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Growth rate of a wild population of the Javelin Sand Boa, *Eryx jaculus* (Linnaeus, 1758): first evidence from a long-term study in Sicily, Italy

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Body size is a pivotal life history trait for snakes, as many aspects of their biology are closely connected to it, such as intraspecific competition, diet, longevity, vulnerability to predation, and reproduction (Boback and Guyer, 2003; Pyron and Burbrink, 2009). In particular, reproduction can be strongly influenced by body size (Shine, 1988, 1994; Madsen, 1983) and by its temporal variation (i.e., growth rate) and, consequently, the age at maturity (Madsen, 1983; Luiselli et al., 1996; Bronikowski and Arnold, 1999). At an intraspecific level, these life history traits can follow divergent patterns between sexes, due to the different factors and pressures to which males and females are exposed (e.g., courtship, sexual competition, fecundity, resource allocation) (Madsen, 1983; Shine, 1993).

The Javelin Sand Boa, *Eryx jaculus* (Linnaeus, 1758), is a sexually dimorphic snake (Tokar, 1991; Eskandarzadeh et al., 2018; Faraone et al., 2019) belonging to the Erycidae family. It is found in North Africa, the Balkans, the Middle East, and Caucasus (Tokar and Obst, 1993; Sindaco et al., 2013). Recently, the presence of this species was confirmed for Italy, in a small area of south-central Sicily (Insacco et al., 2015), where Tokar (1991) had doubtfully reported its presence based on a specimen kept at the Florence Zoology Museum “La Specola” (see also Razzetti and Sindaco, 2006). *Eryx jaculus* is widely considered very hard to detect in the field due to its nocturnal and fossorial habits (Tokar and Obst, 1993; Gherghel et al., 2009), and therefore very little is known about its ecology and natural history. Notably, to date no information is available about its longevity and growth rate in the wild. Following the confirmation of its presence in Italy, some studies were conducted on the morphology and ecology of this elusive species (Faraone et al., 2019, 2021, 2022), including a long-term “capture-marking-recapture” program that is currently underway. Here we report the first data on growth rate in *Eryx jaculus*, based on data from recaptures of wild individuals belonging to the Sicilian population of the species.

Sampling was carried out between April 2018 and November 2023 during active nocturnal surveys performed both by car and on foot, within the currently known local distribution range of the Javelin Sand Boa in south-central Sicily (see Faraone et al., 2017). Three transects were covered almost daily during the presumed active period of the species, from the beginning of March to the end of October (see Faraone et al., 2022). A transect of approximately 12 km, which mainly crosses agricultural lands, was covered by car. Two additional transects of approximately 500 m and 1200 m were covered on foot in an agricultural environment along a river and in a sandy coastal environment, respectively (Fig. 1). Each observed snake was visually identified using the diagnostic characters reported by Di Nicola et al. (2022). Each Javelin Sand Boa was photo-identified based on a dorsal image of the head and cervical area, to allow individual recognition via colour and scale patterns visual comparison (Bauwens et al., 2017). Each photo-marked individual was coded with a numerical code in ascending order.

Two morphometric characters, snout–vent length (SVL) and body weight (BW), were registered for both living and recently deceased snakes that were in good condition. A soft ruler was used to measure SVL to the nearest 1 mm, while BW was measured using a digital scale with 1 g precision. Sex was determined by examining external sexual features (i.e., spurs and tail shape), by cloacal popping in living specimens, and by

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Figure 1. View of (A) coastal transect, (B) riparian transect, (C) car transect, and (D) javelin sand boa, male #198, sampled on 22 July 2020. Photos by Salvatore Russotto (A–C) and Francesco Paolo Faraone (D).

probing recently deceased individuals (Faraone et al., 2019). The morphometric values were expressed as mean ± SD (min–max). We checked the normality and homogeneity of variance of the data using the Shapiro-Wilk test and Levene's test, respectively. To compare the mean values of both variables between sexes, we conducted either parametric (independent t-test for equal variances or Welch's t-test for unequal variances) or non-parametric (Mann-Whitney U test) analyses, with a significance level set at 0.05. Furthermore, with the aim of establishing size classes, the size ranges of SVL and BW of both sexes, including outliers, were divided into quartiles. Growth rate per day was calculated as reported by Wastell and Mackessy (2016), setting the annual *E. jaculus* inactive season from 1st November through 1st March (152 days) which was not considered in the calculation (see Faraone et al., 2022). For the calculation of the growth rate, we selected capture-recapture intervals longer than two months, since for shorter time intervals the body weight can be influenced by temporary factors such as the presence of recently ingested prey.

Between April 2018 and November 2023, we marked and measured 240 individual Javelin Sand Boas (127 males and 113 females). Excluding recaptures, mean SVL was 320.2 ± 90.9 (164–494) mm for males and 382.2 ± 121.2 (170–620) mm for females. Mean BW was 38.6 ± 26.6 (4–100) g for males and 70.6 ± 54.1 (4–204) g for females. Females were significantly larger than males in terms of both SVL ($T = 4.50$; $p < 0.001$) and BW ($T = 5.70$; $p < 0.001$). The quartile thresholds obtained to define the size classes for each sex are: males SVL (mm): $q0 = 164$, $q1 = 246.5$, $q2 = 329$, $q3 = 411.5$, $q4 = 484$; males BW (g): $q0 = 4$, $q1 = 28$, $q2 = 52$, $q3 = 76$, $q4 = 100$; females SVL (mm): $q0 = 170$, $q1 = 282.5$, $q2 = 395$, $q3 = 507.5$, $q4 = 620$; females BW (g): $q0 = 4$, $q1 = 54$, $q2 = 104$, $q3 = 154$, $q4 = 204$.

Five individuals (three males and two females) were recaptured in an interval longer than two months, ranging from approximately one to three years (Table 1). Additionally, a male (#315) was recaptured within a 35-day interval (13 September 2022 – 18 October 2022). All snakes were recaptured only once. Based on the five selected recaptures, the average growth rate was 0.09 mm per day (SVL) and 0.01 g per day (BW) in males, and 0.42 mm per day (SVL) and 0.13 g per day (BW) in females. The shape of the colour pattern elements and the cephalic pholidosis of each recaptured specimen remained unchanged. In two and a half years, female #244 increased its size from the first to the third quartile, both in terms of SVL and BW (Table 1), spanning from a yearling size to the 70.5% of the maximal SVL and 24.1% over the mean of female SVL. During this period, female #224 showed a darkening of the dorsal pattern and head surface (Fig. 2). Conversely, in almost three years, male #146 remained inside the second quartile range in terms of SVL and went from the second to the third quartile in terms of BW (Table 1). Male #31 and female #32 were both captured in the spring of 2018 with similar body sizes, comparable with those of yearlings (Tokar and Obst, 1993; Cattaneo, 1984), and recaptured the following year (Table 1). Male #31 increased in SVL by 15.3% and in BW by 50.0% while female #32 increased in SVL by 50.0% and in BW by 200.0%. The position of each snake at capture and recapture in the context of the relationship between SVL and BW from the whole dataset is shown in Figure 3.

Despite the large sample size, the regularity of the sampling, and the narrowness of some of the study

Table 1. Measurement and growth rate of the recaptured *Eryx jaculus* individuals. SVL: Snout-Vent Length; BW: Body Weight; M: Male; F: Female.

Sex	Individual code	Capture date	Measurement		Growth/day	
			SVL (mm)	BW (g)	SVL (mm)	BW (g)
M	31	30 May 2018	170	4	0.14	0.01
		10 May 2019	196	6		
M	143	25 Jul 2019	237	13	0.08	0.02
		29 Jun 2020	252	16		
M	146	01 Aug 2019	295	27	0.04	0.01
		27 May 2022	317	35		
F	32	06 Jun 2018	170	5	0.36	0.04
		02 Jul 2019	255	15		
F	224	21 Apr 2021	184	6	0.48	0.23
		20 Oct 2023	473	144		

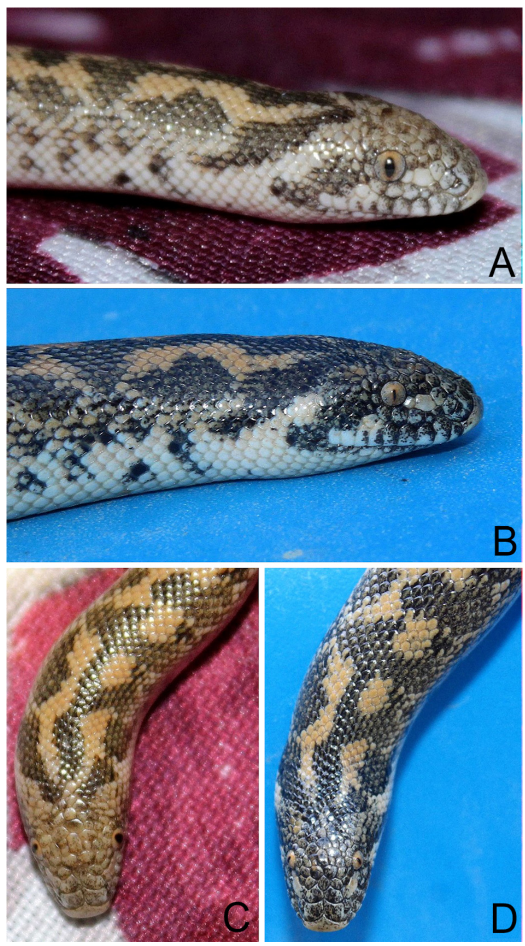

Figure 2. Female #224: (A, C) lateral and dorsal view at 21 April 2021 (B, D) lateral and dorsal view at 20 October 2023. Photos by Salvatore Russotto.

areas, a small number of recaptures were obtained compared to other long-term studies on other snake species (Hasegawa and Mori, 2008; Stevenson et al., 2009; Bayrakci and Ayaz, 2022). Further investigations are needed to confirm this observed pattern, which may be due to a large population size, high mortality, secretive behaviour, and rapid turnover (Semlitsch and Moran, 1984; Baron et al., 2010; Govindarajulu et al., 2011).

Our results provide the first information on the growth rate in a wild population of the genus *Eryx*. Based on measurements taken over time in five individuals, we observed notable differences in the inferred growth rates between sexes. The increase in SVL and BW of recaptured individuals indicates much faster growth in females than in males, also in the smaller size classes, that probably represent new-borns or yearlings (see Tokar and Obst, 1993 and references therein). This pattern reflects what can be observed in other viviparous snake species such as *Vipera berus* and *Coronella austriaca* (Madsen and Shine, 1992; Madsen et al., 1993; Luiselli et al., 1996). Moreover, in sexually dimorphic snakes the maternal body size could be positively linked to litter size and offspring survival (e.g., Shine, 1993; Kissner and Weatherhead, 2005). Furthermore, in this population the increase in size of females is associated with a dietary shift towards larger prey (from lizard eggs to mammals) and, probably, with a 'sit-and-wait' foraging strategy (Faraone et al., 2021), which entails a greater energetic advantage, exactly as happens in other sexually dimorphic species (Shine, 1986; Vignoli et al., 2015).

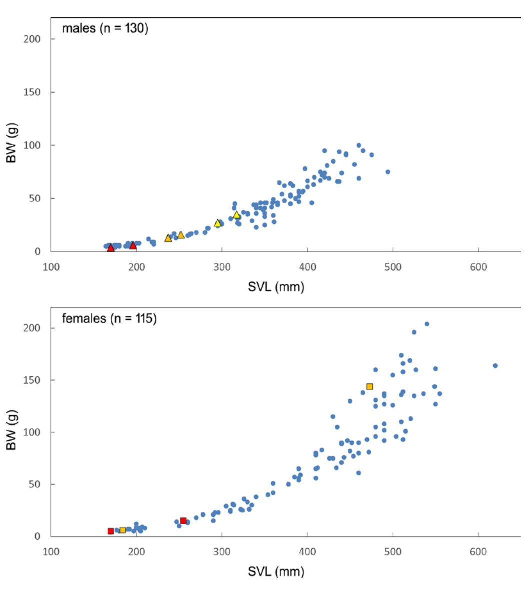

Figure 3. Relationship between snout to vent length (SVL) and body weight (BW) in males (top) and females (down) and position along the BW/SVL distribution of the recaptured specimens. Red triangle = male #31; orange triangle = male #143; yellow triangle = male #146; red square = female #32; orange square = female #224.

Considering the increase in SVL detected of specimen #224 (Table 1; Fig. 2, 3), some considerations on the sexual maturity of this species can be made. In just two and a half years this female went from the size of a yearling to well beyond the average SVL length of females (Fig. 3), i.e., a length greater than previously observed in pregnant females (see Mus'cheliswili in Tokar and Obst, 1993). Unfortunately, to date there are no clear data on the reproduction of the Sicilian *E. jaculus* population (see Faraone et al., 2022), however, our results indicate that sexual maturity could potentially take place in less than three years, an age hypothesised on using indirect elements by Tokar and Obst (1993).

Available data are currently insufficient to precisely trace the growth trajectories of this *Eryx jaculus* population, since this still requires a large sampling effort. However, they represent sound evidence and a reliable starting point to delve deeper into some remaining unknown aspects of Javelin Sand Boa natural history, such as age at sexual maturity, and timing of mating and birth periods (see Faraone et al., 2022).

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