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# Illegal online pet trade in venomous snakes and the occurrence of snakebites in Brazil

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ABSTRACT

Greater access to the Internet has boosted the online pet trade and especially enabled the trade in niche-targeted groups, such as venomous species. Despite their fearsome reputation, an array of venomous animals, such as snakes, spiders and scorpions arise interest among pet hobbyists, which exposes owners, sellers, and others involved in their transport and maintenance to potentially serious accidents by envenomation. To assess the potential risk to human health posed by the trade and ownership of venomous pet snakes, we examined social media posts trading or portraying native and exotic venomous species as pets (Facebook™ and YouTube™) and official seizures in Brazil between 2015 and 2020. In addition, we recorded all venomous snakebite events occurring in the country during the same period from the Brazilian Ministry of Health database. We compiled 114,931 venomous snakebite events resulting in over 600 human deaths. *Bothrops* spp. and *Crotalus* spp. were responsible for 86% and 10% of these events. We recorded 241 individual venomous snakes kept as pets of at least 16 species (seven native and nine non-native). The taxa with higher numbers of snakebites were also those most often kept as pets. Venomous pet snakes were sold at low prices, US$ 71.70 ± 18.44 on average. Our findings highlight a dangerous market, given the similarity of taxa raised as pets and those causing snakebites, combined with low availability of anti-venom for exotic species in Brazil. Additionally, several of the venomous pet snakes recorded are invasive species in many countries. Trade in venomous snakes is prohibited in Brazil, but the law is not well-enforced. To curb this illegal market and discourage consumer demand, we suggest that tougher penalties for sellers and owners should be considered, along with the development of awareness campaigns on the consequences of the snakebite injuries and the lack of antivenoms.

## 1. Introduction

Wildlife trade affects one in every four species on the planet (Scheffers et al., 2019) and mobilizes billions of dollars worldwide (Herrel and van der Meijden, 2014). One of the most prominent wildlife markets involves the pet trade, which has increased substantially in the last 15 years, in part due to improvements in goods transportation and facilitated international travel (Bush et al., 2014). Due to the increase in Internet access, wildlife trade has been shifting from brick-and-mortar markets to virtual marketplaces (Siriwat et al., 2020). Online platforms, particularly social media, likely facilitate the connection between sellers and buyers, decrease the cost of advertising, and provide an environment of apparent anonymity, especially when involving illegal specimens. In addition, online posts displaying wild animals may also stimulate the desire to have a wild species as a pet (Nekaris et al., 2013). While lucrative, such markets may present harmful consequences for the conservation of the target animals, as well as for ecosystems they are taken from and, occasionally, introduced to (Sutherland et al., 2009; Alves et al., 2019; Toomes et al., 2020), especially when combined with other anthropic activities, such as land-clearing and, and climate change.

Among the animals affected by the pet market are an array of venomous or poisonous species. Differing from poisonous animals, venomous animals possess the ability to inject venoms in another organism by using specialised anatomical structures (Ericsson et al., 2006; Fry et al., 2008). Despite their fearsome reputation, snakes, frogs, spiders, scorpions, fish and centipedes arise interest among pet hobbyists (Souza et al., 2007; Magalhães and São-Pedro, 2012; Hierink et al.,

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2020; Hauke and Herzig, 2021). For instance, in 2012, there were 1.15 million pet snakes traded solely in the USA, including venomous snakes (Hierink et al., 2020). Furthermore, venomous snakes accounted for almost 10% (over 500,000 individuals) of all live traded snakes reported to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) between 1975 and 2018, part of which are supposedly used to supply the pet market. The worldwide trade in venomous snakes, which are mostly wild-caught, exposes owners, sellers, customs officials, and others involved in their transport and maintenance to potentially serious accidents by envenomation (Hierink et al., 2020). Although the primary use for the venom by a snake is to kill their prey, it can also be used for defence, which is the reason for most of the accidents involving humans. Venom composition can vary widely based on the snake species and can cause health complications from pain and local tissue damage to largely systemically destructive effects on haematological or neurological tissues (Gutiérrez et al., 2017).

Snakebite envenoming was regarded by the World Health Organization as a top priority neglected tropical disease in 2017 (Williams et al., 2019). Cases of snake bites by pet specimens are persistently reported worldwide, however even so it is likely that many go unreported (Schaper et al., 2009; Warrell, 2009, Valenta et al., 2014; Hierink et al., 2020). Over 5 million snakebites were estimated to occur per year, with up to 1.8–2.5 million envenoming cases (Chippaux, 1998; Kasturiratne et al., 2008). Among those, there are between 20.000 and 94.000 deaths and numerous permanent disabilities, such as amputations, caused by snakebites each year (Kasturiratne et al., 2008). Another factor that raises public health concerns is the potential introduction and dissemination of pathogens by snakes, such as *Salmonella* sp., responsible for intoxication, *Mycobacterium* sp., responsible for lung injuries; *Leptospira* sp. responsible for leptospirosis, and *Porocephalus crotali*, a pentastomid parasite responsible for causing visceral pentastomiasis (Bastos et al., 2008; Tappe and Büttner, 2009; Biscola et al., 2011; Yabsley et al., 2015; Ebani, 2017). In the USA, the snakes *Python regius, Malayopython reticulatus* and *P. bivittatus* are also responsible for the introduction in the wild of exotic ticks that are vectors of spotted fever, which were reported to have spilled over to native snakes (Burridge et al. 2000).

Brazil stands out in terms of the number of snake species currently regulated by CITES for international trade (Hierink et al., 2020). Considering the domestic market, the trade, breeding and possession of any venomous species in Brazil are currently prohibited by law, as is the import of any exotic snakes, whether venomous or not (Alves et al., 2019). Conversely, a few states have allowed the trade in non-venomous native snake species, despite the national prohibition. In Brazil, since 1967 it is prohibited to capture and keep native species from the wild without previous permission (Law nº 5197/67). In order to meet the domestic demand for wild pets, in 1997, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) regulated breeding enterprises of native wild species for commercial purposes, including snakes (IBAMA Ordinance nº 118-N/1997). However, due to the high risk of accidents involving venomous species in households, in 2002, IBAMA prohibited the establishment of commercial breeders aimed at selling all reptiles (along with amphibians and invertebrates) species to the domestic pet market (Normative Instruction IBAMA nº 31/2002). Meanwhile, in 1998, IBAMA regulated imports of live exotic animals under CITES recommendations and banned the import of live specimens of reptiles for breeding purposes and for keeping in captivity as a pet (IBAMA Ordinance nº 93). Therefore, since 1998 and 2002, respectively, with no exception, it has not been possible to breed or import any live exotic venomous snake for the pet market, nor to keep native venomous snakes as pets in Brazil.

Despite the prohibitions, previous data on official seizures, voluntary surrender (Magalhães and São-Pedro, 2012; IBAMA, 2019) and interviews with pet owners (Alves et al., 2019) show evidence that several species of venomous snakes are being illegally owned as pets in the country, all of them with potential to threaten human health by envenomation (Souza et al., 2007). Although those past studies reported cases of venomous snakes being kept as pets in Brazil, instances of trade have not heretofore yet been recorded; neither was their relationship with the occurrence of snakebites. Here we aimed to assess the online pet trade and pet ownership of venomous snakes in Brazil and its potential risk to human health. For that purpose, we recorded native and exotic pet venomous species traded online and seized in Brazil, and compared the composition found in the pet market with the species responsible for snakebite events in the country.

## 2. Methods

### 2.1. Data collection

We compiled data on snakebites in Brazil from the Brazilian Ministry of Health through the Notifiable Diseases Information System platform – in Portuguese, *Sistema de Informação de Agravos de Notificação* (SINAN) between 2015 and 2019 (data on 2020 was not yet available). We gathered information on the number of snakebite events per year, city and snake species. The city declared in those reports represents the locality of the healthcare where the person received its first treatment. Please note that there is no differentiation in the database whether the snakebite was caused incidentally by pet snakes in a domestic environment or by accidental contact with native snakes in the wild.

Between July and August 2020, we searched data on online trade, abandonments and official seizures of venomous pet snakes in Brazil, compiling reports from August 2015 to July 2020 on Google™, YouTube™ and Facebook™. We classified venomous snakes to be those species with the morphological, and histological capability of producing and delivering toxins which have led to recorded accidents resulting in systemic symptoms and hospitalization; hence, we opted to include the South American green racer *Philodryas olfersii,* for the species produces similar toxins as Viperidae (Ching et al., 2006; Fry et al., 2008; Correia et al., 2010; Barbosa et al., 2020). We created the search terms based on our previous research experiences on monitoring online pet trade in Brazil. For data collection on Facebook™ and YouTube™, we searched for all posts and videos of venomous snakes on sale or kept as pets using a combination of the following terms: scientific and popular names of the species, “trade”, “$“, “inbox”, and “experienced”. ‘Inbox’, which stands for ‘direct message’, is the local term used to encourage people to message the seller for more information about the animal. ‘Experienced’, exclusively used for venomous or aggressive species, is the term the sellers used to define their target audience, i.e. to highlight that venomous or aggressive species are too dangerous to be purchased by beginner hobbyists, requiring a certain amount of maturity or experience with exotic pets. We searched for all Brazilian native species and the main exotic venomous snake groups traded worldwide according to Hierink et al. (2020). All recorded posts were made in Portuguese. For each post, we recorded the locality of posting, the price per specimen, the species advertised and the number of specimens on sale; when not specified, we conservatively considered this to be one individual. To avoid duplication, we did not record any advertisement on the same species from the same profile in an interval of six months. For ethical considerations, we did not record the name of the vendor in our database, and we only collected information that was publicly available or that required only a simple request of access that is often granted within 24-h (following Siriwat et al., 2020). For prices, we used the exchange rate R$5.30 = US$1.0 to convert the Brazilian real into US dollars.

Official seizure data were obtained from reports from IBAMA on our request. Among the information included on the seizure reports, we compiled the species, number of individuals and date and local of the seizure. Only individuals identified by their scientific names were considered due to the high number of species that might share similar popular names (Barbosa et al., 2007; Moura et al., 2010; Lima et al., 2018). We also considered additional seizures and abandonments reported on the news, searching on Google for the name of the venomous snake species and the terms “found” and “seized” in Portuguese. The

species involved were included when their scientific names were provided, or when identification was possible through pictures. To avoid duplicated data, we prioritized the official database over media reports in case of similarity.

### 2.2. Data analysis

We first used descriptive statistics (mean and standard deviation) to present an overview of trade in venomous pet snakes and of snakebites in Brazil. We ran a Student T-test to assess the difference in the average price per individual between the two most traded genera (*Bothrops* and *Crotalus*). We ran a Generalized Linear Model (GLM) to assess, at the species level, the relationship between the total number of snake bite events and the total number of individuals recorded in the pet trade (seizures plus trade/pet ownership) per species between 2015 and 2019. In order to meet the assumptions of normality of residuals, we log-transformed both the number of snake bite events and the number of individuals recorded per species. We used the family of distribution Zero-Adjusted Gamma. Previous to all tests, we tested for normality and homoscedasticity. We considered significance at $p < 0.05$. For all statistical analysis and graphs we used R 3.6.3 software (http://www.R-project.org/), and the R-packages vegan (version 2.5–6) and ggplot2 (version: 3.3.0).

Based on the reports of snakebites, we built a map with the total number of reports considering all venomous species during the period per Brazilian city, and the locations of instances of trade, seizure or pet ownership of venomous snakes. We included a heat gradient based on Kernel Estimation Density, considering a 10 km diameter surrounding each city. We used Quantum GIS 2.18.9 (https://quantum-257 gis.en.softonic.com/) to create the map.

## 3. Results

### 3.1. Snakebites

A total of 140,929 snakebite events were reported between 2015 and 2019 in Brazil, of which at least 82% involved venomous snakes (n = 114,931), resulting in 614 human deaths (Table 1). There are no details on the circumstances in which the accident occurred, which means that is impossible to determine what fraction of the snakebites reported involved pet snakes. An annual average of 22,986 (SD 1085) snake bites by venomous snakes were recorded in the period, with *Bothrops* spp. and *Crotalus* spp. being responsible for 86% and 10% of these events, respectively (Table 1). All species identified are native to Brazil, but an additional 33,350 cases did not have the species identified. The Brazilian states with the highest concentration of snakebites were Pará, Minas Gerais and Bahia, which reported 23,928, 14,988 and 12,203 cases, respectively (Fig. 1; Appendix 1). It is noteworthy that at least 14 cases of snakebites happened between 717 and 1700 km from the species' known native distribution range, 12 in São Paulo state, and one in Santa Catarina and Rio Grande do Sul states. All of them involved species of the genus *Lachesis,* which includes mainly Amazonian species.

### 3.2. Trade and maintenance of venomous snakes as pets

Considering all sources, we recorded 241 individuals of venomous snakes being traded or kept as pets, accounting for at least 16 different species, seven native species and nine non-native species (Table 2). Although we acknowledge that correlation may not be causation, we noticed that the taxa involved in higher numbers of snakebite events, genera *Bothrops* and *Crotalus*, were also the taxa that were most often kept as a pet (GLM: Est: 0.237, St. Err = 0.091, t = 2.6, p = 0.04; Fig. 2).

We recorded 24 individuals of at least 9 different species being traded or exhibited on social media. Brazilian native species encompassed ~90% of all individuals recorded (Table 2). Based on official seizures, we recorded 60 venomous pet snakes of at least 9 different species, five native and four non-native (Table 2). Based on news reports, we recorded an additional 159 individuals seized of at least 5 different species; two of them are non-native species (Table 2). Cascabel rattlesnake *Crotalus durissus* was the most recorded species (178 individuals), followed by jararaca *Bothrops jararaca* (34), both native species. Among the exotic species, only monocled cobra *Naja kaouthia* was recorded more than once (Table 2). Considering all records, we identified at least six different cities over the country with venomous snakes being traded or kept as pets (Fig. 1); the majority of the reports were in São Paulo (38% of all reports), but the report with highest number of individuals kept as pet was recorded in Mandaguari, Parana state (92% of all individuals recorded). The place of origin of the exotic species recorded varied largely, including the Gaboon viper *Bitis gabonica,* native to Sub-Saharan Africa, the Chinese cobra *Naja atra*, native to East Asia, and the Northern copperhead *Agkistrodon contortrix*, native to Eastern North America.

The average price per pet snake was US$ 71.70 (SD 18.44), with prices not differing between the most recorded genera (*Bothrops* vs *Crotalus*, US$ 75.70 vs US$ 66.04, T-test = 0.78, df = 8, p = 0.46). The most expensive pet snake advertised was a *B. jararacussu* priced at US$ 113.21, and the cheapest was a *B. jararaca* priced at US$ 47.17. In addition, we recorded a Brazilian YouTube™ channel devoted to exhibiting snakes as pets, with three videos showing three venomous pet snakes (*Bothrops moojeni*, *Bothrops alternatus*, and *Bitis gabonica*), totalling over 77,000 views as of September 5, 2020.

## 4. Discussion

Increased access to the Internet has enhanced online pet trade worldwide and promoted access to animals that were previously rare to find and buy, such as venomous snakes (Hierink et al., 2020). Given that one of the alleged motivations of having a venomous animal as a pet is related to the social status of keeping a dangerous animal, social media also allows owners to show off the specimen and their ability and audacity while handling the animal. This matches with the stereotypical profile of the owner-victims of exotic snakes in the USA and Europe, young men, often hypermasculine, tattooed, and that frequently had used alcohol before the accident (Warrell, 2009). In addition to being a serious conservation concern for some target species and the environment, especially when in synergy with other impacts, such as habitat

**Table 1**
Details on the records of snake bite events per year and genera, and the number of deaths resulted from the snake bites from the Brazilian Ministry of Health through the Notifiable Diseases Information System platform (SINAN). All reported taxa are native to Brazil.

| Year | Total snake bites | Total venomous snakebites | Genera | | | | | Deaths |
|---|---|---|---|---|---|---|---|---|
| | | | *Bothrops* | *Crotalus* | *Lachesis* | *Micrurus* | Not identified | |
| 2019 | 30,482 | 24,453 | 20,897 | 2610 | 620 | 326 | 3680 | 159 |
| 2018 | 28,641 | 23,184 | 19,859 | 2513 | 549 | 263 | 3342 | 119 |
| 2017 | 28,500 | 23,373 | 20,134 | 2485 | 477 | 277 | 3229 | 113 |
| 2016 | 26,365 | 21,596 | 18,677 | 2162 | 516 | 241 | 3267 | 116 |
| 2015 | 26,941 | 22,325 | 19,453 | 1949 | 715 | 208 | 3157 | 107 |
| Total | 140,929 | 114,931 | 99,020 | 11,719 | 2877 | 1315 | 16,675 | 614 |

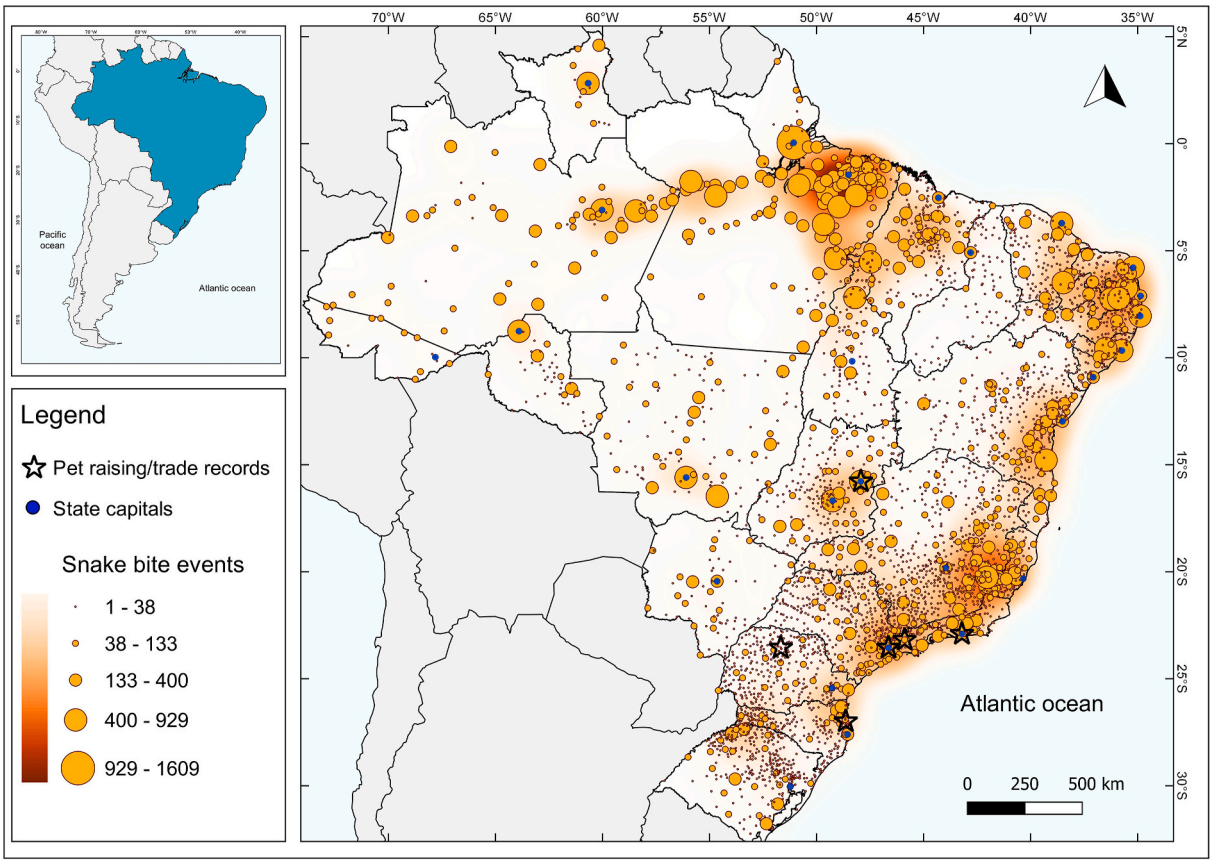


**Fig. 1.** Map of the occurrence of snakebite events per Brazilian city considering all venomous species between 2015 and 2019, and regions where we recorded trade advertisements, pet ownership or seizure of venomous snakes.

loss and fragmentation, this segment of the pet trade also poses risks to public health. Despite being illegal, the ownership and trade in venomous reptiles as pets has increased in Brazil over the last few years (Alves et al., 2019). The illegal possession of venomous animals, especially snakes, has been occasionally reported since 2007, based on official seizures and voluntary surrender (Souza et al., 2007; Magalhães and São-Pedro, 2012; IBAMA, 2019). By interviewing owners on social media, Alves et al. (2019) recorded three venomous snake species not included in our study, while we complement their list with an additional 10 species. In sum, so far there are at least 19 venomous snake species and 9 genera recorded as pets in Brazil.

Worryingly, the taxa responsible for the majority of snakebite events in the country coincide with the ones most frequently raised as pets. Thousands of snakebites occur annually in Brazil, causing hundreds of deaths or permanent injuries to survivors, even upon treatment (Bertolozzi et al., 2015; WHO, 2019). Agricultural workers, particularly men between 20 and 59 years-old, and rural inhabitants, are the most affected by snakebites in Brazil (da Silva et al., 2015). We acknowledge here that correlation is not causation, and that pet snakes are possibly responsible for only a minimal proportion of the total snakebites reported. However, the lack of details on the circumstances of the accident impedes a proper estimative of the importance of pet snakes within the accidents reported. Nonetheless, ownership of venomous pet snakes adds potential risks to a situation that is already a concern from the public health point of view (Warrell, 2009; (Gutiérrez et al., 2010); WHO, 2019). Only Brazilian native species were reported in the database, but considering that the taxa identification is often made by the healthcare based on the clinical diagnose (symptoms) of the patient, some species may be misidentified. In this sense, exotic pet species are harder to identify and may account for some of the non-identified species in the database. Records of snakebites outside the species known natural range, for instance, if correctly identified, are unlikely to be a natural accident in the wild and may be a consequence of pet ownership too. Nevertheless, the possibility of misidentification should still be considered, since such accidents would have required specific antivenom that is not regionally available, thus being likely reported by the media.

*Bothrops* species stand out as the most recorded taxa on online pet trade advertisements, while *Crotalus* species stand out as the most seized taxa as a pet; together, these taxa are responsible for 96% of the snakebites across Brazil. The wide distribution and high abundances of the genus *Bothrops* in the wild (Melgarejo, 2009) may turn the group into a promising target for the pet market through the ease of obtaining wild-caught individuals at the same time that favours the risk of encounters in rural areas that results in a snakebite (Silva et al., 2020). It is noteworthy to address the genus defensive behavior, since most *Bothrops* species occurring in Brazil possess a cryptic coloration that aids in their outstanding camouflage. Once approached by an unaware predator or human, these snakes are prone to strike when there is no escape route available (Araujo and Martins, 2006), which leads to accidents where people end up accidently stepping on the animals and consequently being bitten. This defensive behavior might be especially dangerous to snake keepers, since the animals are usually kept in closed spaces like boxes and terrariums.

*Bothrops* currently comprises 27 different species, including *B. pirajai* from northeast Brazil that is currently classified as Vulnerable, and the endemic *B. insularis* and *B. alcatraz* that inhabit islands very close to São Paulo coast, both Critically Endangered according to the International Union for Conservation of Nature (IUCN). Martins et al. (2008) presented evidence that the removal of *Bothrops insularis* from its insular habitat is responsible for the species' population decline, and found that there were people at the Santos city harbour willing to pay U$30.000 for

**Table 2**
Number of individuals of venomous snakes recorded in the pet trade or pet ownership in Brazil according to the species and the type of record, and the average advertised prices.

| Species | Origin | Quantity | Type of record | Price per individual in US$ (SD) |
|---|---|---|---|---|
| **Jararaca *Bothrops jararaca*** | Native | 3 | Advertisement | 69.06 (23.74) |
| | | 2 | Owner | – |
| | | 29 | Seizure | – |
| **Jararacussu *B. jararacussu*** | Native | 1 | Advertisement | 113.21 (0) |
| | | 1 | News report | – |
| **Brazilian lancehead *B. moojeni*** | Native | 1 | Advertisement | 66.04 (0) |
| | | 1 | Seizure | – |
| **Urutu *B. alternatus*** | Native | 1 | News report | – |
| | | 3 | Seizure | – |
| **Whitetail lancehead *B. leucurus*** | Native | 2 | Advertisement | 66.04 (0) |
| **Lancehead *Bothrops* sp.** | Native | 1 | Advertisement | – |
| | | 1 | Owner | – |
| | | 1 | News report | – |
| | | 1 | Seizure | – |
| Total *Bothrops* | | **48** | | – |
| **Cascabel rattlesnake *Crotalus durissus*** | Native | 3 | Advertisement | 66.04 (0) |
| | | 6 | Owner | – |
| | | 155 | News report | – |
| | | 13 | Seizure | – |
| | | 1 | Seizure/News report | – |
| **Rattlesnake *Crotalus* sp.** | Native | 4 | Seizure | – |
| Total *Crotalus* | | **182** | | |
| **Bushmaster *Lachesis muta*** | Native | 1 | Seizure | – |
| Total *Lachesis* | | **1** | | |
| **Monocled cobra *Naja kaouthia*** | Non-native | 2 | Seizure/News report | – |
| **Chinese cobra *N. atra*** | Non-native | 1 | Advertisement | – |
| Total *Naja* | | **3** | | |
| **Gabon viper *Bitis gabonica*** | Non-native | 1 | News report | – |
| **Rhinoceros viper *B. nasicornis*** | Non-native | 1 | Seizure | – |
| Total *Bitis* | | **2** | | |
| **Vogel's pit viper *Trimeresurus vogeli*** | Non-native | 1 | Seizure/News report | – |
| **Barat bamboo pit viper *T. sabahi*** | Non-native | 1 | Seizure | – |
| Total *Trimeresurus* | | **2** | | |
| **King cobra *Ophiophagus hannah*** | Non-native | 1 | Seizure/News report | – |
| Total *Ophiophagus* | | **1** | | |
| **Inland taipan *Oxyuranus microlepidotus*** | Non-native | 1 | News report | – |
| Total *Oxyuranus* | | **1** | | |
| **Lichtenstein's green racer *Philodryas olfersii*** | Native | 1 | Seizure | – |
| Total *Philodryas* | | **1** | | |
| TOTAL | | **241** | | |

an individual. Therefore, the venomous snake pet market may lead to the reduction of some populations, putting species at risk and adding threat to the conservation of sensitive or already endangered snake species.

Although recorded in this study in lower quantities than native taxa, the variety of exotic species raised as pets is substantial. Occurrences of bites by exotic pet snakes have been reported in North America (Warrick et al., 2014), Europe (de Haro, 2014), and Asia (Wong et al., 2009). A worldwide challenge when dealing with snakebites by exotic species is the low availability or even complete absence of specific antivenom serum, together with the limited experience of local healthcare (Hierink et al., 2020), which are potentially life threatening for the patients. In July 2020, an Brazilian pet owner was bitten by an illegally-owned monocled cobra *Naja kaouthia* when handling the animal. However, Brazil does not produce antivenom for cobras, since their possession is not expected to occur in the country. The owner-victim received a single sample of antivenom stored in the country for research purposes, and additional samples had to be imported from the USA to complete the treatment. He has been recovering after a period of coma but remains severely affected with sequelae. The repercussion of this accident led to a country-wide discussion on the hidden pet trade and further investigations that dismantled a huge operation of snake trafficking in Brazil (Agence France Presse, 2020).

Poor information and identification of snakes by sellers and buyers is also a major issue. The lack of knowledge about the biology and ecology of species by owners may lead to violations of welfare directives, which may lead to a mortality rate that can reach up to 75% due to inadequate care (Toland et al., 2012). Inadequate care may also lead to higher rates of abandonment, escape and inappropriate release of the animals in urban environments or in a nearby forested area, posing risks to humans and native species. Several improperly introduced non-venomous pet snakes have turned into an environmental problem by becoming invasive species and competing or predating native species, such as *Python bivittatus* in the USA, *Pantherophis guttatus* in Australia and the notorious case of the brown catsnake *Boiga irregularis* in Guam Island, which was responsible for extirpating the majority of the native birds from the island (McFadden et al., 2017; Siers et al., 2017; Harvey and Mazzotti, 2019). In Brazil, two individuals of *Pantherophis guttatus* were recently found in Bahia on different occasions (Fonseca et al., 2014). It has been shown that common pet species, such as *Pyhon bivittatus* and *Pantherophis guttatus*, have a concerning potential of establishment in Brazil (Fonseca et al., 2017). The impacts could be immeasurable and even more serious in case of venomous species become invasive.

Imports of venomous snakes and pet ownership has been prohibited in Brazil for over two decades (1998); however, our findings indicate that the law is often not enforced sufficiently. Given its large area, keeping efficient surveillance in the entire Brazilian territory is challenging. In addition, wildlife crimes such as collecting native specimens from the wild or trafficking prohibited and protected species are not considered a serious crime in Brazil. According to the United Nations Convention against Transnational Organized Crime, serious crimes are those punishable by a minimum of four years in prison, while the penalty in Brazil for catching or trafficking wild species varies from administrative penalties to three months, or sporadically three years, in prison (Environmental crime law nº 9.605/1998). We therefore recommend amendments in the legislation that focus on increasing penalties for wildlife traffickers and, possibly, owners that break the law. Additional actions, such as training personnel in order to increase the accuracy of snake identification and proper release spots for removal of unwanted or seized snakes, could be beneficial for the conservation of these species and to avoid risking biological invasions by snakes. Finally, to discourage new purchases or the maintenance of current venomous snake, massive public campaigns must address the potential risk of keeping venomous snakes as pets by informing the serious damages made by different types of venom in the human body and warning owners about the risk posed to other people in case of abandonment or escape of the individuals kept as a pet.

## Author contributions

**Daniel Zani La Laina** and **Thais Q. Morcatty:** Conceptualization, Data curation; Methodology, Analysis, Writing - original draft. **K.A.I. Nekaris** Writing - review & editing. **Vincent Nijman:** Writing - review & editing.

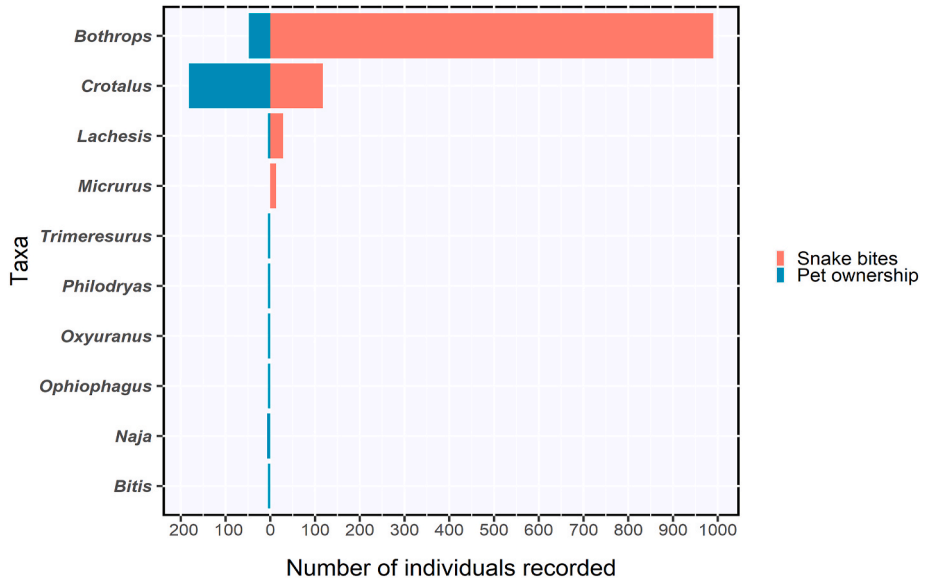


**Fig. 2.** Comparison between the number of snake bite events (in thousand events; red bars, right side) and the number of individuals recorded as being traded or raised as a pet (blue bars, left side) per snake genus. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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