

## CHARACTERIZATION AND FREQUENCY OF ANOMALOUS SCALES IN THE BOETTGER'S SIPO (*CHIRONIUS FLAVOLINEATUS*)

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**Abstract.**—Studies on anomalous scales in snakes are still very incipient. Little is known about their causes, and they may or may not imply performance disadvantages for individuals bearing them. In addition to being rarely reported, these anomalies are seldom used to assist in snake identification in capture-mark-recapture studies. We describe the types, frequency, and occurrence patterns of anomalous ventral and subcaudal scales, as well as their use alongside marking techniques in a capture-mark-recapture study of a Boettger's Sipo (*Chironius flavolineatus*) population in the Atlantic Forest of northeastern Brazil. We found 11 types of anomalies in 24 individuals, of which we recaptured four of the snakes with no change in the location or type of anomalies present. Some types of anomalies tended to occur in only one sex and were recorded in both adult and newly hatched individuals, suggesting no negative influence on the survival of an individual.

**Key Words.**—anomaly; Brazil; Colubridae; scales; snake

### INTRODUCTION

Anomalous morphological characteristics are commonly reported in reptiles (Velo-Antón et al. 2011; Pola and Kolečka 2017; Idrisova and Khairutdinov 2018) and are derived from different causes, such as temperature (Brown et al. 2017), light exposure (Zhang et al. 2016), humidity (Cedillo-Leal et al. 2017), and congenital alterations (Carvalho et al. 2019). Nevertheless, the heritability of these traits is low in populations due to selective pressures that tend to exclude these individuals (Forsman et al. 1994). Reproductive diversity in reptiles reflects evolutionary strategies for the survival of offspring, but during embryogenesis alterations from genetic factors, environmental factors, or both may produce anomalies in specimens (Brown et al. 2017; Idrisova and Khairutdinov 2018; Dillenburg et al. 2024).

In snakes, anomalies include physiological and morphological changes that may vary between sexes (Forsman et al. 1994; Carvalho et al. 2019; Turner 2021). Some observed integumentary anomalies in snakes include the absence, asymmetry, and deformity of dorsal, ventral and subcaudal scales. These phenotypic changes in scales can occur

due to disturbances during the embryonic period (Lowenborg and Hagman 2016). Anomalous scales in snakes may be related to skeletal malformation, with the presence of duplicated or fused vertebrae and ribs (Löwenborg et al. 2011; Löwenborg and Hagman 2016). Such changes can impair locomotion and, consequently, the survival of individuals (Forsman et al. 1994; Lowenborg and Hagman 2016). Nonetheless, some studies report that these deformities are not extreme enough to be selectively disadvantageous for the individual (King 1959). Few studies, however, address scale anomalies in snake populations and their possible causes (Forsman et al. 1994; Turner 2021), and few species with records of anomalous scales are found in the literature (Table 1). Some studies use anomalous scales on the ventral, dorsal, and head regions as an aid in capture-mark-recapture studies. The location, number, and shape of these anomalous scales allow for individualization and recognition of specimens in possible recaptures (Shine et al. 1988; Lenz et al. 2000; Herczeg et al. 2005). Although anomalous morphological traits in reptiles are commonly reported, specific records of anomalous ventral and subcaudal scales are relatively rare, and these features are seldom used to aid in

**TABLE 1.** Snake species recorded in the literature with the presence of anomalous scales, distributed by country.

Family/Species	Common name	Country	Reference
Colubridae			
<i>Coronella austriaca</i>	Smooth Snake	Russia	Idrisova and Khairutdinov 2018; Idrisova 2019
<i>Chironius flavolineatus</i>	Boettger's Sipo	Brazil	This study
<i>Dolichophis caspius</i>	Balkan-Springnatter	Romania	Ile et al. 2020
<i>Ophedrys aestivus</i>	Northern Rough Greensnake	USA	Plummer 1980
<i>Stegonotus cucullatus</i>	Bird's Head Peninsula Groundsnake	Australia	Brown et al. 2017
Dipsadidae			
<i>Diadophis punctatus</i>	Southern Ringneck Snake	USA	King 1959
Elapidae			
<i>Notechis scutatus</i>	Eastern Tiger Snake	Australia	Schwaneer 1990
<i>Pseudechis porphyriacus</i>	Red-bellied Black Snake	Australia	Shine et al. 1988;
<i>Suta flagellum</i>	Whip Hooded Snake	Australia	Turner 2021
<i>Ophiophagus hannah</i>	King Cobra	Thailand	Jones et al. 2020
Natricidae			
<i>Natrix natrix</i>	Common Grass Snake	USA	King 1959; Löwenborg et al. 2011; Löwenborg and Hagman 2017; Idrisova and Khairutdinov 2018; Idrisova 2019
<i>Natrix tessellata</i>	Dice Snake	Germany; Italy; Switzerland	Lenz et al. 2000; Gautschi et al. 2002
<i>Nerodia fasciata</i>	Southern Water Snake	USA	Osgood 1978
<i>Thamnophis brachystoma</i>	Shorthead Garter Snake	USA	Barton 1956
<i>Thamnophis s. parietalis</i>	Common Garter Snake	Australia	Shine et al. 2005
<i>Liasis fuscus</i>	Brown Water python	Australia	Shine et al. 1988
Viperidae			
<i>Bothrops jararaca</i>	Jararaca	Brazil	Sant'Anna et al. 2013
<i>Crotalus atrox</i>	Western Diamond-Backed Rattlesnake	USA	McCrary et al. 1994
<i>Crotalus durissus</i>	Cascabel Rattlesnake	Brazil	Sant'Anna et al. 2013
<i>Vipera berus</i>	Northern Viper	Russia; Sweden	Merila et al. 1992; Forsman et al. 1994; Idrisova and Khairutdinov 2018; Idrisova 2019
<i>Vipera r. bashkirovi</i>	Steppe Viper	Russia	Idrisova and Khairutdinov 2018; Idrisova 2019

identifying snakes in population ecology studies. We describe the types, frequency, and occurrence patterns of anomalous ventral and subcaudal scales in a population of Boettger's Sipo (*Chironius flavolineatus*) studied over 5 y. We also evaluated the use of these anomalous scales alongside marking techniques in capture-mark-recapture studies.

#### MATERIALS AND METHODS

The *C. flavolineatus* population we studied occurs in fragments of Atlantic Forest in northeastern

Brazil in Rio Tinto municipality (24L; 6°48'10.0"S 35°04'51.0"W), Paraíba State. We sampled the population from 2019 to 2024 (Barbosa et al. 2022) by active search and manually. To identify anomalous scales, we adapted the methodology of Peters (1969): we differentiated ventral and subcaudal scales, and when an anomaly was found, it was recorded through drawings or photographs. We did not evaluate anomalous scales in the head region and we did not perform scale counts other than recording anomalies because our focus was exclusively on anomalous ventral and subcaudal scales.

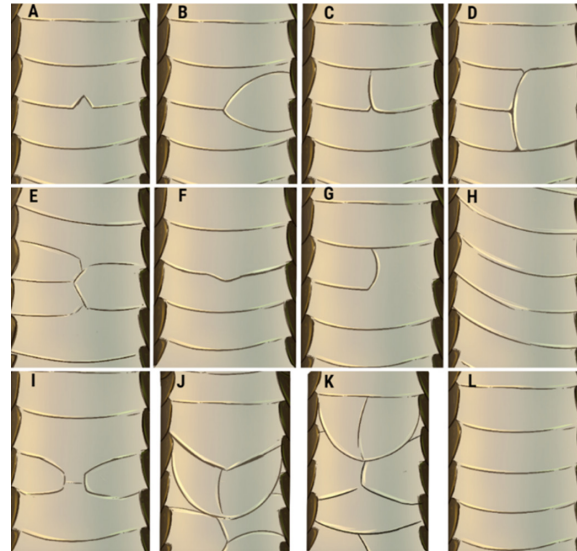
During the mark-recapture study, we released snakes in the same area they were captured after they were marked with fluorescent elastomers without the use of anesthetics. We applied fluorescent elastomer marks in predetermined ventral scale positions, creating a unique combination for each individual (Amaral et al. 2022a). Two gravid females were opportunistically captured during the reproductive season of the species. We determined gravidity by gentle abdominal palpation, which revealed the presence of developing eggs. Female No. 1 laid two eggs and Female No. 2 laid three eggs. We incubated the eggs under controlled laboratory conditions, and three hatchlings were born with anomalous scales: two from Female No. 1 and one from Female No. 2. After hatching, we released all offspring at the same site where the females had originally been captured. For more details on the incubation methodology, see Amaral et al. (2022b).

We performed a Chi-square Test with Yates' Continuity Correction to assess differences between males and females in the occurrence of anomalies. Additionally, we used a Chi-square Test to evaluate differences in the types of anomalies between sexes. To compile Table 1, we conducted a literature survey using the databases Google Scholar, SciELO, ResearchGate, and Web of Science. The search was carried out in both English and Portuguese, employing the keywords anomalies + snake; anomalous scales + snakes and their equivalents in Portuguese (anomalias + serpentes and escamas anômalas + serpentes). We only included studies that explicitly reported the presence of anomalous scales in snakes in the final list.

## RESULTS

Our literature survey identified 22 studies reporting the presence of scale anomalies in snakes, corresponding to five families and 20 species across 10 countries (Table 1). The countries with the largest number of works were Australia, the U.S., and Sweden (six, five, and four works, respectively); the others had one work each, with the exception of Russia with two. Brazil had two species of Viperidae (genus *Bothrops* and *Crotalus*) with reports of anomalous scales.

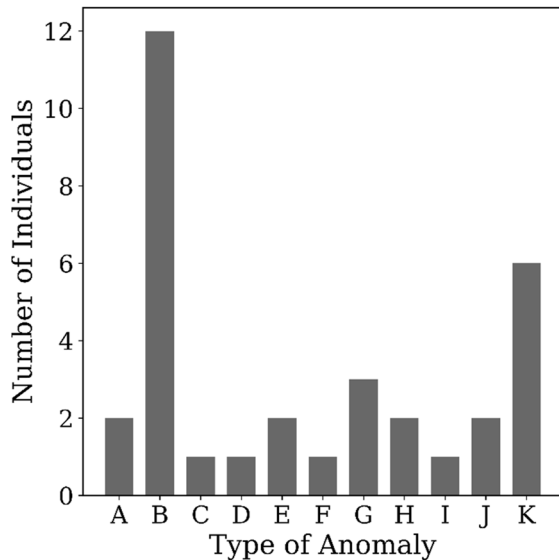
Among the 264 individuals (179 males and 85 females) captured in the population, 25 specimens (9.09%, 16 males and nine females) exhibited anomalies. Most snakes with anomalous scales (70.8%, 17 snakes) presented a single anomaly,



**FIGURE 1.** The 11 types of anomalous scales found in the Boettger's Sipo (*Chironius flavolineatus*) population, Paraíba State, Brazil, 2019–2024, compared to normal scale patterns (L).

whereas five snakes (20.8%) had two distinct anomalies and two individuals (8.3%) exhibited three different anomalies. Additionally, two specimens had the same anomaly in two or three different locations on their bodies. Among the 25 specimens with anomalous scales, three were newly hatched individuals from two clutches incubated in the laboratory.

The frequency of individuals with anomalies in *C. flavolineatus* did not differ significantly between sexes ( $X^2 = 1.39$ ,  $df = 1$ ,  $P = 0.230$ ). In contrast, the types of anomalies in males and females differed ( $X^2 = 18.69$ ,  $df = 10$ ,  $P = 0.044$ ), indicating that the distribution of anomaly types differed between sexes in the studied population. We identified 11 types of anomalies (Fig. 1). Certain anomalies lack bilateral symmetry (B, D, E, and G), whereas others are symmetrical (A, C, F, I, and J). Two of them (A and C) involve a split scale, referred to as split scale anomalies (Turner, 2021) or divided scales (Jones et al. 2020), and appeared alone or alongside other anomalies. Anomalies B and G form a half-scale on one side of the body, whereas anomaly E involves two half-scales on one side, and I forms two half-scales on each side of the body. Anomaly H consists of an irregular-edged scale with a lateral decline, and exclusively co-occurred with anomaly B. Anomaly F form a peak in the middle of the scale, extending a tip to the next scale. Anomaly J forms a peak from both lateral edges, overlapping part of the cloacal scale. We observed anomaly K exclusively in subcaudal scales, which consists of a



**FIGURE 2.** Frequency distribution of anomalous scales in Boettger's Sipo (*Chironius flavolineatus*) individuals in northeastern Brazil, 2019–2024.

single first or second subcaudal scale, in contrast to the characteristically divided subcaudal scales of *C. flavolineatus*.

Some anomalies co-occurred, either on adjacent scales or in different locations on the ventral region. For example, anomaly B co-occurred with anomalies A, G, H, J, and K; anomaly A also co-occurred with anomaly G, anomaly C with anomaly F, and anomaly D with anomaly I. Among these, we never observed anomalies C, D, G, H, and I in isolation but occurred in individuals with multiple types of anomalies.

Anomaly B was the most frequent in the population, appearing in 36.4% of snakes with anomalies (equivalent to 9% of all sampled snakes), followed by anomaly K (18.2%). We recorded four anomalies in two individuals each (A, E, H, and J), and we recorded four (C, D, F, and I) in one individual each (Fig. 2). Of the anomalous scales, 79.2% occurred

within the first or second ventral scales anterior to the cloaca. Exceptions included five snakes with anomalies on the 21<sup>st</sup>, 73<sup>rd</sup>, 149<sup>th</sup>, 166<sup>th</sup>, and 200<sup>th</sup> scales, respectively (counting from the cloaca to the head). We exclusively recorded subcaudal scale anomalies in males on the first or second subcaudal scale.

Anomalies were present in 16 of the 179 males (8.5%) and in nine of the 85 females, representing 10.9% of all females captured in the population. Males exhibited anomalies B, D, E, H, I, J, and K, whereas females showed anomalies A, B, C, F, G, and J. Thus, anomalies A, C, F, and G were recorded only in females, and anomalies D, E, H, I, and K were recorded only in males, with only two types of anomalies found in both sexes (B and J).

The use of anomalous scales proved effective in mark-recapture studies within the *C. flavolineatus* population when combined with additional methodologies, such as elastomer tagging. These anomalies served as additional identifiers that support the efficiency and reliability of elastomer marking. Indeed, the type and position of anomalies allowed for unambiguous identification of the specimen, even with individual growth upon recapture. We obtained 91 recaptures during the study period, of which 87 involved individuals without anomalous scales. We recaptured four individuals with anomalies over intervals ranging from 33 to 251 d (Table 2); we chose to present only the anomalous cases in the table, with all showing growth but retaining their original anomalies without alteration or disappearance.

## DISCUSSION

The frequency of individuals with anomalies in *C. flavolineatus* was low and showed no significant difference between sexes, but the proportions of anomaly types differed by sex. About 80% of

**TABLE 2.** Recapture data of Boettger's Sipo (*Chironius flavolineatus*) with anomalous scales, showing variation in body mass (in grams) and snout-vent length (in millimeters) between initial capture and recaptures. Headings are Anomaly = type of anomaly found in the individual, Mass c = mass on capture day, mass r = mass on recapture day, SVL c = snout-vent length on capture day, SVL r = snout-vent length on recapture day, Rec. No. = number of recaptures, and Days = interval in days between capture and each recapture. We obtained 91 recaptures, of which 87 corresponded to individuals without anomalous scales (not shown here).

Individual	Sex	Anomaly	Mass c	SVL c	Rec. No	Mass r	SVL r	Days
1	M	K	28	514	1	82.5	681	251
2	F	G	67	653	1	62.5	678	33
3	F	B	67.5	660	1	70	689	85
4	M	E	19	487	1	41	569	87
4	M	E	19	487	2	38	587	112

**TABLE 3.** Types of snake scale anomalies found in our study and reported in the literature. Anomaly type is the designation given in the original reference and the letters in our study refer to anomalies shown in Figure 1.

Species	Common name	Anomaly type	This study	Reference
<i>Natrix natrix</i>	Common Grass Snake	1	B	King 1959
Family Dipsadinae		1	B	Peters 1969
		2	C	
		5	E	
		6	I	
<i>Natrix natrix</i>	Common Grass Snake	B1	B	Idrisova and Khairutdinov 2018
		E1	E	
		F1	D	
		H1	K	
<i>Natrix natrix</i>	Common Grass Snake	C	E	Idrisova 2019
<i>Coronella austriaca</i>	Smooth Snake	G	B	
<i>Vipera berus</i>	Northern Viper			
<i>Vipera renardi bashkirovi</i>	Steppe Viper	F	K	
<i>Dolichophis caspius</i>	Balkan-Springnatter	–	K	Ile et al. 2020
		–	E	
<i>Ophiophagus hannah</i>	King Cobra	–	K	Jones et al. 2020
		–	F	
<i>Suta flagellum</i>	Whip Hooded Snake	A	A	Turner 2021
		B	B	
		C	C	
		D	D	
		E	E	
		G	F	
		H	G	
		I	H	

anomalous scales occurred near the cloacal region, a pattern consistent with previous studies that reported anomalies in snakes occurring within the first two pre- or post-cloacal scales (Plummer 1980; Merilä 1992) or within the first third of the body near the cloaca (Turner 2021). Of the 11 types of anomalies found in this study, 10 had been previously documented (Table 3), whereas we do not find records about anomaly J in the literature. Anomaly B was the most prevalent in this population, corroborating the findings in other snake families (Peters 1969; Schwaner 1990; Merilä et al. 1992; Plummer 1980; Turner 2021). In the Colubridae, similar results have been observed in Rough Greensnakes (*Opheodrys aestivus*; Plummer 1980).

We only found anomaly K in males in the *C. flavolineatus* population. Although other studies noted

this anomaly in subcaudal scales, they did not specify the sex of the individuals (Idrisova and Khairutdinov 2018; Idrisova 2019; Ile et al. 2020). Turner (2021) reported subcaudal scale anomalies in both sexes, with a higher frequency in males, suggesting a possible link to sexual dimorphism. Although Jones et al. (2020) recorded the same anomaly in both sexes, the sex ratio in their sample was biased toward males, and the authors do not discuss the influence of sex on the occurrence of the K anomaly in the population. Further studies are needed to investigate whether the presence of anomalies in male tails is due to the presence of hemipenes, given that we recorded this anomaly in both adult and hatchling males near the cloaca. Similarly, anomaly H only occurred on one or two scales, which contrasts with the findings of Turner (2021) in the Whip Hooded Snake (*Suta*

*flagellum*), where anomalous scales occurred in groups of five or more.

The anomalies we observed suggest that they do not necessarily prevent survival to adulthood, as we documented their presence in adult individuals, including some with multiple anomalies. Our data do not allow a definitive assessment of whether these anomalies influence survival rates or other aspects of fitness, however, which would require comparative analyses between individuals with and without anomalies across life stages. Studies on other snake species also indicate that these anomalies appear to have minimal effects on species survival. For instance, the survival of Eastern Tiger Snakes (*Notechis scutatus*) on Australian islands was not affected by the presence of anomalies (Schwaner 1990). Yet, certain types of anomalies may influence ecological aspects of populations, such as reproduction. For example, anomalies were associated with reduced egg production in female Bird's Head Peninsula Groundsnakes (*Stegonotus cucullatus*; Brown et al. 2017).

We incubated two clutches of *C. flavolineatus* eggs under consistent room temperature conditions (approximately 26° C). Some authors correlate egg incubation at high temperatures with a higher incidence of malformation and anomalies in hatchlings (Osgood 1978; Brown et al. 2017; Idrisova and Khairutdinov 2018), but we did not evaluate the effects of incubation at varying temperatures. Of the five hatchlings, three presented anomalies, equivalent to 60% of the hatchlings incubated under controlled laboratory conditions. Neither of the mothers presented anomalous scales. Because paternal identity is unknown, however, genetic inheritance cannot be ruled out. Thus, the observed anomalies may reflect genetic influences and/or environmental conditions acting during embryonic development and incubation. Although this observation is based on a small sample size and may reflect incubation conditions, it suggests that developmental environment could play a role in the occurrence of scale anomalies. Although anomalous scales may occasionally assist in recognizing recaptured individuals, their relatively low frequency in the population (< 10%) limits their utility as a primary tool for capture-mark-recapture. We therefore emphasize their value mainly as morphological descriptors and as an additional aspect of natural variation in *C. flavolineatus*.

**Conclusions.**—Although no significant differences were found in the frequency of anomalies between

sexes, the types of anomalies differed between males and females in the *C. flavolineatus* population. Most snakes with anomalous scales exhibited only one of the 11 identified anomaly types, 10 of which have already been reported in other snake species. Anomaly B was the most frequent in our study, consistent with findings in other snake populations. We recommend that long-term studies be conducted with a focus on possible anomalies in different populations to determine whether certain anomaly types affect locomotion, survival, or reproduction within populations. Our findings highlight the importance of documenting scale anomalies as part of the natural morphological variation in *C. flavolineatus* and provide a baseline for future ecological and developmental studies.

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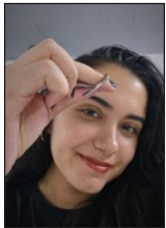
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