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RESEARCH ARTICLE

Age structure and growth of the black-ocellated racerunner (*Eremias nigrocellata*, Reptilia, Lacertidae) in the loess desert of Tajikistan

Artem A. Kidov[1], Vladimir O. Erashkin[1], Roman A. Ivolga[1], Tatyana E. Kondratova[1], Andrey A. Ivanov[1]

1 *Russian State Agrarian University – MTAA, 49 Timiryazevskaya St., Moscow, 127550, Russia*

Corresponding author: Artem A. Kidov (kidov_a@mail.ru)

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Abstract

The paper presents the results of age and growth studying of the black-ocellated racerunner (*Eremias nigrocellata*) by skeletochronology. 23 adult individuals (14 females and 9 males) collected on the border of Shaartuz and Nosiri-Khusrav districts in Khatlon region of Tajikistan were studied. All animals, on the section of tubular bones had a birth (hatching) line appearing shortly after the lizards hatching. Females were 1–7 years old (average 3.64 years), and males 1–5 years old (average 3.11 years). In the group of studied animals, the majority of individuals were 2–4 years old (65.2%). The largest number of females were aged three and four years (21.4% each). The male group was dominated by individuals aged four (33.3%), three and two years (22.2% each). Females and males did not differ in size from each other. The body length of the studied females was 55.25–65.61 mm (average 60.28), and males 58.42–63.32 mm (average 60.11). The calculated maximum body length (SVL_{max}) of females (61.33 mm) did not differ from the length of males (61.57 mm). The growth coefficient (k) of females (0.99) was higher than males (0.87). The annual survival score (S) in females (0.74) was similar to males (0.70). The life expectancy of individuals who survived one wintering (ESP) was 4.35 years for females and 3.88 years for males.

Keywords

True lizards, skeletochronology, Tajikistan, Central Asia

Introduction

One of the dominate groups of vertebrate animals in the arid ecosystems is lizards (Lacertilia Owen, 1842) among which representatives of the genus *Eremias* Fitzinger 1834 are most widespread and numerous in the Palearctic (Vashetko 1974; Shcherbak 1974; Bannikov et al. 1977; Shcherbak et al. 1993). They play an important role in the functioning of deserts and semideserts trophic chains (Bannikov et al. 1977; Ananyeva et al. 1997). Despite the continuing interest in the taxonomy and phylogeography of this group (Khan et al. 2021; Tian, Guo 2022; Masroor et al. 2022; Orlova et al. 2023), there is no actual information about the age structure of most species or it is assumed. In general, this statement is true for the entire Eremidini tribe (Kim et al. 2010; Altunişik et al. 2013; Üzüm et al. 2014, 2015; Beşer et al. 2019).

Age determination by counting the lines of arrested growth in the tubular bones of the limbs remains the main method in studying the demography of lizards (Smirina, Ananyeva 2001; Smirina, Roitberg 2012; Klevezal, Smirina 2016). In the vast majority of cases, skeletochronological studies are carried out on massive wide-ranging representatives (Roitberg, Smirina 2006; Comas et al. 2016; Mermer et al. 2020; Gidiş, Başkale 2021; Altunışık et al. 2023; Bülbül et al. 2023), but in recent years, the age of Central Asian species has also been actively studied (Ma et al. 2022; Kidov et al. 2023a, 2023b).

Black-ocellated racerunner (*Eremias nigrocellata* Nikolsky 1896) is known from the south of Central Asia (southwestern Tajikistan, southern Uzbekistan, southeastern Turkmenistan), from northeastern and eastern Iran and northern Afghanistan, where it inhabits loess deserts (adyrs) (Bannikov et al. 1977; Sindaco, Jeremcenko 2008). Despite its relatively widespread distribution, no the age structure special studies of *E. nigrocellata* have been carried out so far.

The aim of current study is to establish the age of sex maturity, the average and maximum life expectancy of the black-ocellated racerunner, as well as to assess the characteristics of its growth.

Materials and methods

Collection of the racerunners was made in the second half of the November 2019 in the border line of Shaartuz (Shakhritus) and Nosiri-Khusrav districts (37°14′ N, 68°04′ W, 450 m a.s.l.) of Khatlon region in the Republic of Tajikistan. In this locality *E. nigrocellata* (Fig. 1) inhabits loess desert together with *Tenuidactylus caspius* (Eichwald 1831), *Phrynocephalus raddei* Boettger 1888, *Trapelus sanguinolentus* (Pallas 1814), *Varanus griseus* (Daudin 1803), *Eremias lineolata* (Nikolsky 1897), *Platyceps karelini* (Brandt 1838) and *Psammophis lineolatus* (Brandt 1838).

Figure 1. An adult female of *Eremias nigrocellata*.

Body length was measured with an accuracy of 0.1 mm in animals fixed in 70% ethanol solution. The sex of the animals was determined by external signs, and in doubtful cases, the gonads were examined at autopsy. Age was assessed with a standard method using skeletochronological analysis (Smirina 1989). Sections of the femoral bones were used as recording structures. In total, 23 lizards were studied, including 14 females and 9 males.

Statistical data processing was performed in Microsoft Excel and STATISTICA 12 programs. The arithmetic mean and its standard deviation (M ± SD) were calculated, as well as the range of feature changes (min–max). Hypotheses about the normality of the sample distribution were tested using the Lilliefors criterion. The statistical significance of differences in body length in different age and sex groups and age composition, depending on gender, was determined using a single-factor analysis of variance ANOVA (*F*) and Student's t-test (t_{st}). To assess the relationship between lizard body length and age, the Pearson linear correlation coefficient (*r*) was calculated.

The growth was described with the von Bertalanfi's equation (von Bertalanffy 1938):

$$SVL_t = SVL_{max} - (SVL_{max} - SVL_0) * e^{-k*(t+t_0)},$$

where SVLt is the average body length at a certain age; SVL_{max} – the maximum body length (may differ from the maximum recorded body length); SVL_0 – the average body length of lizards emerging from the egg; *k* – the growth coefficient; *t* – the number of wintering; t_0 – the duration from the moment the lizards hatching to the date of collection.

Data on the average body length of newly hatched fingerlings caught in nature (27–32 mm, average 29.5 mm) were taken for SVL_0 (Shcherbak 1974). According to literature data (Bannikov et al. 1977; Kidov et al. 2019), black-ocellated racerunners lays eggs from March, and the young hatch from mid-May. Since the foot-and-mouth disease collections we studied were made at the end of November, t_0 was considered equal to 0.55.

The values of SVL_{max} and k and their standard errors were calculated using non-linear estimation.

The annual survival rate of sexually mature racerunners was determined using the Robson and Chapman formula (Robson, Chapman 1961):

$$S = T / (T + n - 1) ,$$

where S is the annual survival rate; $T = n_{i+1} + 2n_{i+2} + 3n_{i+3} + \ldots$; $n = \Sigma n_i$, where n_i – the number of individuals in the age group i (beginning with 1+).

The life expectancy of individuals who survived one hibernation was calculated using the Seber's formula (Seber 1973):

$$ESP = 0.5 + 1 / (1 - S) ,$$

where ESP is life expectancy; S – the survival rate. The ESP may differ from the maximum recorded age of the studied individuals.

Results

Black-ocellated racerunner in loess desert of Tajikistan is characterized by the presence of diapause, what is evidenced by the well-distinguishable lines of arrested growth formed in the tubular bones during the hibernation period. Also, on the studied sections of the femurs there was noticeable a hatching line, which appears in lizards after leaving the egg (Smirina 1974; Smirina, Ananyeva 2001). The hatching line differed from the lines of arrested growth by a weakly chromatophilic layer on the side of the bone marrow cavity and a large number of osteocytes inside it (Fig. 2).

Only adult animals were recorded in *E. nigrocellata* collections, which indicates that all young lizards reached sexual maturity after the first wintering. Females in the studied sample were 1–7 years old (on average 3.64 ± 1.87), and males 1–5 years old (on average 3.11 ± 1.27). Statistically significant differences between the average age of males and females were not observed ($t_{st} = -0.75$; $p = 0.463$).

In general, in the group of studied animals, the majority of individuals were 2–4 years old (65.2%). The largest number of females were aged 3 and 4 years (21.4% each), there were fewer six-year-olds, two-year-olds and one-year-olds (14.3%

each). The male group was dominated by individuals aged 4 (33.3%), 3 and 2 years (22.2% each) (Fig. 3).

Males and females did not differ in size from each other (t_{st} = -0.15; p = 0.880) (Table 1).

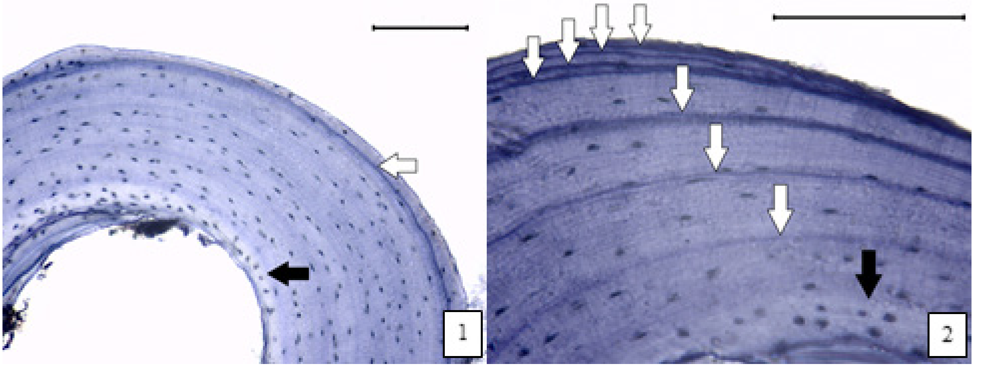

Figure 2. Transverse sections of the femoral bones of *Eremias nigrocellata*: **1** – one-year-old individual (male, SVL = 62.30 mm); **2** – seven-year-old individual (female, SVL = 61.11 mm). The white arrows indicate the lines of arrested growth formed during the hibernation period. The black arrow marks the juvenile line (hatching line). The scale in all figures is 0.1 mm.

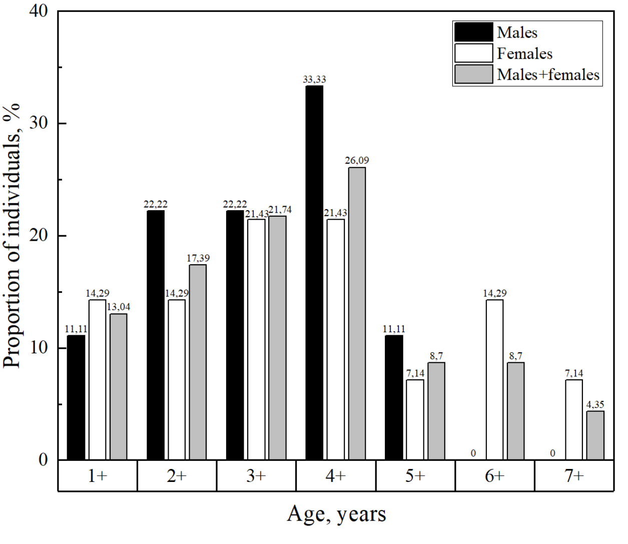

Figure 3. Age structure of *Eremias nigrocellata* (23 individuals, including 9 males and 14 females).

Table 1. Body length of *Eremias nigrocellata* (23 individuals, including 9 males and 14 females) in different age and sex groups

Age, year	Sex	n	Snout-vent length, mm		
			M	SD	min–max
1+	male	1	62.07	–	–
	female	2	59.46	4.02	56.62–62.30
2+	male	2	59.69	1.80	58.42–60.96
	female	2	63.74	3.07	61.57–65.91
3+	male	2	60.49	0.92	59.84–61.14
	female	3	57.41	2.16	55.25–59.57
4+	male	3	59.46	1.27	58.58–60.91
	female	3	59.65	1.27	57.40–61.48
5+	male	1	60.18	–	–
	female	1	63.51	–	–
6+	female	2	60.71	4.52	57.51–63.90
7+	female	1	61.41	–	–

The body length of the studied females was 55.25–65.61 mm (on average 60.28 ± 3.13), and males 58.42–63.32 mm (on average 60.11 ± 1.27), which is significantly less than the maximum value indicated for this species (83.2 mm) (Bannikov et al. 1977). Animals in different age groups did not significantly differ in size ($F_{2,4}$ = 0.365; p = 0.715 for males and $F_{4,7}$ = 1.370; p = 0.335 for females). The body length of the animals was significantly independent of age (r = -0.38; p = 0.316 for males and r = 0.11; p = 0.719 for females).

Based on the size of the newborn juveniles, the relative increase in each age group was calculated (Table 2).

Table 2. An increase in the body length of *Eremias nigrocellata* (23 individuals, including 9 males and 14 females) in different age and sex groups relative to newborn juveniles

Age, year	Sex	n	Relative increase, %		
			M	SD	min–max
1+	male	1	110.41	–	–
	female	2	101.56	0.14	91.93–111.19
2+	male	2	102.34	0.06	98.03–106.64
	female	2	116.07	0.10	108.71–123.42
3+	male	2	105.05	0.03	102.85–107.25
	female	3	94.60	0.07	87.29–101.93
4+	male	3	101.55	0.04	98.58–106.47
	female	3	102.19	0.07	94.58–108.41

Age, year	Sex	n	Relative increase, %		
			M	SD	min–max
5+	male	1	104.00	–	–
	female	1	115.29	–	–
6+	female	2	105.78	0.15	94.95–116.61
7+	female	1	108.20	–	–

The calculated maximum body length (SVL_{max} ± m) of females (61.33 ± 1.96 mm; $p < 0.001$) did not differ from the length of males (61.57 ± 3.04 mm; $p < 0.001$). The growth coefficient (k ± m) of females (0.99 ± 0.33; $p = 0.010$) exceeded that of males (0.87 ± 0.37; $p = 0.048$). The annual survival rate (S) in females (0.74) and males (0.70) was similar, and the life expectancy of individuals who survived one wintering (ESP) was 4.35 years for females and 3.88 years for males.

Discussion

Earlier it was supposed (Bannikov et al. 1977) that *E. nigrocellata* is specified with high rate of growth and sex maturity after the first hibernation. Also, it was mentioned that this species may be ephemeral (Bogdanov 1960). In the current study it is performed that *E. nigrocellata* really belongs to the number of early maturing (at the age of 1), but relatively long-lived (up to 5 years for males and up to 7 years for females) species.

E. nigrocellata is characterized by very rapid growth rates in the first year of life and its almost complete stopping after the first hibernation (Fig. 3). This is probably due to the redirection of resources to generative metabolism to the detriment of somatic growth after sex maturity, which was noted for many other lizard species (Kidov et al. 2023a, 2023b, 2023c). In this regard, adult *E. nigrocellata* of different age groups do not differ in size, and the oldest racerunners are not the largest. The growth of females and males is characterized by similar dynamics, although the calculated growth coefficient of females is higher (Fig. 4).

In comparison with other studied Palearctic species of the Eremedini tribe, black-ocellated racerunner differs in large body size after the first hibernation, but has less maximum size and age than to most representatives (Kim et al. 2010; Altunişik et al. 2013; Üzüm et al. 2014, 2015; Beşer et al. 2019). Thus, the growth coefficient of *E. nigrocellata* exceeds that of the Mongolia racerunner (*E. argus* Peters 1869) from the territory of South Korea by 3.8 (females) – 4.0 (males) times (Kim et al. 2010).

The most similarity with *E. nigrocellata* in age structure and height is demonstrated by the steppe-runner *E. arguta* (Pallas 1773), belonging to the same subgenus *Eremias* (Polynova et al. 2021). Both of these species are also the most prolific racerunners (the maximum number of eggs in a clutch reaches 10 and 12 eggs respectively, with 2–3 clutches per season) (Vashetko 1974; Shcherbak 1974; Bannikov et al. 1977; Shcherbak et al. 1993). Probably, the forced achievement of maximum sizes by the age of one year and, as a result, the further laying of the maximum possible number of eggs with a relatively short lifespan is a characteristic feature of the reproductive strategy of these two closely related racerunners, while in other representatives of the Eremedini tribe lower growth rates to sex maturity and lower fertility are compensated by a longer lifespan.

Thus, *E. nigrocellata* in the loess desert of Tajikistan demonstrates a peculiar life strategy compared to other studied foot-and-mouth diseases of the arid zone: along with rapid growth rates before the first hibernation and early sex maturity.

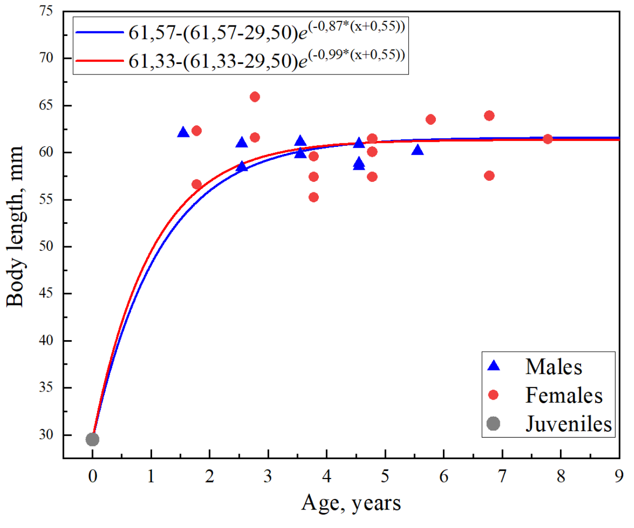

Figure 4. The change in body length of *Eremias nigrocellata* (23 individuals, including 9 males and 14 females) with age.

Ethics approval and consent to participate

All applicable international, national, and/or institutional principles of animal care and use were observed. Compliance of the study with international ethical standards was confirmed by the Bioethics Commission of the Russian State Agrarian University, Moscow Timiryazev Agricultural Academy (protocol no. 1 dated September 6, 2019).

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