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Sexual size dimorphism in the tail length of the Caspian Whip Snakes, *Dolichophis caspius* (Serpentes, Colubridae), in south-western Hungary

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Abstract. Sexual size dimorphism is widespread among snakes and has also been observed in lengths of body appendages such as in tails. Males typically possess longer tails than females and this dimorphism in tail length has generally been attributed to the importance of the tail in mating and reproduction. We used body size measurements, snout-vent length (SVL) and tail length (TL) as well as a body condition index (BCI) as a measure of quality in Caspian Whip Snakes from Hungary, in order to shed light on sexual dimorphism patterns. The SVL of males (1061 ± 133 mm, n = 25) were significantly longer than that of females (887 ± 208 mm, n = 41). However, the proportion of TL to total length was lower in males than in females (0.257 ± 0.018 and 0.274 ± 0.017, respectively). The BCI of females (386 ± 10) was significantly higher than that of males (343 ± 15). Females having proportionally longer tails compared to males seems to be the reverse of the usual trend. Selective pressures on the tails of female snakes are less obvious, as tail length may be linked to more than one function, and hence be simultaneously subjected to more than one type of selective force.

Keywords. Colubridae, Hungary, sexual size dimorphism, tail length.

Sexual size dimorphism (SSD) is a common phenomenon and has been studied in snakes for decades (Klauber, 1943; Shine, 1978; King, 1989; Shine, 1994). Intersexual differences could be attributed to several evolutionary and ecological factors (Shine, 1978; King, 1989; Luiselli, 1996; Sheehy et al., 2016; Sivan et al., 2020). Dimorphism may result from sexual selection (e.g., male-male combat or female choice), may occur when natural selection favours different traits in females and males, additionally, morphological constraints imposed on members of one sex or another may also result in sexual dimorphism (King, 1989; Sivan et al., 2020). Though these mechanisms are not mutually exclusive, morphological traits may be simultaneously subjected to more than one type of selective force.

Tails are important for a variety of functions in snakes, including locomotion (Jayne and Bennett, 1989; Shine and Shetty, 2001; Sheehy et al., 2016), predation (Heatwole and Davison, 1976) and reproduction (King, 1989; Shine et al., 1999; Sivan et al., 2020). Snakes are sexually dimorphic, and differences in relative tail lengths between sexes have been described in various species (King, 1989; Shine et al., 1999). The difference in tail length was initially attributed to structural differences between sexes, as males possess a hemipenis in an elongated pocket at the base of the tail (Klauber, 1943). Later on, tail length has been shown to be a sexual selective trait, at least by some species, where males with relatively longer tails would have an advantage in reproduction (King, 1989; Luiselli, 1996; Shine et al., 1999; Sivan et al., 2020). This could be because longer tails are advantageous when competing with other males during ball mating (Luiselli, 1996; Shine et al., 1999), or because the length of

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the tail is an index signal by choosing mating partners (Sivan et al., 2020).

The Caspian Whip Snake, *Dolichophis caspius*, is a large-sized colubrid with a distribution area ranging from the Carpathian Basin to the west side of the Caspian Sea and covering most of the Balkan Peninsula and several neighbouring Near East countries (Puky et al., 2005). At the north-western edge of its distribution, populations tend to be fragmented and isolated (Tóth, 2002; Puky et al., 2005). A major part of scientific literature concerning the species deals with its geographic distribution and occurrence data. Life-history traits have been studied in the main distributional range in Frontier Asia and Balkans, studies conducted on north-western populations were less prominent.

We analysed body size measurements of Caspian Whip Snakes from Hungary, in order to shed light on sexual dimorphism patterns. At the north-western edge of its distribution, in south-western Hungary, the largest remnant Caspian Whip Snake population is harbouring Szársomlyó Hill, a strictly protected nature reserve (Tóth, 2002; Frank et al., 2012). During the period 1998-2003 road surveys were carried out from April to September. Snakes were captured by hand, weighed to the nearest 1 g by a digital balance and measured for snout-vent length (SVL) and tail length (TL) to the nearest 1 mm by stretching the animal out along a measuring tape. Snakes were probed to determine the sex of the animal. After measuring, snakes were released at the location of capture. Recaptures were not included in the statistical analyses. Two snakes had damaged tails and were omitted from the analyses.

Differences in body measurements (SVL and TL) and BCI between sexes were compared using t-tests. To examine the difference between the two regression estimates of TL on SVL in males and females an ANCOVA was used. Measurements are presented as means ± SE and $P < 0.05$ was accepted as the level of significance. All statistical analyses were performed with the software PAST (Hammer et al., 2001).

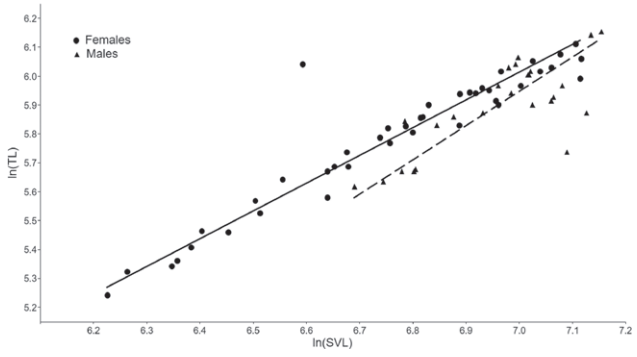

Fig. 1. The effect of snout-vent length (SVL) on tail length (TL) in female (circles, solid line) and male (triangles, dashed line) free-ranging Caspian Whip Snakes, *Dolichophis caspius*.

Average SVL of males (n = 25), 1061 ± 133 mm, was significantly longer than that of females (n = 41), 887 ± 208 mm ($t = -4.091$, $P = 0.0001$). However, average TL in males, 367 ± 54 mm, and females, 333 ± 72 mm was only marginally different ($t = -1.997$, $P = 0.0501$). The regression of TL on SVL (Fig. 1) was calculated in males as $\ln(TL) = 1.1734 \times \ln(SVL) - 2.2721$, ($R^2 = 0.597$, $F = 5.840$, $P = 0.0002$); and in females as $\ln(TL) = 0.9503 \times \ln(SVL) - 0.6407$ ($R^2 = 0.896$, $F = 18.339$, $P = 0.0001$). The proportion of TL to total length was lower in males than in females (0.257 ± 0.018 and 0.274 ± 0.017, respectively). Both size (as SVL) and sex affected TL ($F_{1,64} = 8.129$, $P = 0.0059$).

Size dimorphism between sexes is widespread among snakes; in a list of 129 species of the family Colubridae compiled by Shine (1994), males were the larger sex in 24% of species. Within the group of longer males, SSD ranged between -0.01 and -0.50 (Shine, 1994), the calculated SSD of *D. caspius* (Frank and Dudás, 2018) lies in the middle of this range. All 31 colubrids with longer males than females were oviparous (Shine, 1994), as is *Dolichophis*.

Difference in relative tail length between sexes is very widespread in snakes, and relative tail length might be a biologically relevant trait that affects reproduction (King, 1989; Shine, 1994; Shine et al., 1999; Sivan et al., 2020). Dimorphism in TL is usually male-biased, i.e. male snakes typically possess longer tails than females. This has generally been attributed to the importance of the tail in mating and reproduction (King, 1989; Luiselli, 1996; Shine et al., 1999; Shine and Shatty, 2001; Sivan et al., 2020). As pointed out by King (1989), males might benefit from a longer tail because it may provide space for larger hemipenes ("morphological constraint hypothesis") or because it confers an advantage in mating success ("male mating ability hypothesis"). Additionally, females might increase reproductive output due to an increase in body capacity and a secondary reduction of TL ("female reproductive output hypothesis").

Females having proportionally longer tails compared to males seems to be the reverse of the usual trend (King, 1989; Shine et al., 1999); thus, has been reported substantially less. In a list of 103 colubrid species compiled by King (1989), females had relatively longer tails than males in seven cases (King, 1989). Selective pressures on the tails of female snakes are less obvious (Shine and Shetty, 2001), as tail length may be linked to more than one function, and hence be simultaneously

subjected to more than one type of selective force. Sexual selection of longer tails in females would imply that individuals with longer tails have a higher reproductive output than females with shorter tails. Unfortunately, there are no data to confirm this hypothesis in *D. caspius*, and no finding of selective forces acting on the tails of female snakes has been published in any other species.

Relative tail length may also be influenced by ecological factors when, for example, males and females use different microhabitats, or have different defensive tactics. Arboreal snakes have been shown, in general, to have relatively longer tails than non-climbing species (Sheehy et al. 2015), but this trend was not investigated intraspecifically before. Besides, it is not likely that female *D. caspius* are more arboreal than males. However, this is the first study in which the sexual dimorphism in tail length in Caspian Whip Snakes was investigated and as for now the influence of tail length on female reproductive output or any other life-history trait remains unexplained.

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