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Article

Threats to health and conservation of free-living sloths (*Bradypus* and *Choloepus*) under anthropic influence in the city of Manaus, Amazonas state, Brazil

***Laynara Silva dos Santos*[1]*, *Carlos Roberto Teixeira*[1], *Alessandra Ferreira Dales Nava*[2],**

***Laerzio Chiesorin Neto*[3], *Ricardo Shoiti Ichikawa*[1] & *Sheila Canevese Rahal*[1]**

[1]*Universidade Estadual Paulista, Faculdade de Medicina Veterinária, Programa de Pós-Graduação em Animais Silvestres, Botucatu, SP, Brasil.*
[2]*Fundação Oswaldo Cruz, Instituto Leônidas e Maria Deane, Manaus, AM, Brasil.*
[3]*Secretaria Municipal de Meio Ambiente, Refúgio Sauim Castanheiras, Manaus, AM, Brasil.*
**Corresponding author: laynara.santos@unesp.br*

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Abstract: Anthropogenic disturbances affecting forest areas can increase disease prevalence and susceptibility in several species of arboreal mammals, such as sloths. Thus, this study aimed to evaluate the most common conditions in body systems of free-ranging sloths admitted at the Wildlife Triage and Rehabilitation Center of Amazonas of the Institute of Environment and Renewable Natural Resources. A total of 227 individuals (139 retrospective cases from 2015 to 2019, and 88 prospective cases from July 2020 to July 2021) were evaluated over a six-year period. Cases from the genus *Bradypus* showed involvement of the following body systems: 44% respiratory, 29% integumentary, 15% musculoskeletal, 5% digestive, 3% visual, 2% auditory, 1% circulatory and 1% genitourinary, while that distribution in the genus *Choloepus* was: 39% musculoskeletal, 27% integumentary, 19% respiratory, 9% digestive, 3% circulatory, 1% visual, 1% auditory and 1% genitourinary. The results reveal significant differences between the condition detected and the genus (*Bradypus* and *Choloepus*), age and case outcome. These results can provide data for future investigations of sloth diseases, confirming lesions, as well as motivating and suggesting adequate management methods.
Keywords: *Wild animals; Xenarthra; Pilosa; clinic; diseases.*

Ameaças à saúde e conservação de preguiças (*Bradypus* e *Choloepus*) de vida livre sob influência antrópica em Manaus, Estado do Amazonas, Brasil

Resumo: Distúrbios antrópicos que afetam áreas florestais podem aumentar a prevalência de afecções e a suscetibilidade às doenças em diversas espécies de mamíferos arborícolas, como as preguiças. Desta forma, este estudo teve como objetivo avaliar as condições mais comuns nos sistemas orgânicos de preguiças de vida livre admitidas no Centro de Triagem e Reabilitação de Animais Silvestres do Amazonas. Um total de 227 indivíduos (139 casos retrospectivos de 2015 a 2019 e 88 casos prospectivos de julho de 2020 a julho de 2021) foram avaliados durante um período de seis anos. Para o gênero *Bradypus* foram diagnosticadas 44% de afecções do sistema respiratório, 29% tegumentar, 15% musculoesquelético, 5% digestório, 3% visual, 2% auditivo, 1% circulatório e 1% genitourinário. Por sua vez, para o gênero *Choloepus* foram detectadas 39% de afecções do sistema musculoesquelético, 27% tegumentar, 19% do sistema respiratório, 19% do sistema respiratório, 9% digestório, 3% circulatório, 1% visual, 1% auditivo e 1% genitourinário. Os resultados mostraram diferenças significativas na prevalência da afecção e gênero das preguiças (*Bradypus* e *Choloepus*), a faixa etária e desfecho do caso. Esses resultados podem fornecer subsídios para investigar as doenças de preguiças, confirmando afecções, motivo e sugerir métodos adequados de manejo.
Palavras-chave: *Animais selvagens; Xenarthra; Pilosa; clínica; doenças.*

Introduction

Urban expansion, habitat loss, fragmentation, and climate change represent complex scenarios that can alter health in the human-animal-plant-environment interface, increasing the risk of zoonotic diseases in the One Health perspective (Jones et al. 2008, Thompson et al. 2016, OHHLEP et al. 2022). The monitoring of diseases in wildlife plays a fundamental role in the zoonotic disease dynamics in nature and may contribute to the evaluation of the prevalence, surveillance, and dissemination of important diseases for animal and environmental health (Jones et al. 2008, Rahman et al. 2020).

The Amazon, the largest biome in South America, is located in a humid tropical area with constant temperatures and climatic oscillations that vary between dry and wet rainy seasons (Veblen et al. 2007). However, more and more Amazon areas are threatened by anthropic factors, such as constant fires and deforestation, which pose threats of extinction to endemic species (Silva et al. 2020). These anthropic factors increase the risks to diversity, even in species with high adaptation to environmental changes, since they become not only vulnerable to habitat fragmentation and degradation but also susceptible to diseases, which can occur in ecotones among wildlife, domestic animals and humans (Santos et al. 2017).

The superorder Xenarthra is divided into two orders, Cingulata (armadillos) and Pilosa (anteaters and sloths), comprising about 31 living species distributed throughout the Neotropical region (Rose & Gaudin 2010, Martins et al. 2015). The order Pilosa, suborder Folivora, includes two distinct families of sloths, Bradypodidae (three-toed sloths), and Megalonychidae (two-toed sloths) (Gardner 2007, Gibb et al. 2016). The family Bradypodidae contains the species *Bradypus pygmaeus*, *B. tridactylus*, *B. variegatus*, *B. torquatus* (Gardner 2007), and more recently *B. crinitus* according to a new taxonomic rearrangement (Miranda et al. 2023). Members of the genus *Bradypus* are generally solitary and arboreal, exhibit strictly folivorous habits, are excellent swimmers and use treetops exposed to the sun for thermoregulation (Medri et al. 2006, Miranda 2014). The family Megalonychidae with two species of the genus *Choloepus* (*Choloepus didactylus* and *Choloepus hoffmanni*) is characterized by omnivorous sloths that consume a greater variety of food items, including fruits, flower buds and small vertebrates (Esbérard 2001, Miranda 2014). In addition, this family is primarily nocturnal, using trees with lianas, vines, and tree-creepers for rest and protection against possible predators (Wetzel 1982, Medri et al. 2006). Sloths depend on trees to perform various daily activities, so deforestation and urban expansion imply habitat loss (Medri et al. 2006, Dünner & Pastor 2017). Besides mortality from anthropic factors, human-wildlife interaction can trigger the increase in diseases that these sloths can acquire, in addition to other conditions.

The Brazilian Amazon harbors four sloth species: two of the genus *Choloepus* (*Choloepus didactylus, Choloepus hoffmanni*) and two of the genus *Bradypus* (*Bradypus tridactylus* and *Bradypus variegatus*) (Wetzel 1985, Medri et al. 2006, Chiarello et al. 2022, Moraes-Barros et al. 2022, Plese et al. 2022, Pool et al. 2022). Three of these species are found in forest areas and neighborhoods in the city of Manaus, Amazonas. Studies in a forest fragment in the Manaus region found that *Bradypus tridactylus* and *Choloepus didactylus* were equally abundant in primary and secondary forests (Carmo 2003, Mata 2009). Despite the threats to which they are exposed, the IUCN (International Union for Conservation of Nature) classifies them as threat status in the Least Concern (LC) category (Chiarello et al. 2022, Moraes-Barros et al. 2022, Plese et al. 2022, Pool et al. 2022). However, urban expansion compromises conservation areas for the species (Andrade et al. 2020), making it one of the leading causes of admissions to the Wildlife Sorting Center that receives animals rescued, trafficked, or delivered by the population.

In order to contribute to the comprehension and conservation of wildlife species, this study aimed to evaluate the most common conditions in body systems of free-ranging sloths admitted at the Wildlife Triage and Rehabilitation Center of Amazonas of the Institute of Environment and Renewable Natural Resources (CETAS/IBAMA-AM) and to discuss the possible implications of the urban expansion for the sloths' health. To the best of the authors' knowledge, data have not yet been documented for sloths in the Manaus region, Amazonas state, Brazil.

Material and Methods

This study was approved by Ethics Committee for Animal Care and Use from the School of Veterinary Medicine and Animal Science, UNESP Campus Botucatu, SP-Brazil (no. 0031/2020–CEUA). Data from sloths (*Choloepus didactylus, Bradypus tridactylus, Bradypus variegatus*) admitted at the CETAS/IBAMA-AM were collected, analyzed and categorized over a period of six years (2015 to 2021). Data were collected from two different information sources: (a) retrospective consultation of the files and database from the Supervisory nucleus (NUFIS) of the CETAS/IBAMA-AM from 2015 to 2019; (b) prospective analysis, with follow-up for one year (July 2020 to July 2021) of all sloths received at CETAS/IBAMA-AM with an individualized clinical record. In both data collections, the variables checked included locality, admission history, sex, age group (adult, juvenile, young), body weight, clinical diagnosis and case outcome (survival or death).

To categorize the data, a nominal qualitative variable analysis was performed, identifying the main conditions according to the following systems: musculoskeletal, integumentary, visual, auditory, digestive, respiratory, circulatory and genitourinary. Since the cases of the musculoskeletal system presented a high percentage, the occurrence registration was based on the degree of case concentration in the neighborhoods. A map of Manaus city, Amazonas state, enabled estimation of the locations where the highest numbers of animals were found. By calculating Cramér's V coefficient (Cramér 1999), implemented in the R package "rcompanion" (R Core Team, 2021; Mangiafico 2022), we evaluated the existence of a prevalence between age and condition type, as well as animal mortality and/or outcome predictors (death or survival). The correlation was defined as strong, moderate, or weak (range, 0.63–0.81) (Cohen 1988). The calculation was repeated for 10,000 bootstraps to obtain a 95% confidence interval.

Results

Data were analyzed from 227 sloths, including 139 retrospective (2015 to 2019) and 88 prospective cases (July 2020 to July 2021). A total of 60% of the animals were males, 30% were females, and 10% had no information as to sex. Sloths were 48% adult animals, 31% young and 21% juveniles. Body weight was not provided in the retrospective data.

Body weight information was only obtained in prospective cases (n = 88), ranging from 203 g to 6.3 kg for the genus *Bradypus* and from 307 g to 8.8 kg for the genus *Choloepus*. The reasons for admission included: rescue (73%) carried out by a competent authority associated with electrocution, dog attacks, or having been hit by a car; and admission volunteer agreement to deliver the animal (27%) was usually related to being orphaned/abandoned or dispersed in backyards. There was no information in 8% of the cases. The conditions according to the systems are shown in Table 1.

Table 1. Conditions on body systems in 227 free-ranging sloths of the genera *Bradypus* and *Choloepus* admitted at the Wildlife Triage and Rehabilitation Center of Amazonas of the Institute of Environment and Renewable Natural Resources (CETAS/IBAMA-AM).

Body systems	Conditions	*Bradypus* (n = 125)	*Choloepus* (n = 102)
Musculoskeletal	Fractures, Luxations	15%	39%
Integumentary	Skin laceration, Burns Ectoparasites	29%	27%
Visual	Corneal ulcer	3%	1%
Auditory	Fungal otitis	2%	1%
Digestive	Bloat, Parasitism, Malabsorption syndrome, Fecaloma	5%	9%
Respiratory	Bronchopneumonia, Pneumonia	44%	19%
Circulatory	Endocarditis, Cardiomyopathy	1%	3%
Genitourinary	Obstruction, Prolapse	1%	1%

The highest percentage of cases occurred in *Bradypus* related to respiratory (44%) and integumentary (29%) systems. In the respiratory system were observed mainly bronchopneumonia and pneumonia, but there were cases with no specific cause. A correlation coefficient of 0.72 was detected between these respiratory diseases and age, which was most frequent in young *Bradypus* sloths (20%). In relation to the integumentary system, the most significant lesions were skin lacerations caused by dog bites and burns due to electrocution, besides mites (*Sarcoptes scabiei*) and ticks (*Amblyomma* spp.), which had a high prevalence of infestation.

In the genus *Choloepus*, the prevalence of lesions were associated with the integumentary (39%) and musculoskeletal (27%) systems. Cases related to the integumentary system involved skin lacerations of the head caused by an attack by a domestic animal (dog); palmar and facial lacerations due to conflict with conspecifics; and burns of different degrees due to electrocution. The lesions in the musculoskeletal system consisted of fractures and luxations. In general, the fractures involved the femur, radius/ulna, or multiple ones involving more than one bone, caused by being hit by a car or by electrocution. There was also one case of osteosclerosis of the interphalangeal joints attributable to deformity of the claws/nails.

Figure 1 shows primary conditions according to the following systems: musculoskeletal, integumentary, visual, auditory, digestive, respiratory, circulatory, and genitourinary. The west zone of Manaus presented the greatest concentration of musculoskeletal and integumentary system conditions (example fractures, skin laceration and burns), and reported the second-highest rate of population growth of the decade in the region and ecological consequences of forest fragmentation in the Amazon rainforests (Figure 2).

Regarding the other systems, the percentage was very similar for both genera, as shown in Table 1. Eye injuries and traumatic corneal

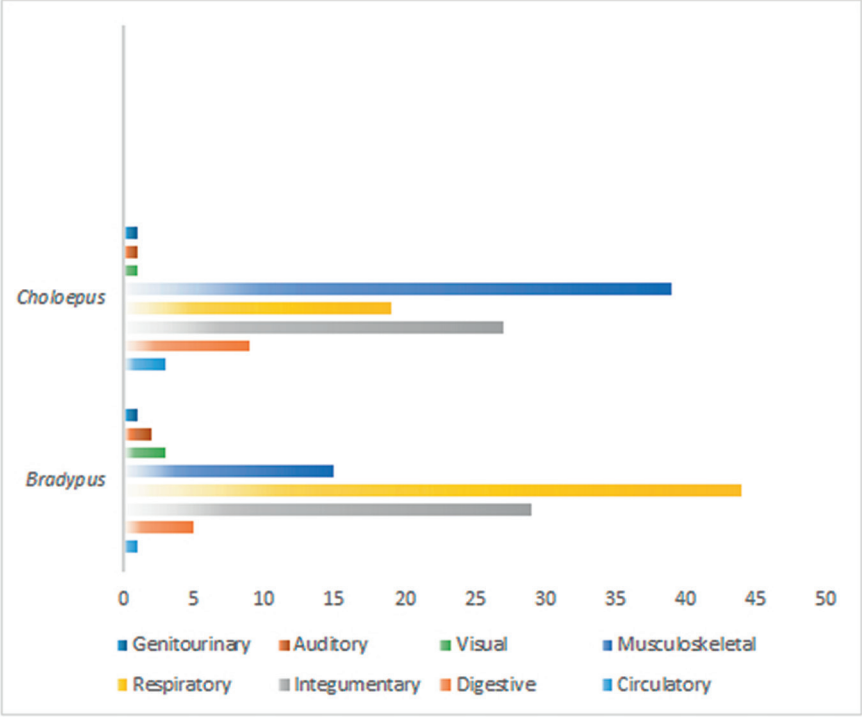

Figure 1. Prevalence between affected system and sloth genus (*Bradypus* and *Choloepus*).

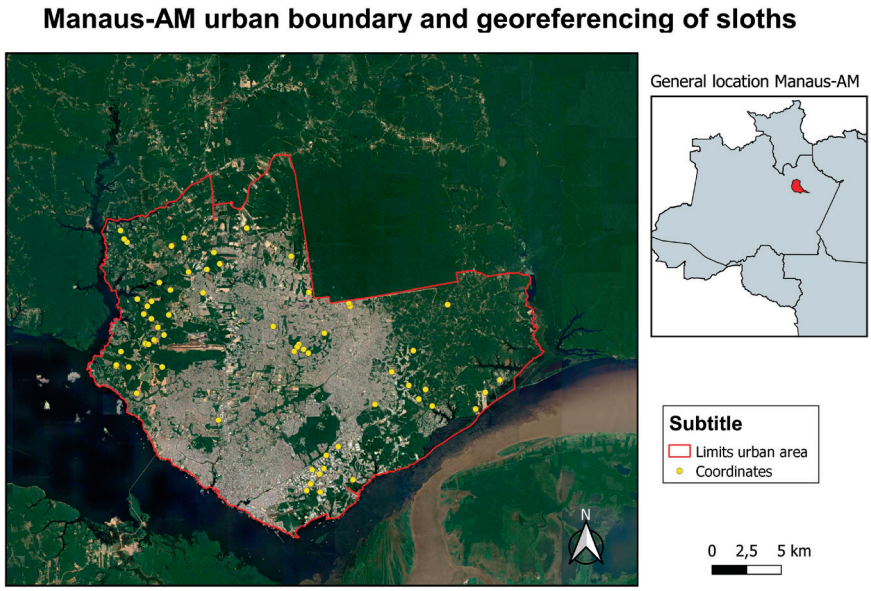

Figure 2. Records of the occurrence of musculoskeletal and integumentary lesions in sloths verified in the city of Manaus-AM.

ulcers were detected in the visual system. In the auditory system, only one sloth of the genus *Bradypus* presented fungal otitis (*Malassezia* spp.) with no defined history. In the digestive system, the following were observed: bloat associated with multiple traumas and gastric impaction, parasite infections (coccidiosis/giardiasis), malabsorption syndrome and fecaloma because of inadequate diet, and rectal prolapse due to constipation. Age was associated with the affected system, and a correlation coefficient of 0.81 was detected between these digestive diseases and age, which was most frequent in young *Choloepus* (22%). As to the circulatory system, animals were identified with endocarditis and cardiomyopathy, whereas the genitourinary system presented cases of urinary obstruction.

The outcome of the cases (death or survival) did not differ statistically in relation to age ($p > 0.05$), but there was a significant difference when comparing outcome and affected system ($p < 0.001$). The musculoskeletal, respiratory and integumentary systems were the main outcome predictors of death, comprising 70% of the cases, while the survival outcome corresponded to 30%.

Discussion

The present study showed data on the principal conditions in body systems of sloths that live in the region of Manaus, Amazonas state, Brazil. Studies on sloths are generally focused on taxonomy and ecology (Xenarthra, Pilosa) (Carmo 2003, Aguiar 2004, Réus & Sousa 2007, Moraes-Barros 2011, Vidal 2018). Although such studies contribute to conservation, they have not address the health problems resulting from anthropization, which may threaten the conservation of these mammals (Lopes & Ferrari 2000).

In the genus *Choloepus*, the highest percentage of lesions corresponded to the integumentary and musculoskeletal systems confirming that free-living sloths are subject to traumas such as being hit by a car, falling trees, electrocution, and fights with domestic animals. A sloth rehabilitation center in Colombia also verified that *C. hoffmanni* has been subjected to several injuries, including being hit by cars, stoned by children, or electrical shocks, even with the greater adaptability of these sloths to habitat alteration (Moreno & Plese 2006).

The integumentary system presents a similar morphology for both genus (Dünner & Pastor 2017), which probably influenced this system to have a high proportion of cases in both genera in the current study. Two ectoparasites were detected in the sloths, *Sarcoptes scabiei* and *Amblyomma* spp. The infestation by *Sarcoptes scabiei* has also be described in *C. hoffmanni* and *B. variegatus* in captivity from Costa Rica (Sibaja-Morales et al. 2009). The zoonotic potential of this mite must be considered due to the risk of transmission to the persons who rescued or are responsible for the care of the infested animal. Sarcoptic mange has a global distribution and is considered an emerging disease in some wildlife species (Escobar et al. 2022), as observed in the current study. Among the ticks, the *Amblyomma varium* presents high host specificity and is frequently verified in the *Choloepus* and *Bradypus* genera (Marques et al. 2002). Ticks, lice, and algae are observed in sloths under natural conditions but must be treated in captivity animals if a host-parasite imbalance occurs.

The musculoskeletal system of sloths presents disparities in functional adaptations, and variation may occur eventually in individuals within the same species (Mendel 1985, Miranda 2014, Dünner & Pastor 2017). The activity pattern and movement rates also differ between sloths, since *Cholloepus* ones are nocturnal with a cyclic activity pattern, and *Bradypus* decrease activity before and after sunrise (Sunquist & Montgomery 1973). Therefore, injuries may have different impacts between species and individuals, as verified in the current study, since the musculoskeletal system had the second-highest percentage of lesions in the sloths of the genus *Choloepus* and the third in the genus *Bradypus*.

Sloth genera differ in ecological behavior, which may have influenced the differences in lesion percentages, especially in the integumentary, musculoskeletal, and respiratory systems. While sloths of the *Bradypus* genus move less often, staying for a prolonged period in a tree and with both daytime and nighttime activity in less frequency, sloths of the *Choloepus* genus present strictly nocturnal activities spending little time at a single location (Sunquist & Montgomery 1973, Chiarello 2008).

In addition, a study showed that activity patterns in *Bradypus variegatus* are influenced by environmental temperature, besides nutritional requirements and protection against predators (Chiarello 1998, Castro-Sá et al. 2021, Lopes et al. 2023). These differences influenced the high percentage of electrocution and being hit by a car for *Choloepus*, resulting in fractures, injuries, lacerations, and burns. Therefore, the activity pattern of these species, associated with the high rates of destruction and fragmentation of the habitat, may be considered the main consequence of the large number of traumatic conditions distributed throughout the neighborhoods, as verified in the spatial analysis. There were significantly more abundant rescue points in forested areas, where anthropization levels are considered high (De Andrade et al. 2020).

Electrocution, for example, is a common problem for several arboreal mammals due to urban expansion, causing injuries of different degrees and complexity (Dünner & Pastor 2017, Carmo et al. 2019, Almeida et al. 2022). In this context, the modified ecological matrix (roads, constructions, invasions in neighborhoods, industries, electrical wiring) can account for the high number of traumatic conditions related to the behavior of species in search of new areas to establish territory and use for foraging. The evaluation area of the present study has been subjected to different types of anthropic pressure due to exacerbated urban growth of the city and population growth with a percentage increase of 25.5% in a decade. Manaus, the state capital of Amazonas, has experienced significant population growth in recent years (IBGE, 2023), a fact that has resulted in areas of destroyed or fragmented forests. Faced with such challenges, public bodies must seek solutions through public policies that guarantee the sustainable development of the city, including by actions that conserve the environment and species of the Amazon region. The houses present lands adjacent to forest fragments that generate direct and indirect human - domestic animal - wildlife interactions (Gontijo 2008, Santos et al. 2017). Consequently, the populations of free-living sloths (*Choloepus didactylus, Bradypus tridactylus, B. variegatus*) that inhabit green areas, anthropic forest fragments, and permanently protected areas in Manaus presented lacerations or injuries from attacks/bites by dogs when descending to the soil or when trying to connect to another forest fragment through the resident backyards. A study around a cacao farm in Costa Rica detected that most mortality of the adult sloths of the genera *Bradypus* and *Choloepus* was associated with predation by coyotes and domestic dogs and suggested that *B. variegatus* require immigration to maintain a stable population (Peery & Pauli 2014).

Since the present study did not consider specific variables for spatial epidemiological analysis, further studies must be conducted to correlate clinical lesions with negative interactions that threaten sloth survival and to promote conservation strategies. The urban matrix directly influences threats to arboreal mammals, such as sloths and primates (Gordo et al. 2013, Katsis et al. 2018, Brandão et al. 2019, Carmo et al. 2019), vulnerable to urbanization because of the high dependence on trees for displacement.

The lesions verified in the respiratory and digestive systems probably were influenced by the time in captivity. Stressed animals can develop enteric and respiratory disturbances (Messias-Costa & Esbérard 2001). Bronchopneumonia and pneumonia were the most frequent respiratory diseases in the present study. Severe climate changes were associated with developing pneumonia among sloths living in captivity at one São Paulo zoo (Diniz & Oliveira 1999). Bronchopneumonia and acute edema of the lungs was also the major causes of death in sloths received at a zoo in Belém, Amazonia (Messias-Costa 2001). The sloths have poor thermoregulatory ability and are sensitive to temperature changes (Gilmore et al. 2000), which must be considered in captivity animals.

Parasitism, bloat, and malabsorption syndrome were some of the digestive alterations detected in the present study. Coccidia and Giardia were the intestinal protozoan parasites identified. Free-living sloths may have coccidian infection without disease manifestation (Messias-Costa 2001). *Giardia duodenalis* has already been diagnosed in baby sloths rescued in Manaus and must be considered part of the zoonotic scenario in the region (Reis et al. 2023). Traumas and gastric impaction occurred in cases of bloat in the present study, evidencing that veterinary complications and the maintenance of a standardized and adequate nutritional protocol for the pup in captivity are crucial for its maintenance. (Gage 2002, Larrazábal 2004, Dünner & Pastor 2017). Tympanism and constipation are common in sloths and related to stress factors (Messias-Costa 2001). A study of young *Choloepus didactylus* in captivity reported tympanism as the most frequent alteration, which was attributed to the food and position feeding position (Larrazábal 2004). In addition, tympanism has been observed in politraumatized free-ranging sloths (Dünner & Pastor 2017), as verified in animals with bloat in the present study.

It should be *mentioned that* the respiratory and digestive conditions in the current study were mainly associated with young sloths of the genus *Bradypus* removed from their natural environment, often resulting in death. Common problems reported in young and newly arrived captive animals include milk maladaptation (diarrhea), bloat, and fecaloma, as well as malabsorption syndrome that causes poor body condition and peeling of the skin and nails (Messias-Costa 2001, Dünner & Pastor 2017). Furthermore, the lesions related to the visual, auditory, circulatory and genitourinary systems were considered isolated and punctual cases.

In conclusion, the most common conditions in body systems of free-ranging sloths from Manaus included the musculoskeletal, integumentary, and respiratory systems; however, there were differences between genera. These results can provide data for future investigations about clinical diseases in sloths and their respective causes, to support adequate management measures that contribute to the health and conservation of these mammals.

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Associate Editor

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Author Contributions

Laynara Silva dos Santos: substantial contribution in the concept and design of the study, contribution to data collection, contribution to manuscript preparation.

Carlos Roberto Teixeira: substantial contribution in the concept and design of the study, contribution to data collection.

Sheila Canevese Rahal: contribution to manuscript preparation and substantial contribution in the concept and design of the study.

Alessandra Ferreira Dales Nava: contributed to data collection and manuscript preparation.

Laerzio Chiesorin Neto: contribution to data collect and interpretation.

Ricardo Shoiti Ichikawa: contribution adding intellectual content and analyzes.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgements section. A signed document has been filed in the journal archives. This study was approved by the Ethics Committee for Animal Care and Use of the School of Veterinary Medicine and Animal Science, Unesp Campus Botucatu (no. 0031/2020– CEUA), and it was authorized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) through the System of Authorization and Information on Biodiversity (SISBIO) (no. 74815/1).

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on a reasonable request.

All data supporting the results in papers published in the journal must be archived in an appropriate public archive offering open access and guaranteed preservation (http://hdl.handle.net/11449/236499).

The datasets generated during and/or analyzed during the current study are available at: https://doi.org/10.48331/scielodata.7YO9P7.

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