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Demographic life-history traits in two populations of *Cyrtopodion scabrum* (Squamata: Gekkonidae)

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Abstract. In the present study, some demographic life-history parameters (e.g., age structure, age upon attaining sexual maturity, longevity, adult life expectancy, growth, and survival rate) and body size were investigated for the first time in two populations (urban and rural populations) of the rough bent-toed gecko, *Cyrtopodion scabrum*. A total of 69 (26 males, 30 females, and 13 juveniles) *C. scabrum* individuals were studied. Our findings indicated that age upon attaining sexual maturity was 2 and 3 years in both sexes. The maximum longevity was 7 years in females and 6 years in males. We did not find a remarkable difference in body size between females and males. When comparing both populations, neither male and female urban individuals nor both individuals together were significantly different from their counterparts from the rural population with respect to the average age and body size. The body size markedly increased with age in both males and females.

Keywords. Body size; Growth; Life-history; Rough-tailed gecko; Sexual dimorphism.

INTRODUCTION

The rough bent-toed gecko, *Cyrtopodion scabrum* (Heyden, 1827) (Fig. 1A), is a species of the family Gekkonidae. *Cyrtopodion scabrum,* which is one of the 24 species of the genus *Cyrtopodion* Fitzinger, 1843 (Uetz et al., 2021), has a wide distribution, including the African coast of the Red Sea to the Arabian Peninsula, southeastern Turkey, Syria, Iraq, Jordan, Israel, Iran, Azerbaijan, Pakistan, Afghanistan, India, and localities in the Rajasthan Desert (Leviton et al., 1992; Sindaco and Jeremcenko, 2008; Dadashi et al., 2009; İbrahim, 2013; Mohammed et al., 2015; Koç et al., 2020; Uetz et al., 2021). Additionally, this gecko was introduced into Texas and Nevada, USA (Werner et al., 2010; Stocking and Jones, 2017). The IUCN Red List has classified *C. scabrum* as Least Concern (LC) since 2008 (Werner et al., 2010).

Cyrtopodion scabrum has been reported to be a nocturnal, solitary, and territorial gecko (Khan, 2008). This species especially inhabits man-made constructions (Selcer and Bloom, 1984; Fig. 1B), feeding on some invertebrates like insects (Klawinski et al., 1994). The breeding season begins in March and ends in August. Female geckos lay two eggs per clutch (Kluge, 1967), and juveniles appear from mid-July onward (İbrahim, 2013).

In studies conducted without knowing the age of animals, data accumulation is quite low because many important characteristics of a population's life history can be explained by knowing the age and growth rate of each individual in that population (Altunışık and Eksilmez, 2020). Skeletochronology, based on the counting of traces called resting lines (lines of arrested growth, LAG) formed in bone tissues as a result of the metabolic reduction of bone growth in amphibians and reptiles (Gibbons and McCarthy, 1983; Castanet and Baez, 1991; Pal et al., 2009), is a widely used method for investigating population age structure of amphibians and reptiles (e.g., Altunışık, 2017; Odabaş et al., 2019; Yıldırım et al., 2019; Mermer et al., 2020) without euthanizing specimens.

Informative data on the ecology and life-history parameters of *Cyrtopodion scabrum* are limited (İbrahim, 2013), and the demographic life-history traits of other species of the genus *Cyrtopodion* have not been studied to date. Therefore, we examined the demographic life-history parameters two populations of *C. scabrum* from Turkey.

MATERIALS AND METHODS

Study area and sampling

Cyrtopodion scabrum individuals were sampled from two populations (Fig. 1D): an urban population located in the center of Şanlıurfa (Süleymaniye neighborhood, 37°09′52.01″N, 38°46′02.77″E; 552 m above sea level [a.s.l.], Şanlıurfa province, southeastern Turkey), and a rural population in an area of agricultural activities, ca. 53 km far from the city center (Sınırgören village, 37°50′13.28″N, 38°51′24.62″E, 387 m a.s.l., Akçakale district, Şanlıurfa province, southeastern Turkey) in 2011–2017. The presence/absence of preanal pores at the upper side of the cloaca was used to assess individuals' sex (Leviton et al., 1992).

Following capture, snout–vent length (SVL) was measured with the aid of a digital caliper (Mitutoyo Corp., Kawasaki, Japan) with an accuracy of 0.01 mm. Next, the

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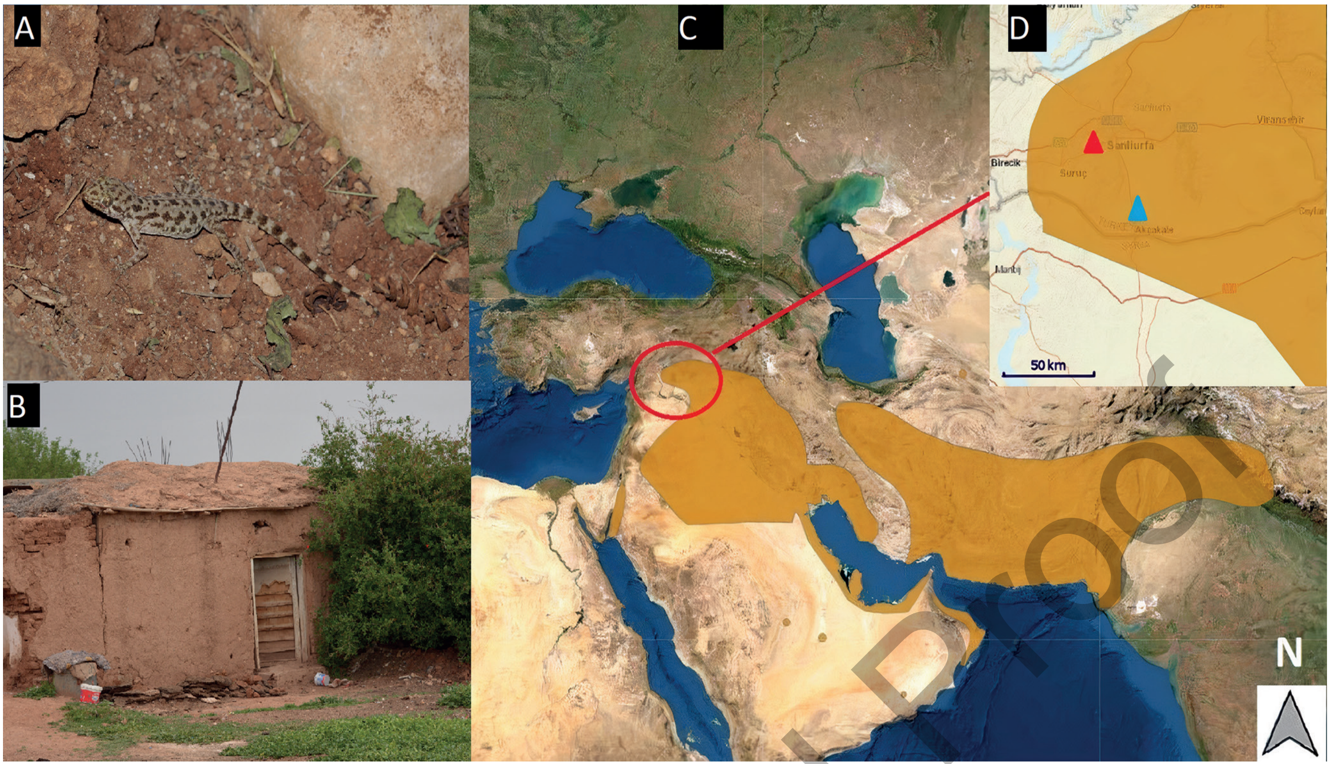

Figure 1. (A) An adult specimen of *Cyrtopodion scabrum* and **(B)** its habitat. **(C)** General distribution map of *C. scabrum* from IUCN (2021), and **(D)** sampling localities in this study in southeastern Turkey (red triangle, Süleymaniye, Province of Şanlıurfa, urban,; blue triangle, Sınırgören, Akçakale, rural).

fourth toe of the left hind limbs, including the first and second phalanges, was clipped and preserved in 70% ethanol solution for subsequent histological analysis, following Smirina (1994). After toe clipping, all individuals were released into their collected habitats.

Age determination

The skeletochronological analysis (Smirina, 1994), which is based on counting the lines of arrested growth (LAG) that appear as a result of reduced bone growth during the previous winter's hibernation, followed the standard procedure adapted from Altunışık et al. (2013). The preserved second phalanx was transferred to distilled water for 1 d and then decalcified in 5% HNO_3 solution for ca. 2 h. Cross-sections of 15 µm thickness were taken by a freezing microtome (Shandon Cryostat), and the collected sections were then stained for 10 minutes with Harris' hematoxylin and eosin. Next, sections with small medullary cavities were selected and observed under an Olympus BX51 light microscope at 10× and 20× magnifications, and the photos of the selected sections were taken with a camera (Pixera) coupled to the microscope. The authors examined all photos and counted and verified the number of LAGs independently.

The distance between two adjoining LAGs is a good indicator of individual growth in a given year (Smirina, 1994). Accordingly, we interpreted an obvious decrease in the interval between periostal growth zone between two subsequent LAGs to indicate the age when sexual maturity was attained (Ryser, 1988; Altunışık and Eksilmez, 2020).

Statistical analyses

Descriptive statistics are reported as the mean ± SD. To assess homogeneity and normality of variances, Levene and Shapiro–Wilks tests were used, respectively. Because the data were normally distributed ($P > 0.05$), parametric tests were used (e.g., Student *t*-test). Pearson's correlation coefficient was used to test the affinity between the life-history parameters. We performed statistical analysis using SPSS v.22 (SPSS, 2013) at a significance level of $P < 0.05$.

Sexual size dimorphism (SSD) was described by the index (sexual dimorphism index, SDI) of Lovich and Gibbons (1992):

$$SDI = \left(\frac{\textit{size of larger sex}}{\textit{size of smaller sex}} \right) \pm 1,$$

whereby SDI < 0 indicates that males are larger than females and SDI > 0 indicates that females are larger than males.

The survival rates were calculated with respect to a formula generated by Robson and Chapman (1961):

$$Sr = \frac{T}{(R + T - 1)}.$$

According to this formula, a constant survival rate is assumed for all the investigated specimens and age classes, where T = N1 + 2N2 + 3N3 + …, R = ΣNi, and Ni = the

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Table 1. Body size (snout–vent length, SVL), longevity, and median age in some representative gekkotan populations.

Species	Population	Mean or range SVL (mm)		Mean or range age (years)		Longevity		References
		Male	Female	Male	Female	Male	Female	
Homonota darwini	Estancia	41	43	10.2	8.7	14	17	Piantoni et al. (2006)
Woodworthia maculata	Motunau Island	26.7–64.5				36		Bannock et al. (1999)
Aeluroscalabotes felinus	Borneo Island	45–98	45–117			4		Kubička et al. (2013)
Gekko gecko (Linnaeus, 1758)	Thailand	170				20		Werner et al. (1993)
Hemidactylus turcicus	Yeşilbağlar	50.69	49.35	5.33	5.20	7	7	Altunışık (2017)
Asaccus barani	Çiçekalan	46.99	46.89	3.85	3.80	6	5	Kalaycı et al. (2015)
Mediodactylus amictopholis (Hoofien, 1967)		38				3		Werner et al. (1993)
Mediodactylus kotschyi	Sultan Mountains	38.5	38.1	4.2	4.5	7	8	Çiçek et al. (2015)
Mediodactylus kotschyi	Jerusalem	44	48	4–7		7		Werner et al. (1993)
Cyrtopodion scabrum	Süleymaniye	41.65	41.76	3.55	3.41	6	6	This study
	Sınırgören	43.57	44.08	3.42	3.83	6	7	

number of specimens in the age group i. Sr refers to the finite annual survival rate.

The adult life expectancy that indicates the expected longevity of animals reaching sexual maturity (ESP) was estimated according to Seber's (1973) formula:

$$ESP = 0.5 + \frac{1}{1 - Sr},$$

where Sr is the survival rate.

To estimate growth patterns, we used Von Bertalanffy's growth model, following previous studies (e.g., Roitberg and Smirina, 2006a; Guarino et al., 2010). A gen-eralized growth formula of Von Bertalanffy (1938) is:

$$SVL_t = SVL_{\max}\left(1 - e^{-k(t - t_0)}\right),$$

where SVL_t is the size at age t, SVL_{max} is a parameter that expresses the asymptotic maximum SVL, k is the growth coefficient which estimates the growth curve and thus the rate at which the SVL_{max} is reached, e is a constant, and t_0 is the hatching age that corresponds to the beginning of the growth period. Since information on the body size at hatching is not available for the populations under study, we assumed a hatching size ($SVLt_0$) of 20 mm, as indicated by İbrahim (2013). Growth rates were computed by using the equation r = k (SVL_{max} − SVL_t) and estimated parameters of SVL_{max} and k using Microsoft Excel (Microsoft Corporation, 2007; Altunışık and Eksilmez, 2020).

RESULTS

A total of 69 individuals (26 males, 30 females, and 13 juveniles) were studied, including 47 (20 males, 17 fe-males, 10 juveniles) from the urban population and 22 (7 males, 12 females, 3 juveniles) from the rural population (Table 1). In Fig. 2, a photograph of the cross-section of the phalanx of a five-year-old female specimen is shown, and a periostal growth zone and thin hematoxylinophilic LAGs that serve as an indicator of the winter season were observed in each cross-section. Endosteal resorption, which results in the partial erosion of the periosteal bone on the edge of the marrow cavity, was observable from the cross-sections in 18% of all specimens.

In the urban population, the age was 2–6 years in males (3.55 ± 0.24 years) and females (3.41 ± 0.29). There is no statistical difference between males and females with respect to the average age in this population (*t*-test, $t = 0.361$, df = 35, $P = 0.720$). The third age group is the most common in the population, with 25.53% (n = 12; Fig. 3). Age at sexual maturity was found to be 2–3 years for both breeding individuals. ESP, which indicates the expected lifespan of individuals having sexual maturity, was calculated as 4.06 years for females and 4.18 years for males. Sr was calculated as 0.72 and 0.71 for males and females, respectively (Table 2). Although females were slightly larger than males, the difference was not significant (*t*-test,

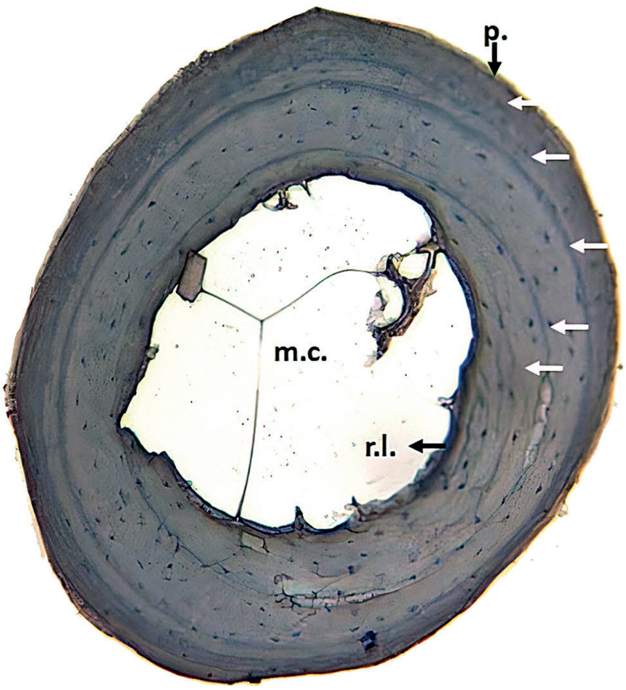

Figure 2. Cross-section (16-µm thick) at the diaphysis level of the phalanx of a female *Cyrtopodion scabrum,* age 5 years. White arrows indicate lines of arrested growth. Abbreviations: m.c., marrow cavity; r.l., resorption line; p., periphery.

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Table 2. Descriptive statistics of growth rate (mm per year), growth coefficient (k), maximum snout–vent length ($SVL_{max,}$ mm), adult life expectancy (ESP, years), survival rate (Sr, years), and sexual dimorphism index (SDI) in urban and rural populations of *Cyrtopodion scabrum* in southeastern Turkey.

Population	Elevation (m)	Sex	*n*	Mean growth rate ± SE	k	SVL_{max}	ESP	Sr	SDI
Urban	552	Male	20	2.83 ± 1.86	0.57	47.24	4.18	0.72	0.003
		Female	17	3.49 ± 2.69	0.76	47.97	4.06	0.71	
Rural	387	Male	7	3.67 ± 0.96	0.14	71.35	3.50	0.67	0.011
		Female	12	3.95 ± 1.81	0.40	56.54	4.59	0.76	

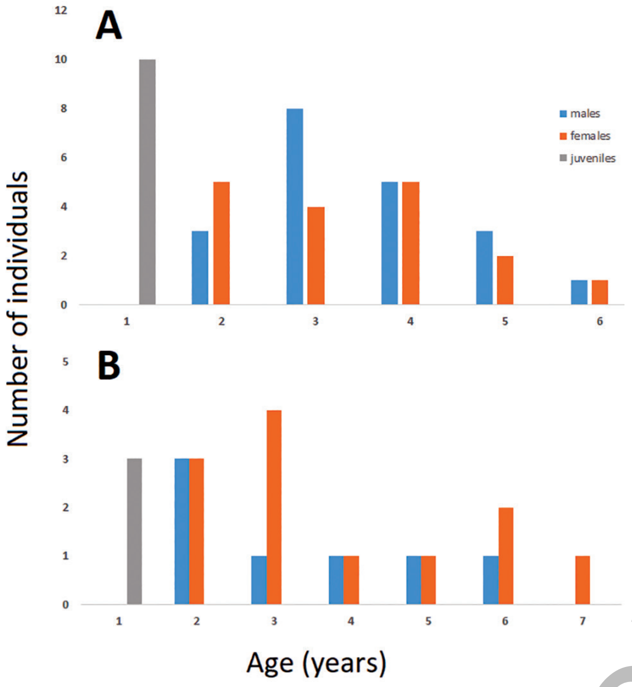

Figure 3. Age distribution of two populations of *Cyrtopodion scabrum* in southeastern Turkey. **(A)** Süleymaniye (urban), **(B)** Sınırgören (rural).

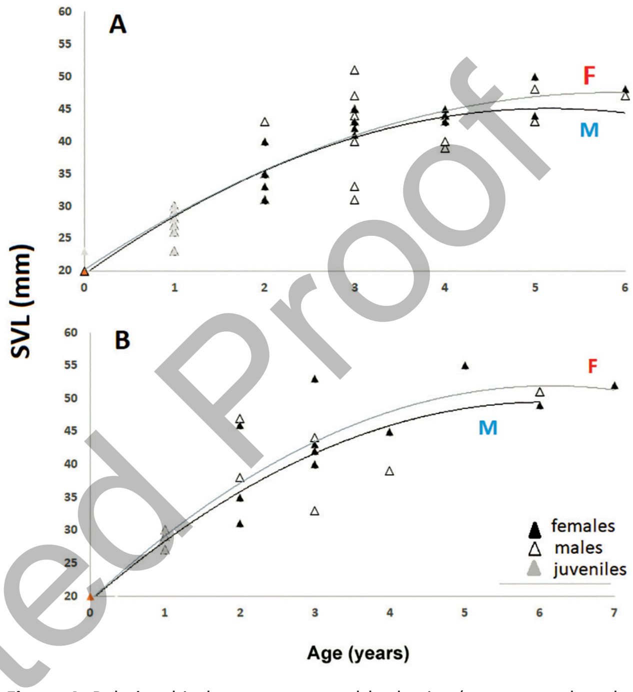

Figure 4. Relationship between age and body size (snout–vent length, SVL). **(A)** Süleymaniye (urban), **(B)** Sınırgören (rural).

$t = -0.666$, df = 35, $P = 0.948$), and SDI was computed as 0.003. Growth rates of the males ($\bar{x}$ = 2.83 mm per year) and females ($\bar{x}$ = 3.49 mm per year) were similar in this population (*t*-test, $t = -0.341$, df = 8, $P = 0.742$).

In the rural population, the age was 2–6 years in males (3.42 ± 0.61) and 2–7 years in females (3.83 ± 0.50; Table 1). The average age did not differ between sexes (*t*-test, $t = -0.499$, df = 17, $P = 0.624$). Unlike the urban population, the group with the highest frequency in the age distribution of this population was that of 2-year-olds (Fig. 3B). Age upon attaining sexual maturity was estimated to be 2–3 years for both males and females. ESP was calculated as 3.50 years for males and 4.59 years for females. Sr was calculated as 0.67 and 0.76 years for males and females, respectively. Although females were slightly larger than males, no significant difference was detected between the sexes (*t*-test, $t = -0.150$, df = 17, $P = 0.882$), and SDI was computed as 0.011. Although the growth rate of females ($\bar{x}$ = 3.95 mm per year) was greater than that of males ($\bar{x}$ = 3.67 mm per year), the difference was not statistically significant (*t*-test, $t = -0.208$, df = 9, $P = 0.840$).

The average age of the urban and rural populations did not differ significantly whether comparing males (M), females (F), or pooling both sexes (M: $t = 0.222$, df = 25, $P = 0.826$; F: $t = -0.764$, df = 27, $P = 0.451$; M + F: $t = -0.522$, df = 54, $P = 0.604$) and SVL (M: $t = -0.0731$, df = 25, $P = 0.472$; F: $t = -1.042$, df = 27, $P = 0.307$, M + F: $t = -1.331$, df = 54, $P = 0.189$).

Body size markedly increased with age in females for both urban and rural populations (urban: r = 0.812, $P < 0.001$; rural: r = 0.882, $P < 0.001$). However, in males, body size positively increased with age only in the rural population (r = 0.879, $P < 0.01$). The growth parameters predicted by means of the Von Bertalanffy equation indicated a fit that reflects the real relationship between age and SVL (Fig. 4). When all data were evaluated regardless of sex, the growth rate of the urban population ($\bar{x}$ = 3.16 mm per year) was still not different from that of the rural population ($\bar{x}$ = 3.82 mm per year; $t = -0.143$, df = 9, $P = 0.89$).

DISCUSSION

Variation in life-history evolution is influenced by two main components: environment (e.g., resources such as food and space; temperature: Roff, 1992; Stearns, 1992) and genetics (evolutionary history: Ballinger, 1979; Dunham and Miles, 1985). The life-history characteristics of geckos vary greatly among both different species and conspecific populations in different ecological conditions (Stark et al., 2020; Table 1). For example, in Kotschy's

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gecko (*Mediodactylus kotschyi* [Steindachner, 1870]), the lifespan was reported to be 8 years for females and 7 years for males of the Turkish population (Çiçek et al., 2015). For Israeli populations of that species, Werner (1993) report-ed a lifespan of 6 years for an adult female in captivity, but 4 years for male adults in captivity. Moreover, it was reported that when the animal attained sexual maturity in its first year in Jerusalem (Israel), the maximum lifespan was 7 years (Werner, 1993). On the other hand, the lifespan of *Woodworthia maculate* (Gray, 1845) individuals is 36 years (Bannock et al., 1999). The lifespan and age at maturity of *Hemidactylus turcicus* (Linnaeus, 1758) were reported as 7 and 2–3 years, respectively (Altunışık, 2017). In *Homonota darwinii* Boulenger, 1885, which is distributed in the southernmost extreme for Gekkonidae, longevity was estimated to be 17 years (Piantoni et al., 2006). The maxi-mum age of the Baran's leaf-toed gecko, *Asaccus barani* Torki et al., 2011, fromTurkey, was reported as 6 years in males and 5 years in females (Kalaycı et al., 2015).

Our findings indicate that this gecko is a relatively short-lived species. In the studied populations of the *Cyr-topodion scabrum,* longevity was found to be 6 years for both females and males of the urban population and 7 years for females and 6 years for males of the rural popu-lation. The similarity in the age structures of these two populations could be related to the similarity between the two habitats in terms of food abundance and local conditions.

Males and females of the *C. scabrum* attained sexual maturity at 2 or 3 years, with no difference between sexes. Contrary to our findings, *Mediodactylus kotschyi* reached sexual maturity at least 1 year earlier than the *C. scabrum* (Werner, 1993; Çiçek et al., 2015). This result shows that the age of sexual maturity can differ among species and local conditions.

In the present study, despite females being slightly larger than males, this difference was not significant. Al-though sexual size differences are less known in reptiles compared to other vertebrate groups (Fitch, 1981), SSD has been documented in several reptile species (Roitberg and Smirina, 2006b; Altunışık et al., 2013; Ramírez-Bautis-ta et al., 2015; Cruz-Elizalde et al., 2020). Specifically, SSD in geckos can be either male- (e.g., Griffing et al., 2018) or female-biased (e.g., Kubička et al., 2013). The potential causes of different SSD patterns among and within species are diverse (John-Alder and Cox, 2007; Roitberg, 2007) and include differentiated evolutionary responses to ecologi-cal conditions in males and females. Sexual dimorphism is usually explained by three different hypotheses; natural selection, sexual selection, and fecundity selection (An-derson, 1994). Natural selection entails a tendency that benefits survival; for example, food competition among individuals can drive sexual dimorphism in a different way (Fairbairn, 1997). However, this hypothesis favors neither females nor males. Further, SSD is formed by a discrep-ancy in growth rates that depend upon food abundancy and temperature conditions (Adolph and Porter, 1993) in several reptile species (Werner, 1993; John-Alder and Cox, 2007; Kolarov et al., 2010; Altunışık, 2017). The similar growth rates between sexes contribute to our explanation of sexual dimorphism in the present study.

A positive correlation between age and SVL has been reported in many studies on reptile species (Piantoni et al., 2006; Altunışık et al., 2013; Çiçek et al., 2015). How-ever, some species do not show this positive correlation (Odabaş et al., 2019) while in others it varies depending on sex (Cabezas-Cartes et al., 2015). In this study, it was found that body size is correlated with age in both sexes.

In conclusion, our preliminary data presented on age structure, longevity, age upon attaining sexual maturity, growth and survival rate, body size, and adult life expectancy of two populations of *Cyrtopodion scabrum* from Turkey have contributed to the ecological knowledge of this gecko species.

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