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# Head shape divergence between parthenogenetic and their paternal bisexual rock lizards in sympatry

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## ABSTRACT

Head shape plays a crucial role in ecological and evolutionary processes in lizards, and scientists have studied head shape using traditional and 3D geometric morphometrics. Lizards are classic subjects for ecological studies because closely related and ecologically similar species coexist. Sympatric species tend to show higher levels of morphological divergence compared to allopatric species.

In this study, we focus on two parthenogenetic *Darevskia* species (*Darevskia dahli* and *Darevskia armeniaca*) that share a maternal species, *Darevskia mixta*, but have different paternal species (*Darevskia portschinskii* and *Darevskia valentini*). We aim to assess the relative importance of morphologically inheritable traits and environmental conditions on head shape in these parthenogenetic species. Specifically, we aim to determine whether local adaptations or intermediate phenotypes between parental species drive head shape variation in parthenogens. To accomplish this, we analyze the head shapes of samples from both parthenogens, their paternal species, and their common maternal species from 3 sites in Georgia. Our study shows that certain aspects of head shape are associated with body size and habitat climate, with high mountain species exhibiting larger and deeper heads with stronger jaws regardless of breeding mode. In addition, both parthenogens exhibit narrower and more elongated jaw areas, flatter mandibles, and thus weaker jaws compared to females of their maternal and paternal species.

## 1. Introduction

Head shape is an important feature in lacertid lizards. There are relationships between the morphology of lizards (head size or any other body parts) with bite force capacity, prey handling efficiency, microhabitat use (Herrel et al., 2004; Barros et al., 2011; Verwajen et al., 2002; Oliveira et al., 2023), even with breathing and brain protection (De Meyer et al., 2019). Simultaneously, morphological variations in lizard heads are related to environmental and ecogeographic variations. For example, the altitude and/or temperature has been shown to affect the head length (Ortega et al., 2019) and shape (Alagić et al., 2021) in some *Podarcis* lizards; geographic gradient on Tenerife island affects the head shape of Lacertid *Gallotia galloti* (Thorpe and Baez, 1987). Besides these functions, one of the largest drivers of head shape variation are phylogenetic relationships of the species (Openshaw and Keogh, 2014; De Meyer et al., 2019). Closely related lizard species resemble each

other more than distantly related ones (Openshaw and Keogh, 2014), the phenomenon generally referred to as phylogenetic signal in morphological traits (Blomberg et al., 2003; Tarkhnishvili et al., 2020a).

When closely related ecologically similar species coexist, their morphologies tend to diverge due to competition and/or reinforcement, and the level of divergence is commonly higher compared to areas of allopatry (Taylor, 1965; McDowall, 1998; Wijesundara and Freed, 2018), e.g. fish from the genus *Paragalaxias* from a lake of submontane Tasmania (McDowall, 1998), brown frogs from the Caucasus (*Rana macrocnemis* complex) (Tarkhnishvili et al., 2001), songbirds from the genus *Zosterops* in Sri Lanka (Wijesundara and Freed, 2018).

Some lizard groups include both parthenogenetic and bisexual forms (Lowe and Wright, 1966; Darevsky, 1967; Moritz, 1991; Adams et al., 2003; Tarkhnishvili et al., 2010; Petrosyan et al., 2020). Parthenogenetic species are usually of hybrid origin and share genes from both maternal and paternal ancestors. It is not clear whether the parental

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species are able to contribute their genes to the parthenogenetic vertebrate lineages after the initial hybridization (Tarkhnishvili et al., 2020b), and whether or not the hybrid origin is reflected in the morphology of the daughter species. Parthenogenetic daughter species often do not show intermediate morphological characteristics, despite their intermediate genome (Heiser Jr et al., 1965; Bemis et al., 1970; Pembleton and Baker, 1978; Parker Jr, 1979). For example, *Aspidoscelis tessellatus* (formerly–*Cnemidophorus*) resembles more its maternal species *Aspidoscelis gularis* in size than the paternal species *Aspidoscelis tigris*, although it is more widely sympatric with the latter one.

One of the groups, combining sexually breeding and parthenogenetic species, are Caucasian rock lizards (*Darevskia*) (Arribas, 1999), found mainly in the Greater and Lesser Caucasus Mountains. Parthenogenetic species (*Darevskia dahli* and *Darevskia armeniaca*) are phenotypically similar to female individuals of their paternal species, coexist in some locations and share a similar diet in rocky habitats (Darevsky, 1967; Bakradze, 1977; Tarkhnishvili, 2012), but never overlap spatially with maternal species *Darevskia mixta* (Tarkhnishvili et al., 2010).

In this paper, we focus on two parthenogenetic *Darevskia*–*D. dahli* (Darevsky, 1957) and *D. armeniaca* (Méhely, 1909), who share the maternal species *D. mixta* (Méhely, 1909), but have different paternal species, *Darevskia portschinskii* (Kessler, 1878) and *Darevskia valentini* (Boettger, 1892). *D. dahli* and its paternal species *D. portschinskii*, coexist in the mountain forest belt of central Georgia, 800–1200 m a.s.l. (Tarkhnishvili et al., 2010; Barateli et al., 2022) and the average length of adult individuals of both species varies between 5.4 and 5.8 cm. Relatively bigger-bodied, *D. armeniaca* and its paternal species *D. valentini*, coexist at elevations 1900–3100 m a.s.l. (Arakelyan et al., 2011; Galoyan et al., 2019; Barateli et al., 2022) with average body length–6.1–6.4 cm. *D. mixta*, an endemic species of Georgia (Gabelaia et al., 2017; Petrosyan et al., 2020), is distributed from 300 to 2100 m a.s.l. (Ciobanu et al., 2003; Tarkhnishvili, 2012; Gabelaia et al., 2015). The average body length of *D. mixta* varies between 4.9 and 6.3 cm (Darevsky, 1967). The paternal species are closely related, but ecologically and morphologically distinct (Darevsky, 1967; Murphy et al., 2000) (Fig. 1). For example, according to Darevsky (1967) *D. valentini* has a large central temporal scale, while in *D. portschinskii* it is smaller or absent. Also, the postorbital or postfrontal bones are similar in length in most *D. valentini* and *D. portschinskii*, but unlike *D. valentini* postocular is either greater or equal to postfrontal in *D. portschinskii* (Arribas et al., 2022).

We tried to infer the relative importance of genetic inheritance and environmental conditions on the head shape of *D. armeniaca* and *D. dahli*. Specifically, if adaptations to local geographic conditions play an important role, one should expect a higher similarity of the parthenogens with females of the paternal species, with whom they commonly coexist, than with the females of the maternal species, which never share the habitat with the parthenogens. On the other hand, the phenotype of the parthenogens may be just intermediate between the two parental species, or show some specifics common for the parthenogenetic lineages but absent in the bisexual forms. For this purpose, we analyzed the head shapes of samples of both parthenogens (*D. dahli* and *D. armeniaca*), two paternal species from the same locations

(*D. portschinskii* and *D. valentini*, respectively), and their joint maternal species, *D. mixta*, from a separate location in Georgia.

## 2. Material and METHODS

In June–July 2018 and 2023, we collected 60 female adult individuals of five lizard species from three locations in Georgia (Table 1). Since male and female individuals of most *Darevskia* show significant sexual dimorphism in head shape, we used only female individuals from bisexual species to compare with unisexuals (Tarkhnishvili et al., 2020a). The Ilia State University Commission ethically approved all procedures with live animals for Ethical Issues and were in accordance with Article 259 of Georgian Criminal Law. General anesthesia of the lizards was used to avoid killing the animals collected in the wild. After photographing, the lizards were released to their natural habitats.

For morphological studies, we placed the individual in a plastic tube with its head pointing upwards and secured it to prevent movement. The tube was placed in the center of a cardboard circle. We then photographed 36 times from a perspective of 90° to the midline and 36 times from a perspective of 45° to the midline, moving the camera around the lizard every 10° (Fig. 2). The images were uploaded to AgiSoft PhotoScan Pro v.2.0.2 (AgiSoft, 2023), which first aligned the images in 3D space and then generated 3D models of the head surface onto which 54 homologous landmarks were subsequently digitized (Fig. 3). Then we exported the 3D coordinates in a “Survey points” format and imported them in R studio (R 4.2.0, 2022) for the analysis. Missing landmarks were estimated using the function “estimate.missing” and landmarks were aligned using the “gpagen” function. We extracted symmetric components using the function “bilat.symmetry” and checked it for outliers using “plotOutliers”. To illustrate the levels of differences in head shape between the individuals we conducted a principal component analysis (PCA). PCA simplifies multidimensional data by reducing dimensions to two or three, facilitating the visualization and comprehension of relationships between data points (Richardson, 2009; Paul et al., 2013). To visualize which shape patterns were reflected in these ordinations, and thus which were the most discriminating shape differences between groups, we generated landmark wireframes that reflect principal component (PC) axis variation from a PCA on the total dataset of the 54 original landmarks in R studio (R 4.2.0, 2022). The used package was “geomorph” (Adams et al., 2016; Baken et al., 2021).

In order to test for significant differences between species head shapes, we used the Procrustes aligned landmark configurations and ran Procrustes Anova with Species as terms using “lm.rpp” in the package “RRPP” (Collyer and Adams, 2018, 2023). This function uses ordinary least squares (LS) to compute the effect coefficients by performing the randomized residual permutation (Collyer et al., 2015). Afterward, we checked if the LS means of each pair of species were significantly different using the “pairwise” function in “RRPP”.

Since studied individuals substantially differ in body size, we repeated the test and included the body size in the model as a covariate to make sure the observed interspecific differences were not influenced by allometric trends. We checked in prior the model shape ~ log(SVL) + species + log(SVL):species to make sure there is no significant difference

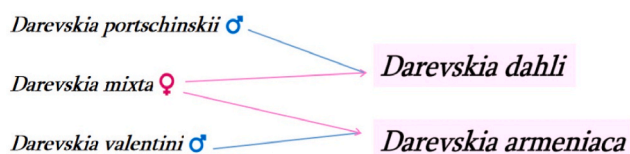
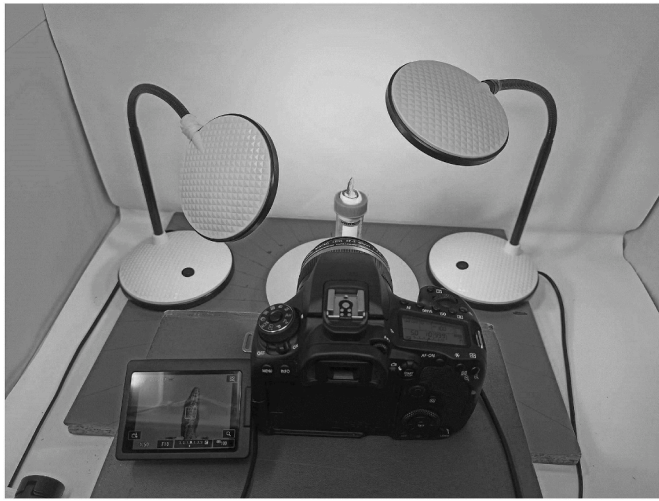


Fig. 1. Cladogram of studied species, representing the maternal parent species (*Darevskia mixta*) of both parthenogenetic species (marked in red). Based on Murphy et al., 2000; Yanchukov et al., 2022. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1

Sample sizes and key characteristics of three sampling locations of 5 species of *Darevskia*.

	Location	Easting	Northing	Altitude a.s.l.	Female
<i>D. dahli</i>	Kojori	44.683337°	41.648891°	1120	13
<i>D. portschinskii</i>	Kojori	44.683337°	41.648891°	1120	11
<i>D. armeniaca</i>	Sagamo Lake	43.730600°	41.293600°	2015	16
<i>D. valentini</i>	Sagamo Lake	43.730600°	41.293600°	2015	15
<i>D. mixta</i>	Rveli	43.416361°	41.871489°	824	5



**Fig. 2.** Set-up for photographing the head of an immobilized lizard at different degrees and angles.

between the allometric trends of each species. After running ANCOVA, we predicted the head shape means based on the fitted values of the model and by keeping the body size associated head shape component constant. For that, we used the “predict” function in “RRPP”. All calculations were done in the R studio (R 4.2.0, 2022).

### 3. Results

#### 3.1. ANOVA test on head shape

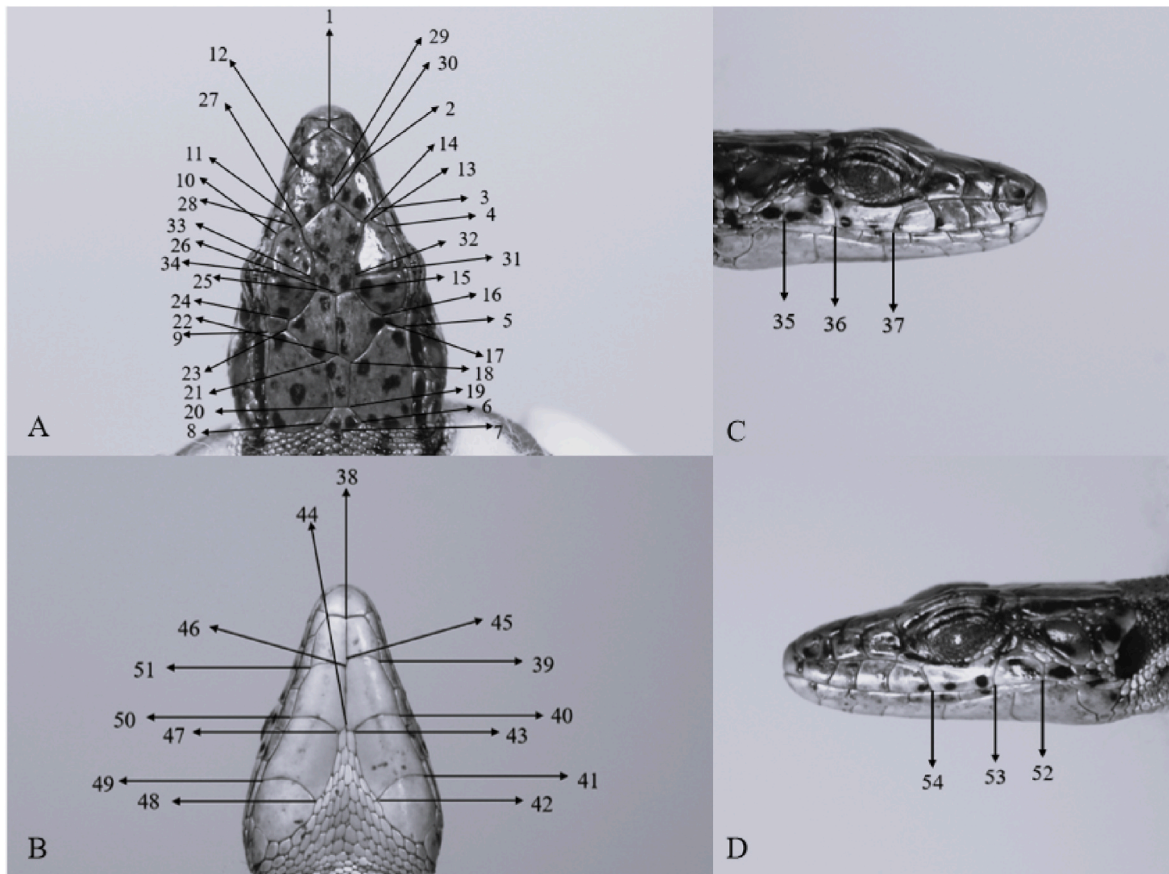
The Procrustes ANOVA and pairwise tests based on the head symmetric landmarks significantly separated all studied species pairs. According to the effect sizes ( $Z$ ), females of *D. valentini* are better separated from both parthenogenetic species, *D. dahli* and *D. armeniaca* than *D. portschinskii*. *D. mixta* is in general more similar to the parthenogens than both paternal species (Table 2).

Species exhibited an allometric effect on head shape, but it was not significantly different between the studied species ( $p = 0.09$ ), so we excluded the interaction effect ( $\log\text{SVL}:\text{species}$ ) from the model and reran the model as  $\text{shape} \sim \log(\text{SVL}) + \text{species}$ . After correcting for body size, *D. mixta* and *D. armeniaca* were not significantly differentiated (Table 3). The rest of the species had a similar pattern to the previous test, e.g. *D. valentini* was most strongly separated from both parthenogenetic species, then *D. portschinskii* and *D. mixta* (Table 3).

#### 3.2. Principle component analysis of head shape

Principal Component Analysis (PCA) resulted in five meaningful components comprising 73 % of the total variation.

Shape variation in PC1 (29 % of the total variation) was mainly concentrated in the jaw area. It varied from a narrow and elongated head shape with a flattened mandible in the jaw area (lower PC1 scores) to a wide and shortened head with a deepened mandible in the jaw area (higher PC1 scores). The PC1 axis separated *D. valentini* (higher PC1 scores) from *D. dahli* and *D. armeniaca* (lower PC1 scores), while *D. mixta* and *D. portschinskii* had intermediate scores on this axis (Fig. 4). In short,



**Fig. 3.** Digitized three-dimensional landmarks. Landmarks are shown with black numbers. A–dorsal view of the head; B–ventral view of the head; C–view of the right profile of the head; D–view of the left profile of the head. The specimen in the photograph is *Darevskia armeniaca*.



**Table 2**

Results for Procrustes ANOVA for the model shape ~ species, and pairwise distances between the Least Square means on only female individuals. The statistics are performed based on randomized residual permutations. The abbreviations in the Anova table: Df–degrees of freedom, SS–Sum of Squares, MS–Mean Squares, Rsq–R-squared, F–effect size, Z–effect size which is a standard deviation of observed statistics from distributions of random outcomes, Pr(>F)–P value of the F statistics. Abbreviations in the pairwise test table: d–the difference between Species Least Square means, UCL–upper confidence limits, Pr > d–P value of the difference between Species Least Square means.

ANOVA table	Df	SS	MS	Rsq	F	Z	Pr(>F)
species	4	0.085	0.021	0.482	12.8	9.4	0.0001
Residuals	55	0.091	0.002	0.518			
Total	59	0.176					
Pairwise tests	d	UCL (95 %)	Z-effect Size	Pr > d			
<i>armeniaca:dahli</i>	0.048	0.028	3.7	0.0001			
<i>armeniaca:mixta</i>	0.054	0.039	3	0.0011			
<i>armeniaca:portschinskii</i>	0.061	0.03	4.5	0.0001			
<i>armeniaca:valentini</i>	0.067	0.028	5.1	0.0001			
<i>dahli:mixta</i>	0.051	0.04	2.7	0.0029			
<i>dahli:portschinskii</i>	0.052	0.031	3.6	0.0001			
<i>dahli:valentini</i>	0.07	0.029	5	0.0001			
<i>mixta:portschinskii</i>	0.059	0.041	3.1	0.0007			
<i>mixta:valentini</i>	0.066	0.039	3.9	0.0001			
<i>portschinskii:valentini</i>	0.062	0.03	4.4	0.0001			

**Table 3**

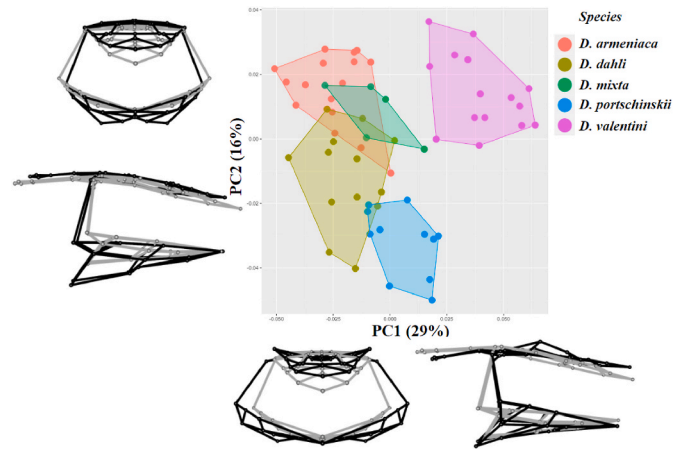
Results for the linear model shape ~ log(SVL) + species, and pairwise distances between the means on only female individuals with its statistics. The abbreviations in the linear model table: Df–degrees of freedom, SS–Sum of Squares, MS–Mean Squares, Rsq–R-squared, F–effect size, Z–effect size, Pr(>F)–P value of the F statistics. Abbreviations in the pairwise test table: d–the difference between Species Least Square means, UCL–upper confidence limits, Pr > d–P value of the difference between Species Least Square means.

Anova table	Df	SS	MS	Rsq	F	Z	Pr(>F)
logsvl	1	0.022	0.022	0.126	13.4	5.2	0.0001
species	4	0.065	0.016	0.369	9.9	7.4	0.0001
Residuals	54	0.089	0.002	0.505			
Total	59	0.176					
Pairwise tests	d	UCL (95 %)	Z-effect Size	Pr > d			
<i>armeniaca:dahli</i>	0.044	0.032	2.9	0.001			
<i>armeniaca:mixta</i>	0.043	0.045	1.4	0.0758			
<i>armeniaca:portschinskii</i>	0.058	0.042	2.9	0.0011			
<i>armeniaca:valentini</i>	0.07	0.029	4.7	0.0001			
<i>dahli:mixta</i>	0.049	0.039	2.6	0.0035			
<i>dahli:portschinskii</i>	0.053	0.032	3.4	0.0001			
<i>dahli:valentini</i>	0.072	0.04	3.8	0.0001			
<i>mixta:portschinskii</i>	0.06	0.039	3.2	0.0001			
<i>mixta:valentini</i>	0.064	0.054	2.3	0.0091			

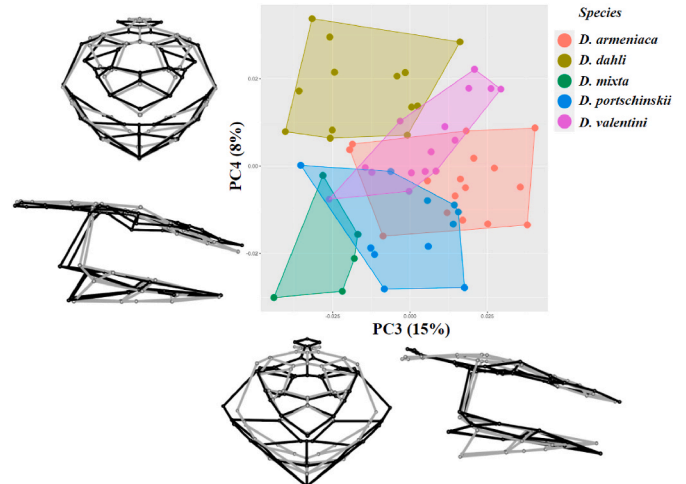
both parthenogens had narrower and more elongated jaws and flatter mandibles than the females of any of their ancestral species.

PC2 (16 % of the total variation) varied from a long dorsal head with a shorter and flatter mandible and in general flat head (low PC2 scores) to a short dorsal head with a longer and deeper mandible and overall deeper head shape (high PC2 scores). It separated *D. portschinskii* and partially *D. dahli* (lower PC2 scores) from *D. armeniaca* and *D. valentini* (higher PC2 scores). *D. mixta* was grouped with *D. valentini* and *D. armeniaca*, but leaned toward intermediate scores on the PC2 axis (Fig. 4). PC2 positively correlated with the log-transformed snout–vent–length (Pearson’s R = 0.62) (Fig. 5).

PC3 (15 % of the total variation) varied from the deep head with rounded dorsal and deep mandible (low PC3 scores) to the flatter head and wide and flatter mandible (high PC3 scores). PC4 (8 % of the total variation) varied from a shorter and laterally more curved (outwards) mandible and narrow dorsal head (low PC4 scores) to a longer and inward-curved mandible and wider dorsal head (high PC4 scores).



**Fig. 4.** Principal component analysis (PCA) score plot. Black lines represent maximum PC values and gray–minimum PC values. PC1–shows that *D. valentini* has a wider head, while according to PC2–*D. dahli* and *D. portschinskii* have longer and flatter heads, with slightly wider jaw areas. The numbers in the parentheses represent the percentage from the total variation for each axis.



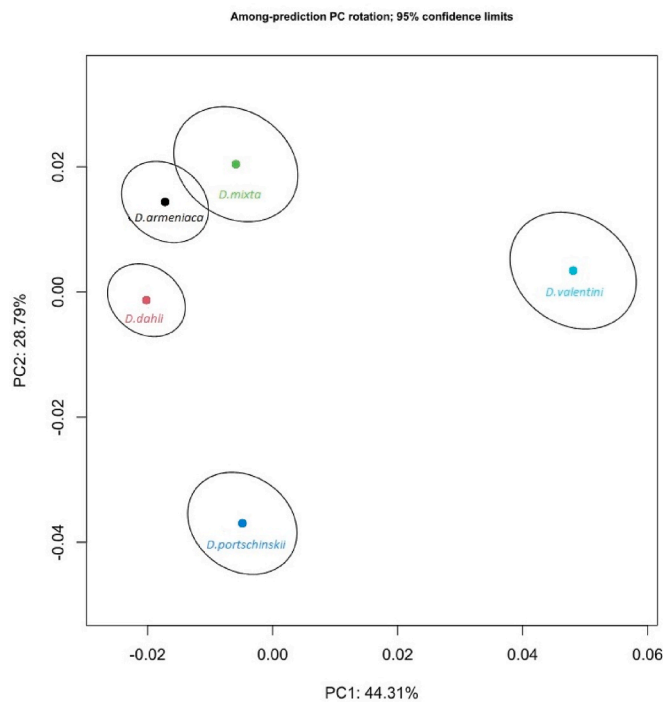
**Fig. 5.** Principal component analysis (PCA) score plot. PC3 overlaps in all species. PC4 shows that *D. dahli* has a longer and flatter mandible and a larger/broader interparietal scale compared to the other four species. The numbers in the parentheses represent the percentage from the total variation for each axis.

Combined, PC3 and PC4 axes separated *D. mixta* from both parthenogens and *D. valentini*, with *D. portschinskii* keeping the intermediate position (Fig. 5).

To visualize the morphospace after excluding the effect of body length on head shape, we used the fitted values from the model shape ~ log(SVL) + species and predicted the 95 % confidence intervals for the mean shape of each species, by keeping the body length effect on the head shape constant (Fig. 6). The 73 % of the total allometry-free shape variation showed that maternal *D. mixta* is much closer based on the head shape to the parthenogenetic species, than paternal *D. valentini* and *D. portschinskii*. Also, *D. valentini* and *D. armeniaca* are less similar to each other than *D. portschinskii* and *D. dahli* (Fig. 6).

**4. Discussion**

To summarize our results, there is no clear reflection of mixed genetic ancestry in the head shape of the parthenogens, although they have more affinity to females of the maternal, than of the paternal species. Simultaneously, there are certain specifics of head shape associated with



**Fig. 6.** 95 % confidence ellipses of the predicted values for species means generated by bootstrapped residuals. Residuals are derived from the model fit with the formula: shape  $\sim$  log(SVL) + species.

body size and/or climate of the habitat (high mountain species are bigger irrespective of the breeding mode and have deeper heads with stronger jaws). Besides, both parthenogens have narrower and more elongated jaw areas with flatter mandibles, hence weaker jaws than females of their respective paternal and maternal species. For example, *D. armeniaca* from Sagamo Lake have stronger jaws and deeper heads than low elevation inhabiting species, but weaker (narrower) jaws compared to females of paternal *D. valentini*, which also live at Sagamo Lake.

The morphological variation of lizard species is influenced by genetic (e.g. gene drift, mutations) as well as environmental factors (e.g. temperature, humidity, food availability, etc.) (Runemark et al., 2010; Oliveira et al., 2023). According to Adams (2011), despite shared selection pressures, different genetic patterns could drive unique head–shape evolution in *Plethodon* salamanders. If the environment has a substantial impact on head shape in *Darevskia*, we should expect higher similarity of the parthenogens with females of the paternal species, with whom they commonly coexist, than with the females of the maternal species, with whom they never share the habitat. Simultaneously, the previous morphological studies on parthenogenetic hybrids show that unisexual species tend to exhibit an intermediate morphological resemblance to either both parental species or a closer resemblance to one of them (Espeche et al., 2023). According to studies on parthenogenetic *Teius suquiensis*, it demonstrated intermediate morphological traits compared to bisexual *T. teyou* and *T. oculatus* (Espeche et al., 2023), whereas parthenogenetic *A. tessellatus* is morphologically more similar to its maternal than to the paternal species (Parker Jr, 1979).

Our study suggested a complex interaction of inheritance and environment in the determining head shape of the parthenogens. The general shape, relative size and depth of the head, and size of jaws are correlated with the body size of the individuals, which in turn is under the strong influence of climate and elevation (Darevsky, 1967). Indeed, body size growth with the elevation and related temperature and precipitation is shown for many *Darevskia* species, including the studied *D. valentini*, and other *Darevskia*, such as *Darevskia caucasica*, *Darevskia*

*parvula* (Darevsky, 1967; Volynchik, 2014; Bülbül et al., 2016) and some other lizard species, such as *Podarcis liolepis* (Ortega et al., 2019), *Lio-laemus* spp. (Pincheira–Donoso et al., 2008). This is most likely a simple pattern following Bergmann’s rule (1847), suggesting that a decrease in surface/volume ratio makes body temperature better controlled because heat loss is slower. However, this is not the sole trend in lizards (Ashton and Feldman, 2003), e.g. lacertid *Eremias argus* shows the reverse of Bergmann’s rule (Deme et al., 2023). Many squamates at higher altitudes have larger individuals of the same species than at lower altitudes. Obviously, head shape is linked with body size with allometric dependencies, which causes the inevitable shape change following the size change.

#### 4.1. Differences between bisexuals and parthenogens

Even though there were slight differences in the sizes of *D. dahli* (SD=0.35) with *D. portschinskii* (SD=0.40) and *D. armeniaca* (SD=0.32) with *D. valentini* (SD=0.36), in addition to the latter two being much larger than the former two, the differences between the parthenogens and paternal species’ females were clearly expressed in the degree of head and mandible width. The parthenogens have much narrower and elongated heads with flatter mandibles, whereas the paternal species have a stronger head shape, especially *D. valentini*. Moreover, these differences account for nearly one–third of the total variation in head shape, whereas body size–associated changes explain only 16 % of the variation. One potential reason for that could be behavioral differences between the parthenogens and their bisexual ancestors. Specifically, it was repeatedly shown that both males and females of bisexual rock lizards perform territorial behavior, forcing conspecific females to avoid occupied individual plots (Galoyan, 2011; Galoyan, 2013; Tselariou et al., 2016; Barateli et al., 2021) and, wider jaws lead to stronger bites (Kohlsdorf et al., 2008; De Meyer et al., 2019), which is obviously important for successful defense of the territory. In contrast, parthenogens do not display territorial behavior, and having broad and strong jaws is way less important. Although the strength of the jaws may also be related to the size and morphology of most commonly consumed food organisms (Verwajen et al., 2002), this is an unlikely explanation of the differences between coexisting parthenogenetic and paternal lizards, since the lizards are not specialized feeders and just consume invertebrates that are present in a specific habitat (Darevsky, 1967).

The impact of shared ancestry on the morphology of the parthenogens is way less clear. The body size of *D. armeniaca* and *D. dahli* is closer to their respective parental species than to the body size of the parental species of the other parthenogen; however, this can equally be a result of the concurrent adaptation of a parthenogen and its parental species to a similar environment. Procrustes ANOVA analysis showed a higher similarity of size–removed head shape of the parthenogens, especially that of *D. armeniaca*, to their maternal *D. mixta* than to the females of the patrilineal ancestors. A stronger maternal effect on the head shape is recorded for some other squamates, including parthenogenetic lizard *A. tessellatus* (Parker Jr, 1979) or meadow viper (*Vipera ursini rakosiensis*) (Oliveira et al., 2023). Noble et al. (2014) had shown experimentally that maternal effect rather than simple Mendelian inheritance determines body size and some behavioral characteristics in skinks. Maternal effect can explain the higher similarity of the parthenogens to their matrilineal than to the patrilineal ancestors. On the other hand, females of some of the parental species may be less territorial than the others, dependent on their habitat type (e.g. *D. mixta* is more broadly using various microhabitat types than *D. valentini* and especially *D. portschinskii*, which are strict rock dwellers (Darevsky, 1967; Tarkh-nishvili, 2012)), and parallel behavioral adaptations could explain different degree of similarity between the parthenogens and their ancestors rather than direct ancestral influence. Detailed behavioral observations on these species may shed light on this question in the future.

In summary, some characteristics differentiate the parthenogens from their bisexual ancestral species, and others are associated with

body size and elevation of typical habitats. Although the effect of maternal species is also likely present, the impact of intermediate genetics or habitat type on head shape is shaded by the differences between the reproductive biology, which is not associated with aggressive territorial behavior in parthenogens, in contrast with their bisexual ancestors.

### ORCID iD authorship contribution statement

**Natia Barateli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mariam Gabelaia:** Writing – review & editing, Visualization, Supervision, Software, Methodology, Formal analysis, Conceptualization. **Giorgi Iankoshvili:** Writing – review & editing, Investigation, Data curation. **David Tarkhnishvili:** Writing – review & editing, Methodology, Conceptualization.

### Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Natia Barateli reports administrative support and equipment, drugs, or supplies were provided by Ilia State University. Natia Barateli reports a relationship with Ilia State University that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

Data will be made available on request.

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