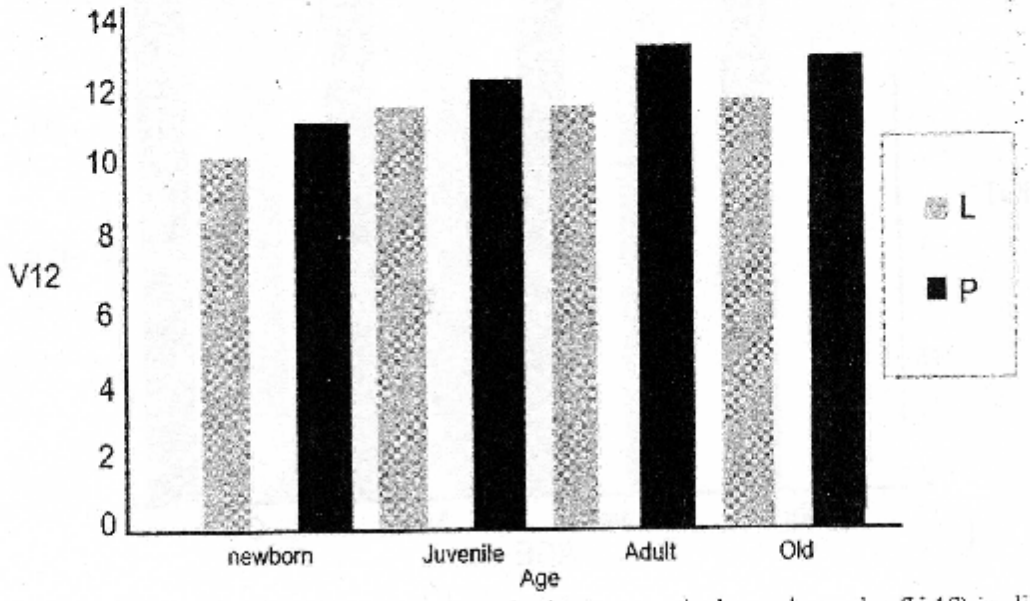

FIG. 6.-From incisor alveolar distance to the point between articular and angular (V 12) in different age classes; L: *M. libycus* P: *M. persicus*

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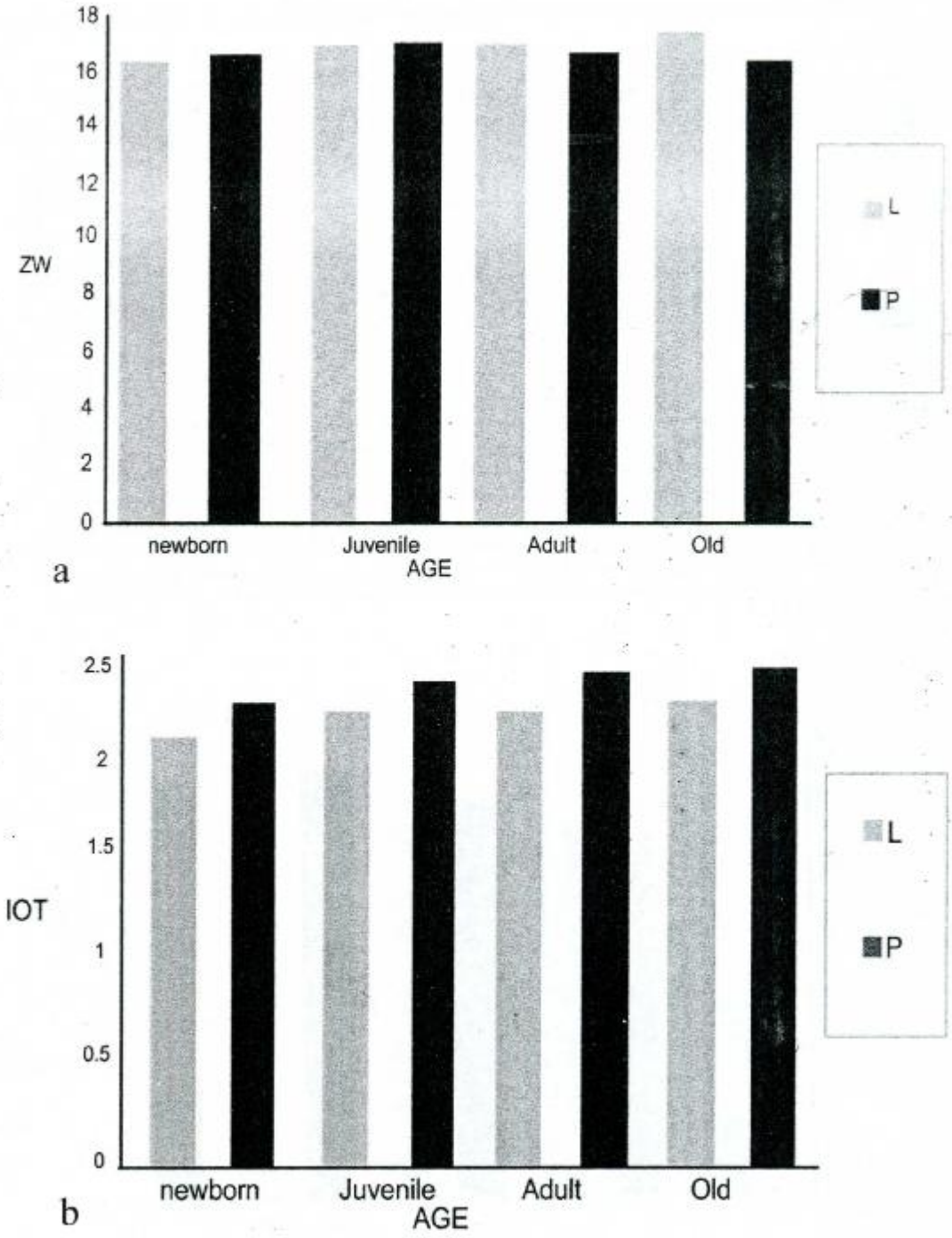

FIG. 7.- a) Zygomatic width (ZW), and b) Infraorbital thickness (IOT) diameter in different age classes; L: *M. libycus* P: *M. persicus*

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Therefore, Infraorbital thickness, diameter mean, Mastoid Length, Zygomatic Width, Lower first molar length, and lower cheek teeth row length from alveole, Zygomatic Width in different age classes show no significant differences. Bullar volume measurements in adult specimens of *M. libycus* of Birjand show that the volume varies between minimum of 0.31, and maximum of 0.54, which can orderly, be observed in Tabas Masina and Bojd of Birjand. The maximum variance of bullar volume is observed in Tabas Masina (table 3).

TABLE 3.- Sampling localities, maximum, minimum and variance of bullar volume in adult specimens of *M. libycus* of Birjand on the basis of population density in the region.

Row	Town	village	maximum	minimum	variance
1	Birjand	Ahvaz	0.40	0.37	0.00045
2		Bojd	0.54	0.40	0.0029
3		Boshgaze	0.40	0.37	0.00045
4		Burang	0.45	0.38	0.00053
5		Tabas Masina	0.48	0.31	0.0054
6		Mansorabad	0.41	0.35	0.0024

Thus, among one species there are considerable differences from the point of view of distribution. Adult specimens which live in higher elevations of Ahvaz, Boshgaze, Burang, Mansoorabad and Bojd, because of better climatic conditions have smaller bullas, while specimens which live in low elevations, have eventually bigger tympanic bullas. The variance quantity shows the difference between the minimum and maximum volume of the bulla in the region, so, mutually the distance between localized studied specimens from each other increases. Specimens of *M. libycus* reveal two important points: more dryness and less population density of Tabas Masina. In this study frequency of male specimens were significantly more than female ones in both of the species *M. persicus* and *M. libycus*.

For *M. libycus* frequency of male was 86%, while it was 14% for the females. This value for *M. persicus* was 82% for males and 18% for females. *M. libycus* was observed in low lands with hard sediments (clay) in Sarakhs and Bajestan, at 1950 meters altitude in Mian of Birjand, while *M. persicus* is found in Babaneisan Mountains of Tandooreh. Compared with northern Khorasan provinces, in southern regions *M. libycus* is found in higher elevations because of the heat and dry climate.

DISCUSSION

This study showed that in the two species molar teeth, unlike the incisors, are not hypsodont. Among cranial characters (table 2), five characters out of 20 are just significantly different in the four age classes, at the level of 5%. As cranial characters show allometric growth, finding characters which are constant and similar during ontogeny in both species is very valuable in biosystematic studies. These characters which are constant in different age classes are as fallows: Infraorbital thickness, Mastoid length, Zygomatic width, first mandibular molar length, and lower cheek teeth row length from alveole.

Bullar volume and the variance increase is a sign of intra population variation of *M. libycus* in Southern Khorasan which introduce local populations or demes. Demes distributions are on the basis of living facilities of *M. libycus* in the distribution area, like feeding and reproduction (Darvish, 1992). Climatic factors like dryness, heat and decrease in food sources produce local adaptive responses. The species survival relates to reproduction, conservation and generation continuity, so that adequate reproduction ensures the species survival. One of the main factors of *M. libycus*

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continuity in desert and semi-desert areas is the bullar volume, so that they can hear sounds from long distances. For this reason a strong adaptive pressure will be imposed on the members of each deme in a local population, and the result is the selection of the members with larger tympanic bullas in desert and semi desert areas. Climatic factors like the weather dryness increase are together with density decrease, on the one hand, and bullar volume increase, on the other hand. Tympanic bulla acts like a resonance box, and its role is increasing the ability to receive sounds. So, increasing the bullar volume can be considered as an adaptive character. So, in low density regions the tympanic bulla is very large and the members of such populations can find home and each other again, after keeping out of home for kilometers. Actually, as pointed out before, specimens with smaller bullas are not favored by natural selection throughout time, and the specimens with hypertrophied tympanic bullas are the most characterized ones. Individuals of one species, at the center of distribution, show more densities, and have smaller tympanic bullas. On the basis of founder effect, a number of marginal populations, especially the most hermitic ones, are the result of reproduction of a fertilized female or a small group of founders, which only contain a very small proportion of whole genetic variation of the species. In such conditions there will be a strong selection on a restricted number of genotypes resulting from founder effect. Central populations are located in a region which is the most competent ecologically, so they tend to cause large colonies whose dimensions are just controlled by the factors depending on density. In the end low density colonies which are formed around the range of the species tolerance, are basically selected for adaptation with density-free factors like the temperature, dryness and food shortage (Khosravi, and Darvish, 1999). Our knowledge about bullar volume in each region can be used by other researchers for obtaining information about density quantity, and investment for rodents control (Momenzadeh, 2001).

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