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External morphological and osteological features of Turkish populations of *Laudakia stellio* (LINNAEUS, 1758)

(Squamata: Sauria: Agamidae)

Eidonomische und osteologische Charakteristika türkischer Populationen von *Laudakia stellio* (LINNAEUS, 1758)

(Squamata: Sauria: Agamidae)

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KURZFASSUNG

Die Studie vergleicht äußere morphologische und osteologische Merkmale der Schleuderschwanzagame, *Laudakia stellio* (LINNAEUS, 1758) aus sechs ihrer türkischen Vorkommensgebiete. Dazu wurden Merkmalsausprägungen der Färbung und Zeichnung, Beschuppung, und Körperproportion von 173 Individuen sowie osteologische Merkmalsausprägungen bei 40 Repräsentanten dieser Populationsgruppen im Hinblick auf signifikante Unterschiede untersucht. Nach den vorliegenden Befunden hebt sich die Population von Hatay von allen übrigen in ihrer äußeren Morphologie und osteologisch ab.

ABSTRACT

The authors conducted a comparative study of the morphology and osteology of six Turkish populations of the agamid lizard *Laudakia stellio* (LINNAEUS, 1758). Color and pattern characteristics, pholidosis features and body measurements of 173 specimens were examined for morphological differences between the populations. Besides the analysis of external morphological traits, 40 specimens from five localities/populations were examined osteologically. In conclusion, the Hatay population differed morphologically and osteologically from the other populations.

KEYWORDS

Reptilia: Squamata: Sauria: Agamidae, *Laudakia stellio*, external morphology, osteology, subspecific variation, distribution, Turkey

INTRODUCTION

Laudakia stellio (LINNAEUS, 1758), the Hardun or Roughtail Rock Agama, is distributed in the east Mediterranean area from Greece across the Levant as far as Egypt, including neighboring countries of the Near East (SINDACO & JEREMČENKO 2008). It is found in almost all of Anatolia except for Thrace and the Black Sea regions (BARAN & ATATÜR 1998; GÜL et al. 2010).

Studies of particular Anatolian populations dealt with taxonomy (BARAN & ÖZ 1985; BARAN et al. 1989; GÖÇMEN et al. 2003; ALMOG et al. 2005), distribution (BARAN 1980; MULDER 1995; BUDAK et al. 1998; TOK 1999; UĞURTAŞ et al. 2000; KUMLUTAŞ et al. 2004), feeding biology (DÜŞEN & ÖZ 2001) and enteric protozoa (ÜÇÜNCÜ et al. 2001). Color-pattern, pholidosis, morphometry and molecular traits were utilized to distinguish subspecific units (DAAN 1967; BEUTLER & FRÖR 1980; GÖÇMEN et al. 2003; ALMOG et al. 2005; ÖZDEMIR et al. 2011).

On the basis of color-pattern, pholidosis and morphometric studies, all *L. stellio* populations of Anatolia were previously treated as representatives of the nominate subspecies (DAAN 1967; BAIG 1992; LEVITON et al. 1992). In the following years they were assigned to two subspecies, viz. *L. s. stellio* and *L. stellio daani* (BEUTLER & FRÖR, 1980), again in terms of color-pattern, morphometry and pholidosis (BEUTLER & FRÖR 1980; BARAN & ÖZ 1985; BARAN &

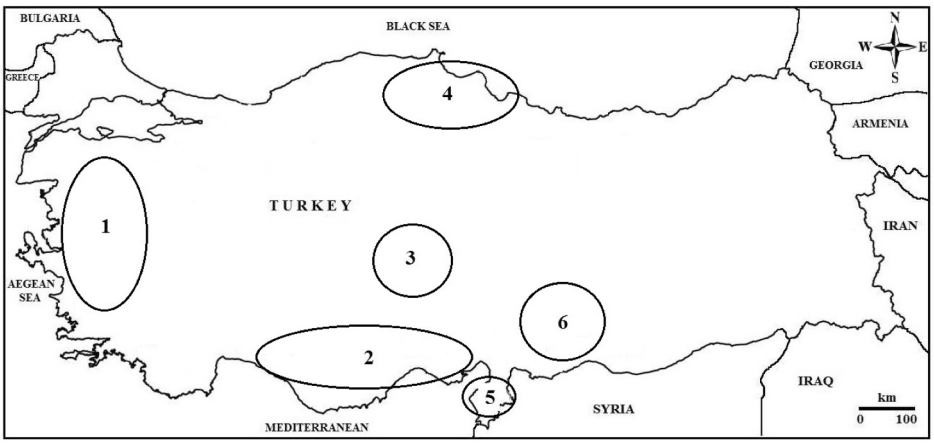

Fig. 1: Sampling regions of *Laudakia stellio* (LINNAEUS, 1758) in this study. 1 - West Anatolian population (Balıkesir, Çanakkale, İzmir, Muğla, Manisa), 2 - South Anatolian population (Antalya, Mersin, Adana), 3 - Central Anatolian population (Karaman, Kayseri), 4 - North Anatolian population (Tokat, Amasya, Sinop), 5 - Hatay population, 6 - Southeast Anatolian population (Kahramanmaraş, Gaziantep, Adıyaman, Şanlıurfa).

Abb. 1: Die Gebiete, in denen die in der vorliegenden Untersuchung verwendeten Exemplare von *Laudakia stellio* (LINNAEUS, 1758) gesammelt wurden. 1 - Westanatolische Population (Balıkesir, Çanakkale, İzmir, Muğla, Manisa), 2 - Südanatolische Population (Antalya, Mersin, Adana), 3 - Zentralanatolische Population (Karaman, Kayseri), 4 - Nordanatolische Population (Tokat, Amasya, Sinop), 5 - Hatay Population, 6 - Südostanatolische Population (Kahramanmaraş, Gaziantep, Adıyaman, Şanlıurfa).

ATATÜR 1998; GÖÇMEN et al. 2003; KETE & YILMAZ 2006). In one of the latest studies (ALMOG et al. 2005), however, the authors concluded that, according to external morphology traits, all the Anatolian populations represented *L. s. daani*.

Regarding the color-pattern, *L. s. stellio* was said to have a yellow-red temporal and occipital region, in contrast with the brown body, and an inconspicuous gular area displaying a dark striped pattern. In *L. s. daani*, however, the top and posterior portions of the head were reported to be blackish grey like the rest of the body, and the gular region bears large black spots in most specimens (DAAN 1967; BEUTLER & FRÖR 1980; ALMOG et al. 2005). ALMOG et al. (2005) and BEUTLER & FRÖR (1980) declared that there were no blue colored scales present in *L. s. stellio* populations, whereas blue elements could be found in *L. s. daani*.

Regarding the pholidosis, ALMOG et al. (2005) stated that the number of preanal pores was less than 30 and the number of subdigital lamellae underneath the fourth toe of the hind limb ranged from 17 to 20 in males, and 16 to 21 in females of *L. s. stellio*, whereas, the number of preanal pores was more than 30 and the number of subdigital lamellae under the fourth toe of the hind limb ranged from 16 to 23 in males, and from 17 to 22 in females in *L. s. daani*. As a result of pholidosis and morphometric analyses, KETE & YILMAZ (2006) detected that the number of subdigital lamellae was smaller and the snout-vent length longer in *L. s. daani* than in *L. s. stellio*.

Knowledge about the osteology of *L. stellio* is still fragmentary. In his PhD thesis on the "*stellio* group" within the family Agamidae, BAIG (1992) included some osteological information. However, the only detailed osteology of the species *L. stellio* was the study by EL-TOUBI (1947) about specimens from two localities in Egypt (Bourg El-Arab and the south of the Sina Peninsula), in which the most important characteristics were provided.

Our study aims to present an external morphological and osteological examination of the *Laudakia stellio* populations distributed in Anatolia and to describe the variation among the populations.

Table 1: Inventory numbers (Zoology Section, Biology Department, Çanakkale Onsekiz Mart University, Çanakkale, Turkey) of the Anatolian *Laudakia stellio* (LINNAEUS, 1758) samples studied, and UTM coordinates of the sampling localities. *n* – Sample size, M - Male(s), F - Female(s), J - Juvenile(s).

Tab. 1: Inventarnummern (Sektion Zoologie, Abteilung für Biologie, Çanakkale Onsekiz Mart Universität, Çanakkale, Türkei), UTM Koordinaten und Fundorte der untersuchten anatolischen Exemplare von *Laudakia stellio* (LINNAEUS, 1758). *n* – Stichprobenumfang, M - Männchen, F - Weibchen, J - Jungtier(e).

Inv.-Nr.	*n*	UTM Coordinates UTM Koordinaten			Altitude (m a.s.l.) Höhe (m üNN)	Inv.-Nr.	*n*	UTM Coordinates UTM Koordinaten			Altitude (m a.s.l.) Höhe (m üNN)
2006-24	2M, 3F, 1J	35S	644112	4078077	180 m	2007-130	4F	37S	288429	4096905	531 m
2006-48	3M, 1F	35S	640742	4082573	24 m	2007-131	1M	37S	285392	4203862	1470 m
2006-44	1J	35S	572026	4098952	222 m	2007-132	2M	37S	243719	4230845	1580 m
2006-107	2F	37S	290117	4108709	657 m	2008-62	2M, 3J	37T	273809	4515153	700 m
2006-111	1F	37S	310586	4111471	708 m	2008-63	2F	37T	302273	4504590	670 m
2006-113	3M, 1F, 2J	36S	768519	3994337	8 m	2008-66	1J	37T	327485	4494570	750 m
2006-114	1M	36S	670414	4087994	15 m	2008-67	1M, 1F	37T	329580	4494985	750 m
2007-8	2F, 1J	35S	442940	4371405	220 m	2008-89	1M	37S	363373	4156378	966 m
2007-14	1M	37S	390785	4191433	812 m	2008-90	5M, 2F, 1J	37S	409209	4094660	350 m
2007-16	1M	37S	289134	4108882	700 m	2008-97	5M, 3F, 1J	36S	735291	4094807	60 m
2007-18	1M, 1F	37S	280197	4071991	350 m	2008-98	1M, 1F	36S	456017	4117936	1500 m
2007-23	3M, 1F	37S	265876	4039564	80 m	2008-101	5M, 3F, 1J	35S	691871	4060058	50 m
2007-26	2M, 2F, 2J	36S	766455	3997767	12 m	2008-102	3M, 2F, 1J	35S	510913	4263339	315 m
2007-119	1M	37S	383240	4185378	900 m	2008-103	1M	35S	503923	4263859	14 m
2007-120	1M	37S	404887	4184030	1092 m	2008-104	1M	36S	621902	4087537	1272 m
2007-121	1F	37S	237914	3977034	665 m	2009-91	1M	35S	442940	4371405	220 m
2007-122	1M	36S	249823	4105694	1032 m	2009-110	2M, 3F, 1J	36T	677236	4654893	10 m
2007-123	1M, 1F, 1J	36S	233647	4103427	1600 m	2009-115	4M, 2F	37T	273809	4515153	700 m
2007-124	1M	36S	468720	4055343	1350 m	2009-116	4M, 4F, 2J	36S	690777	4264552	1081 m
2007-125	1M, 5F, 6J	36S	538838	4054388	314 m	2009-117	1M, 2F, 1J	35S	591469	4366341	300 m
2007-126	4M, 2F, 7J	36S	727246	4094577	55 m	2009-118	1J	35S	598734	4358203	378 m
2007-127	3M, 1F	37S	297613	4108757	479 m	2009-119	2F, 1J	35S	669912	4308608	950 m
2007-128	1M	37S	277374	4066326	299 m	2009-120	1M, 1F	35S	510913	4263339	315 m
2007-129	1M, 3F	37S	275580	4042877	80 m	2009-121	4M, 2F	35S	442940	4371405	220 m

Table 2: Evaluation of the differences in the numbers of sublabial scales, subdigital lamellae and scales on 5th caudal whirl between the studied Anatolian populations (see Fig. 1) of *Laudakia stellio* (LINNAEUS, 1758) by means of Mann-Whitney U test (*p* – Probability). P4 – number of subdigital lamellae underneath the fourth toe of the hind limb, P3 – number of subdigital lamellae underneath the third toe of the fore limb, T5 – number of scales on the 5th whirl of the tail as of its proximal beginning. Significant *P* values in bold.

Tab. 2: Bewertung der Unterschiede in der Anzahl der Sublabialia, Subdigitallamellen und Schuppen des 5. Schwanzwirtels zwischen verschiedenen anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758) mittels Mann-Whitney U Tests (*p* – Wahrscheinlichkeit). P4 – Anzahl der Subdigitallamellen an der Unterseite der 4. Hinterbeinzehe, P3 – Anzahl der Subdigitallamellen an der Unterseite des 3. Vorderbeinfingers, T5 – Anzahl der Schuppen des 5. postkloakalen Schwanzwirtels. Signifikante *P*-Werte in Fettschrift.

Population Comparisons	Number of Sublabialia Anzahl Sublabialia *p*	P4 *p*	P3 *p*	T5 *p*
W Anatolia – S Anatolia	**0.028**	0.339	0.145	0.242
W Anatolia – Central Anatolia	**0.019**	**0.012**	**0.012**	**0.000**
W Anatolia – N Anatolia	0.853	0.056	0.109	**0.000**
W Anatolia – Hatay	0.633	0.060	**0.001**	0.059
W Anatolia – SE Anatolia	0.282	0.176	0.349	0.600
S Anatolia – Cetral Anatolia	0.627	**0.001**	**0.000**	**0.002**
S Anatolia – N Anatolia	0.082	**0.008**	**0.024**	**0.002**
S Anatolia – Hatay	**0.022**	0.256	**0.038**	**0.014**
S Anatolia – SE Anatolia	0.239	**0.023**	0.592	0.207
Central Anatolia – N Anatolia	**0.036**	0.983	0.880	0.487
Central Anatolia – Hatay	**0.010**	**0.000**	**0.000**	**0.000**
Central Anatolia – SE Anatolia	0.108	0.115	**0.000**	**0.001**
N Anatolia – Hatay	0.520	**0.003**	**0.001**	**0.000**
N Anatolia – SE Anatolia	0.418	0.205	0.053	**0.001**
Hatay – SE Anatolia	0.126	**0.004**	**0.010**	0.322

MATERIALS AND METHODS

In this study, 173 (77/61/35 male/female/juvenile) specimens were collected from different localities of Turkey in April and August, between 2006 and 2009. Sexes were distinguished by presence/absence of hemipenes and callous glandular scales in pre-anal and midbody position. The specimens were generally caught by hand on, under or between the rocks at sunny hours and kept alive in cloth bags until the color-pattern characteristics were registered in detail, and color photographs were taken. Later, the lizards were anesthetized with ether; 96% alcohol was injected into the body cavity, and the specimens were transferred into 70% ethanol for permanent preservation. The specimens used in this study were registered in the collection of the Zoology Section at the Biology Department in the Faculty of Science and Letters at Çanakkale Onsekiz Mart University, Çanakkale, Turkey.

Each of the 173 specimens was assigned to one out of six populations/regions according to where it was caught, namely, West Anatolia (21/18/8 male/female/juvenile), South Anatolia (14/11/15), Central Anatolia (8/5/2), North Anatolia (9/8/5), Hatay (12/9/4 and Southeast Anatolia (13/10/1) (Fig. 1). The inventory numbers and GPS based coordinates and altitudes of the specimens' record localities are presented in Table 1.

Morphological examinations

Color-pattern.- From each specimen collected, 18 characters of color and pattern (dorsal and ventral ground color; ventral pattern and its range; color of dorsal and head scales; gular ground color, pattern type and its range; coloration of the sides of the head; color of sublabialia and supralabialia; symmetry, number and location of vertebral dots; expression of transverse ledges in the vertebral dots; coloration of arms and legs; coloration of hands and feet) were qualitatively examined . The color-pattern characteristics varying among populations were: dorsal ground color, ventral ground color, pattern of throat, symmetry and shape of the vertebral dots and the extent of blue coloration on the femur.

Pholidosis.- From each specimen collected, eight meristic pholidosis characters (numbers of sub- and supralabials, ventrals, subdigital lamellae underneath the fourth toe of the hindlimb, subdigital lamellae underneath the third finger of the forelimb, scales on the 5th whirl of the tail as of its beginning, ventral glandular scales and preanal glandular scales) were examined and subjected to interpopulation comparison. The characters that varied among populations were: number of sublabialia, number of subdigital lamellae underneath the fourth toe of the hind limb, number of subdigital lamellae underneath the third finger of the fore limb and number of scales on the 5th whirl of the tail as of its beginning.

Morphometry.- Using a digital caliper sensitive to 0.01 mm for the morphological measurements, four body measurements were obtained for each specimen (TL - Tail Length, SVL - Snout-Vent Length, HL - Head Length and HW - Head Width). From these the following ratios and indexes were computed: TL / SVL, SVL / HL, HL / HW, Head Index (HI) [100 x HL / HW], Head Length Index (HLI) [100 x HL / SVL].

Osteological examinations

There are many osteological studies in which the double skeletal staining method was used (Davis & Gore 1936; Green 1952; McLeod 1980; Sunay 2005). Transparent stained skeletons formed the essence of the present study as well. Double staining was applied to the transparent stained total skeletons, i.e. cartilage and bone. After the freshly euthanized specimens were skinned their internal organs were extracted, and the carcass was placed in 95% ethanol for five days and in standard laboratory acetone for two days. The preparations were then left in the stain prepared from a mixture of Alizarin Red-S and Alcian Blue 8GS for three days and went through a glycerin series for one week each. After the cartilages were stained blue, the bones red and the stain remnants completely removed from the muscles using a mixture of glycerin and potassium hydroxide, the preparations were preserved in 100% glycerin (McLeod 1980).

Table 3: The numbers of subdigital lamellae and sublabial scales in several Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758), according to various sources. P3 – number of subdigital lamellae underneath the third toe of the fore limb, P4 – number of subdigital lamellae underneath the fourth toe of the hind limb. Ranges in parentheses.

Tab. 3: Die Anzahl der Subdigitallamellen und Sublabialschilde in verschiedenen anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758), nach unterschiedlichen Quellen. P3 – Anzahl der Subdigitallamellen an der Unterseite des 3. Vorderbeinfingers, P4 – Anzahl der Subdigitallamellen an der Unterseite der 4. Hinterbeinzehe. Spannweiten in Klammern.

Reference / Quelle	Region	P3	P4	Sublabialia
Present study / diese Arbeit	W Anatolia	♂♂ 16.57 ♀♀ 16.52	♂♂ 21.10 ♀♀ 21.12	♂♂ 11.66 ♀♀ 11.58
Present study / diese Arbeit	S Anatolia	♂♂ 17.53 ♀♀ 16.81	♂♂ 22.00 ♀♀ 21.45	♂♂ 11.06 ♀♀ 11.09
Present study / diese Arbeit	Central Anatolia	♂♂ 15.75 ♀♀ 14.80	♂♂ 20.28 ♀♀ 19.60	♂♂ 11.00 ♀♀ 10.60
Present study / diese Arbeit	N Anatolia	♂♂ 16.11 ♀♀ 16.37	♂♂ 21.00 ♀♀ 20.37	♂♂ 11.77 ♀♀ 11.25
Present study / diese Arbeit	Hatay	♂♂ 17.72 ♀♀ 17.87	♂♂ 22.27 ♀♀ 22.88	♂♂ 11.41 ♀♀ 12.00
Present study / diese Arbeit	SE Anatolia	♂♂ 16.81 ♀♀ 16.90	♂♂ 20.83 ♀♀ 20.60	♂♂ 11.50 ♀♀ 11.10
DAAN (1967)	Greece incl. Sporades	16.4 (15-18)	21.8 (20-24)	-
DAAN (1967)	S Anatolia	16.6 (15-18)	21.2 (17-23)	-
DAAN (1967)	Hatay	18.2 (16-22)	23.5 (20-27)	-
BARAN & ÖZ (1985)	W Anatolia	16.3 (14-18)	20.2 (18-24)	-
BARAN & ÖZ (1985	S Anatolia	15.9 (13-18)	19.1 (15-21)	-
BARAN & ÖZ (1985	Hatay	18.5 (15-21)	22.6 (21-24)	-
BARAN & ÖZ (1985	Urfa	16.4 (14-19)	19.4 (17-22)	-
BUDAK et al. (1998)	Antalya *L. s. daani*	15.00	20.00	-
TOK (1999)	-	15.95	19.80	-
GÖÇMEN et al. (2003)	Hatay	♂♂♀♀ 19.10 (18-21)	♂♂♀♀ 25.10 (23-26)	♂♂♀♀ 11.21 (9-12)
KUMLUTAŞ et al. (2004)	W Taurus	16.52 (14-20)	21.11 (19-24)	-
ALMOG et al. (2005)	*L. s. daani*	-	♂♂ 19.8 (17-22) ♀♀ 19.3 (17-22)	-
ALMOG et al. (2005)	*L. s. stellio*	-	♂♂ 18.6 (18-20) ♀♀ 18.4 (16-21)	-
KETE & YILMAZ (2006)	E Amanos	♂♂♀♀ 18.96 (17-22)	♂♂♀♀ 24.48 (21-28)	-
KETE & YILMAZ (2006)	W Amanos	♂♂♀♀ 18.00 (17-20)	♂♂♀♀ 23.25 (21-25)	-
KETE & YILMAZ (2006)	SE Anatolia	♂♂♀♀ 15.92 (14-18)	♂♂♀♀ 20.20 (18-23)	-

Table 4: Statistics of the discriminant analyses of the body proportions HLI and SVL/HL for 34 male and 40 female specimens of the *Laudakia stellio* (LINNAEUS, 1758) populations studied.

Tab. 4: Kenngrößen der Diskriminanzanalysen zweier Körperproportionsmaße (HLI = 100 x Kopflänge / Kopfbreite und SVL/HL = Kopf-Rumpflänge / Kopflänge) von 34 männlichen und 40 weiblichen *Laudakia stellio* (LINNAEUS, 1758) aus den untersuchten Populationen.

Sex	Function	Eigenvalue	% of variance	Cumulative %	Canonical Correlation	Wilks' Lambda	χ^2	*df*	*p*
♂♂	1	0.165	73.6	73.6	0.377	0.810	14.964	10	0.133
♂♂	2	0.059	26.4	100.0	0.237	0.944	4.099	4	0.393
♀♀	1	0.195	74.8	74.8	0.404	0.785	14.047	10	0.171
♀♀	2	0.066	25.2	100.0	0.248	0.938	3.694	4	0.449

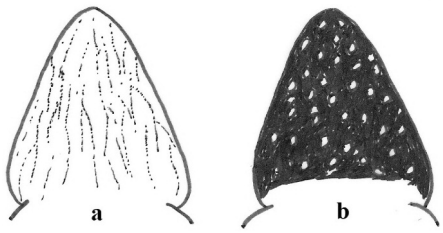

Fig. 2: Gular pattern types in Anatolian *Laudakia stellio* (LINNAEUS, 1758). A - striped pattern, B - mosaic pattern as found in the Hatay population only.

Abb. 2: Kehlzeichnungstypen anatolischer *Laudakia stellio* (LINNAEUS, 1758). A – Streifenmuster, B – Mosaikmuster wie es nur in der Hatay Population vorkam.

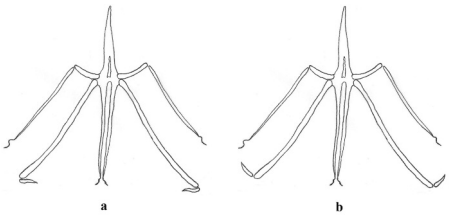

Fig. 3: The hyoid apparatus of Anatolian *Laudakia stellio* (LINNAEUS, 1758). The terminal portion (pharyngobranchial) of the first branchial arc was withdrawn (a) in the majority of populations and bent outwards (b) in the Hatay population.

Abb. 3: Das Zungenbein anatolischer *Laudakia stellio* (LINNAEUS, 1758). Das Endstück (Pharyngobranchiale) des ersten Branchialbogens wies bei der Mehrzahl der Populationen nach hinten (a), bei der Population von Hatay jedoch nach auswärts.

The authors intended to detect skeletal variation among the populations by examining both qualitative and quantitative characteristics of skull and lower jaw (shapes of the nasal, frontal, pineal foramen and hyoid apparatus; skull length, maximum and minimum skull width, rostrum length, orbit length, frontal length and width, nasal length and width, mandibula length, dentale length, and retroarticulare length) and limb bones (lengths of humerus, radius, ulna, third toe of the forelimb, femur, tibia, fibula, fourth toe of the hindlimb). Measurements were done by using a digital caliper sensitive to 0.01 mm. Vertebrae, ribs, sternum, pectoral and pelvic girdles were qualitatively examined.

Statistical analysis

The SPSS 17.0 software package was used in the statistical evaluation of the color-pattern, pholidosis, body measurements and proportions. Whether there were differences between male and female specimens in terms of the pholidosis counts was detected by applying the non-parametric two-sample Kolmogorov-Smirnov test. To understand whether there were sex-related differences in terms of the body and osteological measurements, indexes and ratios, the parametric independent two-sample t test was executed. To compare the pholidosis features of the populations, in a first step the Kruskall-Wallis analysis, a non-parametric test, was applied. And if there was a difference as a result of this test, the Mann-Whitney U test was performed to detect among which populations and at what significance level there was a difference. The comparison of external body and osteological measurements, indexes and ratios among the populations was made by means of Discriminant Function Analyses.

RESULTS AND DISCUSSION

Color-pattern.- The Hatay population differed in the dorsal ground color from the other populations in that the proportion of brownish-grey individuals (40.0 %) was higher than elsewhere (14.4 %). Cream and orange-cream were regularly ob-

Table 5: Morphological ratios and indexes as found in several Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758), according to various sources. TL / SVL – Tail Length / Snout-Vent Length, HI – Head Index (100•Head Length / Head Width), HLI – Head Length Index (100•Head Length / Snout-Vent Length), SVL / HL – Snout-Vent Length / Head Length, HL / HW – Head Lenght / Head Width. Sexual differences were not considered in various papers. Redundant presentation of both HI and HL/HW values was made for easier comparison with literature data.

Tab. 5: Morphometrische Quotienten und Indizes in verschiedenen anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758) nach unterschiedlichen Quellen. TL / SVL – Schwanzlänge / Kopf-Rumpf-Länge, HI – Kopfindex (100•Kopflänge / Kopfbreite), HLI – Kopflängen-Index (100•Kopflänge / Kopf-Rumpf-Länge), SVL / HL – Kopf-Rumpf-Länge / Kopflänge, HL / HW – Kopflänge / Kopfbreite. Geschlechtsunterschiede wurden in zahlreichen Arbeiten nicht berücksichtigt. Die redundante Präsentation von HI und HL/HW - Werten erfolgte zum einfacheren Vergleich mit den Angaben in der Literatur.

Reference/Quelle	Region / Population	TL/SVL	HI	HLI	SVL/HL	HL/HW
Present study/diese Arbeit	W Anatolia	♂♂ 1.48 ♀♀ 1.39	♂♂ 117.20 ♀♀ 120.15	♂♂ 30.84 ♀♀ 28.69	♂♂ 3.24 ♀♀ 3.48	♂♂ 1.17 ♀♀ 1.20
Present study/diese Arbeit	S Anatolia	♂♂ 1.49 ♀♀ 1.42	♂♂ 109.55 ♀♀ 113.56	♂♂ 30.92 ♀♀ 29.56	♂♂ 3.23 ♀♀ 3.38	♂♂ 1.09 ♀♀ 1.13
Present study/diese Arbeit	Central Anatolia	♂♂ 1.37 ♀♀ 1.28	♂♂ 119.14 ♀♀ 125.34	♂♂ 31.17 ♀♀ 27.95	♂♂ 3.20 ♀♀ 3.58	♂♂ 1.19 ♀♀ 1.25
Present study/diese Arbeit	N Anatolia	♂♂ 1.33 ♀♀ 1.29	♂♂ 117.29 ♀♀ 123.56	♂♂ 30.74 ♀♀ 28.21	♂♂ 3.25 ♀♀ 3.55	♂♂ 1.17 ♀♀ 1.23
Present study/diese Arbeit	Hatay	♂♂ 1.38 ♀♀ 1.35	♂♂ 109.81 ♀♀ 117.67	♂♂ 31.79 ♀♀ 29.44	♂♂ 3.14 ♀♀ 3.40	♂♂ 1.09 ♀♀ 1.17
Present study/diese Arbeit	SE Anatolia	♂♂ 1.51 ♀♀ 1.29	♂♂ 113.10 ♀♀ 118.85	♂♂ 30.72 ♀♀ 28.15	♂♂ 3.25 ♀♀ 3.57	♂♂ 1.13 ♀♀ 1.18
DAAN (1967)	W Anatolia	1.44 (1.37-1.50)	-	♂♂ 31.8 (30.4-32.8) ♀♀ 30.0 (28.8-32.3)	-	-
DAAN (1967)	S Anatolia	1.43 (1.19-1.57)	-	♂♂ 31.9 (29.9-33.2) ♀♀ 29.5 (28.4-31.0)	-	-
DAAN (1967)	Hatay	1.43 (1.19-1.57)	-	♂♂ 32.9 (30.8-33.5) ♀♀ 31.3 (30.4-31.9)	-	-
BARAN & ÖZ (1985)	W Anatolia	1.48 (1.42-1.56)	-	30.17 (27.34-32.38)	-	-
BARAN & ÖZ (1985)	S Anatolia	1.45 (1.36-1.56)	-	29.83 (27.16-32.50)	-	-
BARAN & ÖZ (1985)	Hatay	1.49 (1.41-1.62)	-	30.38 (28.95-31.14)	-	-
BARAN & ÖZ (1985)	Urfa	1.34 (1.25-1.45)	-	29.59 (27.21-32.16)	-	-
BUDAK et al. (1998)	Antalya *L. s. daani*	-	-	-	-	0.75
TOK (1999)	-	1.41	-	-	3.37	2.09
KUMLUTAŞ et al. (2004)	W Taurus	1.38	-	-	-	-
GÖÇMEN et al. (2003)	Hatay	1.42 (1.24-1.50)	-	29.89 (24.8-33.5)	-	-
ALMOG et al. (2005)	*L. s. daani*	-	♂♂ 93.4	-	-	-
ALMOG et al. (2005)	*L. s. stellio*	-	♂♂ 85.3	-	-	-
KETE & YILMAZ (2006)	E Amanos	1.44 (1.35-1.56)	-	30.90 (27.23-34.04)	-	♂♂ 1.12 ♀♀ 1.23
KETE & YILMAZ (2006)	W Amanos	1.48 (1.41-1.54)	-	31.00 (29.07-32.79)	-	♂♂ 1.15 ♀♀ 1.24
KETE & YILMAZ (2006)	Gaziantep	1.41 (1.29-1.51)	-	30.82 (28.40-33.72)	-	♂♂ 1.17 ♀♀ 1.22

served as ventral ground colors in the central Anatolian population (23.1 %), whereas orange-cream was rare (1.9 %) in the others. A dark mosaic pattern in the gular region was frequently (55%) seen in the Hatay population, whereas longitudinal dark stripes on a whitish ground were the only pattern present in the other populations (Figure 2). The bright vertebral dots were generally symmetrical relative to the mid-vertebral line in the west and southeast Anatolian populations (84.2 %, 76.2 %) but asymmetrical in the others. The blue color on the femur was frequently present in west and central Anatolian specimens (52.6 %, 69.2 %), but rarer (mean: 38.5 %) in the other populations. In all populations, some blue coloration was present on the scales of the dorsum in adults of both sexes, however, generally more pronounced in males than females.

DAAN (1967), BARAN & ÖZ (1985) and KETE & YILMAZ (2006) reported some bleaching of the coloration to occur from vividly colored individuals in the west to paler in the east. According to KETE & YILMAZ (2006) the character of having blue scales did not vary in west-eastern direction of the range except that blue colored elements were present in the west of the Amanos Mountains and in Gaziantep, but disappeared in parallel with an increase of a general bleaching in the east of the Amanos Mountains. Although having blue scales was reported as a trait of the west Anatolian populations (see DAAN 1967; BEUTLER & FRÖR 1980), scarce to considerable blue coloration was detected in all populations in our study. KLAUSEWITZ (1953) observed that various shades occurred in *Acanthocercus* cyanogaster (RÜPPELL, 1835) [*Agama cyanogaster atricollis* in his paper], depending on the intensity of environmental factors, such as light and temperature; he reported that the agamas failed to fully return to their pevious colors and that initially vividly colored specimens became pale. DAAN (1967) detected that (i) the Harduns from the Limassol region of Cyprus were lead-colored grey, whereas specimens from other regions of Cyprus were of lighter colors and, (ii) that Egyptian specimens caught in the sandy region of the Sina Peninsula were of lighter color than those caught in the rocky region. In summary we conclude that color and pattern characters alone are certainly not sufficient to distinguish between the subspecies of *L. stellio*.

Pholidosis.- Differences in all parameters were observed between males and females (Kolmogorov-Smirnov) and populations (Kruskall-Wallis). The U test results (Table 2) show among which populations and at what level of significance these differences were. According to this data, but also in the descriptive statistics, the numbers of subdigital lamellae were most important meristic features to discriminate between populations in the species *L. stellio*. The Hatay population differed from all the other populations in these characters, but also from the south and central Anatolian populations in terms of the sublabialia count (Table 2, $p < 0.05$), and from the south, north and central Anatolian populations in the number of scales forming the fifth tail whirl (Table 2, $p < 0.05$).

The data obtained, as regards to the numbers of subdigital lamellae of the fore and hind limbs, were in agreement with the minimum and maximum counts by DAAN (1967), BARAN & ÖZ (1985), BUDAK et al. (1998), TOK (1999), KUMLUTAŞ et al. (2004) and KETE & YILMAZ (2006) for *L. stellio daani* (Table 3). BUDAK et al. (1998) counted 20 subdigital lamellae underneath the fourth toe of the hind limb in the specimens of Antalya (=south Anatolian population in this study) and, thus, included them into the subspecies *L. stellio daani*. In all populations studied, the number of subdigital lamellae underneath the fourth toe of the hind limb was higher in our study than indicated by ALMOG et al. (2005); this discrepancy, however, was not well understood.

DAAN (1967) and BARAN & ÖZ (1985) reported the Hatay population to have higher numbers of subdigital lamellae than the other populations (Table 3) which is fully mirrored by our results, however, the high numbers of subdigital lamellae observed in the Hatay population by GÖÇMEN et al. (2003) surpassed our counts.

DAAN (1967) argued that increased numbers of fore and hind leg subdigital lamellae as found in the Hatay individuals might point to their particular status as a

Table 6: Descriptive statistics of nine proportions of the adult skull in five Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758). The central Anatolian population was not included due to insufficient sample size. Since differences between males and females were not significant, data was pooled. SL - Skull Length, SW_{max} - Skull Width maximum, SW_{min} - Skull Width minimum, RL - Rostrum Length, OL – Diameter of Orbit, FL - Frontal Length, FW - Frontal Width, NL - Nasal Length, NW - Nasal Width, ML - Mandibula Length, DL - Dentale Length, RAL – RetroArticular Length, SE – Standard Error, Min – Minimum, Max – Maximum.

Tab. 6: Beschreibende Statistiken von neun Proportionen des adulten Schädels bei fünf anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758). Zentralanatolische Tiere wurden wegen unzureichender Stichprobengröße nicht berücksichtigt. Da die Meßwerte der Männchen von denen der Weibchen nicht signifikant verschieden waren, wurden ihre Daten gemeinsam analysiert. SL – Schädellänge, SW_{max} – maximale Schädelbreite, SW_{min} – minimale Schädelbreite, RL – Schnauzenlänge, OL – Augenhöhlenlänge, FL – Länge des Frontale, FW – Breite des Frontale, NL – Länge des Nasale, NW – Breite des Nasale, ML – Länge der Mandibel, DL – Länge des Dentale, RAL – Länge des Retroarticulare, SE – Standardfehler, Min – Minimum, Max – Maximum.

Population	W Anatolia (n = 8)				N Anatolia (n = 8)				S Anatolia (n = 8)			
Proportion	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
SWmax / SL	0.86	0.01	0.82	0.93	0.85	0.01	0.81	0.90	0.83	0.02	0.73	0.88
SWmin / SL	0.42	0.00	0.42	0.43	0.43	0.00	0.42	0.45	0.43	0.00	0.41	0.45
RL / SL	0.20	0.00	0.18	0.21	0.23	0.01	0.21	0.27	0.18	0.01	0.16	0.21
OL / SL	0.39	0.01	0.37	0.41	0.38	0.00	0.36	0.40	0.39	0.01	0.34	0.41
KGmin / SWmax	0.49	0.01	0.45	0.51	0.51	0.00	0.49	0.53	0.52	0.01	0.49	0.59
DL / ML	0.54	0.01	0.51	0.56	0.54	0.01	0.50	0.57	0.53	0.01	0.51	0.56
RAL / ML	0.18	0.01	0.16	0.20	0.17	0.00	0.16	0.19	0.18	0.00	0.15	0.19
FW / FL	0.27	0.01	0.23	0.32	0.24	0.01	0.20	0.28	0.31	0.01	0.29	0.34
NW / NL	0.35	0.01	0.31	0.39	0.44	0.03	0.36	0.62	0.38	0.02	0.30	0.43

Population	Hatay (n = 8)				SE Anatolia (n = 8)			
Proportion	Mean	SE	Min	Max	Mean	SE	Min	Max
SWmax / SL	0.85	0.01	0.83	0.89	0.82	0.01	0.79	0.87
SWmin / SL	0.43	0.01	0.41	0.46	0.42	0.00	0.40	0.43
RL / SL	0.20	0.00	0.18	0.22	0.20	0.01	0.17	0.22
OL / SL	0.39	0.01	0.37	0.43	0.38	0.00	0.37	0.41
KGmin / SWmax	0.51	0.01	0.48	0.53	0.51	0.01	0.48	0.55
DL / ML	0.52	0.00	0.50	0.54	0.54	0.00	0.52	0.56
RAL / ML	0.18	0.00	0.17	0.19	0.21	0.01	0.18	0.24
FW / FL	0.29	0.01	0.23	0.33	0.29	0.01	0.23	0.35
NW / NL	0.37	0.02	0.29	0.47	0.38	0.01	0.33	0.42

Table 7: Descriptive statistics of the length measurements of limb bones in adults of five Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758). The central Anatolian population was not included due to insufficient sample size. Since differences between males and females were not significant, data was pooled. HL – Humerus Length, RaL – Radius Length, UL – Ulna Length, P3L – Length of third toe of the fore limb, FeL – Femur Length, TiL – Tibia Length, FiL – Fibula Length, P4L – Length of fourth toe of the hind limb, SE – Standard Error, Min – Minimum, Max – Maximum.

Tab. 7: Beschreibende Statistiken der Länge der Extremitätenknochen bei adulten Tieren aus fünf anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758). Zentralanatolische Tiere wurden wegen unzureichender Stichprobengröße nicht berücksichtigt. Da die Meßwerte der Männchen von denen der Weibchen nicht signifikant verschieden waren, wurden ihre Daten gemeinsam analysiert. HL – Humeruslänge, RaL – Radiuslänge, UL – Ulnalänge, P3L – Länge des dritten Fingers der Vorderextremität, FeL – Femurlänge, TiL – Tibialänge, FiL – Fibulalänge, P4L – Länge der vierten Zehe der Hinterextremität, SE – Standardfehler, Min – Minimum, Max – Maximum.

Population	W Anatolia (n = 8)				N Anatolia (n = 8)				S Anatolia (n = 8)			
Parameter	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
HL	21.83	0.67	19.76	25.01	18.78	0.58	15.79	20.73	18.97	0.45	17.29	20.58
RaL	15.18	0.56	12.82	17.33	13.66	0.40	12.10	15.61	13.97	0.56	12.07	16.23
UL	16.44	0.72	13.82	20.31	14.31	0.42	12.39	15.63	14.51	0.67	12.43	17.73
P3L	16.73	0.66	14.07	19.22	14.19	0.56	12.36	16.76	15.03	0.53	12.92	16.99
FeL	27.66	1.10	23.83	31.83	23.86	0.83	20.77	27.34	24.48	0.97	20.85	27.85
TiL	21.03	0.77	18.74	24.94	19.02	0.85	16.20	23.40	19.62	0.65	16.89	21.51
FiL	20.75	0.80	18.29	24.39	18.02	0.55	16.32	20.92	19.14	0.67	16.73	21.08
P4L	26.93	0.96	24.37	31.60	23.30	0.79	20.81	27.61	24.53	0.55	22.56	26.64

Population	Hatay (n = 8)				SE Anatolia (n = 8)			
Parameter	Mean	SE	Min	Max	Mean	SE	Min	Max
HL	19.20	0.59	16.55	22.00	18.91	0.81	16.94	21.93
RaL	15.23	0.52	13.28	17.60	13.87	0.60	12.08	16.17
UL	15.34	0.41	13.90	16.86	14.54	0.49	12.90	16.19
P3L	15.90	0.32	14.39	16.84	14.97	0.55	13.15	16.73
FeL	24.78	0.60	22.05	27.29	24.03	1.29	20.40	28.80
TiL	20.62	0.62	17.51	22.96	19.38	0.94	16.70	22.86
FiL	20.32	0.48	18.00	22.07	18.94	0.95	16.13	22.47
P4L	24.67	0.46	22.52	26.87	24.20	0.97	21.64	28.06

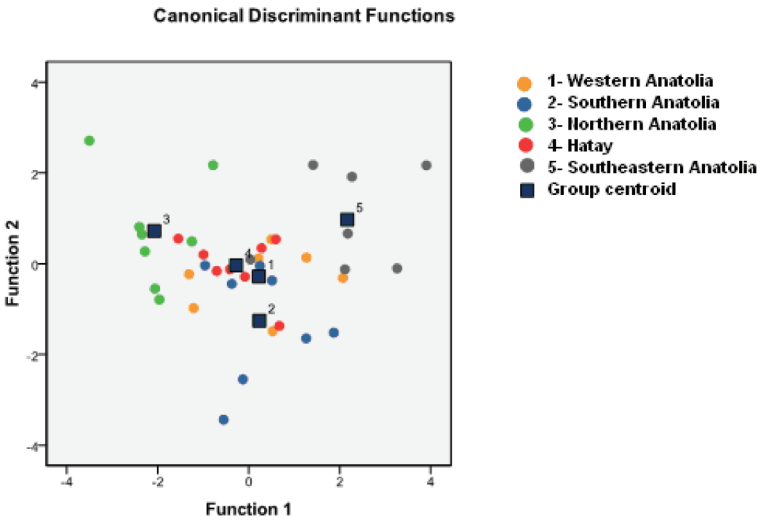

Fig. 4: Discriminant function analysis of nine proportions of the skull (see Table 6) in five Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758). The central Anatolian population was not included due to insufficient sample size.

Abb 4: Diskriminanzanalyse von neun Schädelproportionen (siehe Tab. 6) bei fünf anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758). Zentralanatolische Tiere wurden wegen unzureichender Stichprobengröße nicht berücksichtigt.

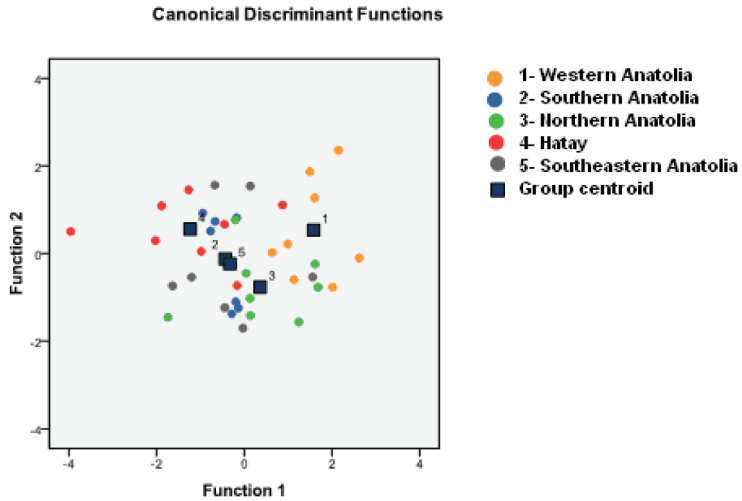

Fig. 5: Discriminant function analysis of eight quantitative parameters of the limb bones (see Table 7) in five Anatolian populations of *Laudakia stellio* (LINNAEUS, 1758). The central Anatolian population was not included due to insufficient sample size.

Abb. 5: Diskriminanzanalyse von acht quantitativen Merkmalen des Extremitätenskeletts (siehe Tab. 7) bei fünf anatolischen Populationen von *Laudakia stellio* (LINNAEUS, 1758). Zentralanatolische Tiere wurden wegen unzureichender Stichprobengröße nicht berücksichtigt.

subspecies different from *daani*, rather resembling the populations of Lebanon, Jordan and Israel in these characters (Table 3). KETE & YILMAZ (2006) found that the west and south Anatolian as well as Gaziantep (=southeast Anatolian) specimens were close to each other in terms of the number of subdigital lamellae, whereas these values increased in the east of the Amanos Mountains to resemble those in Syria, Lebanon and Israel where the subspecies *L. stellio stellio* lived. According to our findings, the number of subdigital lamellae of the Hatay population differed from those of the west, central, southeast and north Anatolian populations (Table 2) by their higher values (Table 3).

Ratios and indexes calculated from morphological measurements.- Differences in the Head Length Index (HLI) and the ratio Snout-Vent Length / Head Length (SVL/HL) were found between males and females in all populations studied. Individual discriminant function analyses of these characters applied to adult male and female specimens did not reveal groups/ populations that significantly differed from each other (Table 4, $p > 0.05$).

Our HLI data resemble the data in DAAN (1967) and BARAN & ÖZ (1985), including the Hatay values given by GÖÇMEN et al. (2003) (Table 5). BARAN & ÖZ (1985) reported that the Hatay and West Anatolian populations were similar in terms of HLI.

Our information about the ratio TL/ SVL was similar to that reported in DAAN (1967), TOK (1999), KUMLUTAŞ et al. (2004) and GÖÇMEN et al. (2003) (Table 5). BARAN & ÖZ (1985) provided the minimum to maximum intervals of this ratio of four populations and reported that the Hatay population resembled the west Anatolian population in this respect. The data we obtained were within these intervals, except for the Hatay population, for which they were strikingly lower than the values given by BARAN & ÖZ (1985) (Table 5).

The Head Index (HI) values of the present study were within the range given for the subspecies *L. stellio daani* by ALMOG et al. (2005) and our data of the ratio Snout-Vent Length to Head Length (SVL/HL) resembled the values given by TOK (1999) (Table 5).

Osteology.- Upon the qualitative examination of the skull, some variation was found regarding the shapes of the nasal in dorsal aspect, the anterior portion of the frontal and the pineal foramen, however, more or less evenly distributed among populations. On the contrary, the shape of the hyoid was found to vary clearly among populations in that the Hatay specimens differed from all others by their longer first branchials with their ends (pharyngobranchial) turned outwards (Fig. 3).

The results of the skull morphometry are presented in Table 6. The discriminant function analysis revealed that the north and southeast Anatolian populations definitely differed from each other in the skull proportions (Fig. 4). The two first discriminant functions accounted for 100% of the total variance at significant p values. The ratios Retroarticular Length / Mandibular Length (RAL/ML) and Rostrum Length / Skull Length (RL/SL) were the characters that best distinguished the populations in the stepwise analysis.

Further results of the quantitative examination comprise the observation of individual variation in the numbers of vertebrae and oval fenestrae in the sternum. Statistics of the limb bone measurements are presented in Table 7. The discriminant function analysis of the osteological quantitative data found that the west Anatolian and Hatay populations definitely differed from each other (Fig. 5). The two first discriminant functions accounted for 100% of the total variance at significant p values. The humerus and fibula lengths were the characters that best distinguished the populations in the stepwise analysis.

In summary, both qualitative and quantitative osteological examinations revealed that the Hatay population differed from all other populations studied.

There was no postfrontal bone in the specimens under examination. BEDDARD (1905a) reported the absence of this bone in agamid genera, such as *Amphibolurus* and *Chlamydosaurus* but observed (1905b) the presence of a very small postfrontal in *Uromastyx aegyptia* BELL, 1825. EL-TOUBI (1945) reported that *Uromastyx* did not have any postfrontal in some cases and that there was a great tendency towards the

disappearance of the postfrontal in Agamidae.

All *L. stellio* specimens studied had incisors, canines, and various molar teeth on the upper and lower jaws. SMITH (1935) pointed out that the members of the family Agamidae differed from all the other Oriental lizards (excluding chameleons) in that both the acrodont type of tooth attachment and the heterodont type of dentition (i. e. dental polymorphism, such as the simultaneous presence of incisors, canines and molars) were jointly observed.

Osteological characteristics of skull, lower jaw, hyoid apparatus, vertebral column, ribs, sternum, pectoral and pelvic girdles, and anterior and posterior limb bones of *L. stellio* were qualitatively examined by EL-TOUBI (1947). His results are in good accordance with most of our observations. Some discrepancies are given below. EL-TOUBI (1945) reported the complete sutureless fusion of frontals and parietals to form a single bone. However, a long suture was visible between the frontals and parietals in all populations of *L. stellio* under examination. EL-TOUBI (1945) found the prevomers to be in contact with each other up to their centers. In the specimens of the presen study, prevomers were small and in contact with each along one-third of their length. EL-TOUBI (1945) observed that the basisphenoid was tightly attached to the pterygoids laterally; however, the connection was found to be loose in the specimens we examined.

Range area.- BAŞOĞLU & BARAN (1977) reported the west, south, center and southeast of Anatolia to represent the distributional range of *L. stellio* in Turkey. Later, BARAN & ÖZ (1985) refined their definition in declaring the islands off the west Anatolian coast, west, south and southeast Anatolia, and the coastal regions of the south, the range area of the species, but did not mention localities from north Anatolia. BARAN et al. (1989) were the first to report *L. stellio* from Amasya and Tokat in the Black Sea region, and added that the presence of the species there was not natural, and the population rather small. A new locality record was given for *L. stellio* from Sinop, the northernmost point of Turkey (GÜL et al. 2010). The locations of Sinop, Taşova and Erbaa, where the specimens of the north Anatolian population were caught belong to the lowland troughs between the Black Sea and the shrub dry forest section.

CONCLUSIONS

In conclusion, all Anatolian populations of *L. stellio*, with the exception of the Hatay population, are within the range of the subspecies *L. stellio daani* as defined by ALMOG et al. (2005) in terms of color-pattern, pholidosis, morphological ratios and index values. Even though the Hatay population is similar to the subspecies *L. s. daani*, it differs from the other Turkish populations in some morphological and osteological characters, namely, the pattern on the throat, the number of sublabialia, the numbers of subdigital lamellae of the forelimb and hind limb and the number of scales on their tail whirls. Also osteologically, the Hatay population was found to differ from the other Turkish populations in qualitative and quantitative examinations. This study is understood as a signpost for further analyses to be made in order to determine the taxonomic statuses of the *L. stellio* populations in Turkey.

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