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Shape variability of the head of *Ophisops elegans* Ménétriés, 1832 (Reptilia: Lacertidae) from Konya, Turkey

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Abstract
Ophisops elegans is a widely distributed lizard species. Like other lacertids, *O. elegans* has characteristic head plates. In this paper, the variation of the head plate morphology between sexes was studied in the subspecies *Ophisops elegans centralanatoliae*. According to our results, both size and shape of the head plates show sexual dimorphism. The most remarkable shape difference between sexes is observed in the parietal region. In addition, the ontogentic allometry of the head plate shapes was investigated.

Keywords: *Sexual dimorphism, head plates,* Ophisops elegans centralanatoliae*, geometric morphometrics, Turkey*

Introduction

The snake-eyed lizard, *Ophisops elegans* Ménétriés, 1832, has a wide distribution from the Eastern Mediterranean region to south-western Asia and North Africa (Lantz 1930; Bodenheimer 1944; Baran 1984; Chirio & Blanc 1993; Schleich et al. 1996; Frynta et al. 2000; Sindaco et al. 2000; Göçmen et al. 2008).

Ophisops elegans occurs in Turkey with five subspecies: *O. e. basoglui* along the Mediterranean coast, from Alanya-Antalya to Adana region; *O. e. macrodactylus* in Trace, west and south-west of Anatolia, and in Aegean and Mediterranean islands; *O. e. centralanatoliae* in middle and central Anatolia; *O. e. ehrenbergii* in south-east Anatolia and along the Syrian border (still problematic); *O. e. elegans*, from Hatay to east and north-east of Anatolia (Olgun et al. 2011).

In lacertids, sexual dimorphism is observed in both size and shape of the head (Bütikofer et al. 2013), the limbs (Herrel et al. 1996), the trunk (Kaliontzopoulou et al. 2007, 2008), the body mass and the body length (Kratochvíl & Frynta 2003; Kaliontzopoulou et al. 2007). Also, males usually have a larger pleus than females (Tok 1992, 1993; Tok et al. 1996, 1997; Olgun & Tok 1999).

The morphology of the head plates of lacertids shows a geometrical organisation, but few researchers have investigated their variation using geometric morphometrics (Bruner et al. 2005; Bruner & Costantini 2007; Kaliontzopoulou et al. 2007, 2008, 2010; Ljubisavljević et al. 2011; Bütikofer et al. 2013).

The aim of this study is to investigate the sexual size and shape variation of the head plates of *O. e. centralanatoliae* from Akşehir-Eber (Konya, Turkey) using geometric morphometrics.

Materials and methods

We examined a total of 40 specimens (22 ♂♂, 18 ♀♀) of the subspecies *O. e. centralanatoliae* collected from Konya, Turkey, in 2007, stored in the collection of the Zoology Department of Ege University-Canakkale Onsekiz Mart University (ZDEU-COMU codes 93/2007, 96/2007).

The heads were photographed in the dorsal projection with a digital CCD (Charge Coupled Device) camera linked to a stereomicroscope; 28 landmarks were digitised on each picture using tpsDig2 (Thin Plate Spline Digitizer) (Rohlf 2008) (Figure 1; Table I). The symmetric landmarks were averaged

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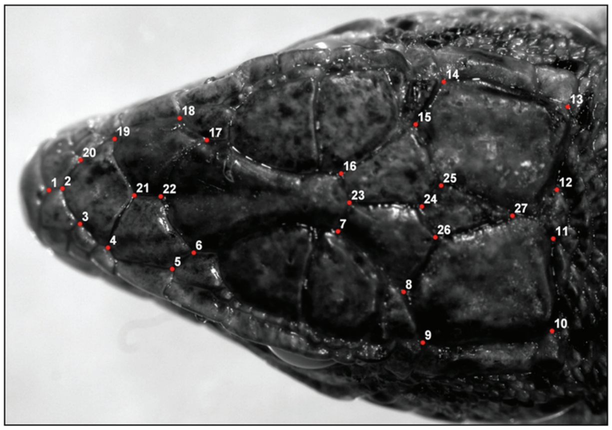


Figure 1. Landmark configuration of the head plates of *Ophisops elegans centralanatoliae*.

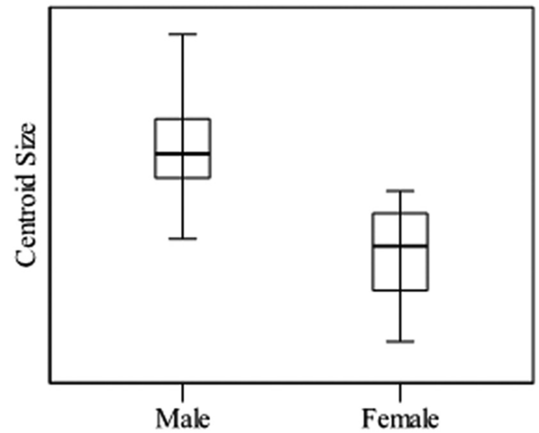


Figure 2. Differences in centroid size between sexes.

Table I. Definitions of the chosen landmarks.

1	Anterior intersection of the supranasals
2	Posterior intersection of the supranasals
3–20	Posterior intersection of postnasal and frontonasal
4–19	Lateral intersection of prefrontal and frontonasal
5–18	Intersection of prefrontal, first supraocular and loreal
6–17	Intersection of frontal, prefrontal and supraocular
7–16	Intersection of frontal, supraocular and frontoparietal
8–15	Intersection of parietal and frontoparietal
9–14	Anterior angle of the parietal
10–13	Posterior edge of the parietal
11–12	Posterior intersection of the occipital and parietal
21	Intersection of the frontonasal, left and right prefrontals
22	Intersection of frontal, left and right prefrontals
23	Intersection of frontal and frontoparietals
24	Intersection of frontoparietals and interparietal
25–26	Intersection of parietal, frontoparietal and interparietal
27	Posterior end of the interparietal

along the mid-line to avoid asymmetric effects, according to Klingenberg (2011).

Procrustean transformations were conducted with MorphoJ software (Klingenberg 2008). Centroid size (CS) was used as a head size index. Sexual dimorphism in size was analysed by Mann-Whitney U test on CS. Shape variations between sexes were examined through Procrustes analysis of variance (ANOVA). Ordination multivariate analysis with principal component analysis (PCA) was used to explore the pattern of variation of shape variables. Allometry was explored by multivariate regression of shape variables into CS. Furthermore, analysis of covariance (ANCOVA) was used to test the relationship between CS and shape for each sex (Figure 2).

Results

Sexual dimorphism in the geometrical organisation of the head plates in *Ophisops e. centralanatoliae* is expressed in both size and shape [Z(1,38) = 3.725, $P < 0.05$)]. Males' head plates are larger than females'. Furthermore, both sexes have a distinct plate shape, especially for the parietals and frontoparietals (Figure 3). In general, frontoparietals are narrower and located more backward in males than in females. Also, the front part of the interparietal is more posterior in males, and parietals are narrower in males.

When all the head plates were evaluated between sexes, the variation of internasal by CS was observed more frequently in females. In males, the frontal plate was seen on the front part, whereas it was on the back part in females. For the parietals, variations are on the front part in females, and on the back part in males.

Males have a longer head plate structure than females do [Z(1,38) = 3.725, $P < 0.05$)] (Figure 2). Procrustes ANOVA shows significant shape differences between sexes (F (1,38) = 8.09, $P < 0.05$). Furthermore, PCA of shape variables analysis of evidenced that shape differences on head plates between sexes (Figure 3), are the first and second PC axis state 40% of the specimens (Figure 3).

There is a significant correlation between CS and shape ($R^2 = 0.526$, F (1,38) = 42.21, $P < 0.05$) of head plates. Analysis showed there are differences between sexes (for males, $R^2 = 0.447$, F = 4.94, $P < 0.05$; for females, $R^2 = 0.672$, F = 32.79, $P < 0.05$). These differences were confirmed by the result of ANCOVA (F(1,38) = 8.87; $P < 0.05$; Figure 4).

Discussion

Landmark-based morphometrics showed that size and sex affect the head plate shape in the snake-eyed lizard *O. elegans centralanatoliae*. Males' head plates are larger than females', and their shape showed differences especially for the parietals and frontoparietals.

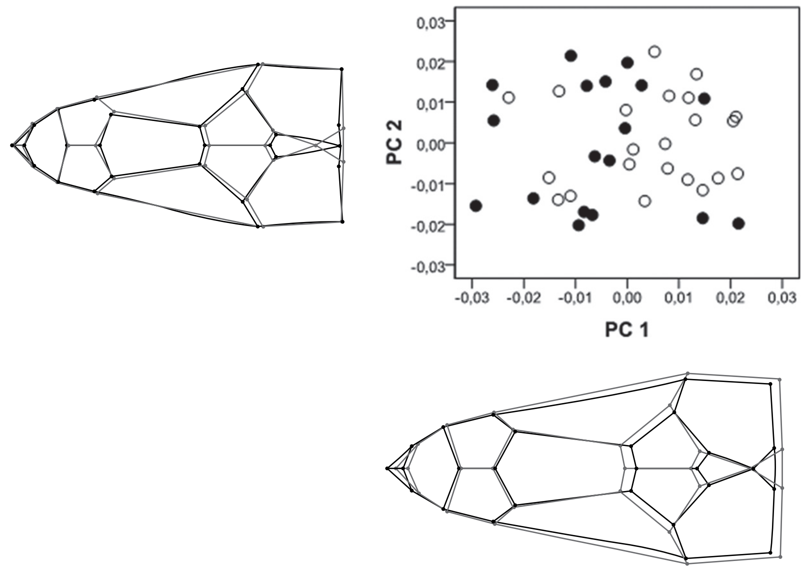
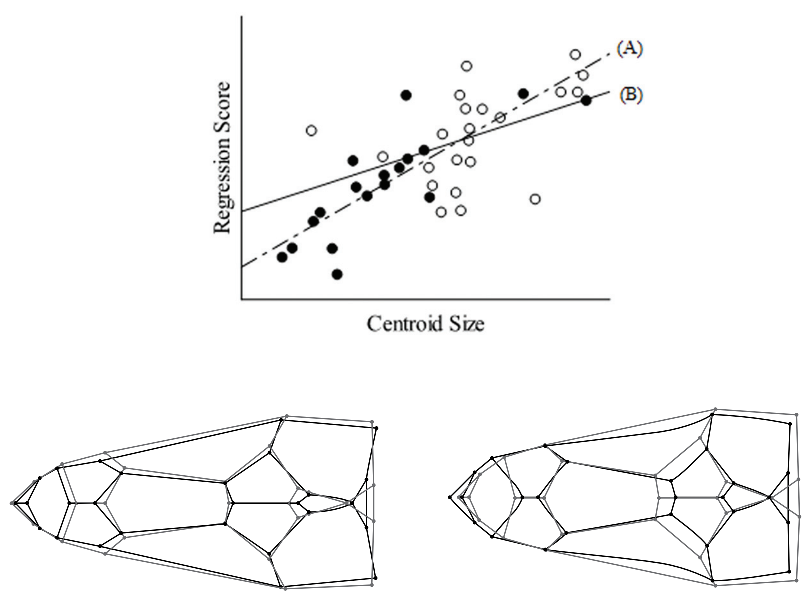


Figure 3. The plot shows first and second principal components, and distribution of sexes (○ = males, • = females). The geometrical patterns associated with the two covariation axes (grey = average shape, black = variation shape) are shown.



(A) (B)

Figure 4. The plot shows the relation ship between centroid size and shape (A = males, B = females). The geometrical patterns associated with centroid size axis (grey = average shape, black = variation shape) are shown.

Some ecological and morphological studies have demonstrated that *O. elegans* shows sexual dimorphism in age, head length-width and snout-vent length, as well as some colour-pattern differences between sexes in the reproductive season (Tok 1992, 1993; Olgun & Tok 1999; Parlak & Tok 2013; Tok et al. 2013).

In other studies, male *O. elegans* individuals were found to be larger and have a longer pileus, and a higher tail length-snouth vent length ratio (Tok 1992; Olgun & Tok, 1999).

The age of the *O. elegans macrodactylus* specimens collected from Çanakkale (Turkey) and Gökçeada (İmbros; Turkey) estimated by skeletochronology was between 1 and 4 years for the Çanakkale population and between 1 and 6 years for the Gökçeada population (Parlak & Tok 2013). Although there were no sexual differences in SVL (snout vent length) in the whole sample collected in Çanakkale (Turkey) versus Gökçeada (İmbros; Turkey), males showed a larger SVL when comparing males and females within the same age classes (Parlak & Tok 2013; Tok et al. 2013), suggesting that males and females grow at different rates. In another study, the same *O. elegans centralanatoliae* specimens that we used were used for a skeletochronological study, and no difference was shown between mean SVL of the sexes, but when individuals of the same age were compared, it was observed that males had a larger SVL than females (Tok et al. 2013). Sexual dimorphism is observed in most lacertid lizards, especially regarding the head and abdomen. Males are known to have a larger head and females have a larger abdomen. Males' ontogenetic development is known to be isometric, especially for the main body segments, head and abdomen, whereas an allometric growth is present in females, especially for the growth of the abdomen (Braña 1996).

Our results are consistent with the results of other studies on other lacertids showing that the shapes of the head plates of some lacertids are sexually dimorphic (*Algyroides*: Ljubisavljević et al. 2011; *Dalmolacerta* and *Dinarolacerta*: Ljubisavljević et al. 2010; *Lacerta*: Bruner et al. 2005; Costantini et al. 2007; *Podarcis*: Kaliontzopoulou et al. 2007, 2008; Ljubisavljević et al. 2010; Raia et al. 2010; Bütikofer et al. 2013). Also, in accordance with our findings, sexual shape variation mainly concerned the posterior region of the head, males always showing a more enlarged parietal area as compared to females (Kaliontzopoulou 2011).

Barahona and Barbadillo (1998) indicated that the parietals are the last bones to ossify; therefore, in this region growth can proceed for a longer time. Thus, Bruner et al. (2005) suggested that the longer ontogenetic ossification process may be the reason for the shape difference in the parietal area in many male versus female lacertid lizards.

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