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BIOLOGY AND CONSERVATION STATUS OF PIRAJA'S LANCEHEAD SNAKE *BOTHROPS PIRAJAI* AMARAL, 1923 (SERPENTES: VIPERIDAE), BRAZIL

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Abstract: The venomous snake *Bothrops pirajai* (Amaral, 1923) is endemic to Brazil. Despite being described almost a century ago, very little is known about this species, which has never been studied in situ. Here, we present new data on the biology and natural history of *B. pirajai* based on a review of existing museum specimens and a field study (1504 man hours) carried out throughout the species range. The distribution of *B. pirajai* was found to be restricted to the eastern Atlantic forest of the state of Bahia, Brazil, between Todosos Santos Bay, Itabuna and Ilhéus (12°50'S–14°50'S, 88–835 m). We recommend the species be uplisted to Endangered in the International Union for the Conservation of Nature's global Red List of Threatened Species as its estimated extent of occurrence is under 5000km². The effective conservation of *B. pirajai* will rely on addressing two key issues: improving our knowledge of the species and successfully mitigating habitat loss and fragmentation.

Keywords: Assessment, conservation status, Reptilia, South America, Squamata, threatened species, viper.



Bothrops pirajai
Piraja's Lancehead Snake



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INTRODUCTION

The Atlantic Forest was one of the largest rainforests in the American continent, originally covering about 150 million ha in highly heterogeneous environmental conditions (Ribeiro et al. 2009). This diversity, combined with a large altitudinal range, has favoured high diversity and endemism, with the Atlantic Forest biome hosting up to 8% of the world's fauna and flora (da Silva & Casteleti 2003), including 6000 endemic plants and around 500 endemic vertebrate species (Câmara 2005). Despite this extraordinary biodiversity and high levels of endemism, the Atlantic Forest has experienced relentless deforestation since the arrival of Portuguese colonists in the 16th century. This has profoundly affected the biome, with only 11–16 % of its original extent in Brazil still in existence (Ribeiro et al. 2009). The combination of high threat, diversity and endemism has earned the Atlantic Forest the designation of a key global biodiversity hotspot (Myers et al. 2000).

Despite the large amount of biological data generated in the Atlantic Forest region in recent decades (da Silva & Casteleti 2003), the lack of standardized inventory protocols and sampling efforts with poor spatial distribution has resulted in important data gaps both at the landscape and species level (Ribeiro et al. 2009). The lack of information, together with the high number of species still to be described (Pimm et al. 2010), have made it difficult to carry out conservation assessments in this region (Ribeiro et al. 2009). This has been reflected in the conservation status assessments of many species in the Atlantic Forest, which have historically been based on very limited, anecdotal or outdated information, even in vertebrates groups such as reptiles (Rodrigues 2005).

An example of the existing limitations is the venomous Piraja's Lancehead Snake *Bothrops pirajai* (Viperidae), a globally threatened species (Argôlo 2000), historically found only in the Atlantic forest of Brazil (Campbell & Lamar 2004). After the species' discovery in 1923, no further peer-reviewed studies have been published on this species, except for research on the biochemical characterization of its venom (Teixeira et al. 2011; Menaldo et al. 2012). The only available information on the Piraja's Lancehead Snake comes from the grey literature, where a handful of anecdotal accounts on its diet, reproduction in captivity and distribution have been published (Argôlo 1989; Argôlo et al. 1999; Argôlo 2004; Argôlo 2007). However, even this minuscule literature has been plagued by errors (Argôlo 2008) with, for example, erroneous reports of the species' presence

for Vitória da Conquista, in Bahia and the Brazilian states of Mina Gerais and Espírito Santo (Freitas 1999; Campbell & Lamar 2004). These inaccuracies resulted from the misidentification of specimens of the related Jararacussu *Bothrops jararacussu* (Argôlo 2008; Freitas 2008).

The present study aims to compile and review the information available on *B. pirajai* and present the results of the first systematic surveys conducted specifically to improve our knowledge of this species. With this information, we hope to start addressing the two key conservation priorities identified for *B. pirajai* in the Brazilian Red Book of Reptiles; to improve our knowledge of the species distribution and increase our knowledge of the species behaviour and natural history (Argôlo 2008).

METHODS

Museum specimens

We examined specimens from the following herpetological collections: Coleção Herpetológica "Alphonse Richard Hoge" (IBSP) of the Instituto Butantan, São Paulo, the Coleção Zoológica Gregório Bondar (CZGB) of the Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC) and Museu de Zoologia da Universidade Estadual de Santa Cruz (MZUESC), both in Ilhéus, Bahia, Brazil. For each specimen, total length, sex and locality were recorded. Where GPS coordinates were unavailable, other information on the collection locality (e.g., name of estates or other geographical features) was used to infer an approximate location. Information on coloration and patterning of preserved individuals was also collected as far as preservation conditions allowed.

Surveys

We conducted ecological field surveys along the southeastern region of Bahia, Brazil, between January 2005 and February 2008. The surveys first focused on the localities where specimens of *B. pirajai* were previously found (Amaral 1923; Freitas 1999; Argôlo 2004) and then moved on to neighbouring regions. Surveys were conducted with one to five observers (most commonly two), throughout the day, but were concentrated between 18:00 and 22:00 hr as this is the time when species of the viper family tend to be most active (Campbell & Lamar 2004). Search effort was calculated as man/hours by summing the total number of survey hours by all surveyors involved. When

encountering individuals of *B. pirajai*, we registered time, date, GPS coordinates, type of habitat in which it was found, straight-line distance to nearest water course and behaviour (see Oliveira & Martins 2001). Unfortunately, the variation in survey effort per site and lack of repeated visits to the different field sites did not allow us to estimate species detectability. Lastly, all specimens were photographed to provide information on color and patterning.

We also interviewed local residents about the occurrence of Piraja's Lancehead. We focused our sampling on current or ex-hunters (i.e., adult males), as these tend to be the group with the most in-depth knowledge of the local fauna and flora. After a few initial questions concerning the most common snakes in the region, we showed the interviewees photos of Piraja's Lancehead and other morphologically similar snakes, including *B. leucurus* Wagler, 1824, *Bothrops jararaca* (Wied, 1824) and *Xenodon rabdocephalus* (Wied, 1824). We then asked local residents which of those species they had seen before. We used the mention of the species' local names, *jaracuçu-tapete* or *tapete* (rug or carpet), as well as the species' body length and species' behaviour (e.g., propensity to flatten itself on the ground when threatened) to determine if they had successfully identified the snake.

Conservation status

Considering the small amount of available data on this species, the most viable method to assess the conservation status of *B. pirajai* is to estimate the species extent of occurrence (IUCN Standards and Petitions Subcommittee 2014), "the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy". To calculate this area we used 27 of the existing 32 records for this species. We decided to exclude the single record for Monte Santo, which is most likely inaccurate (the locality was only added 54 years after the specimen was collected and the habitat has historically been ecologically different from any location where the species was found) and the records for the municipalities of Ilhéus and Itabuna, which are more than 50 years old and which recent surveys did not corroborate. We also did not take into account two records for the municipality of Igrapiuna (for which eight additional records exist) as it was not possible to estimate their GPS coordinates.

RESULTS

The ecological survey effort was just over 1700 man-hours, distributed across 18 municipalities of the state of Bahia. Only five individuals were found (four juveniles and one adult) (Image 1B–E and G). However, another five anecdotal records registered by other researchers in subsequent studies and verified through high-resolution photographs, are also included in the present analysis (e.g., Image 1A, F and H). A total of 310 interviews were conducted across 43 municipalities in the state of Bahia. Only in about 7% of the interviews did the respondents successfully identify *B. pirajai*.

All *B. pirajai* specimens were found in the eastern Atlantic Forest biome, more specifically Ombrophilous forest, between 12°50'S and 14°50'S (Fig. 1), in altitudes ranging from 88–835 m. In terms of geographic distribution, the present study significantly widens the potential distribution of *B. pirajai*, providing evidence from interviews that *B. pirajai* may be distributed across 14 municipalities for which there are no biological records (Fig. 1).

The largest recorded individual of *B. pirajai* was a female measuring 1130mm in length (IB 3008), with 50% of the 22 females in herpetological collections being more than 800 mm in length. The largest recorded male of *B. pirajai* measured 820mm (MZUESC 5104). Although records for two other male specimen exist (one of which is the holotype), these specimens appear now to have been lost.

In terms of coloration, most specimens have a reddish-brown back with dark brown dorsal markings. There is marked sexual dichromatism in adult snakes. Males have disruptive coloration, with less defined and fragmented dorsal spots. Interspaces usually have dark spots in both the vertebral region and on the flanks. It should be noted that when preserved in alcohol, the reddish-brown coloration fades and males become similar to some *B. leucurus* specimens. Unlike males, females have well defined and complete dorsal marks, forming a V or an inverted Y. The vertebral line has interspaces with a dark region and usually with two dark, irregular, opposite and alternate spots (Image 1G and H). On the sides, interspaces are clear and often without spots, thus sharply contrasting with the dorsal spots, which are much more conspicuous than those found on males.

Considering habitat use for all newly recorded individuals were found on the ground, nine of which in a thick layer of leaf litter and one female in a burrow. Individuals were found to be active during evenings



Image 1. A - Juvenile, 37cm in length, found in Elíseo Medrado (CZGB 9431); B - Juvenile, 31cm in length, found in Elíseo Medrado; C - Juvenile, 22cm in length, found in Elíseo Medrado © Marco Freitas; D - Juvenile, 34,5cm in length, found in Ubaíra (MZUESC 6762); E - Juvenile, 28cm in length, found in Ubaíra; F - Adult female, found in Uruçuca (CZGB 5471).



Image 1 (continued). G -Adult female, 90cm in length, found in Eliseo Medrado; H - Adult female, found in Uruçuca (CZGB 1433).

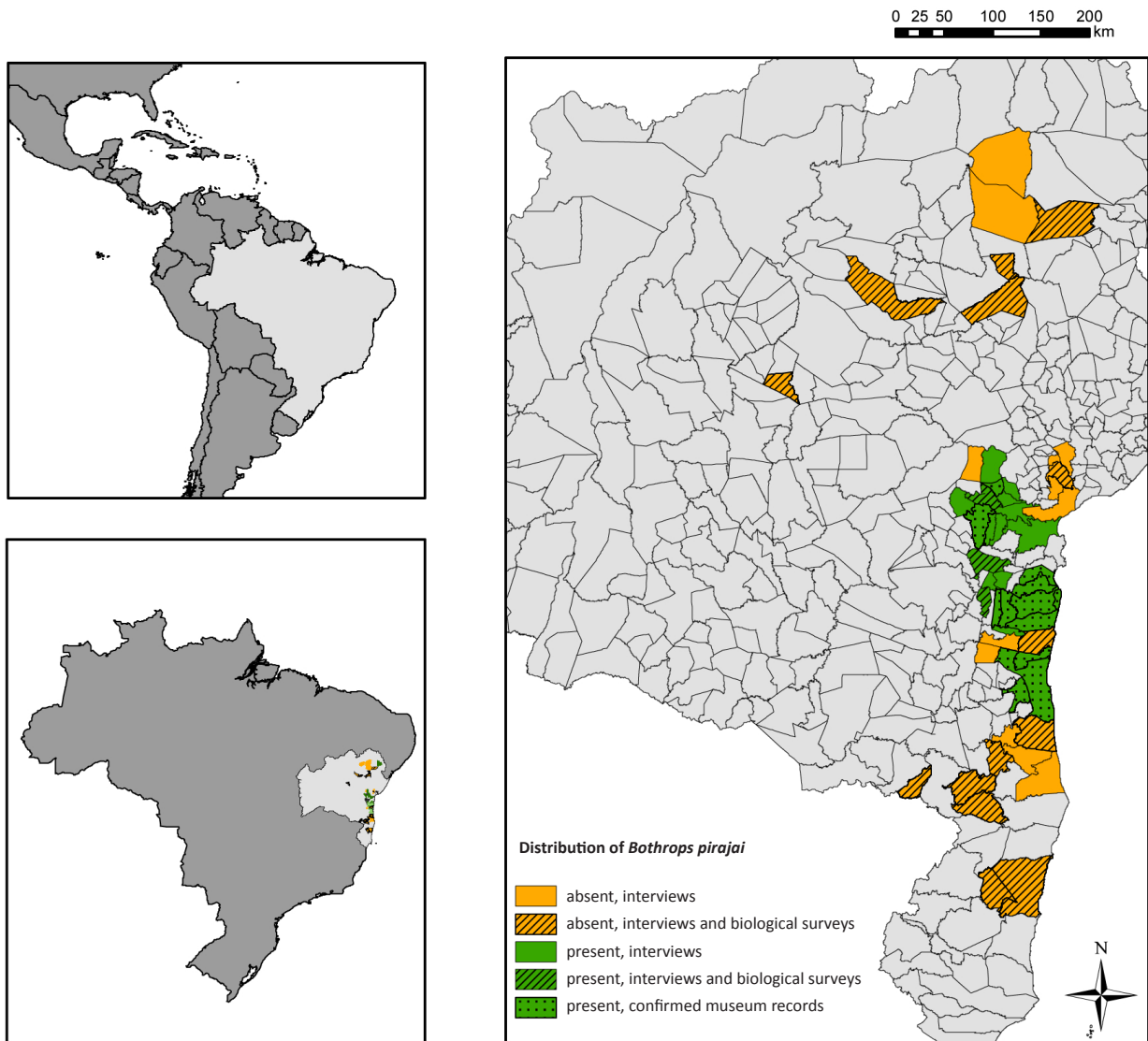


Figure 1. The presence/absence of *Bothrops pirajai* by municipalities, as determined by biological and social surveys

between 20:00 and 22:00 hours and mostly inactive or potentially thermoregulating during the morning. When disturbed, individuals flattened dorso-ventrally and vibrated their tail. Although this species might hunt near water, only half of the specimens found were within 50m of a water source. In relation to diet, a juvenile female housed at the Coleção Zoológica Gregório Bondar (CZGB 9509) was anecdotally found to have a Teiid Lizard in its stomach. Three juvenile females, kept in in situ terrariums for between 48–72 hours, consumed frogs (e.g., *Eleutherodactylus bilineata* and *Haddadus binotatus*). Finally, in terms, of conservation status, the estimated area of extent of occurrence for *B. pirajai* was 4222km². However, it should be noted that the municipalities where the species occurs have a total of only 858km² of forest cover.

DISCUSSION

Much of the published information on the distribution of *B. pirajai* is misleading (Argôlo 2008). The present study highlights a further potential inconsistency around the locality of Monte Santo, where the holotype for this species was allegedly collected. Ecological surveys conducted in this locality not only failed to find any specimens of this species but have also uncovered that the habitat types in this region are different from those where all other records of *B. pirajai* have been obtained. Furthermore, historical data on the snake species collected in that region shows the presence of species from much more arid habitats than those where *B. pirajai* have been recorded. Lastly, it should also be considered that detailed information on the locality was added only 54 years after the specimen was collected (see Amaral 1923, 1977). Based on verified records, *B. pirajai* is likely to be restricted to the dense ombrophilous Atlantic Forest of the state of Bahia, between 12°30'S & 15°00'S (Argôlo 2008). While most of this is lowland, some records, such as the Serra do Timbó in Ubaíra, or the Serra da Jibóia in Elísio Medrado, indicate that *B. pirajai* can be found at higher elevations (up to 880m).

As it is the case with other species in the *Bothrops* genus, *B. pirajai* is terrestrial and primarily nocturnal, although it may thermoregulate in the early morning hours in forest clearings (Martins et al. 2002; Oliveira & Martins 2002; Sasa-Marín et al. 2009). Despite the few male specimens available, sexual dimorphism is likely to occur in *B. pirajai*, with males being generally smaller than females, as is the case in many snake species (e.g., Shine 1994). In addition, there seems to be clear sexual

dichromatism (Amaral 1923; Amaral 1977) in line with other related species, such as *B. jararacussu* (Marques & Sazima 2003). Juveniles of *B. pirajai* have a yellow tail tip, a characteristic shared with other *Bothrops* species, which is likely to be used to attract prey such as lizards and frogs. This behaviour is known as caudal luring and has been reported for other *Bothrops* species (Sazima 1991, 2006).

Regarding diet, the only previous records showed remains of rodents in two individuals of *B. pirajai*, (Argôlo 2004). We found a teiid lizard in the stomach of one juvenile museum specimen (CZGB 9509) and three individuals ate amphibians shortly after they were caught and kept in short-term captivity. As is common with other snake species of the genus *Bothrops* (Greene 1988), individuals of *B. pirajai* were seen to flatten their body dorso-ventrally and vibrate their tail when confronted with a perceived threat, perhaps in an effort to seem larger (Greene 1988). According to residents from Igrapiúna and Camamu, this behaviour explains the common names of the snake: *Jaracuçu-tapete* or simply *Tapete*, which means carpet or rug in Portuguese.

Conservation status

As is the case for most of the reptiles in Brazil, the most important threat to *B. pirajai* is habitat loss (Rodrigues 2005; Argôlo 2008), with the state of Bahia having lost about 4% of its Atlantic forest in the last decade (SOSMA/INPE 2013). Human persecution may also play a role, with local residents reporting killing the species on sight when entering the forest to extract resources such as firewood (Freitas 2008). Nonetheless, only one case of human envenomation has ever been reported (Argôlo et al. 1999).

Bothrops pirajai is currently classified as Endangered B1ab(iii) in the Red Book of Brazilian Reptiles (Argôlo 2008), after not appearing in the Brazilian RedList assessments of 1968, 1972 or 1989. Globally, the species is classified as Vulnerable A1c, having been included in the global RedList of Threatened Species (Argôlo 2000), for the first time in 2000. The latter assessment is, however, now more than a decade old and is in need of an update (see Argôlo 2000). We believe the data gathered in this study could inform this revision.

Both national and global species assessments emphasize the decrease in available habitat, severe habitat fragmentation and the species' restricted distribution. This highlights not only the key conservation threats to the species but also that geographical distribution is one of the few parameters for which there is enough information on which to base

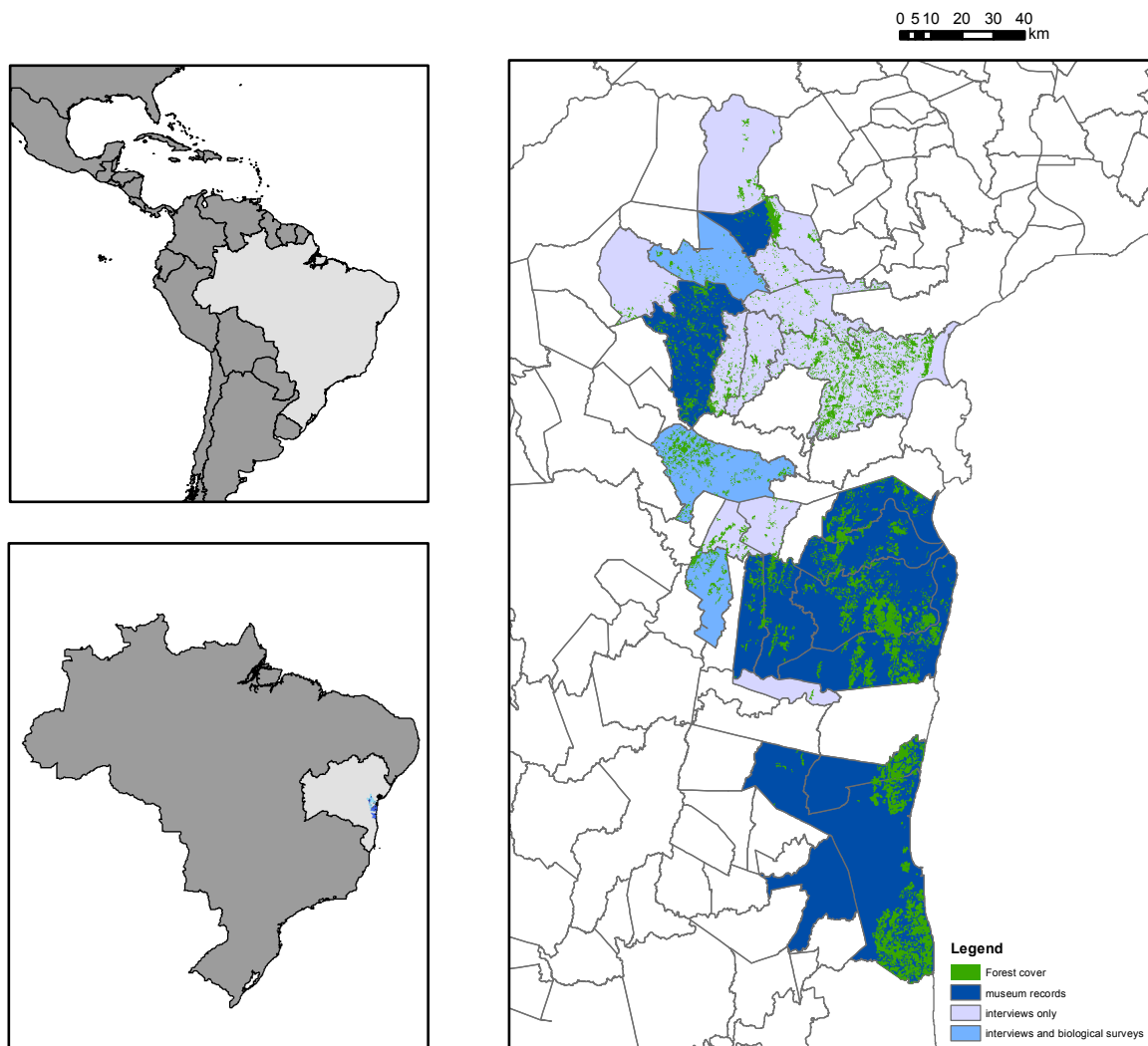


Figure 2. Atlantic forest fragments in the municipalities where *Bothrops pirajai* has been found to be present by biological and social surveys.

a conservation assessment. A similar situation has been found with other poorly known members of the genus *Bothrops* (de Freitas et al. 2012). The estimated extent of occurrence for *B. pirajai* is 4222km², placing the species under the 5000km² threshold required for the Endangered category (IUCN Standards and Petitions Subcommittee 2014). The species should thus be uplisted to Endangered under criteria B1ab(iii). This stems from the species' highly fragmented habitat (the municipalities with confirmed biological records of *B. pirajai* have only 858km² of forest; Fig. 2) and suspected continued decline based on the decrease of area and quality of habitat (SOSMA/INPE 2013). This is the same status and underlying criteria currently used to determine the status of the species in the Red Book of Brazilian Reptiles.

We purposefully restricted our estimate of the

extent of occurrence to the confirmed biological records, although the results of the interviews conducted make it likely that the species could be distributed across a wider area. We adopt this precautionary approach, as the species is expected to occur at very low densities and habitat fragmentation and loss are ongoing (IESB 2007). Further studies are needed to corroborate with biological evidence the records obtained through interviews and thus allow for an eventual recalculation of the species' extent of occurrence. It should also be noted that the only records of *B. pirajai* for a protected area were obtained via interviews of local residents near the Wenceslau Guimarães Ecological Station. Records for the Boa Esperança Municipal Park and Area de Protecção Ambiental Baía de Camamu have recently been discredited. The former due to the 80 years that have elapsed since the collection of the information

combined with the lack of corroboration by recent surveys and the latter due to an error in naming the locality where the specimen was found (Freitas 2008). This means that *B. pirajai* is poorly represented in Brazil's protected area network, making the species even more vulnerable to further habitat loss and fragmentation.

The effective conservation of *B. pirajai* relies on addressing two key issues: improving our knowledge of the species, namely through the study of population density, genetics and dynamics, and successfully mitigating habitat loss and fragmentation. The first will depend on the implementation a species action plan (Argôlo 2008) identifying the priority geographical areas for the species as well as key knowledge gaps, such as understanding the species ecological requirements or its sensitivity to habitat disturbance. The second resolves around ensuring adequate management of existing protected areas, especially those that allow sustainable use, in the face of growing demand for natural resources. As with many other reptiles in Brazil, the future of *B. pirajai* relies on improving the links between livelihoods and biodiversity through an adequate mix of knowledge, management and community-based conservation.

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Portuguese Abstract: A serpente venenosa *Bothrops pirajai* (Amaral, 1923) é endêmica do Brasil. Apesar de ter sido descrita há mais de um século, pouco é sabido acerca desta espécie, que nunca foi estudada em estado selvagem. Neste trabalho, apresentamos novos dados biológicos sobre *B. pirajai* baseados não só numa revisão de espécimes de museu, mas também em amostragens (total cerca de 1700 horas/pessoa) realizadas na área de distribuição da espécie. Os nossos resultados indicam que a distribuição geográfica está apenas confinada ao sudeste da Mata Atlântica do estado da Bahia, Brasil, entre a Baía de Todos os Santos, Itabuna e Ilhéus (12050'S–14050'S, 88–835 m). Neste sentido, recomendamos que a espécie seja elevada ao estatuto de “Em perigo” na Lista Vermelha da União Internacional para a Conservação da Natureza, dado que a sua extensão de ocorrência é menos de 5000km². Uma estratégia de conservação efectiva para esta espécie deverá centrar-se na melhoria do conhecimento existente sobre a história natural e biologia da espécie e na mitigação do impacto da perda e fragmentação do habitat.

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