

Activity and substrate use of *Bothrops atrox* (Serpentes: Viperidae) in a floodplain forest in the western Brazilian Amazon

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ABSTRACT

Basic information on the natural history of species is essential for studies of evolutionary biology and ecology, in addition to being fundamental for developing conservation strategies. This study aimed to provide information on the activity and substrate use of *Bothrops atrox* in a floodplain forest in the western Brazilian Amazon. With a sampling effort of 816 person-hours of time constrained, nocturnal visual search, 28 observations of 27 individuals were made, of which 16 were adults and 11 were juveniles. The encounter rate of *B. atrox* was one snake every 30 person-hours of searching, and most individuals were recorded during the rainy season. Considering the snake assemblage, *Bothrops atrox* represented 20.8% of the sampled snakes, out of a total of 130 individuals of 21 species, being the second most frequent species. The ecological and morphological differences between the congeneric species *B. atrox* and *B. bilineatus* in this floodplain forest, as well as resource availability, likely influence their local abundance. These factors would also help minimize the probability of interspecific competition between these syntopic species.

Key words: Upper Juruá; Reptilia; Squamata; Pitviper; Common lancehead.

RESUMO

Informações básicas sobre a história natural das espécies são essenciais para estudos de biologia evolutiva e ecologia, além de serem fundamentais para desenvolver estratégias de conservação. Este estudo teve como objetivo fornecer informações sobre a atividade e uso do substrato da serpente *Bothrops atrox* em uma floresta de várzea no oeste da Amazônia brasileira. Com um esforço amostral de 816 horas-pessoa de procura visual limitada por tempo noturna, foram realizadas 28 observações de 27 indivíduos, dos quais 16 eram adultos e 11 juvenis. A taxa de encontro de *B. atrox* foi de uma serpente a cada 30 horas-pessoa de procura, e a maioria dos indivíduos amostrados foi registrada durante a estação chuvosa. *Bothrops atrox* representou 20.8% das serpentes amostradas, de um total de 130 espécimes de 21 espécies, sendo a segunda espécie mais frequente. As diferenças ecológicas e morfológicas entre as espécies congêneras *B. atrox* e *B. bilineatus* nesta floresta de várzea, bem como a disponibilidade de recursos, provavelmente influenciam a abundância local das espécies. Esses fatores também podem ajudar a minimizar a probabilidade de competição interespecífica entre as duas espécies.

Palavras-chaves: Alto Juruá; Reptilia; Squamata; Víbora; Jararaca.

Introduction

Snakes are a diverse group of terrestrial vertebrates of the order Squamata, currently with 4145 described species (Uetz *et al.*, 2024). Basic information on the natural history of species is fundamental for studies on evolutionary biology and ecology (Greene, 1997; Martins and Oliveira, 1998) and with the speed at which forest areas in the Amazon are being destroyed, increasing knowledge about the ecology of species is fundamental for future management and conservation actions of species (Martins and Oliveira, 1998).

The family Viperidae is represented by venomous snakes distributed throughout almost all parts of the world, except Australia, the Arctic region of north-central Canada and Antarctica, and extreme southern Argentina (Campbell and Lamar, 2004). The genus *Bothrops* Wagler, 1824, includes 48 species occurring from Mexico to Argentina (Uetz *et al.*, 2024), including Brazil, where 30 species are recorded (Guedes *et al.*, 2023). These snakes are capable of occupying different types of habitats, from forests to anthropized environments (Martins *et al.*, 2001) and are the main species causing snakebites in Brazil (Souza *et al.*, 2022).

Some studies carried out with snakes of this genus *Bothrops* have focused on the activity and habitat use of species (e.g., Sazima, 1988; Oliveira and Martins, 2001; Nogueira *et al.*, 2003; Wasko and Sasa, 2012; Leão *et al.*, 2014; Fonseca *et al.*, 2021). Information on the natural history of species, for example, diet, habitat use, reproduction and period of activity, is fundamental for the implementation and development of conservation strategies for species that occur in a given area (Sawaya *et al.*, 2008). Furthermore, in the case of vipers, this information can help in understanding the circumstances in which snakebites occur (Sazima, 1988; Oliveira and Martins, 2001).

The pit viper *Bothrops atrox* (Linnaeus, 1758) is widely distributed in the Amazon Basin (Nogueira *et al.*, 2019) and the main cause of snakebites in this region (Monteiro *et al.*, 2020). This predominantly nocturnal snake can be found active also during the day and occurs mainly in forested areas, but can also be found in open areas and anthropized environments (Oliveira and Martins, 2001). It has a moderate size, reaching up to 2.1 m in length (Palmeirim *et al.*, 2021). Adults are usually found on the

forest floor, while juveniles can be found hunting or moving over vegetation (Martins and Oliveira, 1998; Oliveira and Martins, 2001; Turci *et al.*, 2009).

Due to its wide distribution and relative ease of recording in the wild compared to other vipers in the Amazon, *B. atrox* is a good model for studies on habitat use and activity (Fraga *et al.*, 2013). This study aimed to provide information on the activity and substrate use of the snake *Bothrops atrox* in a floodplain forest in the western Brazilian Amazon, comparing it with the sympatric congeneric species *B. bilineatus* in this location.

Material y methods

Study area

The study was carried out in a floodplain forest in the Japiim Pentecoste Area of Relevant Ecological Interest (ARIE; 07° 37' 29.5 S; 72° 47' 22.6 W), in the municipality of Cruzeiro do Sul, state of Acre, western Brazilian Amazon (Fig. 1). The climate of the region is considered tropical, hot and humid, with an average annual temperature of 24°C. The months of May to October correspond to the driest period of the year and the rainy season occurs between the months of November to April, with annual precipitation varying between 1,140 and 2,700 millimeters and the relative humidity of the air always above 60% (Miranda *et al.*, 2015).

The Japiim Pentecoste ARIE is seasonally flooded by the influence of the Moa River, and the vegetation is characterized as Open Alluvial Forest with Palm Trees (Acre, 2010). The forest canopy has trees with an average height of approximately 20 m, with some emergent species reaching a maximum height of approximately 35 m. The canopy is closed, composed mainly of individuals of the genera *Brosimum* (Moraceae), *Enterolobium* (Fabaceae), and *Virola* (Myristicaceae). Most of the large trees have tabular roots (sapopembas), common in species that occur in unstable soils and are influenced by floods during a period of the year (Turci *et al.*, 2009). The understory has a great abundance of Poaceae, *Astrocaryum* (Arecaceae), small trees, and a low abundance of herbs (Heliconiaceae, Marantaceae, and Costaceae). The vegetation is not very abundant for representatives of the family Arecaceae (Palm trees), with some individuals of the species *Euterpe precatoria*, *Iriartella stenocarpa* and *Bactris* sp. being observed (Turci *et al.*, 2009; Miranda *et al.*, 2015).

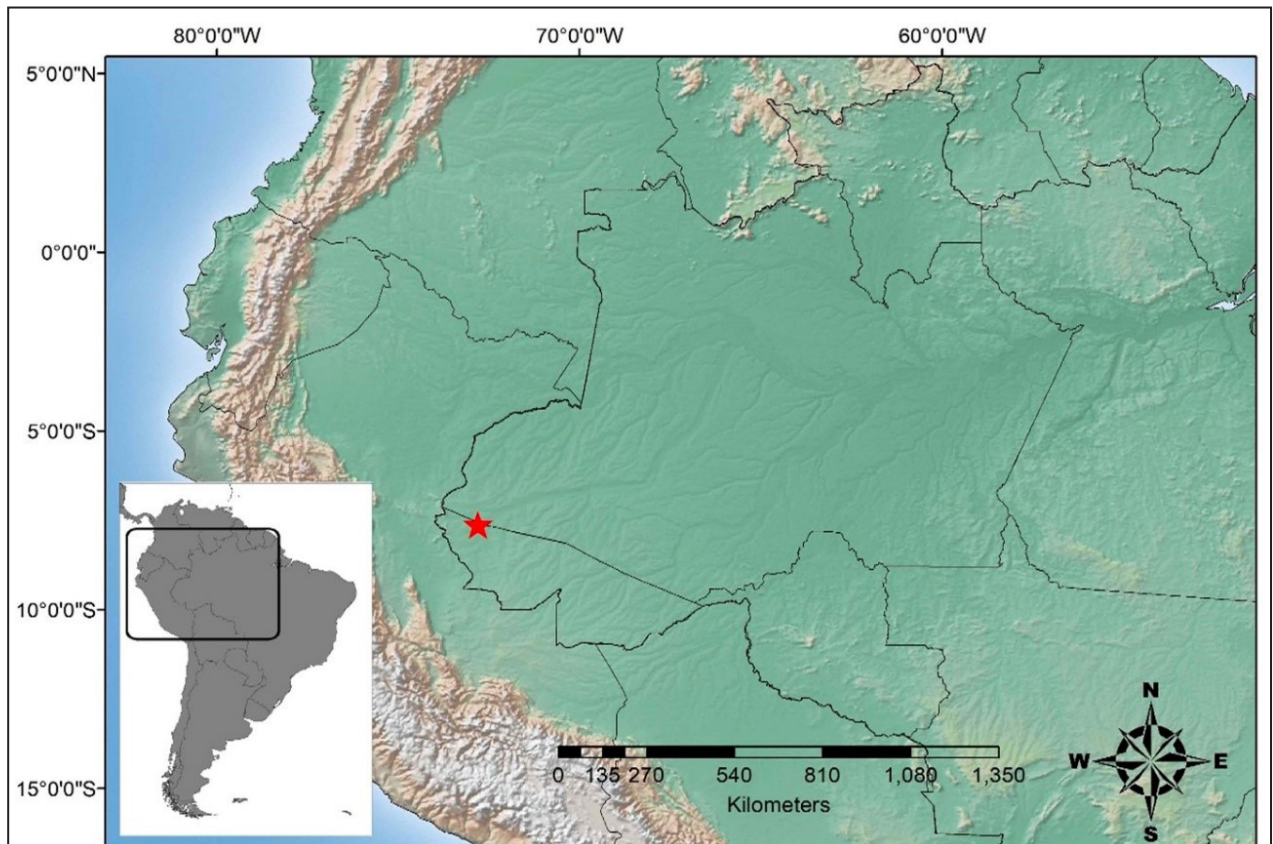


Figure 1. Location of ARIE Japiim Pentecoste in Cruzeiro do Sul, Acre, Brasil.

Data collection

The study was carried out by four researchers on three trails (one 800-m long and two 600-m long) between April 2018 and March 2019. Sampling was carried out at night, from 6:00 p.m. to 10:00 p.m., using the Night-Time Constrained Visual Search (NTCVS) method. This method consists of moving slowly on foot along a transect in search of visibly exposed snakes, and allows the collection of information on the activity and location of the animals in the habitat (Campbell and Christman, 1982).

During the study period, 68 person-hours of NTCVS were carried out per month, totaling 816 person-hours of sampling. On trail I (800 m), sampling was carried out over a three-hour period, with each pair traveling 400 m. Trails II and III were sampled simultaneously by one pair over a four-hour period. On trail I, snakes were not captured, but were only observed for possible records of natural history events, while on trails 2 and 3, all specimens found were collected. Collected specimens (SISBIO collection license 12,178) were deposited in the Herpetological Collection of UFAC Campus Floresta (MC06, MC07, MC28, MC29, MC31, MC32,

MC38). In order to obtain more information about the size of *Bothrops atrox* individuals, some recently dead specimens that were occasionally found and also some that caused snakebites that were received at the Juruá Hospital during the research period were used in this study. The total length of each snake was assessed visually by comparison with a scale (Sazima, 1988), and some individuals were retained and measured with a tape measure (Fitch, 1987). The sex of snakes was verified by inserting a blunt probe into the tail and the collected snakes had their sex identified during the fixation process, with or without the eversion of the hemipenis (Fitch, 1987).

When snakes were found, they were observed for five minutes to record their activity. The following information was recorded: time of encounter, substrate used and activity (hunting, moving or resting), inferred from the posture of each observed snake (see Oliveira and Martins, 2001; Turci *et al.*, 2009).

Data analysis

The data were organized and subjected to descriptive analysis, which included the calculation of simple and absolute frequencies, percentages, and

descriptive measures for the variables studied. The total length (SVL) and tail length (TL) of each snake were measured using a tape measure and they were weighed with portable dynamometers. The snakes were measured and the average total length of the specimens (all individuals, adult males, adult females and juveniles) were calculated using simple arithmetic means. The ages of the specimens were classified following Silva *et al.* (2017) as follows: juvenile males (SVL under 460 mm), juvenile females (SVL under 800 mm), adult males (SVL above 470 mm) and adult females (SVL above 850 mm).

Results

Twenty-eight observations of 27 individuals were made in the floodplain forest, corresponding to 20.8% of the total number of snake specimens recorded (21 species) (See Appendix 1), of which 16 were adults and 11 were juveniles (Fig. 2 and 3). One rediscovered individual was recognized due

to natural markings (heterochromia with one eye having dark spots). The sex could be identified in 20 individuals, of which 11 (55%) were males and nine (45%) were females. Seven individuals were collected from trails 2 and 3 (Table 1). The encounter rate was one individual every 30 person-hours or 0.03 snakes per person-hour, with the majority recorded during the rainy season (20 specimens; 74%) and on trail 1, close to two lakes (Fig. 2).

A total of 21 preserved specimens were obtained in this study: seven during visual surveys (36 cm – 131 cm; \bar{X} = 80.2 cm), 11 that caused snakebites (25.5 cm – 165 cm; \bar{X} = 48.13 cm) and three as occasional encounters (66 cm – 161 cm; \bar{X} = 98.5 cm) (Table 1). Smaller specimens (25.5 cm to 50 cm) were responsible for half of the snakebites (54.5%), while during visual surveys they accounted for 37% of the specimens collected and observed.

The size of the specimens recorded in this study (including all methods!) ranged from 25.5 to 165 cm (\bar{X} = 81.2 cm) (n = 41), with juveniles measuring



Figure 2. Distribution of records of *Bothrops atrox* on the three trails during the study period at ARIE Japiim Pentecoste in Cruzeiro do Sul, Acre, Brazil.

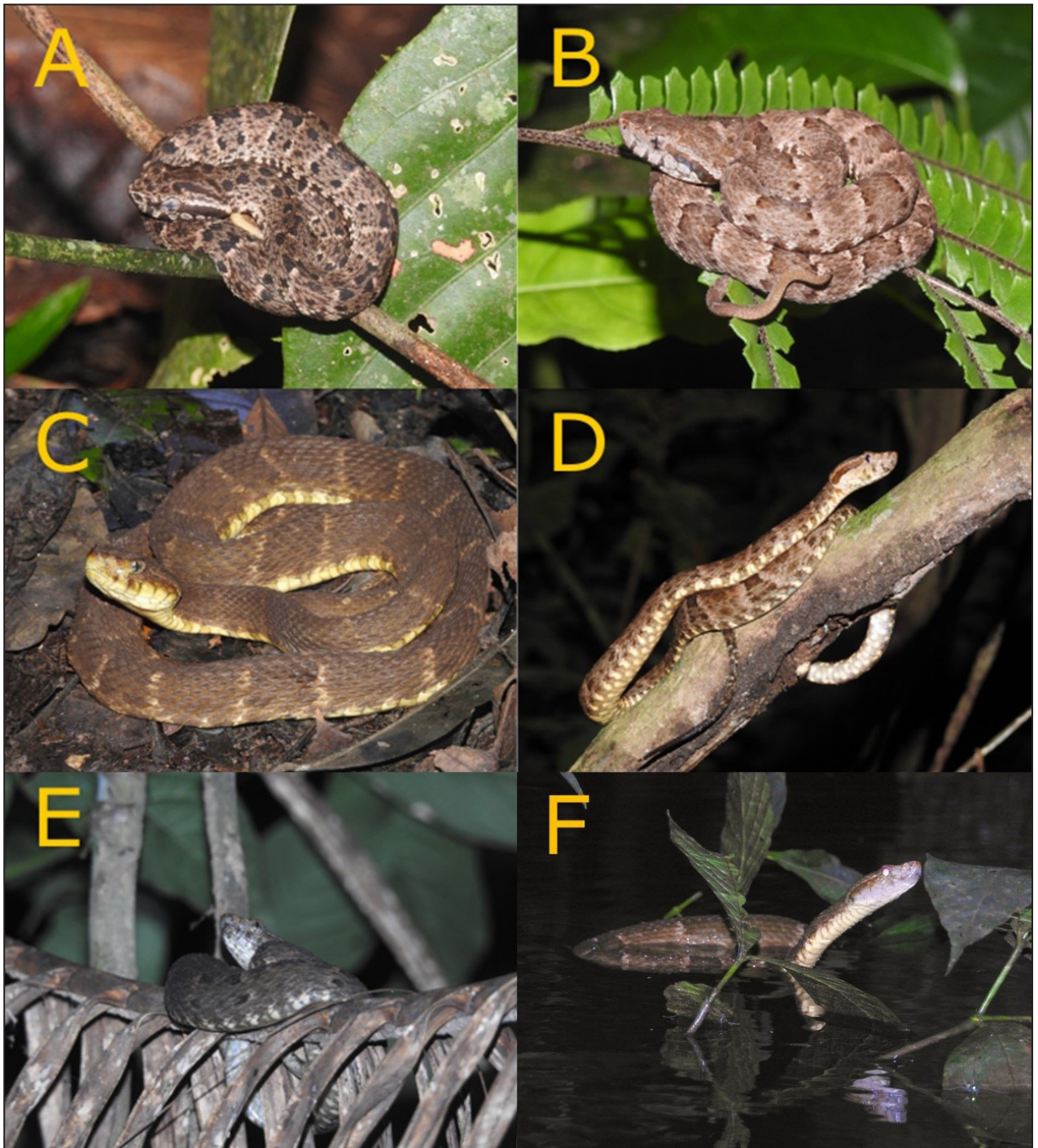


Figure 3. Photographs of some specimens of *Bothrops atrox* in the floodplain forest: A) Juvenile with light-colored tail tip in ambush over vegetation; B) Juvenile with brown tail in ambush over vegetation; C) Adult in ambush on the ground; D) Adult moving over vegetation at a height of 1.5 m; E) Adult in ambush over vegetation at a height of 4.1 m; F) Juvenile moving over water on a flooded trail. Photos A and B: Paulo Bernarde. Photos C – F: Wirven Lima da Fonseca.

from 25.5 to 68.5 cm (\bar{X} = 41.9 cm) (n = 19) and adults measuring from 76 to 165 cm (\bar{X} = 109.1 cm) (n = 22). Adult females ranged from 86 to 165 cm (\bar{X} = 118.7 cm) (n = 9) and adult males from 76 to 130 cm (\bar{X} = 101.9 cm) (n = 13). Analyzing all the specimens collected in this study together with those

obtained in occasional encounters and those causing snakebites (Table 1), we observed that females are larger (up to 165 cm) than males (up to 130 cm).

Of the 11 juveniles recorded, seven (63.6%) had a brown tail tip and four (36.4%) had a white tail tip (Fig. 3A, B). The specimens were observed moving

Table 1. Data on sex, size, weight and source of preserved specimens obtained in this study.

Specimen	Total Length (cm)	Tail Length (cm)	Weight (gr)	Source
Juvenile	25.5	3.9	6	Snakebite
Juvenile	28	4.5	7.5	Snakebite
Juvenile	29	4.8	10	Snakebite
Juvenile	32.5	4.9	9.8	Snakebite
Juvenile	35	4.2	8	Snakebite
Juvenile female	36	4.4	13	Visual survey
Juvenile female	38	5.4	20	Snakebite
Juvenile female	47.6	5.9	18	Visual survey
Juvenile female	57.9	7.9	34	Visual survey
Juvenile female	59	9	40	Snakebite
Juvenile female	66	10.6	66	Occasional encounter
Juvenile female	68.5	9.4	100	Occasional encounter
Adult female	86	10.3	88	Visual survey
Adult male	86.2	13.2	120	Visual survey
Adult male	87.5	13	150	Snakebite
Adult female	89	13.3	155	Snakebite
Adult male	100	14.2	155	Snakebite
Adult female	127	18.5	350	Visual survey
Adult female	131	18.8	450	Visual survey
Adult female	161	22	1,100	Occasional encounter
Adult female	165	21.5	1,100	Snakebite

on 16 occasions and in ambush on 12 occasions. Two male individuals were observed in combat behavior (recorded previously by Fonseca *et al.*, 2022).

Moving snakes ($n = 12$ individuals) were observed on the ground and two, a juvenile (40 cm) and an adult male (100 cm), were recorded moving over vegetation at heights of 0.3 m and 1.5 m, respectively.

Of the juvenile individuals observed in ambush hunting ($n = 5$), three were recorded on vegetation at heights of 30 to 60 cm and two on the ground. Most ($n = 5$) of the adult specimens observed in ambush were on the ground. Two adult individuals (76 cm and 100 cm) were observed in ambush on vegetation at heights of 2.5 m and 4.1 m, respectively (Fig. 3).

Discussion

The snake *Bothrops atrox* is usually the most abundant species in studies on snake communities conducted in the Amazon (e.g., Martins and Oliveira, 1998; Frota *et al.*, 2005; Bernarde and Abe, 2006; Rodrigues *et al.*, 2016; Masseli *et al.*, 2019; Turci

and Bernarde, 2022), and may correspond to up to 17.5% (Santos-Costa *et al.*, 2015) and 35.9% of the recorded species (Fraga *et al.*, 2011). In this study, *B. atrox* represented 20.8% of the snakes sampled in this assemblage out of a total of 130 specimens of 21 species, ranking second in terms of frequency of encounters, behind *B. bilineatus* with 27% of records (Fonseca *et al.*, 2021). However, only nocturnal searches were carried out, which may have influenced fewer records of other species, especially diurnal ones, that is, the frequency of *B. atrox* may be lower when the entire snake assemblage is considered.

The encounter rate of *Bothrops atrox* was 0.03 snakes per person-hour (one snake every 30 hours of searching), which is higher than that obtained by Martins and Oliveira (1998) in the Ducke Reserve (Manaus, AM), a dryland forest, which was 0.02 snakes per person-hour (one snake every 50 hours of searching) during the time-constrained visual search. One of the advantages of this sampling method is that it allows the encounter rate of a species in a location to be compared with another location or with other sympatric species. The en-

counter rate of the congeneric *B. bilineatus* in this location was 0.04 snakes per person-hour (one snake every 23 hours of searching), higher than that of *B. atrox* (Fonseca *et al.*, 2021). In the study by Turci *et al.* (2009) carried out in this location previously (2008 to 2009), *B. atrox* was also less recorded (0.016 snakes per hour or one every 60 hours of searching) than *B. bilineatus* (0.03 snakes per hour or one every 30 hours of searching). In a study on the snake community also carried out in the Alto Juruá region in a terra firme forest in the Riozinho da Liberdade Extractive Reserve by Turci *et al.* (2021), the encounter rate was 0.005 specimens of *B. atrox* per hour (one snake every 180 hours of searching) and no individuals of *B. bilineatus* were found, indicating a possible difference in the faunal composition of snakes between these ecosystems (terra firme and várzea).

The majority (74%) of *Bothrops atrox* individuals were recorded during the rainy season, as in the previous study by Turci *et al.* (2009), a period in which snakes are most frequently found in studies on snake assemblages in the Amazon (e.g., Martins and Oliveira, 1998; Bernarde and Abe, 2006; Turci and Bernarde, 2022). However, the other viper that occurs in sympatry in this floodplain forest, *B. bilineatus*, is more frequently found during the dry season (75.9% of encounters) (Fonseca *et al.*, 2021). The higher encounter rate of *B. atrox* in the rainy season also coincides with the greatest abundance of small mammals during this period (68.8%; Silva *et al.*, 2020) and also with the greatest reproductive activity of anuran amphibians in this location (Miranda *et al.*, 2015). However, the abundance of amphibians in the rainy season recorded on the trails is only slightly higher (52.8%) than during the dry season (47.2%) (Silva *et al.*, 2020), which could explain the greater occurrence of *B. bilineatus* during the less rainy months in this location (Fonseca *et al.*, 2021).

The greater abundance and activity of *B. atrox* during the rainy season also contributes to the increase in the number of snakebites with this species during this period in this region (Mota-da-Silva *et al.*, 2019). Newborns of *B. atrox* also occur in the rainy season (Oliveira and Martins, 2001), which also contributes to the greater encounter of individuals of this species during this period and perhaps explains the occurrence of half of the cases of snakebites with juveniles (smaller than 50 cm in length) (Mota-da-Silva *et al.*, 2019). Despite the greater abundance of newborns, as reported by Fraga *et*

al. (2013) and Silva *et al.* (2020), smaller specimens of *B. atrox* are more difficult for researchers to detect during searches in the forests due to their small size. This would be another reason that could explain the greater number of snakebites involving juveniles (Mota-da-Silva *et al.*, 2019).

Bothrops atrox has a maximum recorded length of 2.1 m (Palmeirim *et al.*, 2021), presenting notable sexual dimorphism due to the larger size of females (e.g., Silva *et al.*, 2017; Silva *et al.*, 2019), which was also found in this study with the largest specimens recorded corresponding to females measuring 1.61 m and 1.65 m. Specimens of *B. bilineatus* are relatively smaller (up to 75.8 cm), also presenting sexual dimorphism with males smaller (\bar{X} = 58.7 cm) than females (\bar{X} = 59.2 cm) (Fonseca *et al.*, 2019).

Most juveniles of *B. atrox* had a light-colored tail tip, which is used as a tail luring strategy during ambush (Martins and Oliveira, 1998). As observed for *B. jararaca* in southeastern Brazil (Sazima, 1991), some juveniles did not have a tail tip with a coloration distinct from the rest of the body. No juveniles were observed performing tail luring, a hunting tactic that is frequently observed in juveniles and adults of *B. bilineatus* in this location (Fonseca *et al.*, 2019). In some species of *Bothrops* (e.g., *B. atrox*, *B. jararaca*) juveniles lose the light tail tip and caudal luring behavior when they become adults and begin to prey on rodents rather than amphibians (e.g., Sazima, 1992; Oliveira and Martins, 2001). Adult individuals of *B. bilineatus* continue to have the tip of the tail with a coloration distinct from the rest of the body and to perform caudal luring, and continue to prey on amphibians besides small mammals (Fonseca *et al.*, 2019; 2021).

Three of the five juveniles of *B. atrox* were observed in ambush on vegetation, as reported in other studies (e.g., Oliveira and Martins, 2001; Turci *et al.*, 2009). The greater use of vegetation during hunting by juveniles than adults is probably associated with the availability of small anurans in this microhabitat (e.g., *Pristimantis fenestratus*) (Oliveira and Martins, 2001) and also as a way to avoid predators that move across the forest floor (Martins, 1993), such as tarantulas that can prey on them (Almeida *et al.*, 2019). Adult individuals are observed less frequently than juveniles on vegetation (Oliveira and Martins, 2001). Oliveira and Martins (2001) observed two inactive individuals at heights of 1.2 and 1.3 m and Melo-Sampaio and Maciel (2018) observed an individual in hunting activity

at a height of 4 m on a palm leaf. The two adult individuals observed in hunting activity in this study on vegetation (2.5 and 4.1 m tall) were during the rainy season when the forest was flooded, and this situation may influence this snake to occur in the arboreal substrate during this period when a large part of the forest is flooded.

In this study, we observed that time constrained visual searches allow the comparison of the relative abundance of sympatric snake species and also allows comparison with other studies that used this method in other locations. Two species of vipers were the most abundant snakes in this floodplain forest, with *B. atrox* being the second most frequent, unlike other studies in the Amazon where it was the most abundant. The two species of *Bothrops* in this study differ in seasonal frequency – with *B. atrox* being more frequent during the rainy season and *B. bilineatus* in the dry season –, in size (individuals of *B. atrox* are larger) and in substrate use (adult individuals of *B. atrox* occur mainly on the ground and offspring also in low vegetation, while *B. bilineatus* is arboreal). These differences between these two congeneric sympatric species, among other factors (e.g., availability of resources), should influence their abundance in this location, potentially minimizing the probability of interspecific competition.

Acknowledgments

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Appendix I

Snakes registered in the Japiim Pentecoste Area of Relevant Ecological Interest (ARIE; 07° 37' 29.5 S; 72° 47' 22.6 W), in the municipality of Cruzeiro do Sul, state of Acre, western Brazilian Amazon between April 2018 and March 2019.

TÁXON	AMOUNT
BOIDAE	
<i>Corallus hortulana</i> (Linnaeus, 1758)	1
<i>Epicrates cenchria</i> (Linnaeus, 1758)	2
COLUBRIDAE	
<i>Chironius carinatus</i> (Wied, 1820)	11
<i>Leptophis nigromarginatus</i> (Günther, 1866)	1
<i>Phrynonax polylepis</i> (Peters, 1867)	1

DIPSADIDAE

<i>Atractus</i> sp.	2
<i>Dipsas catesbyi</i> (Sentzen, 1796)	1
<i>Dipsas indica indica</i> Laurenti, 1768	1
<i>Erythrolamprus reginae</i> (Linnaeus, 1758)	1
<i>Erythrolamprus typhlus typhlus</i> (Linnaeus, 1758)	1
<i>Imantodes cenchoa</i> (Linnaeus, 1758)	14
<i>Leptodeira annulata annulata</i> (Linnaeus, 1758)	1
<i>Helicops angulatus</i> (Linnaeus, 1758)	6
<i>Helicops hagmanni</i> Roux, 1910	1
<i>Oxyrhopus melanogenys melanogenys</i> (Tschudi, 1845)	5
<i>Oxyrhopus petolarius digitalis</i> (Reuss, 1834)	1
<i>Xenoxylbelis argenteus</i> (Daudin, 1803)	11

ELAPIDAE

<i>Micrurus lemniscatus</i> (Linnaeus, 1758)	2
<i>Micrurus surinamensis</i> (Cuvier, 1817)	5

VIPERIDAE

<i>Bothrops atrox</i> (Linnaeus, 1758)	27
<i>Bothrops bilineatus smaragdinus</i> Hoge, 1966	35
TOTAL	130

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