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Morphological variation of the newly confirmed population of the Javelin sand boa, *Eryx jaculus* (Linnaeus, 1758) (Serpentes, Erycidae) in Sicily, Italy

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Abstract. The presence of the Javelin sand boa in Sicily has recently been confirmed. Here the morphological characters and sexual dimorphism of the Sicilian population of *Eryx jaculus* are presented. Seven meristic and six metric characters in 96 specimens from Sicily were examined. The results show that tail length, snout-vent length, the distance between nostrils and the number of ventral and subcaudal scales are different between sexes. The characters found in the Sicilian population of the Javelin sand boa resemble those of the African population (ssp. *jaculus*) rather than the Eurasian population (ssp. *turcicus*), but biomolecular studies are necessary to understand its taxonomic identity.

Keywords. *Eryx jaculus*, Serpentes, morphological variation, folidosis.

The Javelin sand boa *Eryx jaculus* (Linnaeus, 1758), a member of the family Erycidae, is found in the southern Balkans, Middle East and North Africa (Sindaco et al., 2013). Two morphologically defined subspecies are usually recognized for this species. The nominate subspecies is present in North Africa and the ssp. *turcicus* (Olivier, 1801) is found in the Balkans and the Middle East (Tokar and Obst, 1993; Sindaco et al., 2013; Geniez, 2015). According to Tokar and Obst (1993), the Transcaucasian ssp. *familiaris* Eichwald, 1831 could be synonymous with *E. j. turcicus*. Morphological variations of *E. jaculus* have been reported both at a global (Tokar, 1991) and a local scale (Cattaneo, 1984, 2005, 2010; Rhadi et al., 2015; Zarrintab et al., 2017; Eskandarzadeh et al., 2018).

Recently, the presence of *E. jaculus* has been confirmed in a small area of southern Sicily, in Italy (Insacco et al., 2015). Knowledge of the Javelin sand boa in Sicily is currently limited to scant preliminary information on the population's distribution, morphology, habitat and diet (Insacco et al., 2015; Faraone et al., 2017a, b).

In this paper the first comprehensive report of the morphological characters and sexual dimorphism in the Sicilian population of *E. jaculus* is presented.

Sampling was carried out within the currently known geographic range of the Javelin sand boa in South Central Sicily, within an area between Palma di Montechiaro (province of Agrigento) and Butera (province of Caltanissetta) (see Insacco et al., 2015; Faraone et al., 2017b). A total of 55 adult (30 males; 25 females) and 41 juvenile (21 males;

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17 females; 3 undetermined) specimens were examined between August 2014 and September 2018. Among them, 47 specimens were collected during active searches at night, 12 specimens were rescued from abandoned cisterns and the tunnel greenhouse in which they were trapped, four were found dead inside cisterns, one had been killed by domestic cats and 32 specimens were roadkilled.

Sex was determined by examining external sexual features (spurs, tail shape) and, mainly in young snakes, also by cloacal popping. The reliability of external features for sexual determination was also confirmed by cloacal probing in dead specimens. In absence of detailed references, *E. jaculus* with a snout-vent length < 270 mm (see Itescu et al., 2018; Eskandarzadeh et al., 2018) were considered as juveniles.

Seven meristic characters were considered: the number of scales between the eyes (BE), around the eye (RE), posterior to the internasal (PIN), between the eye and the nasal (BEN), the rows of scales between the eye and the supralabial area (BES), the ventrals (VS) and the subcaudals (ScdS). Six metric characters were also recorded: snout-vent length (SVL), tail length (TL), the distance between the eyes (DBE), the distance between the posterior edge of the eye and the tip of the snout (DES), the distance between the nostrils (DBN) as well as body weight (W). For bilateral characters, only the right side was recorded. Biometric characters were measured using a digital caliper accurate to 0.01 mm, except for SVL, which was measured with a mm ruler, and body weight (W), which was measured only on live individuals using a digital scale with 1 g precision.

In order to remove the information related to size, each metric variable was transformed using the formula:

$$Z = Y_i \, (SVL/\, SVL_i\,)^b$$

following Lleonart et al. (2000), where Z is the transformed value of the variable Y, which is the variable affected by size, represented as the snout-vent length (SVL), and b is the slope of the linear regression between logY and logSVL. The data were checked for parametric assumptions using Levene's test and the Shapiro-Wilk test. For each variable, parametric (independent t-test) or non-parametric (Mann-Whitney U test) analysis was conducted, with a level of significance at 0.05. Differences between the sexes were checked by using the Principal Component Analysis (PCA), applied to the correlation matrix. Body weight (W) was not included in PCA, because its value can vary greatly depending on the condition of each specimen (pregnancy, decay, freshly ingested prey, etc.). SVL and the characters with a P value greater than 0.05 were also excluded.

Color morph was classified according to the three types reported by Tokar (1991) and Tokar and Obst (1993). The 'discrete' morph is characterized by a reduced dorsal pattern, with narrow transverse dorsal bars and small scattered spots on the sides. In the 'standard' morph, the dorsal pattern is more extensive than in the 'discrete' morph and the dorsal blotches are spaced by light areas of similar thickness and are not in contact with each other. The 'negative' morph is characterized by a greater development of the dark pattern, while the light parts are reduced to narrow suboval blotches on the back.

The descriptive statistic and a comparison between sexes were made for adults (Table 1). Significant intersexual differences in five characters were found: the num-

Table 1. Descriptive statistics and univariate comparisons between sexes of the Sicilian population of *Eryx jaculus*. The first five characters are in millimetres, the sixth in grams and the others are meristic. Significant differences (P<0.05) are shown in bold. *= transformed values.

	Males			Females			T	U	P
	Mean ± SD	Range	n	Mean ± SD	Range	n			
SVL	342.1 ± 42.4	270.0 - 420.0	26	400.5 ± 86.1	270.0 - 580.0	23	3.2	-	**0.004**
*TL	40.7 ± 6.0	26.9 - 53.9	26	31.4 ± 6.2	20.7 - 45.9	23	**7.9**	-	**0.000**
*DES	7.1 ± 0.7	5.8 - 8.7	26	7.6 ± 1.2	5.9 - 10.5	21	1.8	-	0.086
*DBN	4.0 ± 0.4	3.3 - 4.7	26	4.2 ± 0.6	3.3 - 5.6	21	**2.4**	-	**0.019**
*DBE	7.0 ± 0.7	6.1 - 8.3	26	7.5 ± 1.1	5.5 - 10.0	21	-	165.0	0.194
W	36.9 ± 19.5	18 - 95	14	64.2 ± 49.6	15 – 204	16	-	76.0	0.135
VS	175.9 ± 2.8	170 - 182	26	181.9 ± 3.9	176 - 190	21	6.1	-	**0.000**
ScdS	25.2 ± 1.9	22 - 29	29	19.7 ± 1.4	17 - 22	23	11.8	-	**0.000**
PIN	2.6 ± 0.5	2 - 3	30	2.6 ± 0.5	2 - 3	24	-	357.0	0.958
BE	6.8 ± 0.6	6 - 8	30	6.8 ± 0.4	6 - 7	24	-	358.0	0.972
RE	9.4 ± 0.8	8 - 11	29	9.0 ± 0.7	8 - 10	22	-	238.5	0.126
BEN	3.0 ± 0	3 - 3	30	3.0 ± 0	3 - 3	24	-	-	-
BES	1.0 ± 0.2	1 - 2	30	1.0 ± 0	1 - 1	24	-	348.0	0.835

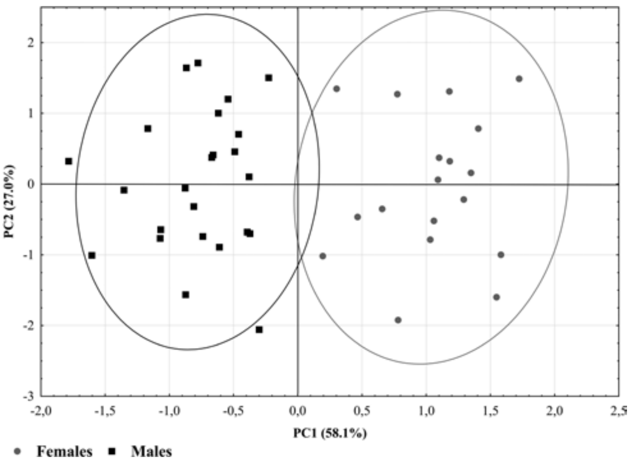

Fig. 1. Scatterplot of scores with the equiprobability ellipses at 95% projected on the first two principal components between sexes of the Sicilian population of *Eryx jaculus*.

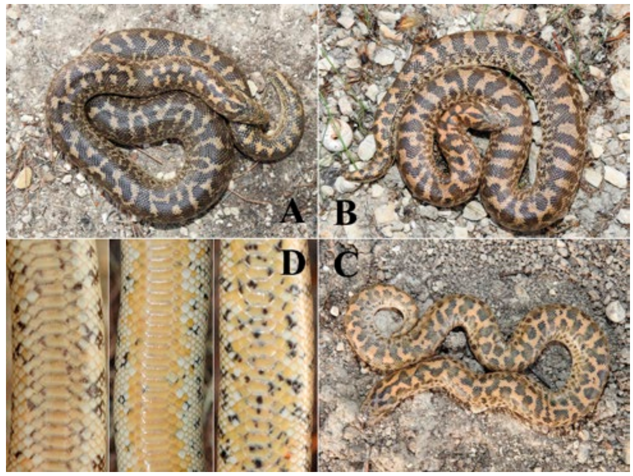

Fig. 2. Examples of color and pattern variation in the Sicilian population of *Eryx jaculus*. (A) Adult, male (B) Adult, female (C) Juvenile, male (D) Ventral variation in three adult females.

ber of ventral scales and snout-vent length have higher values in females and the number of subcaudal scales, the distance between the nostrils and the tail length have higher values in males. The result of the Principal Components Analysis (PCA) shows that 85.1% of the variance is explained by the first two components (PC1 = 58.1%, PC2 = 27.0%). The scatterplot of scores with the equiprobability ellipses at 95% (Lagonegro and Feoli, 1985) projected on the first two principal components (Fig. 1) shows a clear separation between sexes on PC1, with males distributed within the negative values of the axis and the females within the positive values.

The correlation coefficients of the variables (Table 2) show that PC1 has a strong positive correlation with ventral scales (VS) and a negative correlation with subcaudal scales (ScdS) and tail length (TL).

The examined specimens showed different color patterns (Fig. 2). In most of the snakes, the 'standard' morph was identified, however in some individuals the dorsal dark blotches were so extended that they appeared similar to the 'negative' morph, yet these spots were not connected on the sides, so they were assigned to the 'standard' type. Seven snakes could generally be attributed to the 'negative' phenotype, but some small parts of their back looked like the 'standard' morph, similar to what was observed in some *E. jaculus* by Tokar and Obst (1993) and Werner (2016). Young individuals were generally lighter than adults, with a lower contrast in the dark pattern. No difference in dorsal color pattern was noticed between sexes. The dorsal base color is orange, sand or yellowish. The ventral, paraventral and some adjacent scales were usually pale yellowish orange (in only one large female it was a whitish-cream color). Ventral parts were adorned with small blackish spots. The orange color of the belly in a few cases extended to the subcaudal scales, which usually appeared whitish with a few scattered orange scales.

Table 2. Correlation coefficients of the variables for the first two factors used in the Principal Component Analysis (PCA).

Variables	PC 1	PC 2
TL	-0,81	0,52
DBN	-0,40	-0,88
VS	0,81	0,16
ScdS	-0,92	0,07

The results show clear intersexual differences in the Sicilian population of *E. jaculus*. The females usually reach a greater size in terms of snout-vent length and have a greater number of ventral scales than males, and males have a greater number of subcaudal scales, a longer tail and a greater distance between the nostrils. Significant intersexual differences in ventral scales have already been observed in this species (Tokar, 1991) but are not found in some Asian populations (Rhadi et al., 2015; Eskandarzadeh et al., 2018) nor in some other *Eryx* species (Al-Sadoon and Al-Otaibi, 2014; Eskandarzadeh et al., 2013).

The pattern of sexual dimorphism observed in the Sicilian population is also reported in other species of snakes (Marques et al., 2006, Pizzatto et al., 2007, Zanella and Cechin, 2010, Siqueira et al., 2013, Manjarrez et al., 2014). Larger females can provide more space for incubating eggs and embryos and more body reserves to invest in reproduction (Bonnett et al., 1998) and generally, have a larger clutch size (Shine, 1993) and lower mortality in their offspring (Kissner and Weatherhead, 2005). Moreover, in various snake species the number of ventral scales corresponds to the number of dorsal vertebrae, which are generally more numerous in the larger sex (Shine, 2000). On the other hand, smaller males have greater agility during the search for females and a lower metabolic cost (Rivas and Burghardt, 2001). A larger tail and a greater number of subcaudal scales in males are linked to the positioning of the hemipenes within the tail and produce better performance in the courtship phase (King, 1989; Luiselli, 1996; Shine et al., 1999). The males of Sicilian *E. jaculus* also have a relatively larger internasal distance (DBN) than the females. Sexual dimorphism in head shape is a phenomenon known in various snake species and is often linked to a different trophic niche between males and females (Camilleri and Shine, 1990; Vincent et al., 2004). This result deserves to be investigated using appropriate tools (Geometric morphometric analysis) and its relation to the dietary habits of this population, which is currently being studied, should be taken into account.

The three dorsal patterns proposed by Tokar (1991) should be used with caution. It is sometimes difficult to apply these patterns to specimens with mixed phenotypes (see Tokar and Obst, 1993) that may be locally common (Werner, 2016).

The subspecies of *E. jaculus,* proposed by Tokar and Obst (1993), is currently accepted (Sindaco et al., 2013; Werner, 2016). The criteria proposed by Tokar and Obst (1993) are based on an in-depth revision of the morphological variation of *E. jaculus* within its geographical range (Tokar, 1991) and have been confirmed by recent research on a local scale (Eskandarzadeh et al., 2018; Rhadi et al., 2015; Zarrintab et al., 2017).

Comparing the characters reported by Tokar and Obst (1993) with those of the examined specimens in this study, a higher resemblance between the Sicilian population and the North African nominal subspecies, rather than with the Eurasian ssp. *turcicus*, was detected. In the Sicilian population, as well as in *E. j. jaculus*, there are usually seven scales between the eyes (74.7%; n = 95) (usually six in *E. j. turcicus*) and three postinternasal scales (64.6%; n = 96) (usually two in *E. j. turcicus*). Moreover, the Sicilian ventral scales range (170-190) overlaps with both the nominal subspecies (170-198) and ssp. *turcicus* (161-200).

Furthermore, a more frequent presence of the 'standard' phenotype (92.7%; n = 96) is observed with respect to the 'negative' and 'discrete' dorsal patterns, which are very common in European and Asian populations respectively (see also Tokar, 1991). The morphological affinities between the Sicilian and African populations reported here has only a preliminary value and, obviously, a biomolecular approach is necessary in order to properly assess the phylogeographic and taxonomic structure of the Javelin sand boa.

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