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Age and growth of the Artvin Lizard, *Darevskia derjugini* (NIKOLSKY, 1898), in Turkey
(Squamata: Sauria: Lacertidae)

Altersstruktur und Wachstum der Artviner Eidechse, *Darevskia derjugini* (NIKOLSKY, 1898) in der Türkei
(Squamata: Sauria: Lacertidae)

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KURZFASSUNG

Die Autoren untersuchten mögliche Auswirkungen von Klimafaktoren auf Wachstum und Altersstruktur in zwei Populationen von *Darevskia derjugini* (NIKOLSKY, 1898) an unterschiedlichen Höhenstandorten in der Türkei. Obwohl sich die Seehöhen und Jahresmittelwerte von Temperatur, Niederschlag und Luftfeuchte an den Untersuchungsstandorten Şavşat (Hochlandpopulation) und Düzköy (Tieflandpopulation) jeweils signifikant unterschieden, taten dies die Kopf-Rumpf-Längen, das Alter bei Erreichen der Geschlechtsreife, die Lebenserwartung und die Wachstumsraten in den beiden Eidechsenpopulationen nicht. In beiden Populationen war der geschlechtsbedingte Größenunterschied zugunsten der Weibchen deutlich ausgeprägt, der Wachstumskoeffizient war in der hochgelegenen Population größer. Die Ähnlichkeiten in den Wachstumsraten und den geschlechtsbedingten Größenunterschieden zwischen den beiden in unterschiedlichen Höhen lebenden Populationen von *D. derjugini* legen nahe, daß die Lebenserwartung und das Alter beim Erreichen der Geschlechtsreife die zuvorgenannten Parameter stärker beeinflussen als die jeweiligen Klimabedingungen.

ABSTRACT

The authors investigated potential effects of climatic factors on age and growth in two populations of *Darevskia derjugini* (NIKOLSKY, 1898), located at different elevations in Turkey. Although elevation, mean annual temperature, precipitation and humidity were significantly different among the study sites of Şavşat (highland population) and Düzköy (lowland population), the lizards' respective snout-vent-length, age at maturity, longevity and growth rates were not. A strong female-biased sexual size dimorphism was observed in both populations. The growth coefficient was higher in the high-elevation population. The similarities of growth rates and SSD in *D. derjugini* populations from different elevation sites suggest that longevity and age upon arrival at sexual maturity have stronger effects on these parameters than the ambient thermal conditions.

KEY WORDS

Reptilia: Squamata: Sauria: Lacertidae: *Darevskia derjugini*; population ecology, life history traits, skeletochronology, age at maturity, von Bertalanffy growth curve, sexual size dimorphism, body size, growth rate, longevity; Turkey

INTRODUCTION

To successfully conserve and restore a particular species, knowledge of its life-history traits and basic ecology, including physical characteristics of individuals and age structure of natural populations, is a matter of critical importance (GERMANO 1992; ANDREONE et al. 2005).

The Artvin Lizard, *Darevskia derjugini* (NIKOLSKY, 1898), is among the lacertid species classified as "Near Threatened" in the IUCN Red List of Threatened Species (IUCN 2016). It is distributed in the Black Sea coastal region of Turkey (Provinces of Giresun, Trabzon, Rize and Artvin), Georgia, Azerbaijan and Russia (BISCHOFF 1982, 1984; RYANBININA et al. 2002; BISCHOFF et al. 2005). In spite of its wide distribution in the eastern Black Sea region, there is lack of detailed information on population dynamics and life-history traits of the species. Pertinent knowledge is limited to the studies by ORLOVA & SMIRINA (1981, 19839) who

Table 1: Activity and sampling periods of *Darevskia derjugini* (NIKOLSKY, 1898) and climate data of the sampling sites at Şavşat and Düzköy (northeast Turkish Black Sea region).

Tab. 1: Aktivitäts- und Sammelperioden von *Darevskia derjugini* (NIKOLSKY, 1898) sowie Klimadaten der Untersuchungsstandorte in Şavşat und Düzköy (nordosttürkische Schwarzmeerregion).

Site - Altitude (m a.s.l.) / Fundort – Seehöhe (m ü. M.)	Şavşat - 1,690 m	Düzköy - 571 m
Activity period / Aktivitätsperiode	early May - late Sept. Anfang Mai - Ende Sept.	late Apr. - late Oct. Ende Apr. - Ende Okt.
Sampling period / Sammelperiode	September 10-14, 2015	August 20-24, 2015
Average daytime air temperature during sampling / Mittlere Tagestemperatur in der Sammelperiode	22 °C	26 °C
Annual average temperature / Jahresmittel der Temperatur	10.2 °C	12.5 °C
Annual average precipitation / Jahresmittel der Niederschlagsmenge	60.90 mm	52.03 mm
Annual average humidity / Jahresmittel der relativen Luftfeuchte	70.55 %	75.3 %
Activity period average temperature / Temperaturmittel der Aktivitätsperiode	18.7 °C	17.7 °C
Activity period average precipitation / Mittlere Niederschlagsmenge der Aktivitätsperiode	61.18 mm	48.73 mm
Activity period average humidity / Mittlere relative Luftfeuchte der Aktivitätsperiode	66 %	83.5 %

investigated the population structure of *D. derjugini* based on monitoring and age determination in natural populations. Both of those studies did not include results on growth rate, sexual size dimorphism and relationships between age and snout-vent-length.

Age determination for demographic analyses is a standard to obtain information about the vitality and stability of reptilian populations for many years (TINKLE 1967; DAVBIN 1982; GIBBONS & SEMLITSCH 1982; HUTTON 1986; BARBAULT & MOU 1988; FRAZER et al. 1991). Being a most purposeful and economic approach, skeletochronology (CASTANET & SMIRINA 1990) was adopted by the authors to answer age and growth related issues.

The objective of the present study was to evaluate age, body size, sexual size dimorphism (SSD), and growth rate results among individuals and populations of *D. derjugini* and investigate potential effects of climatic factors on life-history traits of two populations located at different altitudes.

MATERIALS AND METHODS

During the breeding season, *D. derjugini* specimens were collected from two populations living at different altitudes in the northeast Turkish Black Sea region (capture permission No. 72784983-488.04-147331 issued by the Ministry of Forest and Water Affairs of Turkey). The Şavşat population (Province of Artvin, 41°13’55”N, 42° 26’17”E) is located in a forested area at an altitude of 1,690 m a.s.l. The specimens were caught among thorny shrubs at the edge of the Artvin-Şavşat highway where *D. derjugini* lives in sympatry with *Darevskia parvula* (LANTZ & CYRÉN, 1913). The Düzköy population (Province of Trabzon, 40° 53’14”N, 39°26’42”E) is located at an altitude of 571 m a.s.l. The specimens were caught from a slope covered with thorny vegetation at the edge of the Düzköy-Kayabaşı highland motorway. Activity and sampling periods of *Darevskia derjugini* (NIKOLSKY, 1898) and climate data of the sampling sites at Şavşat and Düzköy are summarized in Table 1.

The lizards in both populations face different ecological, but similar anthropogenic conditions. Both sites are moderately populated and agricultural activity is not important, traffic-related threats such as roadkill and pollution are similar. Within each site, the lizards were caught by hand and sexed by sounding for the presence or absence of hemipenis pockets and secondary sex characteristics (e.g., dark blue spots on the margins of ventral plates and black color of lateral bands and the wider tail base present in males). Snout-vent length (SVL) was measured to the nearest 0.01 mm using a digital caliper. Sexual Size Dimorphism (SSD) was quantified using the size dimorphism index (SDI) in LOVICH & GIBBONS (1992): SDI = (mean length of the larger sex / mean length of the smaller sex) ± 1. This formula, arbitrarily uses +1 if males are larger than females defining the result as negative, or -1 if females are larger than males defining the result as positive.

The second phalanx of the fourth (longest) toe of a hind limb was clipped in all specimens collected and preserved in 10 % formalin solution for subsequent histologic analyses. After on-site registration and toe-clipping, the lizards were released back to their natural habitats. The animals were treated in accordance with the guidelines of the ethics committee of the Kardeniz Technical University (KTÜ.53488718-342/2015/24).

A total of 61 adult specimens (27 males, 34 females) were caught; 30 (16 males, 14 females) from Şavşat and 31 (11 males, 20 females) from Düzköy. Skeletochronology is based on the number of the lines of arrested growth (LAGs), corresponding to hibernation/starvation phases, in transverse sections of the periosteal bone of the middle part of phalangeal diaphyses using a portion of the second phalanx from the fourth toe (CASTANET et al. 1993). However, the number of phalangeal LAGs does not necessarily reflect the exact age (in years) of individuals since one to two of the innermost LAGs of the periosteal bone can be replaced with endosteal bone in individuals of advanced age (HEMELAAR 1985; SAGOR et al. 1998). In anuran phalanges where the first (innermost) LAG has been entirely decomposed by endosteal resorption, the innermost conserved LAG was actually formed during the second, rather than first hibernation (SAGOR et al. 1998). In the cross-sections of the present study, it was observed that the endosteal resorption zone did not affect the first LAG in all specimens.

Phalangeal bones preserved in 10 % formaldehyde were subjected to decalcification, histological tissue processing, embedding, cross-section and staining (hematoxylin) procedures as described in BÜLBÜL et al. (2016). Finally, the cross-sections were observed under a light microscope.

Age was estimated using standard skeletochronological criteria (CASTANET & SMIRINA 1990; SMIRINA 1994). The number of LAGs on all the cross-sections was independently counted by three observers (M. KURNAZ, F. UZUN & A. İ. EROĞLU) and the results were unified in discussions. Observed double lines were counted as single lines. In the present study, endosteal resorption of the first LAG was diagnosed by comparing the diameters of eroded marrow cavities with the diameters of non-eroded marrow cavities in sections from the youngest specimens as previously described in the study of ÖZDEMIR et al. (2012). The accuracy of age estimation was however never seriously affected by the endosteal resorption process. The distance between two adjoining LAGs is indicative of individual growth in a given year (KLEINENBERG & SMIRINA 1969; ÖZDEMIR et al. 2012). Any obvious decrease in space between two subsequent LAGs was taken as a marker for the age at sexual maturity (RYSER 1998; YILMAZ et al. 2005; ÖZDEMIR et al. 2012).

Since age classes and snout-vent-lengths (SVL) were normally distributed (One-Sample Kolmogorov-Smirnov Test), a parametric test was used for comparison of the means (Independent Sample T-Test); correlations were represented by Spearman's rank correlation coefficient (*r*). All statistical tests were processed with IBM SPSS 21.0 for Windows at a significance level of $\alpha < 0.05$.

In the present study, the growth patterns were estimated according to the VON BERTALANFFY (1938) growth model (JAMES 1991; WAPSTRA et al. 2001; ROITBERG & SMIRINA 2006; GUARINO et al. 2010). The general form of the von Bertalanffy equation, $Lt = L_\infty (1 - e^{k (t\text{-}t0)})$ was followed, where L_t is length at age t, L_∞ indicates the asymptotic maximum length, e is the base of the natural logarithm, k is a growth coefficient, and t_0 is the age at hatching, which is the starting point of the growth curve. Since data on hatching size were not available for the studied populations the value of

Table: 2: Descriptive statistics of snout-vent-length and age in the populations of adult male (M) and female (F) *Darevskia derjugini* (Nikolsky, 1898) studied at Şavşat and Düzköy (Turkey).

Tab. 2: Deskriptive Statistiken von Kopf-Rumpf-Länge (KRL) und Alter in den untersuchten Populationen adulter männlicher (M) und weiblicher (F) *Darevskia derjugini* (Nikolsky, 1898) von Şavşat und Düzköy (Türkei).

Population	Şavşat	Düzköy
Mean SVL - M (mm) / Mittlere KRL - M (mm)	47.42 ± 0.68	48.03 ± 0.94
Mean SVL - F (mm) / Mittlere KRL - F (mm)	51.59 ± 1.32	51.25 ± 0.57
Mean SVL - M+F (mm) / Mittlere KRL - M+F (mm)	49.37 ± 0.80	50.10 ± 0.56
Range of age - mature M (y) / Spannweite des Alters – adulte M (y)	3-8	2-7
Range of age - mature F (y) / Spannweite des Alters – adulte F (y)	3-7	2-7
Range of age - M+F (y) / Spannweite des Alters – adulte M+F (y)	3-8	2-7
Age at sexual maturity - M+F (y) / Alter bei Geschlechtsreife M+F (y)	2-3	1-2
Mean age - M (y) / Mittleres Alter M (y)	4.38 ± 0.30	3.91 ± 0.37
Mean age - F (y) / Mittleres Alter F (y)	5.43 ± 0.37	4.70 ± 0.26
Mean age - M+F (y) / Mittleres Alter M+F (y)	4.87 ± 0.25)	4.42 ± 0.20

L_{t0} = 22.9 mm was taken as indicated by In Den Bosch & Bout (1998). The parameters L_∞ (asymptotic SVL) and k, and their asymptotic confidence intervals (CI), were estimated using the non-linear regression procedure of the IBM SPSS 21.0 software program. The growth rates were calculated as $R = k (L_\infty - L_t)$; growth curves were considered to be significantly different if the 95 % confidence intervals did not overlap (James 1991; Wapstra et al. 2001).

RESULTS

Growth zones and thin hematoxylinophilic lines corresponding to winter lines of arrested growth were present in all 61 cross-sections of adult phalanges (Fig. 1). The resorption zone reached the first LAG in 7 specimens of both Şavşat (23.3%) and Düzköy (22.6%). The resorption zone was clearly formed by endosteal bone in all preparations and never created difficulty in age determination. Double LAGs were seen in 11 (36.7 %) specimens of the Şavşat and 13 (41.9 %) of the Düzköy populations. The oldest females and males were seven and eight years old, respectively, in the Şavşat and seven in the Düzköy populations (Fig. 2). For both sexes collectively, the age upon arrival at sexual maturity was 2-3 years in the Şavşat population while it was

Table 3: Descriptive statistics of snout-vent-length (SVL, mm), age (y) and growth rate (GR, mm per year) in males (M) and females (F) of the studied populations of *Darevskia derjugini* (Nikolsky, 1898) from Şavşat and Düzköy (Turkey). Mean – arithmetic mean, N - number of specimens, SE - standard error of the mean.

Tab. 3: Deskriptive Statistiken von Kopf-Rumpflänge (SVL, mm) Alter (Age, a) und jährlicher Wachstumsrate (GR, mm/a) der Männchen (M) und Weibchen (F) von *Darevskia derjugini* (NIKOLSKY, 1898) aus den Populationen von Şavşat und Düzköy (Türkei). Mean – arithmetischer Mittelwert, N – Stichprobengröße, Range – Spannweite, SE – Standardfehler des Mittelwertes.

	Şavşat				Düzköy			
Parameter	N	Mean	Range	SE	N	Mean	Range	SE
SVL - M	16	47.42	42.32-52.54	0.68	11	48.03	48.16-55.34	0.94
Age - M	16	4.38	3-7	0.30	11	3.91	3-7	0.37
GR - M	5	3.67	2.76-4.70	0.34	4	4.27	2.79-5.61	0.60
SVL - F	14	51.59	38.04-58.29	1.32	20	51.25	45.85-56.51	0.57
Age - F	14	5.43	3-8	0.37	20	4.70	3-7	0.26
GR - F	6	1.87	0.25-5.27	0.78	5	4.08	2.41-6.18	0.68

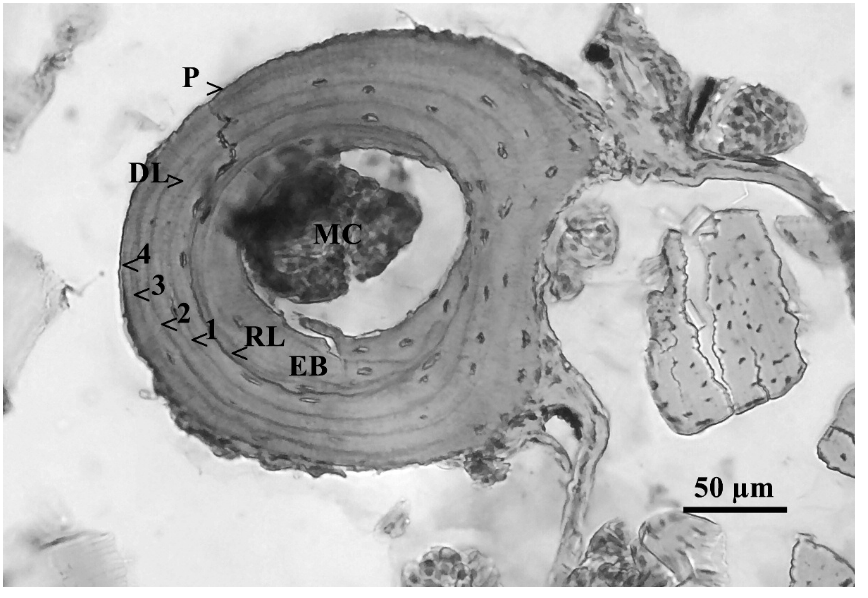

Fig. 1: Cross section (15µm) of a toe bone of a four-year-old female (48.72 mm SVL) of *Darevskia derjugini* (NIKOLSKY, 1898) from the Şavşat population in Turkey. The age was derived from the presence of four Lines of arrested Growth (LAGs 1-4) surrounding the resorption line. MC – marrow cavity; EB – endosteal bone; RL – resorption line; DL – double line; P – periphery.

Abb. 1: Querschnitt (15 µm) eines Zehenknochens eines vier Jahre alten Weibchens (48.72 mm Kopf-Rumpflänge) von *Darevskia derjugini* (NIKOLSKY, 1898) aus der Population von Şavşat (Türkei). Das Alter wurde aus der Anzahl von vier Linien verlangsamten Wachstums (1-4) abgeleitet. MC – Markhöhle; EB – endostaler Knochen; RL – Resorptionslinie, DL – Doppelline, P – Peripherie.

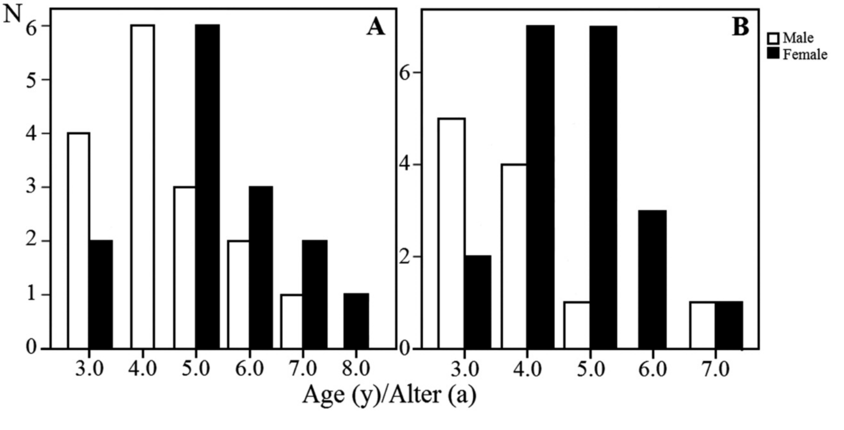

Fig. 2: Age distributions for male and female *Darevskia derjugini* (NIKOLSKY, 1898) from the Şavşat (A) and Düzköy (B) populations. N - Number of individuals.

Abb. 2: Altersverteilung bei männlichen und weiblichen *Darevskia derjugini* (NIKOLSKY, 1898) aus den Şavşat (A) und Düzköy (B) Populationen. N - Anzahl der Individuen.

1-2 years in the Düzköy population. The age at maturity was 2 years in 6 (20 %) and 3 years in 24 (80 %) specimens of the Şavşat population while it was 1 year in 4 (12.9 %) and 2 years in 27 (87.1 %) specimens of the Düzköy population. Descriptive statistics of the parameters of the Şavşat and Düzköy populations are given in Table 2.

Age, body length and growth in the Şavşat population.- Age was ranged from 3-8 years in females and 3-7 years in males. The means of age and SVL were significantly higher in females than males (t = -2.218, *df* = 28, *P* < 0.05 and t = -2.910, *df* = 28, P < 0.05, respectively). The longer female SVL was also expressed by the SDI of 0.088. There was a significant correlation between SVL and age in both males (*r* = 0.889, *P* < 0.01) and females (*r* = 0.799, *P* < 0.01). The growth pattern estimated by von Bertalanffy's equation showed a good fit to the actual relation between age and SVL (Fig. 3). For both sexes, the estimated asymptotic SVL was slightly smaller than the maximum SVL recorded (SVL_{asym} ± CI, males: 52.60 ± 6.13 mm; females: 54.03 ± 4.66 mm). The growth coefficient (k) was higher in females than in males (k ± CI, males: 0.14 ± 0.13; females: 0.61 ± 0.09). The growth curves of males and females were clearly different from each other (Fig. 3). Growth rates of the males and females were not significantly different (t = 1.955, *df* = 9, *P* = 0.08). Descriptive statistics are presented in Tables 2 and 3.

Age, body length and growth in the Düzköy population.- Age was ranged from 3-7 years in both females and males. The mean age did not differ significantly between males and females (t = -1.915, *df* = 29, *P* = 0.065), whereas the mean SVL did (t = -3.101 *df* = 29, *P* < 0.05), and was longer in females (SDI = 0.067). The correlation between age and SVL was insignificant for males (*r* = 0.528, *P* = 0.095) and significant for females (*r* = 0.807, *P* < 0.01). The growth pattern estimated by von Bertalanffy's equation was in good fit to the relation between age and SVL (Fig. 4). For both sexes, the estimated asymptotic SVL was slightly smaller than the maximum SVL recorded (SVL_{asym} ± CI, males: 54.27 ± 19.78 mm; females: 53.22 ± 5.48 mm). The growth coefficient (k) was lower in males than in females (k ± CI, males: 0.18 ± 0.14; females: 0.24 ± 0.10). The growth curves of males and females were largely congruent (Fig. 4). The growth rates of males and females were not significantly different within the population (t = 0.206, *df* = 7, *P* = 0.206). Descriptive statistics are presented in Tables 2 and 3.

Between populations comparison of age and SVL.- Neither male (M) or female (F) Şavşat samples nor both (M+F) samples collectively were significantly different from their counterparts from Düzköy with regard to age (M: t = 0.982, *df* = 32, *P* = 0.335; F: t = 1.751, *df* = 31, *P* = 0.90; M+F: t = 1.376, *df* = 59, *P* = 0.174) and SVL (M: t = -0.536, *df* = 25, *P* = 0.597; F: t = 0.264, *df* = 32, *P* = 0.794; M+F: t = -0.758, *df* = 59, *P* = 0.452). For all individuals in both populations, the estimated asymptotic SVL was slightly lower than the maximum SVL recorded (SVL_{asym} ± CI, Şavşat population: 51.71 ± 3.89 mm; Düzköy population: 53.32 ± 3.94 mm). Growth coefficient was higher in the high-elevation site than the lower elevation site (k ± CI, Şavşat population: 0.24 ± 0.08; Düzköy population: 0.12 ± 0.08). Growth rates were not significantly different between the populations (Independent Sample T-Test; t = -1.057, *df* = 10, *P* = 0.315).

DISCUSSION

Population demography of poikilotherms is strongly affected by the climatic conditions prevailing and, thus, altitude of the habitat (TESTER 1990; FRIEDL & KLUMP 1997; ÖZDEMIR et al. 2012) in that on the average individuals from high-elevation sites live longer than conspecifics from low-elevation sites (WAPSTRA et al. 2001; ROITBERG & SMIRINA 2006; GUARINO et al. 2010). The present results are compared to information from other Caucasian lizard species.

Although the populations of *D. derjugini* studied here lived at different alti-

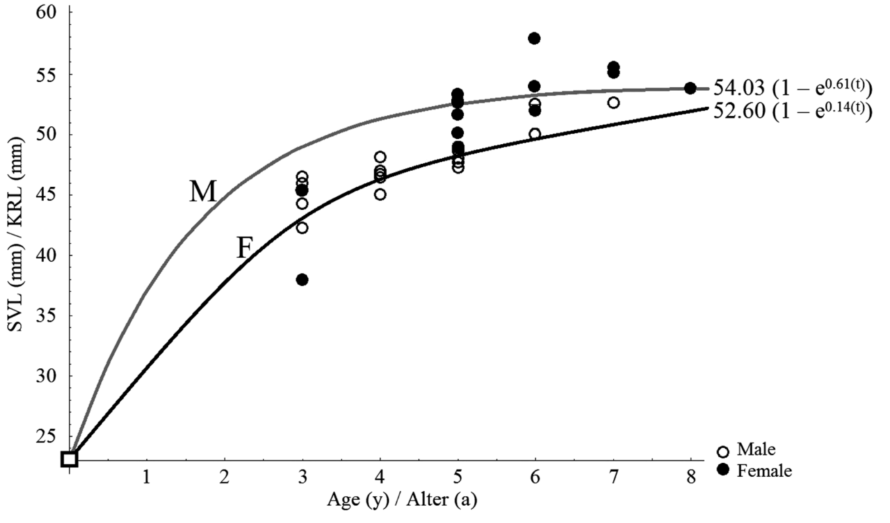

Fig. 3: Von Bertalanffy growth curves for males (open circle, grey line) and females (solid circle, dark line) of *Darevskia derjugini* (NIKOLSKY, 1898) from the Şavşat population. The open square marks the lizards' mean SVL at hatching as reported by IN DEN BOSCH & BOUT (1998). Growth parameters are presented in the text.

Abb. 3: Von Bertalanffy Wachstumskurven für Männchen (offene Kreise, graue Linie) und Weibchen (gefüllte Kreise, dunkle Linie) von *Darevskia derjugini* (NIKOLSKY, 1898) aus der Şavşat-Population. Das offene Quadrat bezeichnet die mittlere Kopf-Rumpf-Länge der Eidechsen beim Schlüpfen wie von IN DEN BOSCH & BOUT (1998) beschrieben. Die Wachstumsparameter sind im Text angegeben.

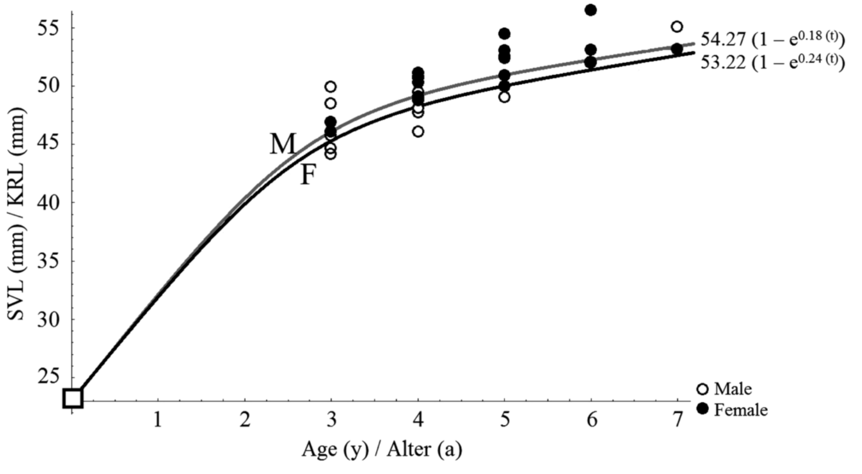

Fig. 4: Von Bertalanffy growth curves for males (open circles, grey line) and females (solid circles, dark line) of *Darevskia derjugini* (NIKOLSKY, 1898) from the Düzköy population. The open square marks the lizards' mean SVL at hatching as reported by IN DEN BOSCH & BOUT (1998). Growth parameters are presented in the text.

Abb. 4: Von Bertalanffy Wachstumskurven für Männchen (offene Kreise, graue Linie) und Weibchen (gefüllte Kreise, dunkle Linie) von *Darevskia derjugini* (NIKOLSKY, 1898) aus der Düzköy-Population. Das offene Quadrat bezeichnet die mittlere Kopf-Rumpf-Länge der Eidechsen beim Schlüpfen wie von IN DEN BOSCH & BOUT (1998) beschrieben. Die Wachstumsparameter sind im Text angegeben.

tudes and climatic conditions, their mean age was not significantly different. Contrary to common expectations, GÜL et al. (2014) reported that the mean age of a highland population (2,137 m a.s.l.) of *Darevskia rudis* (BEDRIAGA, 1886) was lower than in two conspecific lowland populations (700 and 1,277 m a.s.l.). Similar findings were reported for *Lacerta agilis* LINNAEUS, 1758 and *Lacerta strigata* EICHWALD, 1831, by ROITBERG & SMIRINA (2006).

Populations living at cool sites develop delayed maturity and compensate their slower growth rate with larger eggs and hatchlings (BERVEN 1982; LIAO & LU 2010a, 2012). As was expected, the lizards attained maturity at the age of 1-2 years in the lowland population while age at maturity was 2-3 years in the highland population. Age at sexual maturity in natural populations of *D. derjugini* was reported as 1-2 years in both sexes by ORLOVA & SMIRINA (1983).

These authors estimated the oldest males and females of *D. derjugini* to be 4 years and 5-6 years old, respectively (ORLOVA & SMIRINA 1981). The present study found higher longevity values: maximum age was 7 years in males and 8 in females of the highland population while it was 7 years in both sexes of the lowland population. Although elevation, mean annual temperature, precipitation and humidity were clearly different in Şavşat and Düzköy, longevity in the *D. derjugini* populations was identical. Among the climate parameters, "temperature during the active period" was however similar and may be the main determinant of longevity in the studied populations rather than precipitation or humidity. The result showing similar longevity at different altitudes is consistent with the findings of BÜLBÜL et al. (2016) for *D. parvula.*

Contrary to Bergmann's rule, most lizards living in cold environments have smaller body sizes than their conspecifics in warmer habitats (JIN & LIAO 2015). This may be the result of selection towards more rapid heating of the body temperature (PIANKA & VITT 2003). In contrast to the above considerations no reduction in SVL was detected in the highland population of *D. derjugini*. On the other hand, BÜLBÜL et al. (2016) reported increased SVL in highland individuals of *D. parvula* as compared to specimens from a lower elevation site. These results show that differences in body size may also result from environmental factors other than temperature. In the present study the mean SVL of females was significantly longer than of males in both populations. Similarly, ORLOVA & BISCHOFF (1984) reported that females of *D. derjugini* were bigger than males whereas, GÜL et al. (2014) who studied *D. rudis*, found significant differences in SVL between sexes with the females being longer in the highland and males in the lowland population. There are however various biological strategies other than climate that determine the relative size of sexes within a given species.

In the present study, there was a significant positive correlation between SVL and age in both sexes of the highland and females of the lowland populations. Similarly, GÜL et al. (2014) reported a significant positive correlation between SVL and age for females in highland and lowland populations of *D. rudis*, whereas, no significant positive correlation was found in the males.

Strong female-biased sexual size dimorphism (SSD) was observed in both studied populations of *D. derjugini*. GÜL et al. (2014) found the same situation in a highland population of *D. rudis*, whereas, SSD was male-biased in lowland populations. The stronger SSD in the highland population of *D. rudis* was understood by these authors as a result of colder temperatures at higher elevations. In contrast to this hypothesis, the present study of *D. derjugini* reveled a pronounced SSD present in both populations, irrespective of altitude and climate conditions. In accordance with the present homogeneous findings, BÜLBÜL et al. (2016) found low level male-biased SSD in both highland and lowland populations of *D. parvula.* Potential reasons for different patterns of SSD between and within species are manifold (ROITBERG 2007; COX et al. 2007) and include differentiated evolutionary responses to climatic conditions such as temperature and precipitation in males and females. In the present study, the higher elevation site received clearly more rainfall than the lower one. Thus, mean precipitation during the activity period had obviously no mensurable effect on SSD in the *D. derjugini* populations studied. On the other hand, longevity and age at first reproduction have been identified as the main determinants of SSD at an intra-specific or inter-specific level (LIAO & LU 2010b; LYAPKOV et al. 2010; LIAO et al. 2013, 2015). Congruently, longevity and age upon arrival at sexual maturity were similar in both populations of the present study. In *Triturus karelinii* (STRAUCH, 1870), age at maturity was greatly influenced by local conditions, e.g., reduction of the length of the active period (OLGUN et al. 2005). This accords well with similar ages at maturity and similar durations of the active period (five and six months, respectively) in the studied low and high altitude populations of *D. derjugini*.

In many lizard species, adult SSD emerges from sexual differences in the growth rates (JOHN-ADLER & COX 2007; KOLAROV et al. 2010; ÜZÜM et al. 2014). However, in spite of the observed significant female-biased SSD, no significant difference was found between growth rates of the sexes within the populations studied.

Also, growth rates depend on food availability and thermal conditions (ADOLPH & PORTER 1993). In summary, populations living at cooler sites were supposed to grow faster (MERILÄ et al. 2000; CALEY & SCHWARZKOPF 2004; CONOVER et al. 2009) and lizards were observed to grow faster at high elevations due to an environment boosting growth by increased precipitation levels (IRAETA et al. 2006). This phenomenon is however not supported by the present study in which growth rates did not vary significantly among *D. derjugini* populations of different altitudes.

Particular ecological factors such as extraordinary drought or heat and shortage of food can lead to the formation of double lines of arrested growth (JAKOB et al. 2002; GUARINO & ERIŞMIŞ 2008; ÖZDEMIR et al. 2012). Such double lines were observed in 11 (36.7 %) specimens from Şavşat and 13 (41.9 %) from Düzköy. BÜLBÜL et al. (2016) found higher percentages of double lines for *D. parvula* in both highland (54.5 %) and lowland (57.8 %) populations, suggesting this species to be under higher stress than *D. derjugini* at their particular study sites.

In addition to growth processes, environmental conditions also affect endosteal resorption in bone (SMIRINA 1972). Moreover, long bone endosteal resorption is strongly affected by the animals' daily and annual activity patterns and the local climate conditions (HEMELAAR 1988; ESTEBAN 1990; LECLAIR 1990; AUGERT 1992; ESTEBAN et al. 1999). CAETANO & CASTANET (1993) reported e.g., that resorptions were more frequently observed in highland populations than lowland populations. ARAKELYAN et al. (2013) and GÜL et al. (2014) diagnosed a similar process in other *Darevskia* species. In contrast to these reports, the present study found no significant differences in the proportion of endosteal resorption in *D. derjugini* populations at high (Şavşat 23.3 %) and low (Düzköy 22.6 %) elevation sites. Similar results were found for *D. parvula* by BÜLBÜL et al. (2016).

The similarities of growth rates and SSD in *D. derjugini* populations from different elevation sites suggest that longevity and age upon arrival at sexual maturity have stronger effects on these parameters than the ambient thermal conditions.

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