

Body size and shape variation of the skink *Chalcides ocellatus* (Forksål, 1775) along its geographic range

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RESUM

S'ha estudiat la variació morfològica del escinc *Chalcides ocellatus* mitjançant l'anàlisi de 119 espècimens de la major part de la seva distribució geogràfica i 6 mesures morfomètriques lineals. L'espècie presenta una gran uniformitat morfològica a través d'una gran àrea geogràfica en termes de SVL (longitud del musell-cloaca) i proporcions corporals. L'única diferència que les anàlisis revelen és el cap més gran en relació a SVL en els exemplars de les regions occidentals de la distribució geogràfica: el Marroc, Tunis i el nord-oest d'Àfrica.

PARAULES CLAU: Morfologia; *Chalcides ocellatus*; SVL.

ABSTRACT

Morphologic variation on the skink *Chalcides ocellatus* was examined by analyzing 119 specimens from most of their geographic range for 6 linear morphometric measurements. The species shows a high morphologic uniformity through its vast geographic area in terms of SVL and body proportions. The only trait revealed by the analysis is a relatively bigger head in relation to SVL in the specimens of the western regions of the range: Morocco, Tunisia and Northwestern Africa.

KEY WORDS: Morphometrics; *Chalcides ocellatus*; SVL.

INTRODUCTION

Biogeography of the reptiles of the Saharo-Arabian region has been recently investigated in order to elucidate the patterns of origin and posterior dispersal of the major groups. One of them, the genus *Chalcides* comprises 32 species mostly restricted to Morocco in the north western border of this country. Molecular phylogenetics suggested that Morocco has been the center of speciation and diversification of *Chalcides*, experiencing several processes of

morphological diversification, dispersal and speciation to the north western Mediterranean basin, Western Sahara and Canary Islands (CARRANZA *et al.*, 2008). However, the most widespread species of the genus, the ocellated skink (*Chalcides ocellatus*) evolved, based on molecular data, circa 4.5 million years ago in the Moroccan area and dispersed towards the east (KORNILIOS *et al.*, 2010). The species range extends from the post Atlas depression through the Mediterranean areas of North Africa to several Mediterranean islands (Crete, Cyprus,

Sicily, Malta and Sardinia), the Attica region in Greece to the Middle East (SINDACO & JEREMCENKO, 2008). Eastern populations are distributed along the coasts of Arabia and Persia reaching India and Sri Lanka. Furthermore the species lives in some Saharan regions, the Nile river spreading to the south to Ethiopia, Eritrea, Somalia and Kenya. Morphological investigation on the species has yielded the description of several subspecies (*linosae*, *sacchii*, *subtypicus*, *tiligugu*, *zavattarii*) not concordant with the main phylogenetic lineages (KORNILIOS *et al.*, 2010). Along its wide geographic range the ocellated skink experiences a wide diversity of climatic conditions potentially affecting body characteristics as size and shape. The main goal of this research is to examine whether the ocellated skink shows a clear pattern of body shape and shape variation and if this could be related to the biogeographic history of the species.

MATERIALS AND METHODS

One hundred nineteen specimens of *Chalcides ocellatus* from the Natural History Museum of London (appendix I) were examined by measuring the following variables: head length, width and high, fore and hind limb lengths and body size (snout-vent length). Tail length was not recorded because the high frequency of specimens with regenerated tails. Most skink species as in the case of *Chalcides ocellatus*, lack sexual dimorphism. Therefore subadults (adults were considered larger than 55 mm, (ÇİÇEK *et al.* (2013)) were previously discarded and sexes pooled in a single sample for analyses. In order to test for geographic differences on body size and proportions, specimens were pooled based on the available information about the main phylogenetic lineages of the species (KORNILIOS *et al.*, 2010). Thus, the specimens were classified based on locality of collection in the following groups (sample sizes between parenthesis): Morocco (26), Tunisia (18), Western (2) and

Eastern (5) sub-saharan Africa, Zanzibar (2), Arabia (29), Libya (6) and Middle East (31). According to the phylogenetic knowledge on the species (KORNILIOS *et al.*, 2010) insular populations of Sardinia, Sicily, Malta and Linosa were assigned to the Tunisian group and, Crete and Cyprus to the Middle east group. Geographic areas not included in phylogenetic studies (Zanzibar, Western and Eastern Africa, KORNILIOS *et al.*, 2010) have been analyzed by considering each of them as a different lineage. Statistical analysis of data consisted of descriptive statistics, Pearson correlation between variables and tests for differences between the groups previously defined. This was performed using ANOVA and MANCOVA on the log 10 transformed variables (using SVL as a covariable), selecting the post-hoc test of Spjotvoll & Stoline for intergroup comparisons.

In order to visualize differences at multivariable level between groups principal components analysis (PCA) was performed. This analysis does not rely in a prior definition of groups unlike other multivariate analysis of ordination like discriminant analysis. Therefore it represents a way of definition of morphologic patterns neutral respect to previous evidences or subjective criteria.

RESULTS

Specimens measured ranged from 147.4 to 63.7 mm of SVL (see Table 1, for descriptive statistics). All six variables were strongly and positively correlated among them (Table 2). Significant differences on body size between the main predefined phylogenetic lineages were found (ANOVA: $F_{7, 111} = 0.159$; $P = 0.001$). Maximum mean SVL were found in the Western African range (141.9 mm), followed by the northwestern African (108.6 mm) and Tunisian (105.2 mm) ranges, while the smallest values were estimated in Eastern African (83.3 mm). Considering this variable as a covariable MANCOVA found also significant differences between lineages: Lambda Wilks $_{35, 448} = 0.596$, $P = 0.010$. Comparing lineages for each of the

variables, post-hoc test revealed only significant differences on relative head length between the Moroccan lineage and the others with the only exceptions of Tunisia and Western Africa. Allometric examination of the variation of head length on SVL revealed that the westernmost lineages of the species (Tunis, Morocco and Western Africa) had proportionally longer heads (Figure 1).

PCA analysis using all the variables explained almost the 90.0% of the total variation with only the two first factors. The first PC was a typical size factor where all the variables were positively weighted (Table 3). Second PC is negatively weighted by the limbs lengths, especially of hind limb lengths while head width was the most positively weighted variable. Despite the significant differences detected by ANOVA and MANOVA visual examination of the plot of the two first PC showed extensive overlap of the lineages without any discernible pattern (Figure 2).

DISCUSSION

In contrast with other *Chalcides* species, *C. ocellatus* has successfully expanded from its Moroccan origin to northeastern Africa and far away reaching Sri Lanka to the east and Zanzibar to the south. Phylogenetic analysis placed the origin of the species not before 10 mya, starting to diversify at early Pliocene 4.5 mya, following an eastern expansion along a temporal window of 4.5 to 1.3 mya for the main

lineages (KORNILIOS *et al.*, 2010). Despite the old evolutionary history of the group and the vast extent of their distribution area *Chalcides ocellatus* shows a large uniformity of body size and shape. The only differences observed are the relative proportions of the head length in the western African populations, Moroccan and Tunisian populations. Interestingly, such lineages are basally placed in the phylogenetic tree of *Chalcides ocellatus* (KORNILIOS *et al.*, 2010). But anyway the range of the morphological variation in the species is almost negligible. Taxonomy analysis of Sub-Saharan *Chalcides* allowed the description of two new species (*C. bottegi* and *C. ragazzi*), based on escalation traits and pattern of colouration (GREENBAUM *et al.*, 2010). Such traits seem more variable in species closely related to the ocellated skink, although the latter could be subjected upon the action of the sexual selection for cripsis with the habitat. Hence, it could be interesting to investigate scale and pattern of colour variation of *Chalcides ocellatus* (Figure 3) and to combine the mitochondrial and nuclear phylogeography.

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APPENDIX I

Specimens from Natural History Museum of London used in the analyses: 1928.12.8.387-395, 1911.1.16.6, 1962.9.13, 1921.4.14.1, 1975.10.92, 1920.1.20.3855, 87.12.20.9-12, 1959.1.1.57, 1924.12.8.14, 1924.12.8.18, 1957.1.12.98, 1920.1.20.2043, 1934.2.24.2.3, 1997.15.6, 1913.12.30.15.10, 1932.3.615, 1961.6.92, 94.11.13.22.3, 01.5.4.122, 01.5.4.123, 01.5.4.124, 97.10.18.450, 97.10.18.451, 97.10.28.452, 1969.2.147, 1969.2.148, BM1977-75, BN1979-973, BN1972-686, BN1985-896, BN 1973-475, 1943 11-3, 1943 20, 1943 20, 1987-2370, 1975-1384, 1974-5284, 1937.11.1.6, 1937.11.1.7, 85.11.4.13, 85.11.4.14, 85.11.4.15, 22.20.18.453, 1915.7.19.1.2, 1913.12.30.13, 1913.12.30.14, 97.10.28.472, 1954.1.4.14, 1909.10.15.33, 1919.4.4.2.3, 1985.6.17, 1977.1.170, 1977.1.171, 1977.1.172, 1977.1.173, 1977.1.174, 1971.1.656, 1974.3.995, 1986.3.47-348, 1973.3.208, 1973.3.209, 1980.1.93, 99.12.13, 97.3.11.95, 97.3.11.96, 93.8.29.3, 1969-1605, 1969-1604, 1983-1972, 1950.1.6.13, 1969-2823, 1969-2751, 1969-2750, 1969-2749, 1969-2154-61, 1913.7.3.85, 1913.7.3.86, 1913.7.3.87, 1913.7.3.88, 1913.7.3.89, 1913.7.3.90, 1947.1.5.5, 1945.11.9.7, 1954.1.4.18, 1954.1.4.19, 1936.9.1.13, 1936.9.1.14, 1938.8.4.42-49, 12.26-78, 1906.8.29.12, 1908.4.3.37-38, 1921.6.817, 1921.6.818, 91.5.4.133, 1901.10.18.2, 98.3.30.25, 85.4.20.3, 14.9.4.1-4, BM 1969 2150, BM1970 231, 1967 101, 1943 9.16.14, BM1972.2324, 11661, 11664, 11666, 11665, 11663, 11662.

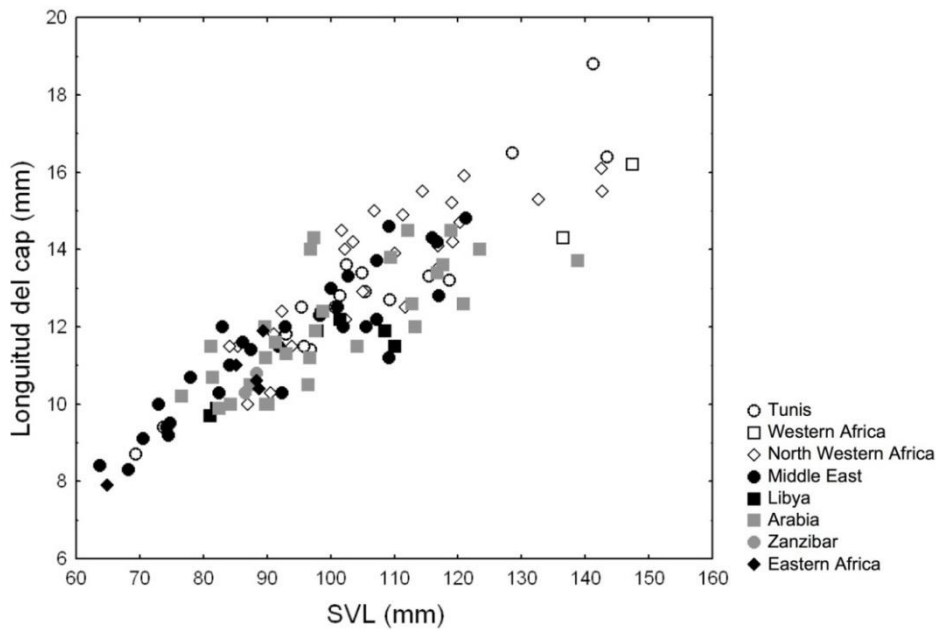


Figure 1.- Variation of head length respect SVL in *Chalcides ocellatus* specimens analyzed.

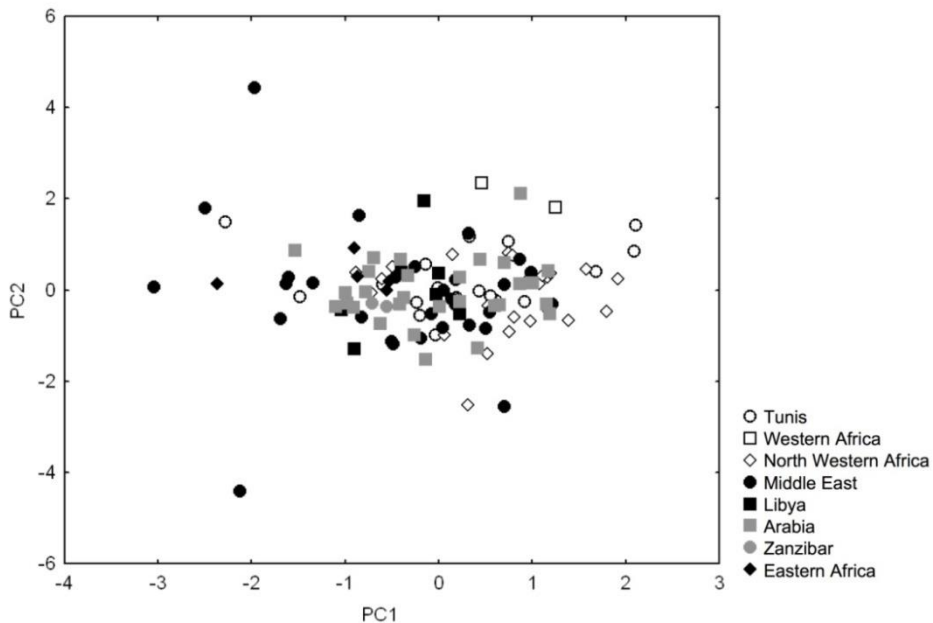


Figure 2.- PCA of the main phylogenetic lineages and other geographic areas of *Chalcides ocellatus*.



Figure 3.- Morphology and pattern of colouration of *Chalcides ocellatus* in several localities of their geographic range: upper Oman, middle Sardinia and lower Morocco.

Variable	Mean \pm SD	Minimum - Maximum
Head length	12.3 \pm 1.9	7.9 – 18.8
Head width	10.8 \pm 2.3	3.0 – 17.8
Head high	9.4 \pm 2.0	4.0 – 16.1
Forelimb length	16.5 \pm 2.9	8.7 – 24.3
Hindlimb length	23.3 \pm 3.7	10.2 – 31.6
SVL	100.6 \pm 17.8	63.7 – 147.0

Table 1.- Descriptive statistics of the linear morphometric measurements in mm.

Variable	Head length	Head width	Head high	Forelimb length	Hindlimb length	SVL
Head length	1.000	0.806	0.871	0.825	0.743	0.894
Head width		1.000	0.821	0.736	0.671	0.818
Head high			1.000	0.832	0.776	0.876
Forelimb length				1.000	0.810	0.832
Hindlimb length					1.000	0.740
SVL						1.000

Table 2.- Pearson correlations between the linear morphometric variables (all significant at $P < 0.005$).

Variable	1st PC	2nd PC
Head length	0.938	0.114
Head width	0.883	0.319
Head high	0.944	0.058
Forelimb length	0.917	-0.199
Hindlimb length	0.860	-0.446
SVL	0.941	0.130
Eigenvalues	5.022	0.374
% explained variability	0.837	0.062

Table 3.- Coefficients of the linear morphometric variables, eigenvalues and proportional variability explained by the two first PC.