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Research Article

An allometry study of Caspian pond turtle (*Mauremys caspica*) in Golestan province, Iran

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Abstract

Caspian pond turtle, *Mauremys caspica* shows allometric growth and sexual dimorphism in the shell. Differences in allometric growth produce sexually dimorphic adults. Our results revealed that females are smaller than males that may be related to the risk of the predation, desiccation, and thermal stress. Allometric changes in shape of the shells are different between males and females. In females shape related characters such as plastral length (Pl_1) and plastral fore and hind lobe width (PFLW, PHLW), gular, pectoral, abdominal and anal seam length (GSL, PSL, AbSL, AnSL) which represent width of plastron and plastral length proportionally change with size (related to SCL_2 as index of size). The most remarkable changes related to size are right and left bridge length (RB_r, LB_r) in females but these changes have not effect on shell shape. For males character TL_2 changes dramatically related to size (SCL_2). Sexual dimorphism of the shell was also evident. ANCOVA indicated that the regression slopes of males and females differed significantly ($p< 0.000$) in 15 of the 24 characters examined.

Keywords: allometric growth, maximum straight carapace length, sexual dimorphism, *Mauremys caspica*, tail length.

Introduction

Most of the morphological variation in turtles could be due to phenotypic responses (plasticity) that act during ontogenetic development as a consequence of environmental pressures (Shreeves and Field 2008). The caspian pond turtle, *Mauremys caspica*, is belonging to Geoemydidae family and is widespread in the Middle East (Yadollahvand and Kami 2014). This species is widely distributed in the north, west and south-west of Iran (Yazarloo *et al.* 2017). Body size is among the most frequently used variables in large-scale macro ecological and evolutionary studies because it is a fundamental property of organisms relevant to physiology, ecology, anatomy, extinction risk, and genomic architecture (Cardillo *et al*. 2005, Lynch 2007). The standard body size measurement in turtles is thetaxon-specific straight carapace length (SCL), a linear measurement of the dorsal shell. When using carapace length, size comparisons between turtles and other groups are possible only through LDM data based on allometric regression equations of limited value (Pough1980). Carapace length often is lauded as a stable measurement of size across turtles, with little or no apparent seasonal or daily variation (Regis and Meik 2017). Each length measurement reflects selection on body size through allometric growth, and each anatomical feature may be subject to its own selective pressures and constraints, independent of or in conjunction with overall body size (Andersson 1994). An important factor to be evaluated within sexual dimorphism is allometry, defined as the association between size and shape, or the covariation of parts due to variation in size. All types of allometry can contribute to the sexual differentiation at the respective levels of variation (Gidaszewski *et al*. 2009). Allometry is classified according to the cause of variation in size that gives rise to the allometric relationship, which is usually ontogenetic growth or evolutionary change; therefore, there is either ontogenetic or evolutionary allometry, respectively (Klingenberg 1996).

Sexual dimorphism and allometry of the turtle shell have been studied extensively (reviews in Berry and Shine 1980, Gibbons and Lovich 1990). More recent studies have varied in phylogenetic hypotheses, body size metrics (i.e., mean versus maximum length), and types of regression analyses (Cox *et al*. 2007, Stephens and Wiens 2009, Ceballos *et al*. 2014, Halámková *et al*. 2013, Werner *et al*. 2016). In recent study (Yazarloo *et al*. 2017), the first sexual dimorphism result is studied in this species. In present study, this species permits the first published study to quantify allometry.

Material and methods

During 2016-2017, 134 (69 males, 65 females) specimens were collected from 14 stations including Sijoval, Mohammad Abad, Imer, AqQala, Voshmgir dam, Anbar Olum, Gharasu, Niazabad, Kordkuy, Khanbebin, Kalaleh, Galikesh, Maravehtappeh and GonbadKavus in aquatic habitats including rivers, ponds, pools and fish farms in Golestan province. The turtles were transported alive to the laboratory in the Golestan University. Morphometric characters were measured by digital caliper to the nearest 0.1mm and photographed. Allometric variation was tested by using SCL as the independent variable for regression analysis (least square method) of the other characters. The data doesn't Normalized, Male and female were analyzed separately. Sexual dimorphism was studied and proved in another study extensively by univariate and multivariate analysis (Yazarloo *et al*. 2017). Sexual dimorphism of characters was tested using analysis of covariance (ANCOVA) with SCL as covariate and sex as factor.

To visual illustrate allometric relationships between SCL_2 and characters (AnSL, RB_r, TL_1 and TL2) in two sexes, Carter plots of the characters represented. Finally all specimens were released to original points.

Results

Allometric growth of the shell in Caspian pond turtle was evident (Table 1). Allometric changes in shape of the shells are different between males and females. In females shape related characters sush as plastral length (Pl_1) and plastral fore and hind lobe width (PFLW, PHLW), gular, pectoral, Abdominal and anal seam length (GSL, PSL,AbSL, AnSL) which represent with of plastron and plastral length proportionally change with size (related to SCL_2 as index of size). The most remarkable changes related to size are Right and left bridge length (RB_r, LB_r) in females but these changes have not effect on shell shape. For males character TL_2 changes dramatically related to size (SCL_2) (Figure 1).

Sexual dimorphism of the shell was also evident. ANCOVA indicated that the regression slopes of males and females differed significantly ($p< 0.000$) in 15 of the 24 characters examined (Table 2). In the parametric compare mean analysis, mean values of characters TL_1 ($p< 0.000$), AnSL ($p< 0.005$) and TL_2 ($p<0.005$) were significantly different between sexes. None of the four nonparametric characters showed significant differences between males and females ($p> 0.66$) (Yazarloo *et al.* 2017).

Discussion

It was found that carapace length is likely an acceptable measurement in turtles; we expect that inferences from body size differences using other length measurements in other groups might be in adequate (Feldman and Meiri 2013). However, more precise hypotheses and more precise quantification of intra- and interspecific selection forces on body size are needed to understand sexual size dimorphism (SSD). Although it would be tempting to conclude that SCL will give more conservative estimates of body size allometry, it is important to recognize that SCL and mass are different measures and therefore different results partly reflect underlying morphological and scaling differences in addition to differences in statistical power. The potentially greater statistical power of body mass compared to SCL to detect allometry of SSD emphasizes differences in inferential capabilities that are inherent when using different measures of body size in macro evolutionary studies (Regis and Meik 2017).

In recent study (Brophy 2006), among males (*Malayemys macrocephala*), shell shape changed as CL increased proportionally more than shell width (CW, APLW, PPLW), shell height (SH), plastral length (PL and APLL), several scute widths (Pleu1W, Vert1W, Vert2W, Vert3W, HumW, FemW, and AnW) and a few scute lengths (Vert1L, BL, and AnL), For females, shell shape did not change as much because CL did not increase proportionally more than shell width or shell height but did increase proportionally more than plastral length (PL and PPLL) and a few scute widths (Vert1W, Vert3W, FemW, AnW) and lengths (BrL, AbdL, AnL), but in present study, for females, shell shape changed as SCL_2 increased proportionally more than Right and Left bridge length (RB_r,LB_r), Tail $Length_2$ (TL_2). Also for males, shell shape changed as SCL_2 increased proportionally more than Tail $Length_1$ (TL_1).

Table 1. Allometric relationships of shell characters to SCL_2 for *Mauremys caspica* from Golestan province (F= female, M= male)

Characters	Sex	n	Linear relation: Y=a+bx (in mm)	R_2
Pl_1	F	65	Pl_1=2.79+0.87SCL_2	0.999
	M	69	Pl_1=5.3+0.76 SCL_2	0.996
AnSL	F	65	AS =2.53+0.07 SCL_2	0.924
	M	69	AS =3.45+0.05 SCL_2	0.833
W	F	65	W =0.032-8.11 SCL_2+0.06 SCL_2	0.954
	M	69	W =0.06 SCL_2^2-8.11 SCL_2+0.032	0.980
PSL	F	65	PSL =2.07+0.16 SCL_2	0.978
	M	69	PSL =2.02+0.12 SCL_2	0.953
AbSL	F	65	ASL =7.55+0.27 SCL_2	0.991
	M	69	ASL =3.59+0.23 SCL_2	0.969
PFLW	F	65	PFLW =1.76+0.4 SCL_2	.973
	M	69	PFLW =4.15+0.35 SCL_2	.988
PHLW	F	65	PHLW =0.1+0.48 SCL_2	0.992
	M	69	PHLW =0.79+0.44 SCL_2	0.990
RB_r	F	65	RB_r =4.32+0.37 SCL_2	0.996
	M	69	RB_r =0.83+0.29 SCL_2	0.989
LB_r	F	65	LB_r =3.7+0.37 SCL_2	0.996
	M	69	LB_r =1.87+0.29 SCL_2	0.990
TL_1	F	65	TL_1=1.36+0.1 SCL_2	0.827
	M	69	TL_1=378+0.19 SCL_2	0.890
TL_2	F	33	TL_2=14.13+0.23 SCL_2	0.922
	M	49	TL_2=22.92+0.11 SCL_2	0.713
GSL	F	65	GSL =0.55+0.11 SCL_2	0.905
	M	69	GSL =1.04+0.1 SCL_2	0.960

Significance levels (p); intercept (a) (H_0:a=0), p<0.000,

Table 2. Comparison of regression slopes (ANCOVA) of shell characters vs. carapace length among males and females of *Mauremys caspica* from Golestan province.

Male vs. female slopes (b) (H_0:b_{males}=bfe_{males})

Characters	Definition	F	df	p
SCL_1	Minimum straight carapace length	0.290	1,125	ns
SCW	Straight carapace width	4.556	1,125	P<0.035
CH	Carapace height	19.274	1,125	P<0.000
PL_1	Minimum plastron $length_1$	182.615	1,125	P<0.000
PL_2	Maximum plastron length $_2$	139.026	1,125	P<0.000
TL_1	Tail $length_1$	127.160	1,125	P<0.000
TL_2	Tail $length_2$	32,268	1,76	P<0.000
W	Weight	36.650	1,125	P<0.000
GSL	Gular seam length	13.859	1,125	P<0.000
GU-w	Width of gulars	1.293	1,125	ns
HSL	Humeral seam length	6.900	1,125	P<0.000
PSL	Pectoral seam length	88.112	1,125	P<0.000
AbSL	Abdominal seam length	34.626	1,125	P<0.000
FSL	Femoral seam length	6.165	1,125	P<0.014
AnSL	Anal seam length	47.308	1,125	P<0.000
FASL	Straight width of femuro-anal suture	5.216	1,125	P<0.024
PFLW	Plastral fore lobe width	40.671	1,125	P<0.000
PHLW	Plastral hind lobe width	63.363	1,125	P<0.000
MLB r	Right bridge length	217.364	1,125	P<0.000
MLB_l	Left bridge length	198.365	1,125	P<0.000
ASO-h	Anterior shell opening height	0.177	1,125	ns
NL	Nuchal length	0.002	1,125	ns
NW	Nuchal width	1.239	1,125	ns
SUP-d	Anterior width of supracaudalscutes	3.709	1,125	ns

For significance levels, ns=p > 0.05.

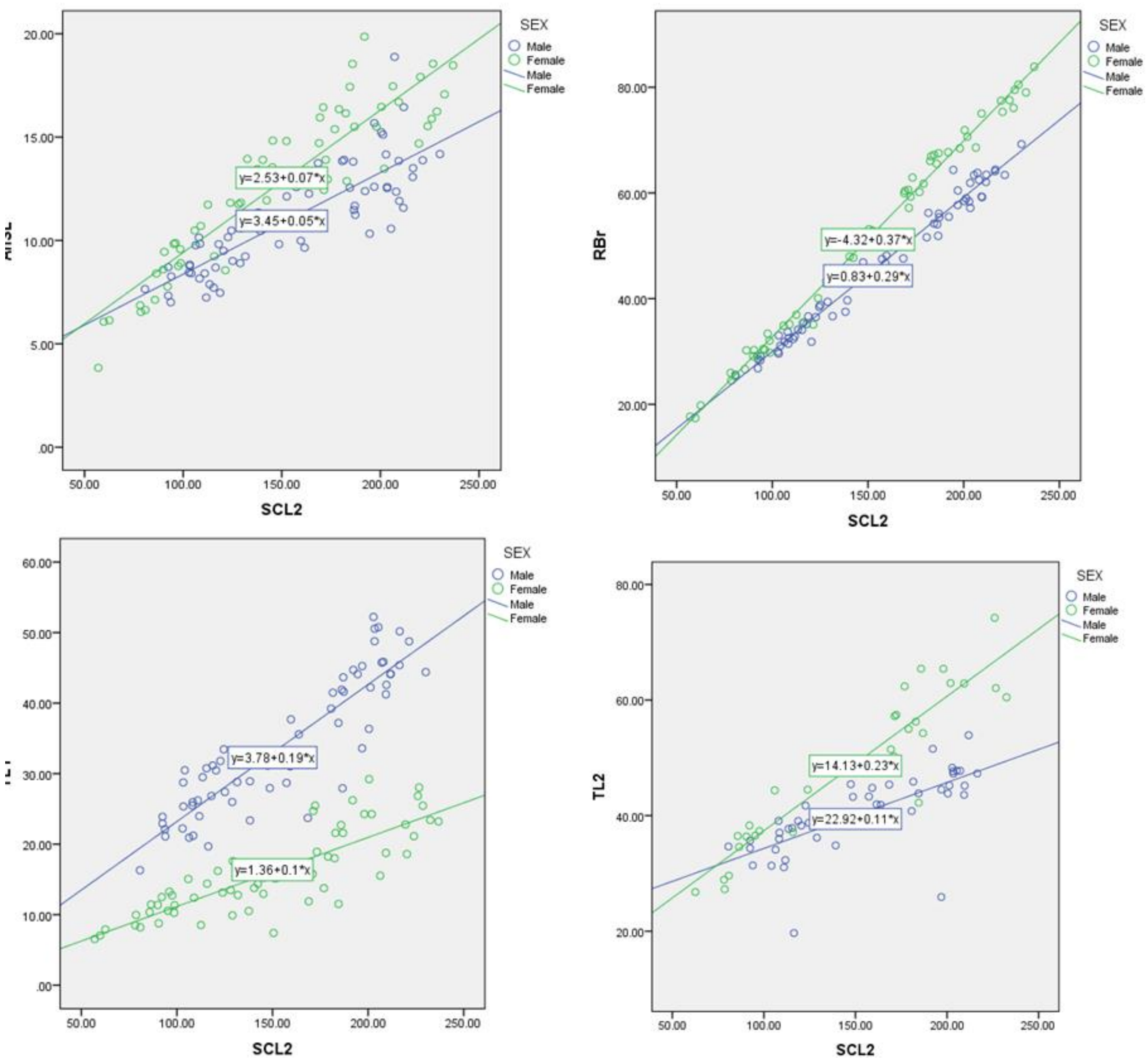

Figure 1. Allometry of Anal seam length, Right bridge length, Tail Length$_1$, and Tail Length$_2$ as a function of carapace length and sex for *Mauremys caspica* from Golestan province.

Some authors (review in Gibbons and Lovich 1990) have suggested that SSD is a result of ecological forces or natural selection. The most frequently cited ecological cause is probably competitive displacement (Brown and Wilson 1956, Dunham *et al*. 1979). In this model, the sexes evolve to exploit different resources in the environment, thereby reducing competition between them.

Past data showed that in green turtles and loggerhead sea turtles, the shape of the carapace changes during early development and as a result, the turtles become wider proportionally faster than they increase in length (Salmon and Scholl, 2014). It is of interest to determine why in previous studies there was little or no evidence for allometric growth in either turtle species. Davenport and Scott (1993) found no evidence allometric growth in young green turtles that they reared, but the purpose of their study was to determine if growth rates were variable and if so, whether there were morphological difference between turtles that grew faster and those that grew more slowly their sample consisted of 12 turtles, measurements began when their subjects were 4-9 weeks old, and measurements were repeated on individual turtles at intervals of 3-4 weeks. But in the result of Brophy (2006), positive allometric growth begins immediately after hatching and so if comparisons are made among turtles several weeks after hatching, they are unlikely to reveal changes in proportional growth. allometric growth is only revealed when comparisons are made between growing turtles and hatchlings.

Kamezaki and Matsui (1997) related these proportional growth chnges to associated ecological ethological and physiological (e.g., habitat, food, and eproduction) shifts that occur as the turtles grow toward maturity. We agree with Kamezaki and Matsui (1997) that the differences they observed in the turtles might be shaped by the differing demands imposed by natural selection upon the turtles as they shift habitats.

Most discrepancies related to discerning a pattern of positive allometry from isometry at the family level, which is the level most often used in comparative studies of SSD (Cox *et al*. 2007, Székely *et al*. 2007, Ceballos *et al*. 2014). Those considerations suggest that inferring and quantifying sexual dimorphism requires more complex measurement techniques related to shape and size rather than simply to mass and length (Gidaszewski *et al*. 2009, Benítez *et al*. 2010).

Conclusion

Allometric growth differences between males and females produce sexually dimorphic adults. In females, the most remarkable changes related to size are Right and left bridge length (RB_r, LB_r) but these changes have not effect on shell shape. For males character TL_2 changes dramatically related to size (SCL2). The regression slopes of males and females differed significantly in 15 of the 24 characters examined.

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References

Andersson M. 1994. Sexual selection. Princeton: Princeton University Press.

Berry J.F., Shine R. 1980. Sexual size dimorphism and sexual selection in turtles (order Testudines). Oecologia 44(2):185–191.

Benítez H., Vidal M., Briones R., Jerez V. 2010. Sexual dimorphism and population morphological variation of *Ceroglossus chilensis* (Eschscholtz) (Coleoptera, Carabidae). Journal of the Entomological Research Society 12(2): 87–95.

Brophy T.R. 2006. Allometry and sexual dimorphism in the snail-eating turtle *Malayemys macrocephala* from the Chao Phraya River Basin of Central Thailand. Chelonian Conservation and Biology *5*(1): 159-165.

Brown, W.C., Wilson, E.O. 1956. Character displacement. Systematic Zoology 5:49–64.

Cardillo M., Mace G.M, Jones K.E. Bielby J., Bininda-Edmonds O.R.P., Sechrest W.,Orme C.D.L., Purvis A. 2005. Multiple causes of high extinction risk in large mammal species. Science 309:1239–1241.

Ceballos, C.P., Hernández O.E., Valenzuela N. 2014. Divergent sex-specific plasticity in long-lived vertebrates with contrasting sexual dimorphism. Evolutionary Biology 41(1):81–98.

Cox R.M., Butler M.A., John-Adler H.B. 2007. Chapter4: the evolution of sexual size dimorphism in reptiles. In: Fairbairn DJ, Blanckenhorn WU, Székely T, eds. Sex, size and gender roles: evolutionary studies of sexual size dimorphism. Oxford: Oxford University Press, 39–49.

Dunham A.E., Smith G.R., Taylor J.N. 1979. Evidence of ecological character displacement in western American catastomid fishes. Evolution 33:877–896.

Feldman A, Meiri S. 2013. Length mass allometry in snakes. Biological Journal of the Linnaean Society 108(1):161–172.

Gibbons, J.W. Lovich, J.E. 1990. Sexual

dimorphism in turtles with emphasis on the slider turtle (*Trachemys scripta*). Herpetological Monographs, 4:1–29.

Gidaszewski N, Baylac M, Klingenberg C. 2009. Evolution of sexual dimorphism of wing shape in the Drosophila melanogaster subgroup. BMC Evolutionary Biology 9: 110.

Halámková L., Schulte J.A., Langen T.A. 2013. Patterns of sexual size dimorphism in *Chelonia*. Biological Journal of the Linnean Society, 108(2):396–413

Lovich J.E., Ernst C.H., McBreen J.F. 1990. Growth, maturity, and sexual dimorphism in the wood turtle, *Clemmys insculpta*. Canadian Journal of Zoology 68:672–677.

Lynch M. 2007. The origins of genome architecture. 1stedition.Sunderland: Sinauer Associates.

Pough F.H. 1980. The advantages of ect other my for tetrapods. American Naturalist 115:92–112.

Regis K.W., Meik J.M. 2017. Allometry of sexual size dimorphism in turtles: a comparison of mass and length data. PeerJ, 5: e2914.

Shreeves G., Field J. 2008. Parental care and sexual size dimorphism in wasps and bees. Behavioral Ecology and Sociobiology 62: 843–852.

Stephens P.R., Wiens J.T. 2009. Evolution of sexual size dimorphisms in Emydid turtles: ecological dimorphism, Rensch'srule, and sympatric divergence. Evolution 63:910–925

Székely T., Lislevand T., Figuerola J. 2007. Sexual size dimorphism in birds. Sex, sizeand genderroles:evolutionary studes of sexual size dimorphism. Oxford: Oxford University Press, 27–37.

Werner YL., Korolker N., Sion G., Gö¸cmen B. 2016. Bermann's and Rensch's rules and the spur-thighed tortoise (*Testudo graeca*). Biological Journal of the Linnean Society 117:798–811

Yadollahvand R, Kami H.G. 2014. Habitat changes and its Impacts on the Caspian Pond Turtle (*Mauremys caspica*) Population in the Golestan and Mazandaran Provinces of Iran. Journal of Aquaculture Research & Development, 5: 232.

Yazarloo M., Kami H.G. 2017. Sexual dimorphism and morphometric study of Caspian pond turtle, *Mauremys caspica*, (Testudines: Geoemydidae) in Golestan Province, southeast of the Caspian Sea. Caspian Journal of Environmental Sciences, 15(4): 321-334.