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A Preliminary Survey of *Testudo graeca* Linnaeus 1758 Specimens from Central Anatolia, Turkey

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Abstract: Sixteen specimens of *Testudo graeca* Linnaeus 1758 from 2 adjacent localities (Meke and Acıgöl) in Central Anatolia were measured. Morphological characters standardised for straight carapace length (SCL) were compared with original raw values from Testudo populations from Aegean and south-eastern Turkey.

The post-ANOVA pairwise analysis (Tukey's) across all groups verified sexual dimorphism in the Central Anatolian populations in terms of anal suture length ($P < 0.05$) and plastron width 2 ($P < 0.05$). Discriminant analysis based on standardised values provided 89.3% and 92.6% correct classification among males and females, respectively. The difference was clearer between the Aegean and Central Anatolian populations, with a more domed carapace (CH) in the males and shorter plastron length (PL) and plastron width 2 (PW2) in the females of the Aegean population in comparison with the Central Anatolian population.

Key Words: Testudines, Testudinidae, *Testudo graeca*, tortoise, Central Anatolia, Turkey

İç Anadolu *Testudo graeca* Linnaeus 1758 Örnekleri Hakkında Bir Ön Çalışma

Özet: İç Anadolu bölgesinde birbirine yakın iki lokaliteden (Meke ve Acıgöl) toplam 16 *Testudo graeca* Linnaeus 1758 ölçülmüştür. Ölçülen morfolojik karakterler düz karapas boyuyla (SCL) standardize edilerek, daha önceki yayınlarda ölçülen Ege ve Güneydoğu Anadolu *Testudo graeca* populasyonlarına ait verilerle karşılaştırılmıştır.

Tüm grupları içine alacak şekilde uygulanan post ANOVA pairwise analizi (Tukey's), İç Anadolu populasyonunda anal sütur uzunluğu ($P < 0,05$) ve plastron genişliği 2 ($P < 0,05$) açısından bir seksüel dimorfizm olduğunu ortaya koymuştur. Standardize edilmiş değerlere dayanarak yapılan ayrım analizi sonucunda erkekler % 89,3, dişiler ise % 92,6 doğru sınıflandırılmışlardır. Gruplar arasındaki farklılık, Ege populasyonundaki erkeklerin karapasının daha bombeli (CH) olması, dişilerin ise daha kısa plastron uzunluğuna (PL) ve genişliğine (PW2) sahip olmaları nedeniyle Ege ve İç Anadolu populasyonları arasında daha belirgindir.

Anahtar Sözcükler: Testudines, Testudinidae, *Testudo graeca*, kara kaplumbağası, İç Anadolu, Türkiye

Introduction

The taxonomy of the *Testudo graeca* complex is a longstanding, unresolved problem in the herpetology of the western Palaearctic. For many years, a model proposed by Mertens (1946) and Wermuth (1958) was generally accepted. More recent research has shown that the taxonomic situation is much more complex. The results of many recent papers are not generally accepted. The situation is compounded by the fact that different species concepts are used in new papers dealing with variation in the *T. graeca* complex, leading to an incompatibility between the results of different authors (Perälä, 2002b; Pieh et al., 2002b). We are still far away from an understanding of the observed variation.

Two species of land tortoise, *Testudo graeca* Linnaeus 1758 and *Testudo hermanni* Gmelin 1789, are known from Turkey. Of these, 4 subspecies of the more widespread *T. graeca* are recognised: *T.g. ibera* Pallas 1814, *T.g. terrestris* Forsskal 1775, *T.g. anamurensis* Weissinger 1987 and, recently, the poorly known *T.g. armeniaca* Chkhikvadze and Bakradze 1991. The existence of this new taxon in Turkey was supported by

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Berglas (2000) and Pieh et al. (2002a). *T. hermanni*, restricted to Thrace, is represented by the eastern taxon, *T.h. boettgeri* Mojsisovics 1889. The description of *Testudo antakyensis* Perälä 1996 is not generally recognised (Baran and Atatür, 1998) although the author makes a convincing case for the existence of a morphologically distinct population in the area around İskenderun Bay. Brinckmeier et al. (1989) reported the occurrence of the marginated tortoise, *Testudo marginata* Schoepff 1792, in the vicinity of the ancient city of Ephesus. Although this record is considered to be a false identification or an introduced specimen by subsequent researchers (Perälä, 1996; Baran and Atatür, 1998), it was taken included in the Turkish chelonian list by Demirsoy (1997). This record was later discarded by Türkozan et al. (2001).

Eiselt and Spitzenberger (1967) carried out a study on the morphology of Turkish tortoises when only the subspecies *T.g. ibera* and *T.g. terrestris* were recognised. This paper remained the seminal contemporary work on the tortoises of Anatolia and Turkish Thrace until the last decade. In recent years, there has been an increasing focus on the taxonomic status of the *Testudo* taxa (Perälä, 1996; Taşkavak et al., 2002; Türkozan et al., 2003a; Türkozan et al., 2003b; Türkozan et al., 2004a). In Turkey, little detailed work on the taxonomic status and ecology of the genus *Testudo* has been carried out. Tok (1999) discusses the taxonomic status and ecology of *T. graeca ibera* populations from the Reşadiye peninsula and Türkozan et al. (2004) discuss the same issues in *Testudo* populations from the western Taurus mountains. Later, Taşkavak et al. (2002) pointed out the morphological difference between Mediterranean *Testudo* populations and those of the Aegean. In the most recent study by Kuyl et al. (2002), 2 main clades of Mediterranean tortoises were identified based on 12S rRNA gene sequences with the application of maximum likelihood and nearest-neighbour methods. They recorded that the first clade was composed of the species *T. graeca*, *T. marginata* and *T. kleinmanni*, and a second of *T. hermanni*, *T. horsfieldii* and *Indotestudo elongata*. Ballasina and Kuyl (2002) found the largest morphological variation in Turkey for *T. graeca*. They also found that *T.g. ibera* in Turkey was represented by 2 haplotypes, TG16 and TG17. Türkozan et al. (2003a) compared the Adıyaman (south-eastern Turkey) and İzmir (Aegean region) populations from morphological and serological points of view. They pointed out some morphological differences between the 2 populations. Türkozan et al. (2003b) discussed the taxonomic status of the Mardin (south-eastern) population. Perälä (2002a) pointed out the occurrence of a newly described species, *Testudo perses* Perälä 2002, at Esendere, Vilayet Hakkari, south-eastern Turkey. This record was confirmed by Türkozan et al. (2004b) and the northernmost range was extended to Başkale, Vilayet Van.

The more recently described subspecies, *T.g. anamurensis* Weissinger 1987 and species *T. antakyensis* Perälä 1996, both from coastal southern Turkey, are based upon limited material without significant statistical comparisons. While Weissinger's description has met widespread acceptance, the latter taxon is viewed with scepticism among Turkish herpetologists. Neither taxon was included in the most recent book of Turkish herpetofauna (Baran and Atatür, 1998).

Perälä (2002b) re-evaluated *Testudo* s.l. using cladistic methodology and concluded that the concept of a monophyletic *T. graeca* is unsupportable. He claimed that the genus *Testudo* is an unnatural taxon consisting of several lineages at generic and possibly subgeneric level, as well as one paraphyletic taxon at species level (*T. graeca*). Pieh et al. (2002b) reported the variability of the spur-thighed tortoise in Turkey and suggested that the Lake Van population is an undescribed taxon.

This study aims to elucidate the status of *Testudo graeca* populations from central Anatolia, as no information has been given on central Anatolian populations.

Materials and Methods

The fieldwork was carried out by the authors between 10 am and 3 pm on 6th April 2002. The specimens were located by manual searching. A total of 16 specimens of *T. graeca* from 2 adjacent localities (Meke Lake [3♂♂ 4♀♀] and Acı Lake [3♂♂ 6♀♀]) in Central Anatolia were measured (Figure 1) using a tape measure, a wooden calliper and a dial calliper. Colour and pattern features were recorded, although not in keeping with the standards given by Eiselt and Spitzenberger (1967). The individuals were then released. Since standard procedures were applied, the original raw values recorded in specimens from İzmir (7♂♂ 9♀♀), representing the

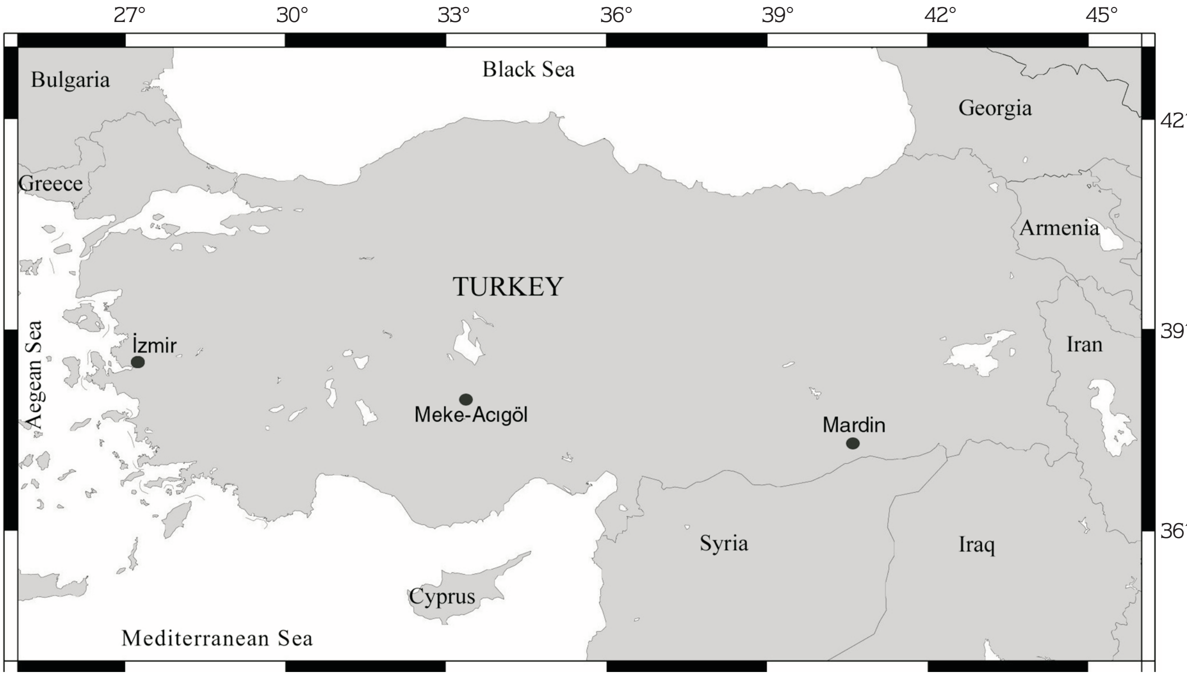


Figure 1. Map of localities (Seaturtle.org Maptool).

Aegean *Testudo* population (Türkozan et al., 2003a), and Mardin (16♂♂ 8♀♀), representing the population from south-eastern Turkey (Türkozan et al., 2003b), were used for comparison.

The morphometric features used in this study to compare the specimens are as follows: Straight Carapace Length (SCL): the straight-line measurement from the outermost projection of the nuchal plate to the posterior end of supracaudalia. Carapace Width (CW): straight-line measurement between the lateral margins of the carapace (mid-line). Carapace Height (CH): the vertical measurement between the highest point of carapace and the lowest point of plastron. Plastron Length (PL): the straight-line measurement from the outermost projection of the gular to the posterior end of the anal scute. Plastron Width (PW-1): straight-line measurement between the lateral margins (from humerals) of the plastron. Plastron width (PW-2): straight-line measurement between the lateral margins (at the level of the abdominals) of the plastron. Gular Suture Length (GSL): length of gular scute at mid-seam. Humeral Suture Length (HSL): length of humeral scute at mid-seam. Pectoral Suture Length (PSL): length of pectoral scute at mid-seam. Abdominal Suture Length (AbSL): length of abdominal scute at mid-seam. Femoral Suture Length (FSL): length of femoral scute at mid-seam. Anal Suture Length (ASL): length of anal scute at mid-seam.

Morphometric ratios were used to indicate similarities and differences between the specimens. These ratios were used due to uncertainty of the age of specimens and as to whether or not their growth was isometric. With this aim, characters used in ANOVA were standardised for SCL. Character variation was compared across all groups using ANOVA pairwise analysis. Males and females were analysed separately. Subsequently, discriminant analysis was carried out to compare populations. The test of equality of group covariance matrices (Box's M test) was accepted for the raw measurement ratios ($P > 0.05$) and therefore canonical discriminant analysis was used to determine the distinctiveness of the populations. Stepwise selection (F for entry: 3.84; for removal: 2.71) was used to obtain a subset of those variables that provided the best discrimination. The significance level for all statistics was set at $\alpha = 0.05$. All morphometric data were analyzed using STATISTICA 6.0 (StatSoft, Tulsa, OK, USA).

Study Area

The Central Anatolian region is located in the steppe subregion of the inner Anatolian ecoregion (Atalay, 2002). The Central Anatolian plateau was formed during the Miocene (25 – 5 million BP) by tectonic movements (Oğuztüzün, 1995). This region served as a refugium during the glacial period (Demirsoy, 1996) The incidence of volcanic eruptions increased during the Pliocene (5 million – 2 million BP); certain volcanoes have now filled with water to form crater lakes. The area in which these lakes occur is known as Meke.

Meke Lake

The circle-like Meke Lake (saltpan) is located in an ellipse-shaped crater situated in the area of Vilayet Konya. The primary conical crater, which was formed by secondary eruptions in the lake, is 800 m in length and 500 m in width. The depth of the conical crater ranges from 25 to 40 m through the water line, the slope is rather steep and becomes perpendicular in places. It is covered with volcanic slag and ash. The real Meke reaches up to 1031 m, which is 50 m higher than the lake level. On the crest, a crater 25 m deep is situated. Such volcanic cones are capable of absorbing a great deal of rainfall, and this property has prevented the demolition of the Meke for many years since there has been no risk of erosion. This saline lake is up to 11 m deep. The lake is fed from the base. A total of 7 more Mekes are situated as small islands, some of which are joined to the main Mekes.

Acı Lake

Acı Lake is situated 2 km north-east of Meke Lake. The lake is 35 m deep and almost circular. It is situated in a collapsed crater. At its widest point, the lake is 1.5 km across. It is situated at the foot of Karacadağ (2025 m). This lake is also saline and, due to sulphate salts in the water, it contains no life. The altitude of the lake is identical to that of Meke Lake (981 m). Travertine stones occur at some places on the edge of lake. This lake is also fed from the base. A hill formed by a secondary eruption is situated in Acı Lake. This is the most important difference between the 2 lake systems. Furthermore, the water level of this lake does not vary seasonally.

Results

It is apparent that females of the Central Anatolian population are larger than those of the Aegean ($P < 0.05$). The maximum SCL measured was of a female in the Central Anatolian population (248 mm), whereas the smallest was of a mature male in the south-eastern population (SCL 135 mm, Table 1). Tok (1999) recorded a maximum SCL of 250 mm from the Reşadiye peninsula. According to Beshkov (1997), the maximum carapace length recorded for *T. graeca* in Turkey is 252 mm. Türkozan et al. (2004) reported a new record size of SCL of 295 mm in the Mediterranean region. Weissinger's type for *T.g. anamurensis* (from Anamur) has a length of 260 mm. Perälä (1996) quotes one specimen of considerable length (267 mm) from Cap Anamur. It is clear, however, that without proportional divergence size is not considered a very useful diagnostic character.

The post-ANOVA pairwise analysis (Tukey's) across all groups verified sexual dimorphism only in the Central Anatolian populations in terms of anal suture length ($P < 0.05$) and plastron width 2 ($P < 0.05$).

Later, discriminant analysis was carried out separately for males and females.

For males, a total of 89.3% of among-group variation was explained by the first canonical variate, which provides discrimination between the Aegean population and other 2 populations (Figure 2a). The remaining 10.7% was explained by the second canonical variate, which separated the south-eastern and Central Anatolian populations. In contrast to the analysis for the females, discrimination was not particularly good for males (Table 2). One of the 6 Central Anatolian males was misclassified into the south-eastern population and 2 of the 7 Aegean males were misclassified into the south-eastern population.

Discrimination was good for females. A total of 92.6% of among-group variation was explained by the first canonical variate, which separated the Central Anatolian population from the other populations. The remaining 7.4% was explained by the second canonical variate, which separated the Aegean population from the south-eastern population (Figure 2b). The only exceptions to correct classification were 1 individual from south-east Anatolia and 1 from Central Anatolia, which were misclassified into the Aegean population (Table 2). The partial Wilks' lambda values indicate that variable

Table 1. Descriptive statistics for males and females of Aegean, Central Anatolian and south-east Anatolian populations. Characters were standardised for maximum carapace length except for SCL (= in mm). N: sample size, Min: minimum, Max: maximum, S.D.: standard deviation, S.E.: standard error of the mean.

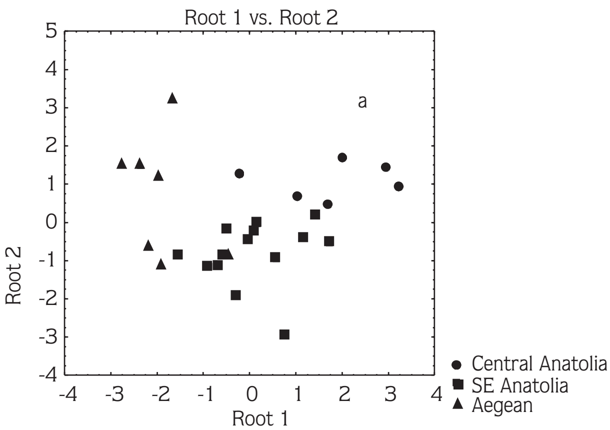
	MALES																	
	AEGEAN						CENTRAL ANATOLIA						SOUTH-EAST ANATOLIA					
	N	Mean	Min.	Max.	S.D.	S.E.	N	Mean	Min.	Max.	S.D.	S.E.	N	Mean	Min.	Max.	S.D.	S.E.
SCL	7	186.71	160	242	27.97	10.57	6	211	193	246	18.53	7.56	16	203.75	135	239	23.49	5.87
CW	7	0.71	0.66	0.75	0.03	0.01	6	0.71	0.69	0.73	0.01	0.01	16	0.70	0.64	0.78	0.04	0.01
CH	7	0.53	0.46	0.57	0.04	0.01	6	0.49	0.45	0.52	0.02	0.01	16	0.49	0.44	0.53	0.03	0.01
PL	7	0.86	0.84	0.90	0.02	0.01	6	0.89	0.86	0.92	0.03	0.01	16	0.87	0.81	0.95	0.04	0.01
GSL	7	0.13	0.12	0.14	0.01	0.00	6	0.13	0.12	0.15	0.01	0.00	16	0.14	0.13	0.16	0.01	0.00
HSL	7	0.14	0.12	0.16	0.01	0.01	6	0.14	0.12	0.15	0.01	0.00	15	0.12	0.09	0.14	0.01	0.00
PSL	7	0.06	0.03	0.08	0.02	0.01	6	0.05	0.03	0.07	0.01	0.01	15	0.05	0.03	0.08	0.01	0.00
AbSL	7	0.29	0.27	0.32	0.02	0.01	6	0.30	0.28	0.31	0.01	0.00	16	0.30	0.26	0.36	0.02	0.01
FSL	7	0.12	0.11	0.14	0.01	0.01	6	0.12	0.11	0.12	0.01	0.00	16	0.13	0.10	0.15	0.01	0.00
ASL	7	0.09	0.07	0.11	0.01	0.01	6	0.10	0.06	0.11	0.02	0.01	16	0.09	0.08	0.13	0.02	0.00
PW1	7	0.44	0.42	0.49	0.02	0.01	6	0.43	0.41	0.46	0.02	0.01	15	0.44	0.40	0.50	0.02	0.01
PW2	7	0.46	0.42	0.48	0.02	0.01	6	0.46	0.44	0.47	0.01	0.00	16	0.45	0.41	0.49	0.02	0.01

	FEMALES																	
	AEGEAN						CENTRAL ANATOLIA						SOUTH-EAST ANATOLIA					
	N	Mean	Min.	Max.	S.D.	S.E.	N	Mean	Min.	Max.	S.D.	S.E.	N	Mean	Min.	Max.	S.D.	S.E.
SCL	9	186.89	172	205	11.87	3.96	10	224.80	194	248	20.17	6.38	8	208.63	155	238	24.38	8.62
CW	9	0.71	0.65	0.75	0.03	0.01	10	0.74	0.70	0.77	0.02	0.01	8	0.72	0.70	0.74	0.01	0.01
CH	9	0.53	0.50	0.57	0.02	0.01	10	0.50	0.45	0.54	0.02	0.01	8	0.51	0.47	0.54	0.02	0.01
PL	9	0.88	0.80	0.91	0.03	0.01	10	0.94	0.91	0.99	0.03	0.01	8	0.91	0.88	0.94	0.02	0.01
GSL	9	0.13	0.12	0.15	0.01	0.00	10	0.13	0.11	0.14	0.01	0.00	8	0.14	0.12	0.15	0.01	0.00
HSL	9	0.14	0.12	0.16	0.01	0.00	10	0.14	0.13	0.16	0.01	0.00	8	0.13	0.11	0.20	0.03	0.01
PSL	9	0.06	0.03	0.08	0.02	0.01	10	0.06	0.04	0.10	0.02	0.01	8	0.05	0.04	0.06	0.01	0.00
AbSL	9	0.30	0.27	0.34	0.03	0.01	10	0.33	0.29	0.35	0.02	0.01	8	0.31	0.28	0.35	0.02	0.01
FSL	9	0.12	0.10	0.15	0.02	0.01	10	0.12	0.09	0.14	0.02	0.00	8	0.12	0.10	0.15	0.02	0.01
ASL	9	0.12	0.09	0.15	0.02	0.01	10	0.13	0.11	0.15	0.01	0.00	8	0.11	0.09	0.12	0.01	0.00
PW1	9	0.42	0.38	0.46	0.02	0.01	10	0.44	0.40	0.47	0.02	0.01	8	0.43	0.41	0.47	0.02	0.01
PW2	9	0.46	0.41	0.50	0.02	0.01	10	0.50	0.46	0.55	0.03	0.01	8	0.46	0.44	0.48	0.01	0.01

PL/SCL ($F = 4.05$, $P < 0.05$) contributes most to overall discrimination.

Results from post-ANOVA pairwise analysis (Tukey's) across the males suggested statistically significant differences between the Central Anatolian and Aegean populations in terms of CH/SCL ($P < 0.05$) and between south-eastern and Aegean populations HSL/SCL ($P < 0.05$). The same analysis also supported morphological differences among females [ASL/SCL ($P < 0.05$), PW2/SCL ($P < 0.05$) between Central Anatolia and south-eastern Anatolia; PL/SCL ($P < 0.001$) and PW2/SCL ($P < 0.05$) between Central Anatolian and Aegean] (Table 3).

The colour and pattern of Central Anatolian *T. graeca* vary even within the population. The ground colour of the



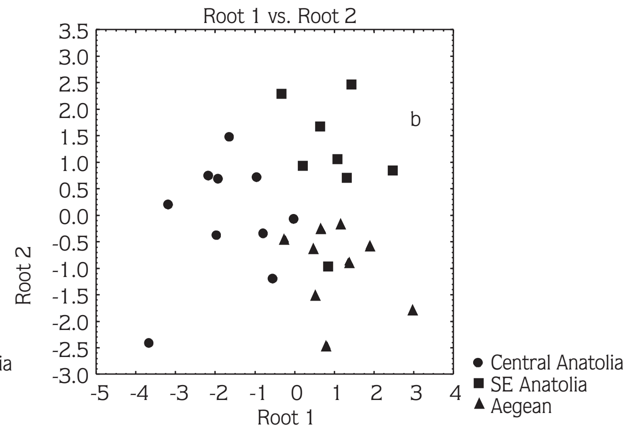


Figure 2. Specimens of Central Anatolia, south-east Anatolia and Aegean plotted in canonical variate space a-males Number of variables in the model: 7 (HSL, PSL, CH, PL, AbSL, PW1, FSL) Wilk's λ = 0.19876, F (14,38) = 3.3739 P < 0.001; b-females Number of variables in the model: 6 (PL, ASL, PW2, GSL, CH, HSL) Wilk's λ = 0.18964, F (12,38) = 4.1051 P < 0.001.

Table 2: Classification matrix from discriminant function analysis. (Rows. observed classifications; columns. predicted classifications).

	Males				Females			
	Percent	Central Anatolia	SE Anatolia	Aegean	Percent	Central Anatolia	SE Anatolia	Aegean
Central Anatolia	83.3	5	1	0	90	9	0	1
SE Anatolia	100	0	15	0	87.5	0	7	1
Aegean	71.4	0	2	5	100	0	0	9
Total	89.3	5	18	5	92.6	9	7	11

Table 3. Statistically significant (P < 0.05) pairwise differences (•) among populations (Tukey's post ANOVA pairwise analysis for unequal N).

	CH/SCL	HSL/SCL	ASL/SCL	PW2/SCL	PL/SCL
MALES					
CA - Aegean	•				
CA - SE					
SE - Aegean		•			
FEMALES					
CA - Aegean				•	•
CA - SE			•	•	
SE - Aegean					

carapace is yellowish with black blotches that vary in size and shape. Marginal scutes possess clear marks. Stubbs (1989) states that colour and pattern features are not reliable for the identification of *Testudo graeca*. However, clear and deep carapacial scute rings were very remarkable on the carapace of Central Anatolian individuals (Figure 3).

Figure 3. A general aspect of a female from the Central Anatolian population.

In conclusion, discriminant analysis based on 7 (for males) and 6 (for females) ratios confirms that Central Anatolian *T. graeca* tend to differ from individuals from the other 2 populations. The difference was clearer between Central Anatolian and Aegean populations. The males have a higher carapace and females have a shorter plastron length (PL) and plastron width (PW2) in the Aegean population in comparison to the Central Anatolian population. The Aegean population is known to represent typical *T.g. ibera*. The taxonomic status of the south-eastern population (Mardin) is marked as unknown on the map given by Başoğlu and Baran (1977). The adjacent localities (Urfa and Diyarbakır provinces) of Mardin were classified as *T.g. terrestris* by Perälä (2002b). Türkozan et al. (2003b) report that morphometric and meristic features of the Mardin population did not correspond to *T.g. terrestris*. The climatic and habitat features of the regions also show differences. The Aegean area typically possesses a Mediterranean climate and bushy habitats. The Central Anatolian area has a terrestrial climate with sand steppes. The south-eastern area has typical eremial elements and is open to penetration by new species from Syria and Iraq. It is, therefore, important to investigate the possibility of new subpopulations in the central Anatolian and south-eastern populations.

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