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Size matters: Sexual dimorphism in the pelvic spurs of the Bahamian Boa (*Chilabothrus strigilatus strigilatus*)

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Abstract. Determining gender in snakes almost always involves highly intrusive techniques that have the potential to harm or at least significantly stress the animal. Clear morphological differences of conspecific males and females, defined as sexual dimorphism, can provide an alternative strategy to determine the sex of a snake with little harm. The commonly used sexual size dimorphism (SSD), however, is not ubiquitously applicable and has its limitations for some taxa and different life stages. The size differences in pelvic spurs, a little investigated morphological feature in some snakes, could provide a minimally invasive method to determine sex in these snakes. We compared the pelvic spurs of 32 Bahamian Boas of different life stages and body sizes to find out if pelvic spurs provide a robust alternative to identify sex in these snakes. We found that male Bahamian Boas possessed spurs nearly twice as long and notably more curved than females and that the proportion of the spurs to body size differed significantly between the sexes. Furthermore, spur length increased considerably more with an increase in body size in males than in females. We conclude that the investigation of the pelvic spurs in these boas allows for a simple and minimally invasive approach to determine gender and may also represent an alternative strategy for other species.

Key words. Boidae, Morphology, Pelvic spurs, Gender determination, Sexual dimorphism, West Indies

Sexual dimorphism refers to differences in the morphology, physiology or behaviour of conspecific males and females (Mori et al., 2017). Knowledge of such sexual dimorphisms can help researchers to readily determine an individual's gender. In snakes, sex is typically determined by the presence or absence of hemipenes - the male reproductive organs. Examining for the presence of hemipenes on live specimen is usually achieved by probing or physically everting the male's reproductive organs (Fitch, 1960). This process is, however, highly intrusive and has the potential to injure the snake if not conducted with care. Furthermore, the probing of a snake requires access to specialised tools and requires practice and finesse to conduct appropriately. The use of sexual size dimorphism (SSD), which refers to the differences in body weight and size between males and females, allows for a less invasive approach to determine a snake's gender (Cox et al., 2007). While valuable, SSD is not equally pronounced across all taxa and is often not suitable for individuals that are not fully grown. Instead, some studies have suggested that differences in the size and shape of pelvic spurs – small claw-like protrusions found laterally on each side of the cloaca in members of the Boidae, Pythonidae, Loxocemidae and Tropidophiidae, could exhibit sexually dimorphic characteristics and thus be used to determine gender (Stickel and Stickel, 1946; Slip and Shine, 1988; Shine and Slip, 1990; Shine et al., 1998; Díaz et al., 2014; Rodríguez-Cabrera et al., 2016).

Pelvic spurs are vestigial remnants of hind legs that remain internally connected to bones and muscle tissue (Pough et al., 2003). These spurs show surprising mobility and males use them during both copulation (Gillingham and Chambers, 1982; Slip and Shine, 1988) and male-to-male combat (Carpenter et al., 1978). Thus, it is plausible that there is selective pressure towards larger and more curved spurs in male boas. Females have not been found to utilise their spurs and generally possess smaller spurs. To date, this relationship between sex and the size and shape of the pelvic spurs has only been explored in a few species and currently no information on sexual dimorphism in the Bahamian Boa (*Chilabothrus strigilatus*) exists.

Here, we measured pelvic spurs in the Bahamian Boa to determine if pelvic spur length could be used

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as a non-invasive method to distinguish between sexes. The Bahamian Boa is a large arboreal boid snake that inhabits mesic and dry forests as well as various other shrubs, trees and bushes across several islands in the Bahamian archipelago (Henderson and Powell, 2009; Powell and Henderson, 2012). Currently, five subspecies of *C. strigilatus* exist across the Bahamian islands with the subspecies *Chilabothrus strigilatus strigilatus* inhabiting the eastern Great Bahama Bank, excluding Cat Island (Fig. 1; Reynolds and Henderson, 2018).

From August 2019 to May 2020, we opportunistically sampled individuals of *C. s. strigilatus* on the island of Eleuthera, The Bahamas. In total, we found 32 Bahamian Boas, 28 dead-on-the-road and 4 live individuals. For each boa, we measured the pelvic spur length to the nearest 0.5 mm and snout-vent length (SVL) to the nearest mm. In addition, sex of each individual was determined by assessing for the presence of hemipenes via dissection or probing. Pelvic spurs in males were on average almost twice as long as in females, with the mean pelvic spur length in males being 2.6 mm (n = 16; range: 0.5 – 5.0 mm) compared to the 1.5 mm in females (n = 16; range: 0.5 – 3.0 mm). Controlled for body length, the proportion of spur length relative to SVL was 0.3% in males and 0.1% in females. We used a generalised linear model explaining spur length by sex while controlling for size and the interaction of sex and size. We scaled size in the model to help with model conversion and the interpretation of model estimates. The model revealed that males had significantly larger spurs (GLM, estimate = 2.12981, SE = 0.16605, *t-value*

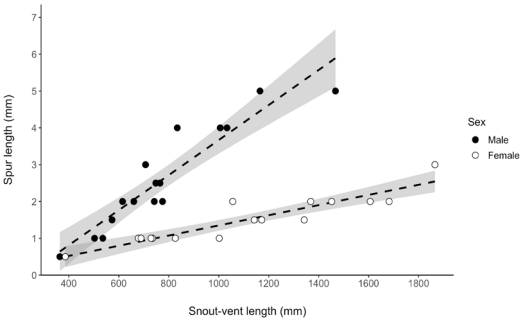

Figure 1. Male and female pelvic spur length in relation to snout-vent length. Dashed lines represent the regression lines and the grey area the 95% confidence intervals.

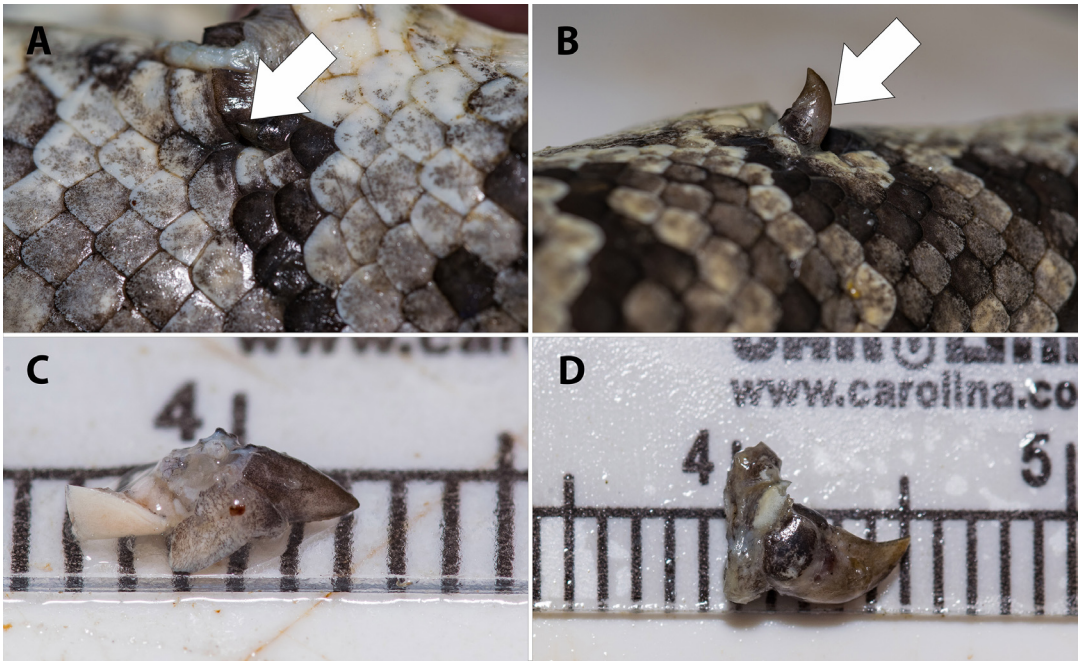

Figure 2. Pelvic spurs of a similarly sized male and female Bahamian Boa (*Chilabothrus strigilatus strigilatus*). Dorsolateral view of the cloacal area of a female (A) and a male (B); white arrows mark the pelvic spurs. Female (C) and male (D) pelvic spurs on a metric ruler for size reference. Photographs © Sebastian Hoefer.

= 12.826, $P < 0.001$***) and that the spur length relative to body size differed significantly between the sexes (GLM, estimate = 1.30894, SE = 0.18087, *t-value* = 7.237, $P < 0.001$***). In juvenile boas (< 700 mm SVL, R.G. Reynolds (pers. comm., March 2020) found that spur length did not differ between the sexes, however adult males possessed spurs at least twice as long compared to females of the same size (Fig. 2). Overall, the slope of the regression in males was notably steeper, showing that spur length in males increased more significantly with an increase in body size compared to females. Moreover, we found distinct differences in the shape of the pelvic spurs between males and females with male pelvic spurs being notably curved whereas female spurs appeared relatively straight (Fig. 3). These clear size and shape differences of the pelvic spurs in male and female *C. s. strigilatus* allow for an easy, safe and fast method to distinguish between sexes without requiring any tools or practice and offer an alternative to probing or everting of hemipenes. Furthermore, this clear sexual dimorphism found in the Bahamian Boa might also be present in other spurred snakes and thus the external examination of pelvic spurs could be used to easily determine sex across various taxa.

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