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## The body size, age structure, and growth of Bosc's fringe-toed lizard, *Acanthodactylus boskianus* (Daudin, 1802)

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**Abstract:** Using skeletochronology, the age structure of a breeding population portion of *Acanthodactylus boskianus* (Daudin, 1802) from the southeast of Turkey was studied for the first time. A total of 21 preserved (9♂♂, 8♀♀, and 4 juveniles) specimens were used in this study. According to the analysis of the age structure based on counting lines of arrested growth, ages ranged from 6 to 9 years (mean:  $7.44 \pm 0.34$  years) in males and from 5 to 7 years (mean:  $6.13 \pm 0.30$  years) in females. Juveniles were from 3 to 4 years old. Age at maturity was estimated to be 4–5 years and the adult survival rates were estimated to be 0.62 for males and 0.56 for females. The mean snout–vent length was calculated as  $79.09 \pm 1.16$  mm in males,  $65.90 \pm 2.02$  in females, and  $43.55 \pm 2.02$  mm in juveniles. The sexual dimorphism index was calculated as  $-0.20$ . The difference between the sexes in age and size was statistically significant.

**Key words:** Lacertidae, *Acanthodactylus boskianus*, age, size, sexual dimorphism, Turkey

### 1. Introduction

The genus *Acanthodactylus* is commonly referred to as the fringe-toed lacertids, owing to the presence of a series of scales on the fingers that provide traction for running over loose sand (Halliday and Adler, 2002; Pianka and Vitt, 2003). Bosc's fringe-toed lizard (*Acanthodactylus boskianus*) (Daudin, 1802) is one of the largest *Acanthodactylus* species (Schleich et al., 1996). It has a long, cylindrical body and well-developed legs, as is common with other lacertids (Pianka and Vitt, 2003). It excavates burrows in hard sand, some of which are equipped with multiple entrances to allow quick retreats (Schleich et al., 1996). The medium-sized lacertid species *A. boskianus* ranges widely throughout arid northern Africa and eastwards in Asia to western Iran and throughout the Arabian Peninsula (Seifan et al., 2009; Baran et al., 2012). According to Arnold (1983), *A. boskianus* inhabits more open areas. Rastegar-Pouyani (1999) mentioned that the habitat of *A. boskianus* in Iran has spiny bushes of *Astragalus*. The habitat of the species is the foothills of the Zagros Mountain, Iran, with dense vegetation (Fathnia et al., 2009). In Turkey, *A. boskianus* inhabits the sandy banks of the Euphrates River in Birecik, southeastern Anatolia (Baran et al., 2012). Its habitat consists of *Astragalus*. The total body length is up to 24

cm. The dorsal surface of the body is greenish brown-gray and spotless, and there are dark and light maculations on the ventral region. It hides in cracks and crevices and can also burrow. The female lays 2 clutches of between 3 and 7 eggs annually (Baran and Atatür, 1998; Baran et al., 2012).

Different studies have been carried out about *A. boskianus* to date: some of these studies concerned sexual dimorphism (Steifan et al., 2009), pheromones (Khannoon et al., 2010; Khannoon et al., 2011), environmental physiology (El-Masry and Hussein, 2001), biogeography (Harris and Arnold, 2000), and taxonomy (Rastegar-Pouyani, 1999). There are no data available about the life history traits, especially age structures, of this species.

Skeletochronology is a method for estimating age using the presence of growth layers in bone tissue and counting the lines of arrested growth (LAGs) (Castanet and Smirina, 1990). In amphibians and reptiles in which annual growth is cyclical, i.e. with alternating periods of rapid and slow growth, skeletochronology can be used to estimate the age of individuals (Castanet et al., 1993). This method has been successfully used for age determination of different lizard species to date [e.g., *Agama stellio*, El Mouden et al. (1999); *Darevskia* spp., Arakelyan (2002); *Lacerta agilis*, Roitberg and Smirina (2006); *Lacerta strigata*, Roitberg and Smirina (2006), Guarino et al. (2010); *Eremias argus*, Kim et al.

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(2010); *Dinarolacerta mosorensis*, Tomašević et al. (2010); *Plestiodon (Neoseps) reynoldsi*, McCoy et al. (2010)].

In the present study, we investigated the body size and age structure, as well as eventual intersexual differences, in terms of these characteristics of this species. We tested whether age estimation of museum samples is possible in order to use this information to characterize the age structure, sexual maturity, and longevity of *A. boskianus*.

## 2. Materials and methods

We used 21 preserved (9♂♂, 8♀♀, and 4 juveniles) *A. boskianus* specimens kept in the herpetological collection of the Dokuz Eylül University Department of Biology. The specimens were collected from Birecik/Şanlıurfa (37°03'N, 37°54'E) at an altitude of 445 m a.s.l. They were found in sandy areas with small amounts of shrubs and grasses. In this study, samples were captured by hand from under stones or on land. The feeding and breeding activities of *A. boskianus* generally start in April and end in October, according to the weather conditions.

The sex of each individual was determined according to the presence of a hemipenis in the cloacal opening. The distance between the tip of the snout and the posterior part of the vent of each individual was also measured using a dial caliper with 0.02 mm of precision in order to obtain the snout-vent length (SVL).

The sexual dimorphism index (SDI) was calculated according to the following formula introduced by Lovich and Gibbons (1992):

$$SDI = (\text{mean length of the larger sex} / \text{mean length of the smaller sex}) \pm 1.$$

In this formula, +1 is used if males are larger than females and defined as negative, or -1 is used if females are larger than males and defined as positive arbitrarily.

Individual age was determined by applying the skeletochronological method on the longest finger of the forelimb. This analysis was also used successfully for the age determination of amphibian and reptile species in various studies (e.g., Castanet and Smirina, 1990; Olgun et al., 2005; Guarino et al., 2010; Tomašević et al., 2010). The skeletochronological analysis followed previous procedures (Castanet and Smirina, 1990) with some small changes according to the samples: preserved phalanges in 70% ethanol were dissected and the larger bone of the phalange was washed in tap water for 24 h, decalcified in 5% nitric acid for 2 h, and then washed again in tap water for about 12 h. The cross-sections (18 µm) from the diaphyseal region of the phalange were obtained using a freezing microtome and the sections were stained with Ehrlich's hematoxylin. The sections were placed in glycerin in order to be observed with a light microscope. Bone

sections from each individual were photographed at the same magnification.

Age was determined by counting the LAGs in cross-sections, because each one corresponds to the annual number of period of arrested growth. We assessed the rate of endosteal resorption (how many LAGs are destroyed?) by comparing the diameters of eroded marrow cavities with the diameters of noneroded marrow cavities in sections from the juveniles.

Adult survival rate was calculated according to Robson and Chapman's (1961, in Krebs et al., 1969) formula:

$$Sr = T / \sum N + T - 1,$$

where Sr = average finite survival rate, i.e. a value of 0.75 means that on average 75% of the population survives from 1 year to the next; T = the sum of the coded ages times their frequencies when age is found by setting the youngest included age class to 0, the next age to 1 and so forth =  $0N_x + 1N_{x+1} + 2N_{x+2} + \dots + iN_{x+i}$ ;  $\sum N$  = number of animals from age class x to x + i =  $N_x + N_{x+1} + N_{x+2} + \dots + N_{x+i}$ ; and  $N_x$  = number of individuals in age class x.

Adult life expectancy (ESP), the expected total longevity of lizards that have reached maturity, was calculated according to Seber's (1973) formula:

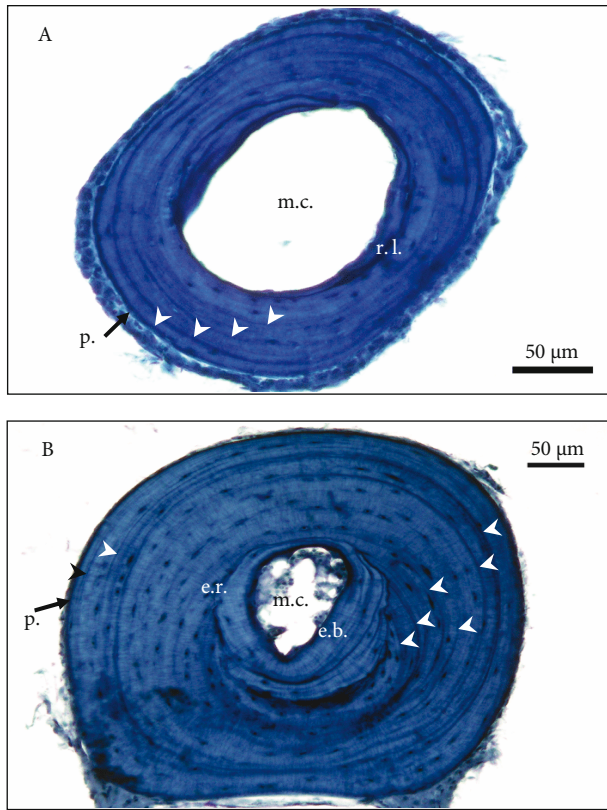
$$ESP = [0.5 + 1 / (1 - Sr)],$$

where Sr = average finite survival rate of adults.

The age and body measurements (SVL) were normally distributed (Kolmogorov-Smirnov D-test, all  $P > 0.05$ ), thus allowing comparisons using parametric tests (t-test). Pearson's correlation coefficient was computed to infer the pattern of relationships between SVL and age. The best regression model was selected according to  $R^2$  values. All tests were processed with STATISTICA 7.0 (StatSoft Inc., USA) and Excel (Microsoft) and were interpreted at  $\alpha = 0.05$ .

## 3. Results

Lines of arrested growth were present in cross-sections of juvenile and adult phalanges. They appeared as thin and approximately concentric layers, more intensely stained than the rest of the cross-section. Endosteal resorption was observed in almost all cross-sections from adults and juveniles (Figures 1A and 1B). By comparing the diameters of eroded marrow cavities of adults with the diameters of noneroded marrow cavities of juveniles, we determined that endosteal resorption was not destroyed in the first LAG in 76% of the individuals, while the first LAG was completely eroded in 24% because of endosteal resorption. Endosteal bone deposition was also observed at certain points (Figures 1A and 1B). It was possible to estimate age for 100% (n = 21) of the available phalanges.



**Figure 1.** Cross-sections (18 µm thick) at the diaphysis level of a phalanx of juvenile (A) and male (B) *Acanthodactylus boskianus*. A) Four-year-old juvenile, 45.14 mm body length. Four LAGs were observed in the periosteal bone. B) Eight-year-old male, 79.86 mm body length. Eight LAGs were observed in the periosteal bone (arrow heads). Endosteal resorption and endosteal bone were present. Periphery (black arrow) was not regarded as a LAG (m.c. = marrow cavity, r.l. = reversal line, e.r. = endosteal resorption, e.b. = endosteal bone).

Descriptive statistics for SVL and age are shown in the Table. SVL of males was significantly larger than females ( $t = 8.654$ ,  $df = 15$ ,  $P = 0.000$ ). SDI was calculated as  $-0.20$ , indicating a male bias. Minimum body length was 74.39 mm for reproductive males and 61.89 mm for females. The juvenile individuals had a mean SVL of  $43.55 \pm 2.02$  mm (ranging from 37.74 to 47.06 mm).

Minimum ages were determined as 6 years for males and 5 years for females. Maximum ages were determined as 9 years for males and 7 years for females (Figure 2). The average ages of the males and females were calculated as  $7.44 \pm 0.34$  and  $6.13 \pm 0.30$  years, respectively (Table). Juveniles were from 3 to 4 years old. The difference in terms of age between the sexes was found statistically significant ( $t = 2.906$ ,  $df = 15$ ,  $P = 0.011$ ). The youngest female was 5 years old, the youngest male was 6 years old, and the oldest juvenile was 4 years old. We thus estimated age at maturity



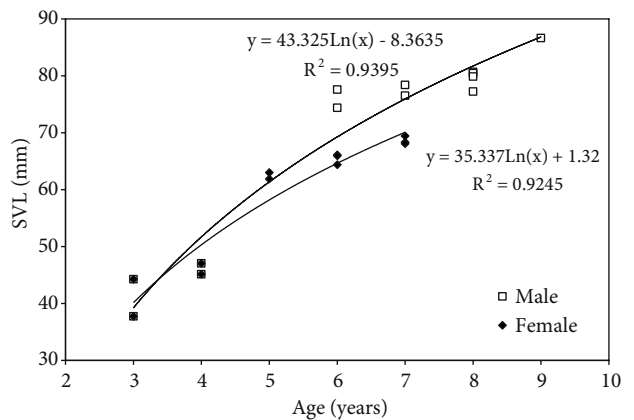
**Figure 2.** Age distribution of male, female, and juvenile *Acanthodactylus boskianus*.

to be 4–5 years. The adult survival rates were estimated to be 0.62 for males and 0.56 for females. ESP was 3.13 for males and 2.77 for females.

A significant positive correlation was found between age and SVL in males ( $r = 0.90$ ,  $P < 0.01$ ) and females ( $r = 0.97$ ,  $P < 0.01$ ). The best regression model was selected as an S-curve model according to  $R^2$  values and the regression equations were  $SVL = 43.325\text{Ln}(\text{age}) - 8.3635$  ( $R^2 = 0.940$ ) for males and  $SVL = 35.337\text{Ln}(\text{age}) + 1.32$  ( $R^2 = 0.925$ ) for females (Figure 3).

**4. Discussion**

In this study, the first demographic data on the age structure of the *A. boskianus* population from southeastern Turkey are provided. The average ages of the males and females were calculated as 7.44 and 6.13 years, respectively, in this study (Table). The difference in age between the sexes was found to be statistically significant. The adult survival rates were estimated to be 0.62 for males and 0.56 for females. The adult survival rates were estimated to be 0.71 and



**Figure 3.** Relationship between SVL and age in male and female *Acanthodactylus boskianus*.

**Table.** Number of sampled individuals (n), SVL (mean ± SE), and range of *Acanthodactylus boskianus* population (min: minimum value, max: maximum value, SE: standard error of the mean).

	SVL (mm)			Age (years)		
	♂	♀	Juvenile	♂	♀	Juvenile
n	9	8	4	9	8	4
Min-max	74.39-86.66	61.89-69.45	37.74-47.06	6-9	5-7	3-4
Mean	79.09	65.90	43.55	7.44	6.13	3.50
Median	78.39	66.04	44.70	8	6	3.50
SE	1.16	0.95	2.02	0.34	0.30	0.29

0.75 for males and females, respectively, in *Dinarolacerta mosorensis* (Tomašević, 2010).

We found the maximum longevity to be 9 years for males and 7 years for females. Nouria (1987) reported a life span of around 4 years in nature for a population of *A. pardalis* from Tunisia. Guarino et al. (2010) found that age ranged from 2 to 4 years in males and from 2 to 3 years in females for a population of *Lacerta agilis* from Italy. However, in *L. agilis* living in Dagestan (Russia), the maximum longevity observed was 6-7 years for males and 5-6 years for females, depending upon altitudes (Roitberg and Smirina, 2006). For the same species living along the western coast of Sweden, maximum longevity was 11 years for males and 12 years for females (Olsson and Shine, 1996). Maximum observed longevity was also reported as 11 years and 8 years for *Eremias argus* females and males, respectively (Kim et al., 2010).

In our study, the mean SVL of males was significantly greater than that of females. Similar to our results, statistically significant differences between the sexes were also reported by Haenel and John-Alder (2002) for *Sceleporus undulates*, Liu et al. (2008) for *Lacerta vivipara*, and Ahmadzadeh et al. (2009) for *Eremias strauchi strauchi*, but in those cases the mean SVL of females was bigger than the males. No sexual size dimorphism in SVL was found between adult males and females in *Dinarolacerta mosorensis* (Tomašević et al., 2010). In contrast to our study, the mean SVL of females was bigger and did not differ significantly between sexes in the studies of *Eremias multiozellata* (Li et al., 2006), *Phymaturus patagonicus* (Piantoni et al., 2006), *Lacerta agilis* (Guarino et al., 2010), and *Eremias argus* (Kim et al., 2010).

In Bosc's fringe-toed lizard, the body size in both sexes significantly increased with age, which appears to be a general phenomenon in lizards that exhibit indeterminate growth (Bauwens, 1999). In this population, SVL of males was significantly greater than females and SDI was calculated as -0.20, indicating a male bias. Fitch (1981) also indicated that males are the larger sex in most lizards. This result is in agreement with the studies of *Agama impalearis* (El Mouden et al., 1999) and *Lacerta agilis boemica* (Roitberg and Smirina, 2006). However, no sexual dimorphism based on SVL was indicated between sexes in the studies of *Dinarolacerta mosorensis* (Tomašević et al., 2010) and *Eremias argus* (Kim et al., 2010). According to some studies, sexual size dimorphism in many adult lizards arises due to sexual differences in the growth rates, and the larger sex grows faster than the smaller sex (John-Alder and Cox, 2007; Tomašević et al., 2010). While some authors have suggested that sexual dimorphism has evolved as a result of competition between the sexes for a limited resource, such as food (Best and Gennaro, 1984), others have proposed that the primary cause of this dimorphism is sexual selection mediated by male-male competition for mates (Vitt and Cooper, 1985; Hews, 1990).

Consequently, we investigated some life history characteristics (i.e. body size, mean age, age at maturity, and longevity) of a breeding population portion of *A. boskianus* from southeastern Turkey. According to our results, the specimens reached sexual maturity at the age of 4 or 5, they had a lifespan of 7 to 9 years, and intersexual differences in body size were male-biased, which was also statistically significant. However, further studies are needed to obtain more comprehensive data about the life history characteristics of this species, especially for its populations in nature.

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