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Sexual dimorphism in the Caspian Pond Turtle, *Mauremys caspica* (Gmelin, 1774)

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Males and females of many animal species attain different body sizes. Biologists generally explained these differences in terms of sexual selection (Berry and Shine, 1980). Variation in body size may also reflect adaptations to environments, and sexual size dimorphism (SSD) arises from ultimate and proximate factors acting differently on males and females in those environments. Sexual dimorphism can result from sexual selection, such as selection for increased female fecundity, leading to an ecological niche divergence (Hendrick and Temeles, 1989; Shine, 1989).

The Caspian Pond Turtle *Mauremys caspica*, (Gmelin, 1774) belonging to the Geoemydidae family, is a medium-sized freshwater turtle that is widespread throughout the Middle East (Vamberger et al., 2013). It is distributed from central Anatolia east and southeastwards across Syria and the Caucasus region to Iraq and Iran. Isolated relict populations are known from Bahrain and adjacent Saudi Arabia (Yadollahvand et al., 2014). In Iran, the species is widely distributed in Golestan, Mazandaran, Guilan, Ardebil, East and West Azarbaijan, Kurdistan, Kermanshah, Lorestan, Ilam, Khuzestan and Fars provinces (Yadollahvand et al., 2013).

In our present study, we collected 118 specimens from 23 sites including lakes, rivers, ponds, pools and fish farms in Golestan (72 specimens) and Mazandaran (46 specimens) provinces, Iran, from 2011-2012. Sex was determined by visual observation of morphological characteristics. Of 118 specimens of *Mauremys caspica* captured, 62 were males and 56 were females. We measured nine standard external characters of each specimen (Figure 1). All morphometric measurements were retrieved using digital callipers (Doulton) (accurate to 0.05 mm), and mass obtained using a digital balance (Doulton) (precision to 0.1 g).

Initially, all data was evaluated for normality requirements using the Shapiro-Wilk test, in order to determine the application of parametric or non-parametric analyses. Later, we created a variable called "body size," defined by the scores of an isometric

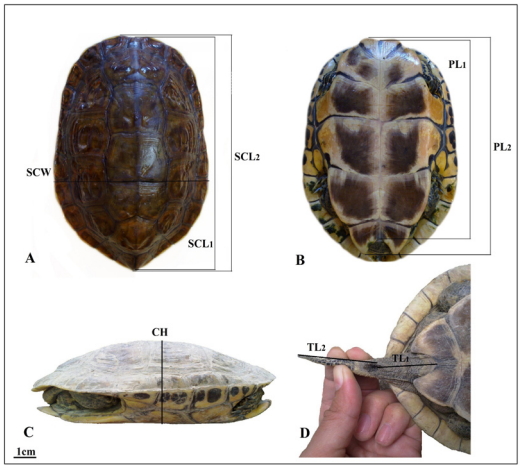

Figure 1. Studied standard characters in *M. caspica*; A) Dorsal view; B) Ventral view; C) Lateral view; D) Tail view. Abbreviation: SCL1=Straight Carapace Length 1, SCL2=Straight Carapace Length 2, SCW= Straight Carapace Width, CH=Carapace Height, PL1=Plastron Length 1, PL2=Plastron Length 2, TL1=Tail Length 1, TL2=Tail Length 2, W=Weight.

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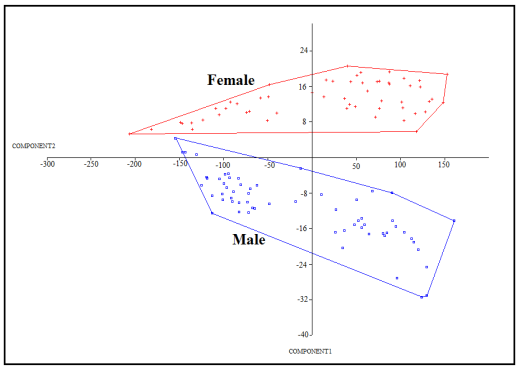

Figure 2. Study of sexual dimorphism in the *M. caspica* in principal component analysis (PCA).

vector (Rohlf and Bookstein, 1987), with values of $p^{-0.5}$ obtained by multiplication of the matrix n x p of the transformed data in log10, where n is the number of observations and p is the number of variables (Jolicoeur, 1963; Somers, 1986). To remove the effect of the body size of the transformed variables on log10, the Burnaby method (Burnaby, 1966) was used according to the following equation:

$$L = I_p - V(V^T V)^{-1} V^T$$

in which I_p is the identity matrix p x p, V is the isometric vector defined above and V^T is the transposed matrix of V (Rohlf and Bookstein, 1987). In order to verify the presence of sexual dimorphism in size, the Wilcoxon (non-parametric test) test and the *t* test (parametric test) were performed between the sexes. Also, we computed a set of intercorrelated measurements with a single size descriptor (Principle Component Analysis, PCA).

Males and females of *M. caspica* do not differ in body size (Wilcoxon W = 1834; P = 0.5993) or in straight carapace length (SCL1: Wilcoxon W = 1957; P = 0.2347; SCL2: Wilcoxon W = 1950; P = 0.2499) however, they differed significantly in mass, with females being heavier than males (Wilcoxon W = 2347; $P < 0.001$), and in tail length (TL1: Wilcoxon W = 259; $P < 0.0001$; TL2: T = 42899; df = 117; $P < 0.0001$). The morphometry and weight of the *M. caspica* are presented in Table 1.

According to the principal component analysis (PCA) (Figure 2), there are evidence of differences in the sizes between sexes, suggesting the presence of sexual dimorphism, with more than 90% in both principal components PC1 and PC2 and sexes are completely separated. Also, in the first principal component (PC1), all characters have a positive effect on male and female separation. In the second principal component (PC2), the SCL1, SCL2, SCW and TL1 have a positive effect on this separation, of which TL1 has the highest contribution; the other characters having no effect on separation between males and females. The KMO coefficient, which is 0.87, confirms this result.

Finally, plastron surface morphology in females is flat to slightly prominent, whereas males exhibit a concave plastral morphology that becomes deeper with age and probably aids them in mating (Figure 3).

Table 1. Values and standard deviation of the morphometric measures (mm) and weight (g) of the individuals of males and females of *M. caspica*. Abbreviation: SCL1=Straight Carapace Length 1, SCL2=Straight Carapace Length 2, SCW= Straight Carapace Width, CH=Carapace Height, PL1=Plastron Length 1, PL2=Plastron Length 2, TL1=Tail Length 1, TL2=Tail Length 2, W=Weight and SIZE=Body Size.

	Female		*Male*			
	Mean	**SD**	**Mean**	**SD**	***Wilcoxon W***	***P***
SCL1	156.43	46.78	145.90	46.39	1957	0.2347
SCL2	158.13	47.05	147.55	46.77	1950	0.2499
SCW	113.81	30.50	105.58	30.09	2005	0.1479
CH	57.61	18.57	47.45	14.78	2347	0.0010
PL1	136.73	41.12	116.37	36.43	2292	0.0027
PL2	147.97	44.40	128.62	39.90	2231	0.0077
TL1	18.66	8.31	34.94	10.19	259	< 0.0001
SIZE	5421647.80	409222.05	5386092.60	360424.07	1834	0.5993
W	645.29	432.97	461.55	386.27	2347	< 0.001
					T (df)	***p***
TL2	54.60	13.16	43.39	8.67	42899 (117)	< 0.0001

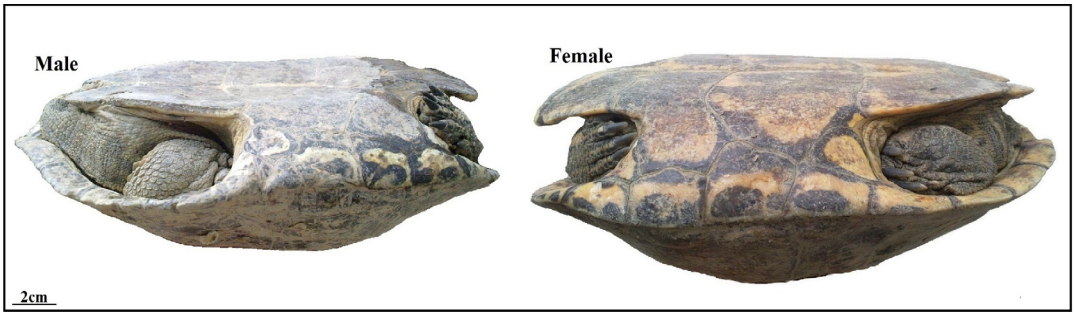

Figure 3. Plastron surface in male and female of *M. caspica*.

The populations with heavier females may be related to reproductive investment in egg production and storage (Lovich & Gibbons, 1992; Anderson, 1994; Kaddour et al., 2008). According to Berry (1980), the presence of larger females than males in many aquatic chelonians may also reflect the behaviour of the species: populations of taxa exhibiting smaller males may be related to an absence of aggressive combat for territory between males. Thus, this evolutionary strategy of sexual selection may be occurring in *M. caspica*.

Morphology proved to be a useful tool to discriminate sex. In addition, a more evident sexual dimorphism was observed in tail length. The pattern found in *M. caspica* followed the general pattern present in turtles regarding tail length, but the patterns of other body measurements and mass may serve for future investigations on sexual dimorphism.

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