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Incidence and characteristics of crocodilian incidents on humans in Brazil in the period 2000–2022

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Brazil has the largest diversity of crocodilians in the world, with six species present in the country. Considered as opportunistic generalist predators, these animals occupy the top of the food chain in river ecosystems. Anthropic actions result in an impact both on habitats and on the behaviour of the crocodilians, in addition to facilitating the encounter between humans and crocodilian species. In this study, we evaluated the characteristics of alligator incidents on humans in Brazil during the years 2000–2022. We used online platforms for scientific articles and news, collecting information about the victims, the species involved, and the locality of occurrence. We found 86 records of incidents, of which 18 resulted in the victim's death. The Amazon biome encompass the highest number of incidents, and the black caiman *Melanosuchus niger* was the species involved most. Most incidents (n = 35) occurred with people who were fishing or on boats. Considering the size of the country's population, alligator incidents on humans in Brazil can be considered rare, but they should not be overlooked. The advancement of activities that degrade the environment, causing imbalances, can cause an increase in the likelihood of encounters and, consequently, incidents, which usually generates critical medical problems and negative consequences for the populations of these animals.

Keywords: Alligator, attack, bite, Caiman, *Melanosuchus*

INTRODUCTION

Crocodilian attacks on humans are considered rare, and when they do occur, they are mainly caused by the improper approach or non-visualisation of the animal (Caldicott et al., 2005; Bury et al., 2012). The incidents caused by these animals can be categorised into territory defense, nest and/or nest defense, self-defense, hunting and mistaken identity (Caldicott et al., 2005). Worldwide, the vast majority of reported cases are related to incidents caused by crocodilians considered to be large (Caldicott et al., 2005), such as the Nile crocodile *Crocodylus niloticus* Laurenti, 1768, saltwater crocodile *Crocodylus porosus* (Schneider, 1801), and american alligator *Alligator mississippiensis* (Daudin, 1802). In Brazil, the species most involved in this type of incident are the black caiman *Melanosuchus niger* (Spix, 1825). In non-fatal cases, the bite of these animals can lead to morbidity and necrosis (Da Silva et al., 2010). Another concern is the potential for infection caused by micro-organisms present in the mouths of these animals (Flandry et al., 1989; Burgess et al., 1997).

Crocodilians, in general, are opportunistic predators (Somaweera et al., 2020) and are considered to be at the top of the food chain in river ecosystems in Brazil (Bataus et al., 2013). These animals have an ontogenetic variation in their diet, which consists of invertebrates in the juvenile phase, and of vertebrates, such as fish and mammals, in the adult phase (Tucker et al., 1996; Da Silveira & Magnusson, 1999; Melo, 2002; Borteiro et al., 2009). Young or smaller individuals of crocodilians can be easily seen in urbanised environments (Beal & Rosenblatt, 2020; Mascarenhas Jr. et al., 2021).

Six species of crocodilians live in Brazil, all belonging to the Alligatoridae family (Costa & Bérnils, 2018). The largest species, *M. niger*, known locally as 'jacaré-açu' (black caiman), can exceed five metres in length (Thorbjarnarson, 2010), and is distributed mainly the Amazon region (Marioni et al., 2013). The species *Paleosuchus palpebrosus* (Cuvier, 1807), or 'jacaré-paguá' (dwarf caiman) and *Paleosuchus trigonatus* (Schneider, 1801), or 'jacaré-coroa' (crown alligator), rarely exceed two metres in length and inhabit much of the Brazilian territory (Costa & Bérnils, 2018). *Caiman latirostris* (Daudin, 1801), or 'jacaré-do-papo-amarelo' (broad-snouted caiman), has a wide distribution in Brazil.*Caiman yacare* Daudin, 1802, or 'jacaré-do-Pantanal' (yacare caiman), occurs in the Pantanal region (Medem, 1983). Finally, the *Caiman crocodilus* species (Linnaeus, 1758), or 'jacaretinga' (common caiman), occurs in all states in the north and central west regions of Brazil. These last three species are considered small to medium-sized, reaching up to three metres in length (Brazaitis, 1973).

Currently, no Brazilian species of crocodilians are considered threatened (ICMBIO, 2018). This can be explained by the implementation of environmental laws

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and conservation programs (Da Silveira & Thorbjanarson, 1999), which successfully reversed the results of overhunting that occurred in the 1970s (Rebêlo & Magnusson, 1983). However, the conservation of these animals remains affected by poaching and the loss of their natural habitats (Mittermeier et al., 2004; Marques et al., 2016). The advancement of urbanisation has caused negative effects, such as the ingestion of anthropic residues by animals (Dutra-Araújo et al., unpublished data), and the reduction in the size of crocodilian populations (Abercrombie & Verdade, 2002; Filogonio et al., 2010). In addition, deforestation, pollution, and the consequent decrease in the number of natural prey species are factors that directly and indirectly increase the likelihood of these animals encountering humans (Campos et al., 1995; Da Silveira & Thorbjanarson, 1999; Campos & Mourão, 2006; Magnusson & Campos, 2010; Dutra-Araújo et al., unpublished data).

In several regions of Brazil, crocodilians have a bad image. For fishermen, they are often considered as a competitor, which may even cause damage to fishing nets (Barboza et al., 2013). For others, these animals are considered a great threat because they are large and predatory, or even because of the lack of knowledge about them, causing incidents with animals or humans (Pooley et al., 2021). These negative relationships between crocodilians and humans are relatively well documented all over the world (Caldicott et al., 2005; Dunham et al., 2010; Bergamasco et al., 2018; Das & Jana, 2018; Grajales & Silva, 2018; Woodward et al., 2019; Sideleau et al., 2021). However, conservation strategies for crocodilian species involve measures of peaceful coexistence with humans, depending on the quantitative documentation, spatialisation, and understanding of the characteristics of these interactions.

In this study, we compiled all the incidents caused by crocodilians on humans, which occurred in Brazil, analysing the general characteristics of these negative interactions.

MATERIALS & METHODS

We performed searches of online databases (Google Scholar, Lilac, and Pubmed), using the words: attack, alligator, crocodilians, and Brazil. We consulted the Worldwide Crocodilian Attack Database (Crocbite), which is associated with Australia's Charles Darwin University, filtering the records that have occurred in Brazil. We also conducted searches of online news sites on Google, with the sentences: alligator attack, alligator bite, and alligator accident, in addition to their Portuguese versions, accompanied by the names of all Brazilian states. We performed all searches from January 2020 to December 2022. We only considered records that reported the presence of witnesses, in addition to prioritising records present in more than one media outlet, or that were found in reputable news programs. For the purpose of comparison with the number of fatalities caused by other animals and the number of homicides, we consulted data from the information system for notifiable diseases (Sinan), the International Shark Stack File (ISAF) and the Brazilian Public Security Forum (FBSP).

The term 'incident' in this paper includes actions from the animal attacking or defending itself, many of which are not easily distinguishable from each other. In this way, we considered 'attacks', as sudden actions or bites from crocodilians involving human beings without any apparent provocation or threat beforehand. We considered unintentional incidents, when the animal reacted to a possible threat from the human being, which can be considered self-defense. We did not use data from attacks intentionally provoked by human beings, such as an attempt to capture, handle or harm the animal. We also disregarded attacks that have been carried out by animals in captivity. We compiled the results highlighting information such as the age of the person affected by the incident, date of the incident, location, and identification of the crocodilian. We searched for the most accurate location co-ordinates, using the information available in the news and articles, and for the elaboration of the map, we used the software QGIS version 2.18.9 'Las Palmas.'

We categorised the activities or situations in which the victims or animals were at the time of the incidents, such as: fishing or in boats, near the water; swimming in or in the water; situations in which the animal felt threatened; and when cleaning fish. To calculate the average number of incidents per year, we used the number of records between the period from 2000 to December 2022, and to compare with the deaths caused by other wild animals, we used data from 2010 from though 2020. The victims' age groups were divided into 10-year intervals. The analyses on the months in which the attacks occurred were carried out only for the Amazon biome due to the low number of attacks that occurred in the other biomes.

We obtained information about the seasonal distribution of the number of attacks by crocodilians in the Amazon biome using circular statistical analysis (Zar, 2010), using ORIANA 4:02 program (Kovach, 2009). The months were converted into angles (30° intervals), and the number of attacks observed in each month was considered as their frequency in each angle (month) (Prudente et al., 2014). From this method, the following values were estimated: a) average vector (μ); b) length of the average vector (r); c) circular standard deviation (SD) in relation to μ; and d) Reyleigh's Uniformity Test. The Rayleigh uniformity test (Zar, 2010) calculates the probability of the data being uniformly distributed ($P > 0,05$) (null hypothesis). A significant result of the Rayleigh Uniformity Test ($P < 0,05$) indicates that the data is not evenly distributed.

RESULTS

We recorded a total of 86 cases of crocodilian incidents on humans in Brazil during 2000–2022, 76 of which were unprovoked attacks, ten unintentional attacks, of which only three records came from scientific articles (Supplementary material).

We highlight a record of a fatal attack in 1886 in Iguape, state of São Paulo, where a boy died from serious injuries

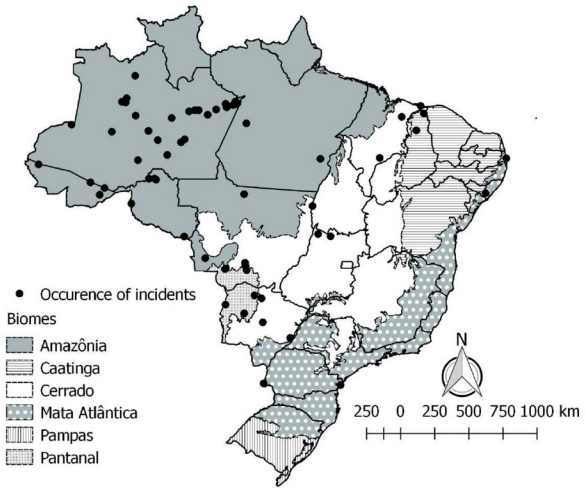

Figure 1. Spatial distribution of records of human crocodile incidents from 2000 to 2022 in Brazil

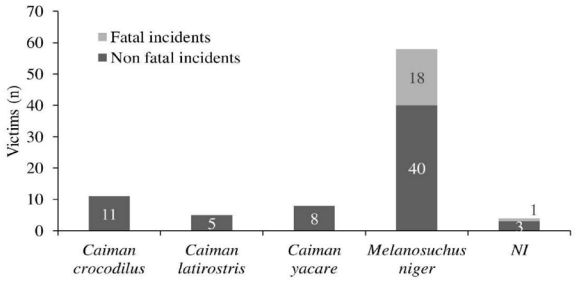

Figure 2. Identification of the species of crocodilians involved in incidents on humans in Brazil, from 2000 to 2022. NI: Not identified

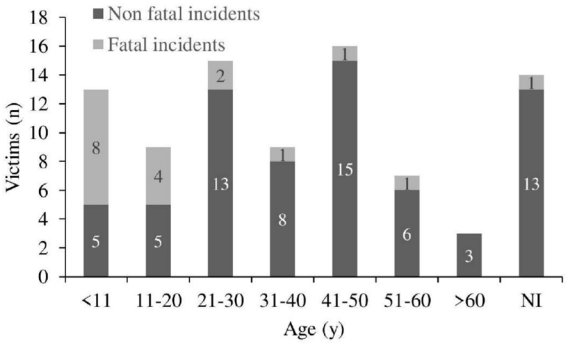

Figure 3. Age classification of victims of incidents by crocodilians in Brazil. NI: Not identified

caused by *C. latirostris*. Eight records where individuals of *M. niger* were found with human parts in their stomach, or pieces of clothing from the victims in their jaws, however, the cause of death cannot be confirmed; the animal may have fed on bodies from drowning or other causes, considered as an occasional event. Both data were not included in the analyses.

The Amazon is the Brazilian biome that concentrates the largest number of records, with 70 % (n = 61) of incidents and 94 % (n = 17) of deaths. The Cerrado biome had the second highest number of records, being a fatal incident, while in Pampas, in the south of Brazil, it is the only Brazilian biome with no records of incidents by crocodilians (Fig. 1 and Table 1).

Table 1. Records of accidents by crocodilians in Brazil from 2000 to 2022

Biome	Fatal accidents	Non fatal accidents	Total accidents per biome
Amazônia	17	44	61
Caatinga	0	3	3
Cerrado	1	10	11
Mata Atlântica	0	4	4
Pantanal	0	7	7
Pampa	0	0	0
Total	18	68	86

Of the six species of crocodilians that occur in Brazil, four were involved in incidents on humans: *C. crocodilus*, *C. latirostris*, *C. yacare* and *M. niger*. In four of the cases, the species could not be identified, being registered as "alligator". The *M. niger* species was the main species involved in incidents, with 67 % of the records (n = 58) being responsible for all the deaths caused by incidents by crocodilians in Brazil, during 2000–2022 (Fig. 2).

Most incidents (n = 16; 18 %) occurred in people aged between 41–50 y, one being fatal. The under 11-y age group had the highest number of fatal incidents (n = 8; 39 %). The age group over 60-y was the only one that did not present any records of fatal incidents. Of all records, 14 did not report the victim´s age (Fig. 3).

In most incidents the victims were fishing or on boats (n = 35; 40 %). In other cases, with people swimming or being present in the water (n = 21; 23 %); were close to the water (n = 18; 22 %); animal felt threatened (n = 9; 11 %); or cleaning fish (n =3; 4 %) (Table 2).

There was a statistically significant difference between the number of records and seasons (p = 0.002). In the Amazon biome, most incidents occurred in the rainy season, between the months of September and December (n = 35; 57 %) (Fig. 4). During the drought period, between April and June, there was a lower number of recorded incidents (n = 6; 8 %).

In the period from 2000 to December 2022, there were a total of 86 crocodilian incidents in Brazil, with an average of 3.7 ± 3.2 incidents per year, of which 22 % resulted in deaths (n = 19; $\bar{x}$ = 0.8 ± 0.7). Comparing with the records of deaths caused by other wild animals in Brazil, during the period 2010–2020, we found that the number of people killed by crocodilians was lower when compared to deaths by snakes, scorpions, bees, and spiders, surpassing only incidents by sharks (Fig. 5). On the other hand, the number of deaths caused by all these animals added together is not close to the number of intentional homicides that occurred in Brazil, only in 2019 (Fig. 5).

DISCUSSION

The reported cases of crocodilian incidents in Brazil may be underestimated due to the absence of a formal record

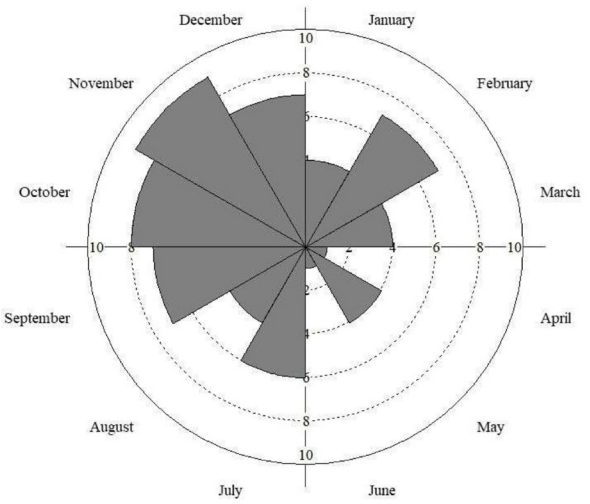

Figure 4. Rose diagram of the circular analysis showing the seasonal distribution of the number of incidents by crocodilians in the Amazon biome

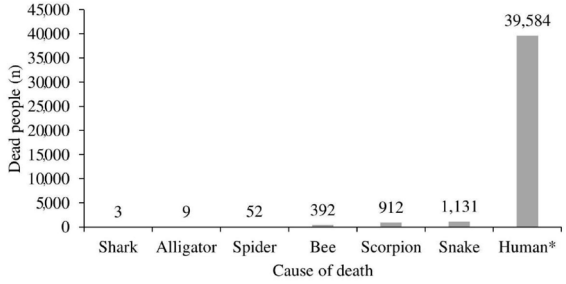

Figure 5. Number of deaths in the period 2010–2020 in Brazil. Number of homicides only in the year 2019. Sources: Ministério da Saúde - Sistema de Informação de Agravos de Notificação - Sinan Net, and Forum Brasileiro de Segurança Pública

Table 2. Activities or situations in which the victim was engaged in at the time of the crocodilian incident

Activities	Incidents (n)	Incidents (%)
Fishing and/or by boat	35	40 %
Swimming or in water	21	23 %
Near the water	18	22 %
Animal felt threatened	9	11 %
Cleaning fish	3	4 %

system, especially when it does not result in serious injury or the death of the victim. In addition, many incidents take place in areas far from large urban centres and areas difficult to access. A platform with official and detailed records could provide full conditions for more detailed studies, such as those in the United States (Woodward et al., 2019). Even so, Brazil is the country with the most crocodilian bite records in South America (Pooley et al., 2021).

During the period 2000–2022, the average number of incidents observed in this study (3.7 / year) was small when compared to other regions, such as Indonesia or India with *C. porosus* (Das & Jana, 2018; Sideleau et al., 2021), or Mozambique, caused by *C. nyloticos* (Dunham et al., 2010). Our results were close to those obtained in Florida (United States) caused by the *A. mississippiensis* (Woodward et al., 2019), and were only higher than those obtained in Australia (Caldicott et al., 2005), by *C. porosus* and by *C. acutus*, in the coastal region of Oaxaca in Mexico (Grajales & Silva, 2018).

Melanosuchus niger was involved in more than 67 % of incidents, and responsible for all fatal incidents that occurred in Brazil. Studies points out that larger adult individuals remain in their habitat, being indifferent to human presence (Medem, 1981). The increase in the natural habitat degradation increases the possibility of human contact with wild animals, both due to competition for space as well as attacks on domestic animals and people (Dunham et al., 2010). Another relevant factor is the population density of *M. niger* which, in some isolated regions in the Amazon, has had a very expressive increase in recent years (Da Silveira, unpublished data, 2001), which may have caused an ecological imbalance in relation to the number of natural preys, as also seen in Florida and Australia with *A. mississippiensis* and *C. porosus*, respectively (Caldicott et al., 2005; Woodward et al., 2019).

Because it is a large species, deaths caused by *M. niger* involving children aged 0-10 y can be considered as predation. This can be reinforced by the fact that *M. niger*, like other predators, prefers to attack young or elderly prey (Cott, 1961; Caldicott et al., 2005). Because they are smaller and more fragile, children tend to die when compared with adults, which is why this age group has such a high proportion of fatalities, which was also observed in Mexico (Grajales & Silva, 2018). The 41–50 y age group has the highest number of incidents and corresponds to the age group with the largest number of fishermen in the Amazon (Inomata & De Carvalho, 2018), the main region of crocodilian incidents.

Most of the victims were fishing or were on boats. Such an observation, added to the victims who were cleaning fish, has also been noted in other studies in Malaysia and Australia (Steubing, 1983; Caldicott et al., 2005). The smell or movement of fish, the main component of the diet of adult crocodilians (Magnusson et al.,1987), can attract these animals as they are opportunistic predators (Somaweera et al., 2020). Their diet varies according to their size, in addition to changing their feeding behaviour according to the availability and abundance of prey (Horna et al., 2003). Thus, attacks on people who were swimming, or were in the water, can be considered an attempt at predation. This information can be reinforced by the high number of fatal attacks on children, as seen above. It is common, in the Amazon and in other parts of Brazil, for children to use rivers as places of play or recreation, especially during the rainy season (Brandão et al., 2020), staying longer in the rivers and, consequently, more time exposed to these predators, causing attacks. Crocodilians

are extremely territorial, especially when in the presence of nests (Caldicott et al., 2005), which may explain attacks on people close to the shore. The other situations can be characterised as incidents related to the animal's defense reflex.

We observed that, in the Amazon, the number of incidents accompanies the rainy season, with more records occurring during the rainy season, which runs from November to March (Fisch et al., 1998). This may be related to the fact that, during the rainy season, there is a natural expansion of the dispersion of these animals due to flooded rivers (Rebêlo & Lugli, 2001), increasing, therefore, the likelihood of encounters between these animals and riverside residents. In addition to the increase in river levels, the nesting period for Amazonian crocodile species occurs at the end of the drought period, starting in September (Herron et al., 1990), making crocodilians more aggressive (Pooley, 2015). These results were similar to those obtained for *Crocodilus acutus* (Grajales & Silva, 2018).

Comparing with the available data on animal deaths in Brazil, crocodilians, in general, are involved in fewer cases than, for example, snakes, bees, scorpions, and spiders, the main venomous animals in Brazil, which can cause death by inoculation of toxins, but which may have their action aggravated by the victim's health characteristics (White, 2010). Crocodilian attacks are more like those of sharks due to large lacerations, excessive bleeding, and serious secondary infections due to the dentition, strength of the jaws and microbiota present in the animal's mouth (De Campos et al., 2013), and both have low numbers of cases during the period 2010–2020.

Although such animals are seen as villains by the general population, the number of deaths caused by them in 10 years is extremely low when compared, for example, to the number of homicides that occurred in Brazil, for only 2019. This shows that the Brazilian population still lacks basic knowledge about the function of the natural environment that surrounds it. Humans have a natural fear of the unknown, that is, a propensity to feel fear, caused by the absence of information perceived at any level of consciousness or point of processing (Carleton, 2016) and, from that fear, actions against the components of nature, in an act that it considers as defense, causing damage that is often irreparable. In this sense, animals are killed because they are considered 'extremely' dangerous, even those that science considers harmless. This commonly occurs with snakes, which makes the act of encouraging the general population to accept conservation programs for snakes, for example, become a difficult task due to the bad reputation that snakes have in various regions of the world (Santos-Fita et al., 2010; Maschio et al., 2016), even though most snakes are admittedly harmless.

Environmental education practices carried out with local populations should be an alternative for people to be properly educated and instructed on the importance of the different components of nature (Silva & Junqueira, 2007), including crocodilians. Likewise, it is necessary to instruct them in relation to the necessary care that they must take when they live in the same environment in which these animals are found. This could certainly reduce the conflict between humans and crocodilians (Moura et al., 2010), while also reducing potential incidents caused by this encounter (Pooley et al., 2021).

The relationship between crocodilians and humans is still poorly documented in Brazil. The lack of systematisation and detailing of incident records ends up hindering accounting, and analysis. The use of data from local news and newspapers, although they do not have the same degree of rigor as scientific articles, can be an important source of data, in topics with a lack of studies. Adequate documentation is important for species conservation strategies, and for infrastructure development and the well-being of the human population, who live in areas that overlap with the distribution of crocodilian species. The coexistence between animals and humans is part of the global theme of sustainable development and should be encouraged (Kônig et al., 2020). For this it is necessary to understand and analyse the real conflicts, with greater incentives for public policies, with the use of protocols, studies aimed at the conservation and preservation of crocodilians (Pooley et al., 2021).

Crocodilian incidents are rare in Brazil, and the number of deaths caused by them is very small when compared to incidents involving other animals. Most incidents are related to the possibility of facilitating feeding, such as catching fish already caught by humans, or as a defense mechanism. We emphasise the need for further studies and greater systematisation of incidents involving crocodilians. Furthermore, studies on the impacts of habitat destruction and fragmentation on these animals are essential to propose environmental education programs that help to minimise ecological and behavioral changes in animals, allowing for a more harmonious coexistence between humans and crocodiles.

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