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Morphological study and comparison of western and eastern goitered gazelle(*Gazella subgutturosa*:Gueldenstaedt, 1780) Populations in Iran

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ABSTRACT: Western and eastern populations of goitered gazelles are separated by Zagors Mountains as a barrier. Bordering Iraq, western population has suffered from drastic decline during and after Iran-Iraq war. Presently, there are small numbers of the goitered gazelles left in the region with no clear understanding of their taxonomic status. It has been normally assumed that there should be a difference between these regions which has been the main objective of the present study. Twenty two skull variables of the goitered gazelles were measured and analyzed. Difference between the mean values of the regions (males only) in eastern and western Zagros as well as populations of western Zagros in Iran and Iraq populations show that western Zagros individuals in Iran have differentiated from eastern Zagros in at least 10 variables. Also, comparison of Iranian and Iraqi specimens indicates that no significant difference between these areas can be seen, seemingly an indication of morphological similarities between these two groups. Accordingly, it was concluded that western and eastern Zagros populations exhibit remarkable variation which can be due to their distinct evolution, phylogeny and environmental variations. Uniqueness of Kermanshah population in western Zagros reveals high priority to promote conservation and management of the habitat which enhancing its conservation level to Protected Area is a significant official step forward.

Key words: Morphological variation, Statically methods, PCA, Zagros Mountain, Iraq, Iran

INTRODUCTION

Iran is confirmed to host 3 species of gazelles whose their taxonomy has been a complicated issue for long debate among experts (Karami and Groves, 1993, Groves, 1993, Hemami and Groves, 2001; Karami *et al.*, 2002; Karami *et al.*, 2008; Ziaie, 2008). However, taxonomic status of most gazelle species, particularly below the species level is not clearly understood. As the most widespread gazelle species in Iran, the goitered gazelle (*Gazella subgutturosa*) exists throughout most of the country, except north and some southern parts of the country (Hemami, 1994; Karami *et al.*, 2002). Beyond the Iranian borders, it is a native species of central Asian steppes from Turkey (Olçer, 2001), Iraq (Al-Robaae and Kingswood, 2001) and Arabian Peninsula (Dunham, *et al.*, 2001) through Iran and Pakistan (Habibi, 2001) to the Gobi desert (Wang and Jiang, 2001).

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According to East, (1992), 4 subspecies of the goitered gazelles have been known within its entire range, including *G.s.hillieriana* in Mongolian Gobi (Heude, 1894), *G.s.yarkandensis* in China (Blanford, 1875), *G.s.subgutturosa* within vast plains of Asia and the Middle East including Iran and Iraq (Gueldenstaedt, 1780) and *G. s. marica* limited to Arabian Peninsula (Thomas,1897). In Iran, the goitered gazelles have been subject to a number of discussions on taxonomy. According to Karami *et al.*, (2002), presence of any subspecies other than *G.s.subgutturosa* in Iran is doubtful which was based on Hemami's (1994) conclusion on the basis of craniometrical analysis of the goitered gazelles. Beyond the Iranian border, the gazelles from northern Iraq near our study area are referred to as the *G. s. subgutturosa* and those from the south are referred to as the *G. s. marica* (Harrison and Bates, 1991), while both subspecies intergrade in Kurdistan and

the lower Tigris-Euphrates Valley (Groves and Harrison 1967). Most of these literatures have regarded Zagros Mountain as a main natural barrier between two sides' populations. However, no sample from western Zagros region was ever used in comparative analysis. On the other hand, the species which was formerly categorized as lower risk/near threaten in the IUCN (1996), was severely reduced both in habitat and population (Karami *et al.*, 2002; Farhadinia *et al.*, 2009) in last decades which has resulted in up-listing to vulnerable in 2006 (IUCN 2010). There are small populations of the goitered gazelles in western Zagros (i.e. Kermanshah and Ilam Provinces), bordering Iraq. Their status is more critical than east Zagros populations, as they suffered from drastic decline during and after Iran-Iraq war. It is supposed that there should be a significant difference between two populations of Zagros (Hemami & Groves 2001). However, they have never been studied based on morphological multivariate analysis and their taxonomic status has never been clarified. On the other hand, Iran's government plans to (re)introduce the goitered gazelle to some of its former habitats in western Zagros which eastern populations are used as a source.

The present research tests the hypothesis that geographical isolation between west and east of Zagros Mountain has led to significant morphological differences between these two populations.It hopefully can help to fill a remarkable gap in our scientific knowledge about the goitered gazelles in Iran as well as neighboring countries and is expected to provide a reliable insight for better management of the most abundant gazelle species in Iran.

MARTERIALS & METHODS

The experimental procedure was carried out based on morphological measurements of skulls of the goitered gazelles categorized in three geographical groups, namely as Kermanshah and Khuzestan (west Zagros, Iran), Khorasan (east Zagros, Iran), and Karbala and Baqdad (west Zagros, Iraq) (Table 1). Samples were obtained from Iranian Museum of Mellie Tarikhe Tabii, Tehran (MMTT) and the Field Museum of Natural History, Chicago (FMNH). All skulls belonged to adult individuals and sex was identified based on presence of long horns which is typical in males comparing to hornless in females (Ziaie, 2008). Spatial distribution of sampling areas is illustrated in Fig. 1.

Twenty two variables were measured, all adopted from Hemami, (1994) (Table 2 and Fig. 2). In order to avoid any bias imposed due to sexual dimorphism, males and females were analyzed separately. Statistical analysis was conducted using t-test by means of SPSS 10.0 software (SPSS Inc., Chicago, IL) and Principal Component Analysis (PCA) was implemented using Ade-4 software (Hugueny and Leveque, 1994; Thioulouse *et al.*, 1997; Doledec *et al.*, 2000).

Fig. 1. Map of Iran and geographical location of the sampling areas

Table 1. Gazella subgutturosa skull samples collected in west and east of Zagros Mountain

Geographical Group	Location	W/E	Identification No.	Sex	Date Collected
1	Iran, Khorasan	E	FMNH 97898	Male	1962
	Iran, Khorasan	E	FMNH 97899	Female	1960
	Iran, Khorasan	E	FMNH 97901	Male	1963
2	Iran, Khuzestan	W	FMNH 92914	Female	1960
	Iran, Kermanshah	W	FMNH 92917	Female	1960
	Iran, Khuzestan	W	FMNH 92919	Male	1960
	Iran, Kermanshah	W	MMTT 300	Male	1970
	Iran, Kermanshah	W	MMTT 301	Male	1970
	Iran, Kermanshah	W	MMTT 302	Male	1971
	Iran, Kermanshah	W	MMTT 303	Male	1971
3	Iraq, Baghdad, NW	W	FMNH 44464	Female	1935
	Iraq, near Baghdad	W	FMNH 46070	Male	1936
	Iraq, near Baghdad	W	FMNH 46072	Male	1936
	Iraq, near Baghdad	W	FMNH 46073	Male	1936
	Iraq, Karbala	W	FMNH 46075	Male	1935

FMNH:Field Museum of Natural History, Chicago, USA
MMTT: Museum Melli-e Tarikhe Tabii, Tehran, Iran
W: West of Zagros and E: East of Zagros

Table 2. Gazella subgutturosa skull and horn characters and abbreviations

1	Greatest Length of Skull	GLS	12	Maxillary tooth-row length	MaxTRL
2	Condyle basal length	CBL	13	Mandibular tooth-row length	ManTRL
3	Palate length	PL	14	Length of Diastema	LD
4	Palate breadth	PB	15	Length of Mandibular	LM
5	Nasal length	NL	16	Horn length	HL
6	Nasal breadth anterior	NBA	17	Tip-to-tip	TIP
7	Nasal breadth posterior	NBP	18	Greatest b. Horns	GBH
8	Preorbital length	PrL	19	Inner horn bases	IHB
9	Biorbital breadth	BiB	20	Outer horn bases	OHB
10	Braincase breadth	BrB	21	Horn core breadth diameter	HCB
11	Zygomatic breadth	ZB	22	Anterior-posterior horn core diameter	APHC

RESULTS & DISCUSSION

A total of fifteen skulls were measured, consisting of eleven males and four females. Based on PCA analysis, three principle components were extracted with a cumulative variance of 75% and 94% for males and females, respectively. Except TIP and IHB, all other variables contributed positively to PC1's loading factor of males. Meanwhile, they were all positive for females' PC1. GLS, CBL and PL possessed highest correlation to the PC1 in males and GLS and CBL in females. Multivariate analysis shows that all males are significantly correlated to different variables on PC1 and PC3 which resulted in formation of different groups (Table 3).

Four different groups are detectable in Fig. 3. In Males, TIP and IHB have negative correlation with the PC1 while other variables are positively correlated to PC1 which has resulted in formation of a separate group with sample FMNH97898 as Group1 (Eastern Zagros, Khorasan, Iran). Specimen FMNH92919 (Khuzestan, Iran) has positive correlation with BiB and BB and represented a distinctive group, namely as Group2 (Western Zagros). Forming a distinctive group around PC1 (Group 3: West of Zagros) by specimens FMNH46072, FMNH46070, MMTT301 and MMTT303, they have positive correlation with TIP, IHB, NBA and BB. FMNH46073 (near Baqdad, Iraq), MMTT300 and MMTT302 (Kermanshah, Iran) have negative correlation with PC3 and owned a separate group (Group 4: Western Zagros). FMNH46075 (Kabala, Iraq) was more biased toward western Zagros samples, but it seems that sample FMNH97901 (Khorasan, Iran) had common characteristics of both eastern and western Zagros (Fig. 3).

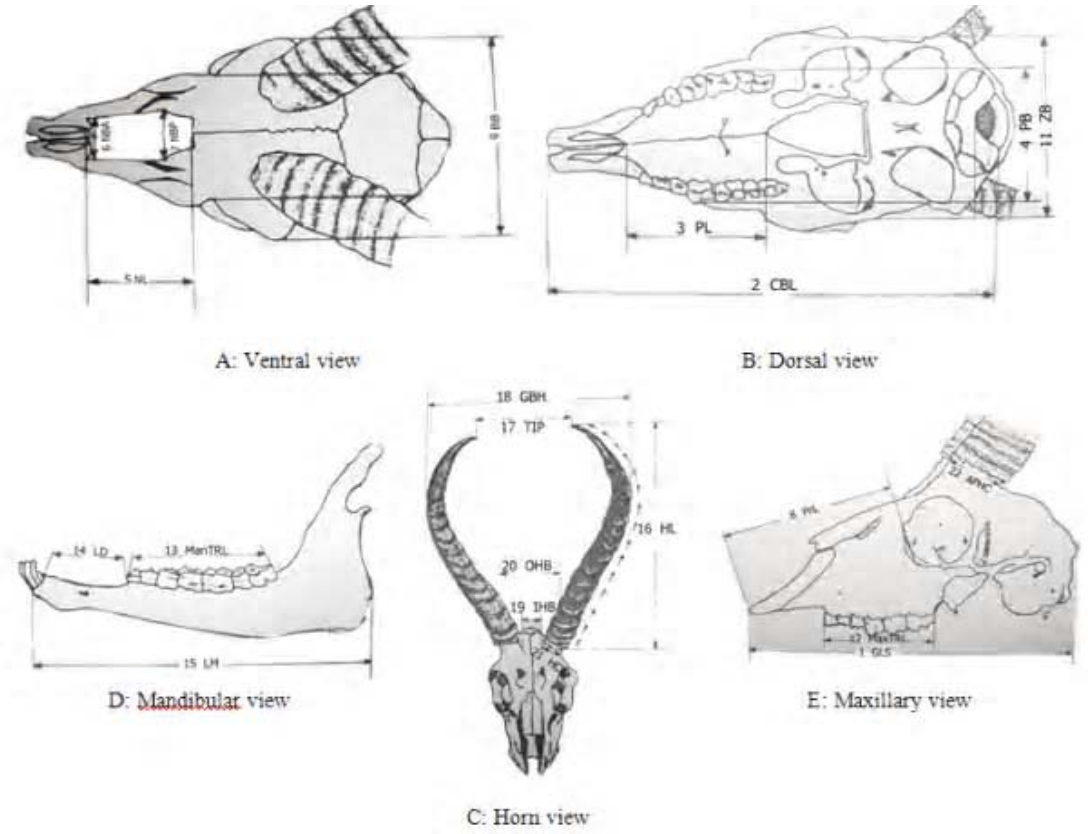
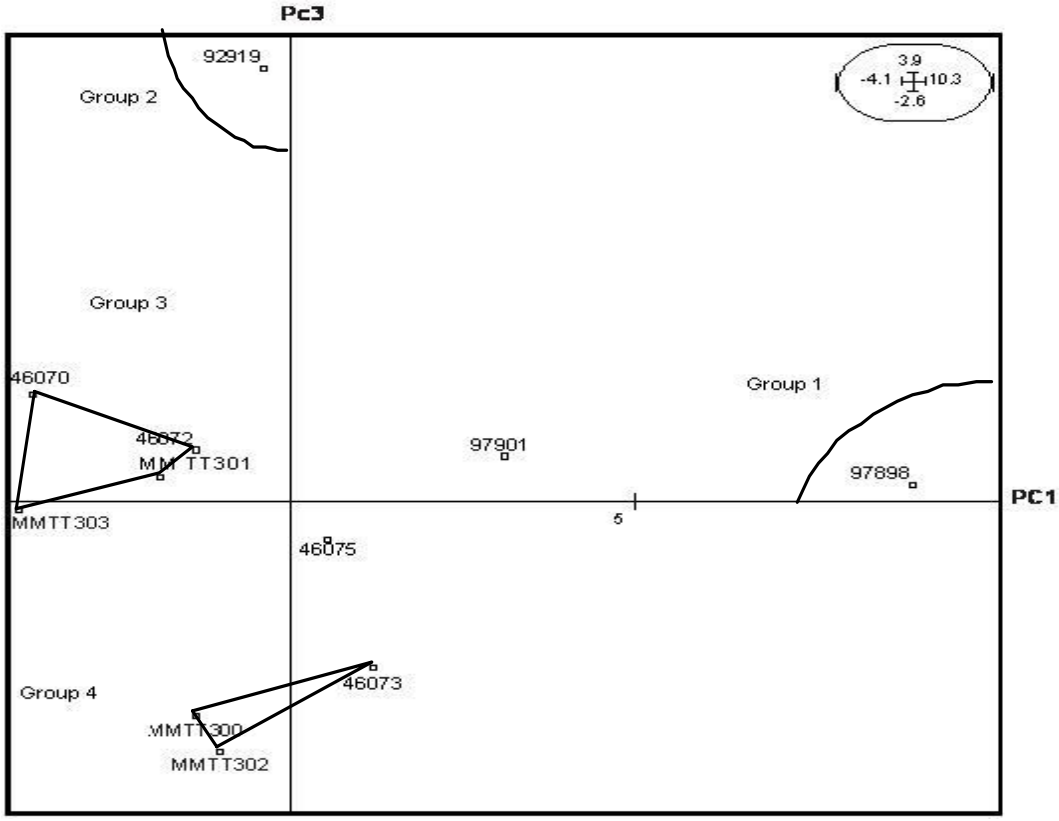


Fig. 2. Morphological measurements of goitered gazelle (*Gazella subgutturosa*)
A: Ventral view, B: Dorsal view, C: Horn view, D: Mandibular view and E: Maxillary view
(Adopted from Hemami, 1994)

Table 3. Skull measurements of males and females goitered gazelles from West and East of Zagros Mountain

		Male			Female	
		PC1	**PC2**	**PC3**	**PC1**	**PC2**
	E.V.	11.96	2.4	2.2	12.70	1.4
	V.P.J.	54%	11%	10%	85%	9%
	C.V. J.P.	54%	65%	75%	85%	94%
No.	**Abbreviations**					
1	GLS	0.95	0.01	0.15	0.98	-0.06
2	CBL	0.94	0.05	-0.10	0.83	0.32
3	PL	0.90	-0.19	0.00	0.97	0.14
4	PB	0.61	0.12	-0.18	0.92	0.36
5	NL	0.62	-0.15	-0.50	0.99	0.07
6	NBA	0.55	-0.51	0.41	0.85	-0.25
7	NBP	0.85	-0.23	0.27	0.98	-0.04
8	PrL	0.94	0.06	0.21	0.99	-0.01
9	BiB	0.61	-0.52	0.46	0.82	-0.55
10	BrB	0.58	-0.25	0.70	0.95	-0.18
11	ZB	0.84	-0.19	0.21	0.68	-0.72
12	MaxTRL	0.70	-0.21	-0.54	0.99	-0.06
13	ManTRL	0.69	-0.36	-0.26	0.85	0.47
14	LD	0.84	0.23	0.16	0.93	0.18
15	LM	0.91	0.23	0.12	0.98	0.13
16	HL	0.50	-0.24	-0.54	-	-
17	TIP	-0.62	-0.22	0.13	-	-
18	GBH	0.67	-0.27	0.12	-	-
19	IHB	-0.42	-0.22	0.17	-	-
20	OHB	0.70	0.54	0.05	-	-
21	HCB	0.67	0.65	0.09	-	-
22	APHC	0.65	0.64	-0.21	-	-

Eigen Value (E.V.), Variance Percent Justified (V.P.J.) Cumulative Variance Justified Percent (C.V.J.P.)



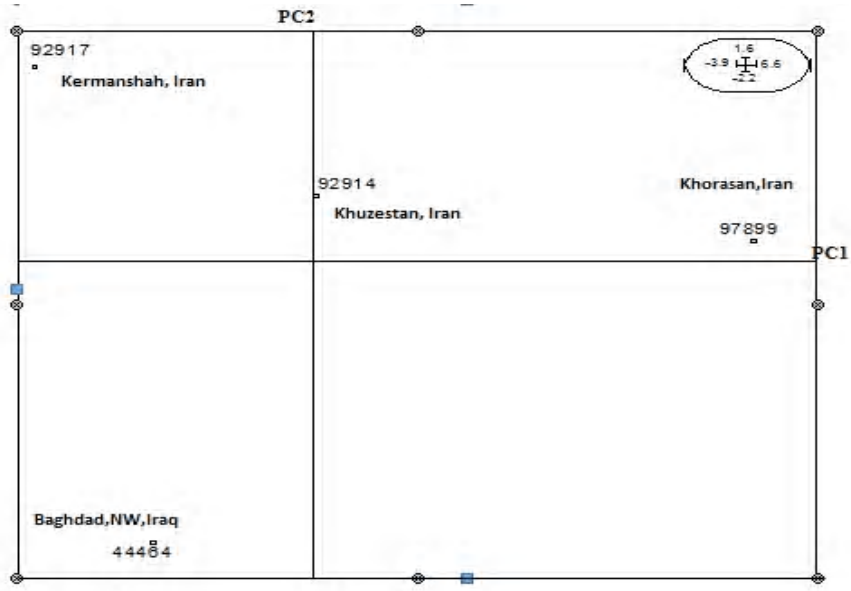
Group1: East of Zagros, FMNH97898 (Khorasan, Iran)
Group2: West of Zagros, FMNH92919 (Khuzestan, Iran)
Group3: West of Zagros, FMNH46070 and FMNH46072
(Baghdad, Iraq), MMTT301 and MMTT303 (Kermanshah, Iran)
Group4: MMTT300, MMTT302 (Kermanshah, Iran), and FMNH46073 (Baghdad, Iraq)

Fig. 3. Multivariate analysis of adult male Gazella subgutturosa, summarized in four distinctive groups

Analysis of 4 adult females shows that all variables are correlated positively with PC1. However, they failed to form group(s) that can be due to our small sample size for female skulls. Specimen FMNH97899 (eastern Zagros, Khorasan, Iran) has correlation with BiB, ZB and ManT on PC1. Specimens FMNH92917 (western Zagros, Kermanshah, Iran) and FMNH44464 (western Zagros, Baqdad, NW, Iraq) are positively correlated to ManT, BiB and ZB on PC2. Sample FMNH92914 (Khuzestan, Iran) is positioned central to the diagram, but biased toward western Zagros (Fig. 4). Spatial configuration of samples around PC1 and PC3 in males and PC1 and PC2 in females also supports differentiation of *G. s. subgutturosa* between eastern and western Zagros Mountain. Difference between the mean values of gazelles populations (males only) in eastern and western Zagros as well as populations of western Zagros in Iran and Iraq populations show that western Zagros individuals in Iran have differentiated from eastern Zagros in 10 variables (namely as GLS, CBL, PL, NBP, PL, ZB, LD, Tip, GBH, and IHB) (Table 4). Also, comparison of Iranian and Iraqi specimens indicates that no significant difference between these areas can be seen, seemingly an indication of morphological similarities between these two groups.

CONCLUSION

Our study revealed inter-specific differentiation of *Gazella subgutturosa* populations in west and east of Zagros Mountain. Inter-sexual comparisons of west Zagros populations resulted in no overlap with those of the same sex from eastern part and they are completely separated in at least 10 variables. Remarkable variation has been already assumed by various authors (Hemami, 1994; Karami *et al*., 2002) which is confirmed by outcomes of the present investigation to be a significant differentiation. Specimens from western Zagros are affected by smaller GLS, CBL and PL comparing to eastern populations, whereas populations in Iraq (near Baqdad and Karbala) show no significant differentiation from west Zagros populations in Iran. Therefore, it supports they are closely related to each other.



Group1: East of Zagros, FMNH97899 (Khorasan, Iran).
Group2: West of Zagros, FMNH92917 (Kermanshah, Iran).
Group3: West of Zagros, FMNH44464 (Baghdad, NW, Iraq).

Fig. 4. Multivariate analysis of 4 adult female gazelles, summarized in 4 distinctive groups (PC1 and PC2 accounted for 85% and 9% cumulative variance, respectively)

Table 4. Mean standard deviations and P-value of skull and horn measurements of adult male gazelles of western and eastern Zagros Mountain belonging to Iran and Iraq

	IRAN			**IRAQ**	
Abbreviations	W. Zagros Mean ± S.D.	E. Zagros Mean ± S.D.	*P-value*	Baqdad and Karbala Mean ± S.D.	*P-value*
	(millimeter)			(millimeter)	
GLS	173.4 ±7.6	193.4 ± 8.6	0.029*	176.9±5.2	0.47
CBL	167.9 ± 4.9	186.8 ± 11.8	0.023*	171.8±7.2	0.37
PL	85.1 ± 3.8	96.6 ± 9.3	0.050*	89.1± 3.1	0.13
PB	49.5 ± 1.9	51.8 ± 3.5	0.299	50.1± 0.7	0.54
NL	48.0 ± 6.0	57.1± 0.1	0.104	46.4± 5.7	0.70
NBA	20.2± 5.1	29.0± 0.0	0.072	22.2±1.2	0.47
NBP	20.8 ± 1.5	27.1± 0.2	0.003*	22.2±1.3	0.21
PrL	88.6± 4.6	101.8±4.2	0.018*	89.7± 3.7	0.71
BiB	45.9 ± 5.2	52.6± 2.7	0.158	48.7±1.2	0.32
BrB	55.1 ± 3.5	60.8± 0.7	0.080	55.8± 2.5	0.76
ZB	73.6± 2.2	81.1±1.8	0.004*	74.8± 2.5	0.49
MaxTRL	55.2 ± 3.9	60.6± 3.4	0.220	56.9±1.3	0.44
ManTRL	57.0 ± 1.8	62.4±4.9	0.092	59.2±1.1	0.08
LD	26.4 ± 2.7	34.0±5.4	0.048*	27.7±5.0	0.63
LM	130.4 ± 4.8	146.1±17.6	0.060	131.7±8.2	0.78
HL	262.4± 26.3	290.0 ± 0.0	0.158	285.5± 42.2	0.34
TT	182.8 ±19.8	110.0 ± 0.0	0.010*	187.5± 74.1	0.89
GBH	189.0 ± 5.6	280.0 ± 0.0	0.000*	192.7± 42.8	0.84
IHB	15.5± 0.4	13.7± 1.5	0.046*	17.0± 4.9	0.50
OHB	59.4 ± 2.6	63.6± 5.7	0.210	57.1±1.0	0.15
HCB	19.9 ± 1.7	21.5± 2.8	0.411	18.4±1.2	0.18
APHC	27.9 ±1.9	30.0 ± 6.1	0.457	25.5±4.1	0.28

* Significant ($P \leq 0.05$)

Sample size: West of Zagros in Iran (5), East of Zagros in Iran (2), West of Zagros in Iraq (4).
S.D.: Standard Deviation

It seems that western and eastern Zagros populations show remarkable variation which can be affected by their distinct evolution, phylogeny and environmental variations. It can cause variations in skull shape and size, body and horn size as well as body coloration in different parts of Iran as phenotypic adaptations to various environmental circumstances. The only major geographic barrier across the gazelle's range in Iran is Zagros Mountain and populations occurring west of this barrier (extending into eastern Iraq) are noticeably different from those to east of it (the main Iranian population) (Karami *et al.*, 2002).

We do not have any evidence to know the extent of *G. s. subgutturosa* within Iraq, however, only gazelles from northern Iraq near our study area are referred to as the *G. s. subgutturosa* and those from the south are referred to as the *G. s. marica* (Harrison and Bates, 1991). Moreover, it is reported that *G.s. subgutturosa* from western Zagros are distinctive from the Arabian subspecies (Greth *et al.*, 1996).

Their main characters of *G. subgutturosa* are yellowish, reddish or grayish–sandy color on the back and flanks, tones without strong markings with invasion of the mid-facial region by white with maturity. The face is white, with merest traces of brown strips on the cheeks. Specimens from Iraq, which are as small as *G.s.marica*, are however the same darker, yellow-brown color as Iranian *G. s. subgutturosa* (Greth *et al.*, 1996; Karami *et al.*, 2002).

Kermanshah, Ilam, and Khuzestan provinces are within the historical range of the goitered gazelles in western Iran along the borderland with Iraq. Presently, the main population of the goitered gazelle in western Iran is Qaraviz Hunting Prohibited Area (near Kermanshah), not far from Iraq border. The population is recovering and based on recent census, almost 200 animals exist there from an approximately 60 founders in 2004 (Samdzadeh, *personal Communication*).

Southern Province of Khuzestan has experienced severe decline, but the Iranian Department of Environment plans to re-introduce the goitered gazelles. However, due to habitat loss and hazard conditions during Iran-Iraq war (1980-1988), only sporadic populations have survived in Ilam and most of Kermanshah provinces as well as Baqdad and Karbala regions in Iraq. In other word, only Qaraviz was successful to sustain and restore its gazelle population within more than two decades after the war. Therefore, it is highly recommended to use this population as source for translocation in order to restock goitered gazelle population within its former range in western Iran and Iraq.

Moreover, comprehensive genetic studies in each sub-population could be useful to explore highest variations. Uniqueness of Kermanshah population in western Zagros reveals high priority to promote conservation and management of its habitat which enhancing its conservation level to Protected Area is a significant official step forward.

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