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Research Article

Trends of Attacks on Humans by Protected Crocodiles Along Rivers and Associated Habitats in Borneo Island

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ABSTRACT

In the human-crocodile conflict, crocodile attacks on humans pose a serious threat and are becoming a complex conservation challenge in many countries. This study investigates the status and trend of crocodile attacks on humans in Malaysian Borneo (i.e., Sabah and Sarawak) where rivers and estuaries are inhabited by protected crocodile populations. Results show that between 2001 and 2020, a total of 205 attacks were reported which equals an average of nearly 11 cases per year. The number of attacks in Sarawak is estimated to be between 135 to 164 cases which is twice ($p < 0.05$) as high as in Sabah (70 cases), indicating a more serious human-crocodile conflict in the former. In Sabah, most of the attacks (81% or 57 cases) ($p < 0.05$) were in the districts of Lahad Datu, Kinabatangan, Tawau and Sandakan while in Sarawak (82% or 60 cases) ($p < 0.05$) were in Miri, Sri Aman, Kuching and Betong. Almost 80% (173 cases) of the victims were men between the ages of 30 and 39 who were fishing (42%) ($p < 0.05$) or bathing (27%) before the attack suggesting that such activities are risky and should be avoided in areas inhabited by crocodiles. Fatality rates of crocodile attacks have been increasing in recent years (i.e., 2015 – 2020) with an average of 10 cases per year. Therefore, control over the number of crocodile populations, especially the large-sized and dangerous individuals, needs to be implemented in high-risk areas. More research is needed to understand the capacity of their habitats to support optimal populations density and minimize conflicts with humans.

Keywords: Crocodile attacks; Protected crocodile populations; Rivers of Borneo Island

Introduction

The human-crocodile conflict is critical, especially in countries with naturally high crocodile populations (Amarasinghe et al., 2015; Patro & Padhi, 2019). In the past, crocodiles were hunted for their valuable hides, mainly in the production of leather goods that generate a lucrative income in addition to meat and eggs as by-products (Stubbs, 1998; Thorbjarnarson, 1999; Tisdell & Nantha, 2007). The increased demand for crocodile products prompted intensive hunting, which resulted in the population declining drastically in most countries, especially in the late 1980s (Webb et al., 1984; Saalfeld et al., 2015; Patro & Padhi, 2019). This is further exacerbated by the loss of their natural habitat due to competition with the ever-growing human population (Amarasinghe et al., 2015; Saalfeld et al., 2015; Grigg & Kirshner, 2015; Walker, 2016). In Sulawesi, for example, saltwater crocodiles were once widely distributed abundantly throughout the province. However, they were significantly depleted due to hunting and loss of habitat (Platt et al., 2007; Sideleau, 2016a). As a result of uncontrolled human activity, coupled with low survival rates mainly due to aggressive predation among juveniles, crocodiles are at risk of species extinction (Lang, 1987; Grigg & Kirshner, 2015; Walker, 2016). Concerns over the extinction of the species led to the idea of conserving crocodiles and their natural habitats around the world (Read et al., 2004; Mazzotti et al., 2007; Fukuda et al., 2015; Walker, 2016).

In many countries, conservation programmes have successfully restored crocodile populations to at least their optimal numbers, while in some countries, they are becoming increasingly dense and uncontrollable. As a result, cases of attacks on humans by crocodiles, which are considered an endangered species and need to be protected, are increasing (Fukuda et al., 2011; Sideleau & Britton, 2012; Fukuda et al., 2015). Crocodile attacks pose a serious threat and often result in serious injury to the victim, or even death (Gruen, 2009; Wamisho et al., 2009; Aust et al., 2019). Indeed, this conflict has made all crocodile species, including those that are less dangerous to humans, viewed with fear and usually with very negative perceptions (Treves et al., 2006; Fukuda et al., 2015). To date, crocodile attack on humans has been identified as a potential threat to its conservation approaches and alternatives to address this conflict are through prudent management strategy (Grajales & Silva, 2018; Murray et al., 2020). Certainly, this requires an in-depth study, especially the status and trend of crocodile attacks on humans in the areas concerned.

Malaysian Borneo, comprising the states of Sabah and Sarawak, is located on the island of Borneo, bordering the Indonesian province of Kalimantan. It has a large

ecosystem of rivers and estuaries and is a natural habitat for crocodiles (Cox & Gombek, 1985; Tisen et al., 2013). These two states have embarked on crocodile conservation programmes by enforcing legal protections against this threatened species since the mid-1980s. The programme has generally been successful in restoring their populations. However, at the same time, it has led to human-crocodile conflicts, in particular attacks on communities living along rivers and estuaries that use these ecosystems in their daily life (Tisen et al., 2013). Information on crocodile attacks in Malaysian Borneo, especially in the state of Sabah is lacking. On the other hand, existing literature is insufficient to understand and further manage human-crocodile conflicts in these developing states with a growing human population (e.g., Abdul Gani et al., 2022). This study evaluates the status and trend of attack cases on humans by crocodiles, a threatened and protected species in Malaysian Borneo. It determined the geographical distribution, time of occurrence, yearly frequencies, the severity of the attack and personal identity of the victim including gender, age as well as activities performed during the incident, for the years 2001 to 2020 using secondary data generated from various sources. Such a study is imperative to understand the severity of human-crocodile conflicts and in turn, assist relevant agencies in establishing effective management strategies.

Materials and Methods

Data collection and methods

This study uses secondary data on crocodile attacks that have been reported to occur in several types of water ecosystems including rivers, estuaries, and several unspecified water systems including natural and man made ponds in both the states of Sabah and Sarawak (**Figure 1**). These water systems are usually connected to the coastal areas and serve as a natural habitat of crocodiles (Abd. Shukor, 2004; Tangah, 2006), and are particularly critical for their breeding as well as nursery grounds (Nagelkerken et al., 2008). At the same time, these water systems are also vital for the local community, especially for traditional fishing activities and other daily uses.

The secondary data on crocodile attack cases in Sabah was obtained from the Sabah Wildlife Department. Apart from this, data and other related information are also generated and extracted from other sources including local newspapers and interviews with relevant authorities. For Sarawak, data and information is mostly obtained from CrocBITE, the global crocodile attack database which can be found at http://www.crocodile-attack.info. Other relevant information is obtained from various sources including communication with relevant local

authorities, newspapers and local residents through social media (i.e., Facebook). The detailed information on crocodile attacks, such as the location (i.e., state, district, and river), date (month and year), victim status (i.e., age, gender, and victim's activity before being attacked), and severity of the attacks (i.e., fatal and non-fatal), were collected and compiled.

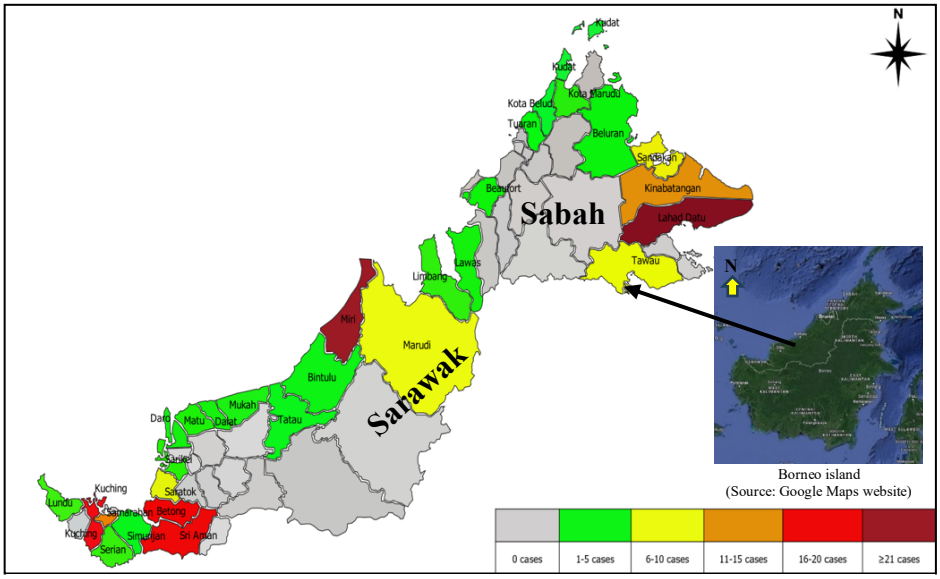


Figure 1. Location of Sabah and Sarawak on the island of Borneo (inset map). The geographic distribution of crocodile attacks by the district for both states is shown. The colour indicators in silver, yellow-green, yellow, brown, red and dark red shows the range in the number of reported cases from 2001 to 2020.

Computation and statistical analysis

The data were subjected to a logarithmic transformation [log10 (x + 1)] to meet statistical analysis requirements. A Shapiro-Wilk test indicated that the data were not normally distributed. Therefore, the Wilcoxon Signed Rank Test and Friedman Test (non-parametric tests) were performed to determine the significant difference between the distribution data of cases within each designated category namely between state (Sabah & Sarawak), district (multiple districts), river (multiple rivers), year (2001, 2002,…2020) months (January, February,…December), gender (male & female), age group (0y–79y) and activities during the attacks (fishing, bathing…etc.). The significant level was set at $p < 0.05$. All statistical tests were performed using SPSS for Windows version 23 software (IBM, Armonk, NY, USA). The mapping of crocodile attack

locations, including the cumulative number of cases for each district and river for both Sabah and Sarawak was presented in simplified heatmap.

Results and Discussion

The magnitude of crocodile attacks in Malaysian Borneo

A total of 205 cases of crocodile attacks were reported to occur over 20 years (2001–2020) in Malaysian Borneo which is equivalent to an average of 10.78 cases per year (**Table 1**). In the neighbouring country of Indonesia, number of attack cases were much higher, for example, a total of 279 attacks were reported in 27 of its 34 provinces over 7 years (2007–2014) which is equivalent to an average of 39.85 cases per year (Sideleau & Britton, 2014). This is nearly three times higher than the average number reported in this study, indicating that human-crocodile conflict in Malaysian Borneo is clearly at a staggering early stage compared to Indonesia. The relatively limited area of natural habitat with only two crocodile species existing may contribute to the low number of attacks in Malaysian Borneo compared to Indonesia. To date, there are two species of crocodiles found in Malaysian Borneo namely saltwater crocodile and Malayan gharial (tomistoma) (Cox & Gombek, 1985). In contrast, at least four species are known to inhabit extensive and diverse natural habitats in Indonesia including the saltwater crocodile, tomistoma, Siamese crocodile and New Guinean freshwater crocodile (Sideleau & Britton, 2014). Nevertheless, the actual number of crocodile attacks is difficult to infer since there are unreported cases, particularly in remote areas (Sideleau & Britton, 2013; Sideleau, 2016a; Sideleau, 2016b; Anonymous, 2017).

Table 1. Key points of the magnitude of crocodile attack cases in Malaysian Borneo from 2001 to 2020 shows the total number and percentage (in parentheses) for both the states of Sabah and Sarawak.

Key Points	Sabah	Sarawak	Total
Total attacks	70 (34%)	135 (66%)	205
Fatal attacks	52 (39%)	83 (61%)	135
Non-fatal attacks	18 (26%)	52 (74%)	70
Male victims	58 (36%)	115 (64%)	173
Female victims	9 (33%)	18 (67%)	27
Group age of victims (30 - 39 y)	19 (39%)	30 (61%)	49
Fishing activities	39 (41%)	56 (59%)	95

In the present study, the total number of fatal cases (135) was significantly higher ($p < 0.05$) than the number of non-fatal (70 cases), equivalent to an average of 6.75 deaths annually (**Table 1**). This is far less than the fatal attacks

in Indonesia, where a total of 139 deaths between 2007 and 2014 or equal to an average of 19.85 annually (Sideleau & Britton, 2014). In Indonesia, the high number of fatal attacks is closely linked to the high population of saltwater crocodiles (Kaiser et al., 2009; Sideleau & Britton, 2012; Sideleau & Britton, 2014; Sideleau, 2016a), similarly, this species has been responsible for the most fatal attacks in Australia (Caldicott et al., 2005) and in India (Patro & Padhi, 2019). Although saltwater crocodiles are known to contribute to most attack cases in Malaysian Borneo (e.g. Tisen et al., 2011; Sabah Wildlife Department, 1992), other species of crocodiles may also be involved. The high number of fatal cases due to saltwater crocodile attacks is attributed to their aggressive nature, especially large-sized individuals with strong jaws and teeth, usually causing severe injury to victims (Caldicott et al., 2005; Kelly, 2006; Webb et al., 2010; Erickson et al., 2012). This is coupled with the ability to open its mouth underwater and perform a "death roll" making it a very effective predator (Hutchins et al., 2003; Doody, 2009).

In Malaysian Borneo, the total number of male victims (173 cases) is nearly seven times higher ($p < 0.05$) than the number of female victims (27 cases) (**Table 1**). A high number of attacks in males than females have also been reported in other countries such as India (Anonymous, 2017), Indonesia (Sideleau et al., 2021), Mexico (Grajales & Silva, 2018), and Australia (Fukuda et al., 2015). This shows that men are more at risk of being attacked by crocodiles than women and this is closely related to male-dominated activities such as fishing, especially those between the ages of 30 and 39.

The total number of attack cases was almost double ($p < 0.05$) in Sarawak (135 cases) compared to Sabah (70 cases) (**Table 1**). In terms of fatalities, the number was significantly higher ($p < 0.05$) in Sarawak (83 cases) compared to 52 in Sabah, while for non-fatal, it was 52 and 18, respectively for Sarawak and Sabah. The number of attacks on males is 58 which is significantly higher ($p < 0.05$) than females (19 cases) in Sabah while these are 115 ($p < 0.05$) and 18 respectively in Sarawak. Overall, the number of crocodile attacks is much higher in Sarawak, indicating that human-crocodile conflict is more critical in this state than in Sabah. In another study, Abdul Gani et al., (2022) reported at least 164 cases of crocodile attacks in Sarawak from year 2000 to 2020, suggesting that many cases are not widely reported especially in remote areas of the state. The relatively high number of attacks in Sarawak may be related to the high population density of crocodiles inhabiting its long and extensive river ecosystem (e.g., Landong & Zaini, 2010; Ngadan, 2015). Based on a separate population survey by the Sarawak Forestry Corporation and the

Sarawak Forest Department repectively in 2012 - 2014, there are approximately 12,000 - 13,507 crocodiles mainly adults (i.e., 34.9 %) in the state with a density of 1.06 individuals per km inhabiting more than 22 main rivers as reported in Anonymous, (2015).

Geographical distribution of crocodile attacks

The geographical distribution of crocodile attacks by district in Sabah (i.e., 9 districts) and Sarawak (i.e., 19 districts) from 2001 until 2020 are shown in **Figure 1.** In Sabah, the district with a significantly ($p < 0.05$) high number of cases is Lahad Datu with more than 21 cases. This is followed by Kinabatangan with 11 - 16 cases, while both Sandakan and Tawau have between 6 -10 cases each. These three districts are known to have extensive river and wetland ecosystems, which account for the majority of the mangrove areas in Sabah (Abd. Shukor, 2004). Beluran, Kota Marudu, Kudat, Kota Belud, Tuaran and Beaufort reported between 1 - 5 cases whereas Kuala Penyu, Pitas, and Papar had very few. In Sarawak, the district with a significantly ($p < 0.05$) high number of attacks is Miri with more than 21 cases (see **Figure 1**). This is followed by Betong, Sri Aman and Kucing with the number of cases between 16 and 20, while Marudi and Saratok recorded between 6 - 10 cases. According to Abd. Shukor (2004), Kuching, Betong, Sri Aman, Miri and Marudi have extensive wetland ecosystems which account for the majority of mangrove areas in the state. The number of cases in Bintulu, Tatau, Mukah, Lundu and other districts near Kuching and Betong is relatively lower (i.e., less than 5 cases). The highest crocodile densities in Borneo are usually found in mid-river areas (Stuebing et. al., 1993), however, they are known to traverse across and utilize different habitats as a result of social dynamics (Web et al., 2010; Anonymous, 2015). This explains the widespread occurrence of crocodile attacks throughout Borneo which has a long network of rivers connecting each district.

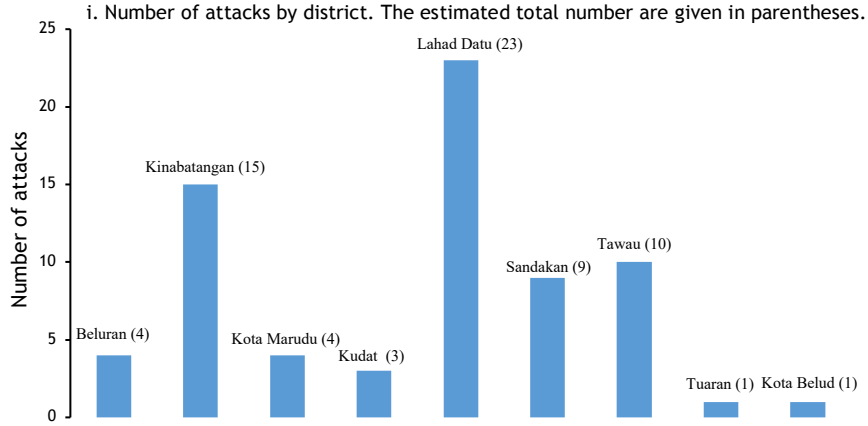
There are 32 rivers and several natural water ponds that have recorded crocodile attacks in Sabah (**Figure 2a**). The number of attacks was significantly high ($p < 0.05$) in the Kinabatangan River which is situated in the Kinabatangan district with a total of 11 cases. The relatively high number of attacks in this area may have coincided with the high number of crocodile populations. According to Evans et al. (2016), the aquatic and semi-aquatic ecosystems found along the Kinabatangan River are very suitable as a natural habitat for crocodiles. The crocodile population has likely undergone rapid recovery following the state-wide protection of the species which was initiated in 1982 (Sabah Wildlife Department, 2010). A high number of attacks were also recorded in the Sahabat River of Lahad Datu with seven cases, followed by the Kalabakan River in Tawau

with five cases, and four cases each for the Paitan River (Beluran) and the Segaliud River (Kinabatangan). Other rivers such as the Long Patau River in the district of Tawau and a few other locations in Sandakan with at least three cases. Numerous other rivers, including Balambangan and Bangi River in Kudat, Bengkoka, Langkon and Bongan River in Kota Marudu, Tanjung Badak River in Tuaran and a few rivers in Kota Belud reported at least 1 or 2 cases. Most of the rivers and wetland areas are known as the natural habitat of crocodiles in Sabah (CITES Malaysia Authorities, 2015; Nordkvist, 2015; Silla Datu, 2015). However, a large portion of these habitats have been developed for extensive oil palm plantations such as in Kinabatangan, Lahad Datu and Sandakan where the number of attacks is the highest. According to Stuebing et al., (2002) agricultural areas located adjacent to rivers will usually be covered by secondary vegetations suitable for nesting crocodiles and potentially attacking humans in the vicinity. This further proves a critical habitat conflict between humans and protected crocodile populations (e.g. Hassan & Abdul Gani, 2013; Abdul Gani et al., 2022).

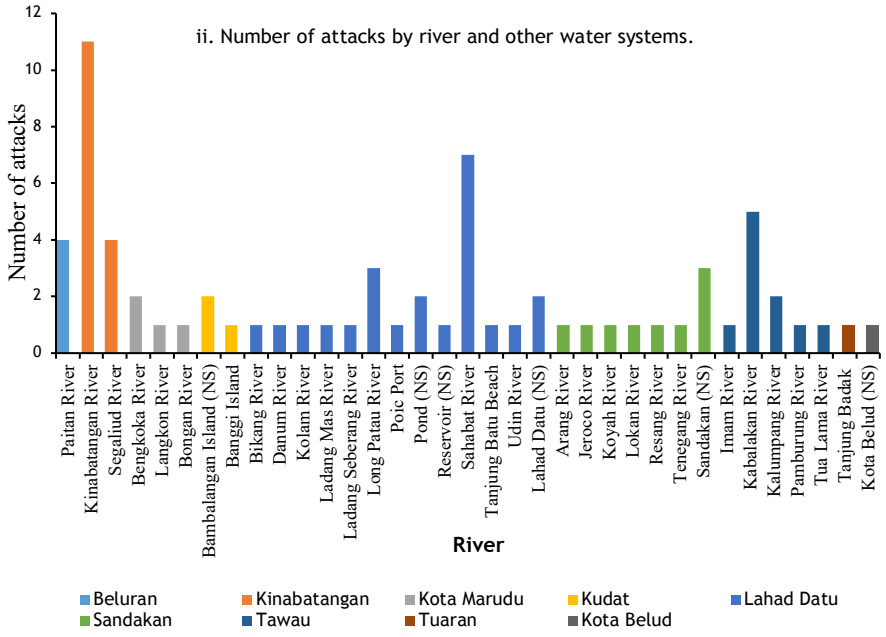
In Sarawak, there are at least 72 rivers and several natural water ponds that have recorded crocodile attacks (**Figure 2b**). The number of attacks is significantly high ($p < 0.05$) in Batang Lupar in the district of Sri Aman with a total of six cases. This is followed by the Seblak River and Semarahan River with 5 cases each. The Niah and Sibuti River in Miri, Baram River in Marudi, Seribas River in Betong and Skrang River in Sri Aman recorded at least 4 cases, while the Oya River, Bako River, Karap River, Suai River and Sabang River recorded at least 3 cases. Crocodiles are known to live in these rivers and associated wetland areas (CITES Malaysia Authorities, 2015; Nordkvist, 2015; Silla Datu, 2015). The number of rivers that recorded crocodile attacks is relatively high in Sarawak and this is likely the result of conservation programmes. This is particularly noticeable with the presence of many hatchlings and yearlings, which is a clear indication of the population recovery in most of its rivers (Engkamat, 2007; Sullivan et al., 2010; Hassan & Abdul Gani, 2013). Crocodile attacks usually occur when protecting nests (Manolis & Webb, 2013), misidentifying humans as prey, and establishing self-defence mechanisms (Caldicott et al., 2005; Saragih et al., 2020).

a). Number of crocodile attacks by district (i) and river (ii) in Sabah.

i. Number of attacks by district. The estimated total number are given in parentheses.



ii. Number of attacks by river and other water systems.



b. Number of attack by district (i) and river (ii) in Sarawak.

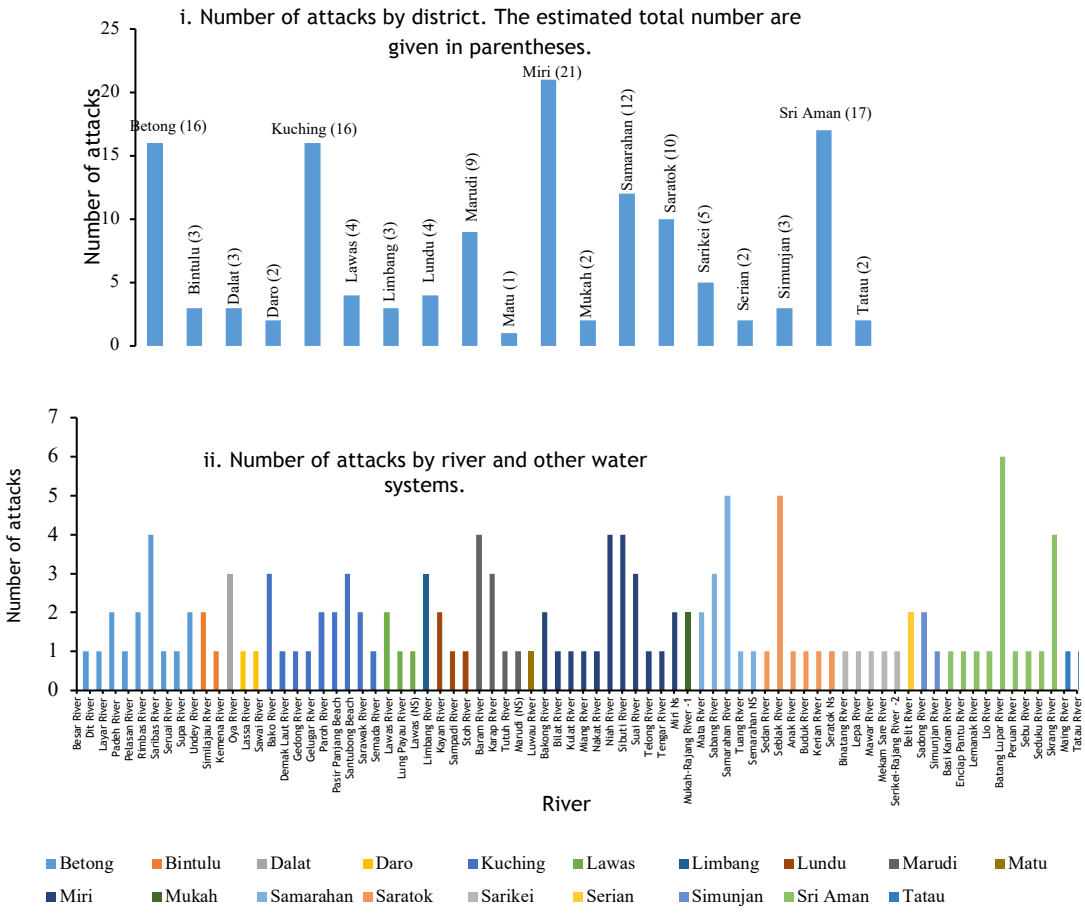


Figure 2. The estimated number of attacks by district and river in Sabah with 9 districts and 32 rivers (a), whereas in Sarawak with 19 districts and 72 rivers (b), recorded from 2001 to 2020.

The yearly trend of crocodile attacks

In both the states of Sabah (**Figure 3a**) and Sarawak (**Figure 3b**), the number of crocodile attacks from 2001 to 2006 was relatively low, i.e., less than two cases. However, the numbers show a linear positive trend ($r^2 = 0.7987$) with a marked increase thereafter. In Sabah, the fatal attacks reached four cases in 2011 and two non-fatal cases in 2008 and 2012, respectively (**Figure 3a**). The drastic increase in the number of attacks occurred between 2015 and 2020 when fatal cases increased significantly ($p < 0.05$) to nine cases while non-fatal cases reached six cases. In Sarawak, the number of attacks increased significantly ($p < 0.05$) from 2007 to 2020, reaching nearly triple the number reported in previous years (**Figure 3b**). Fatal attacks rose to ten cases in 2015 and 2020 respectively, while non-fatal attacks increased to nine cases in 2012. The results show that crocodile attacks including the fatal cases in Malaysian Borneo increased drastically in particular thereafter 2012 suggesting that the human-crocodile conflict has becomemore critical over the years.

In this study, the yearly rate of increase in the number of crocodile attacks was higher in Sarawak than in Sabah, for example, in 2012 there were a total of 12 cases in the former compared to 3 in Sabah. Relatively high number of attacks in Sarawak however is not a new trend, there were many fatal cases between the 1980s and early 1990s prompting the state government to launch an operation to remove large-sized crocodiles to minimize the risk of attacks (Cox & Gombek, 1985). For the record, crocodiles are considered a special animal by the Iban community of Sarawak practicing traditional beliefs (Abdul Gani et al., 2022) and killing or injuring the animal is prohibited. This traditional belief along with the long period of crocodile conservation, i.e., more than 40 years in the state has led to a significant increase in population density (e.g., Anonymous, 2015) and thus likely contributed to the recent high number of attacks. In contrast, Sabah had a low population of crocodiles until the mid 1980s (e.g., Web et al., 2010), however, the numbers have seen a recovery following statewide protection of the species that was initiated in 1982 (Sabah Wildlife Department, 2010). There is no current official estimate of the crocodile population in the state, however according to Sabah Wildlife Department, there were around 13,000 to 15,000 individuals across the state in 2010 as reported by Kan (2019). This indicates that the population increased slowly only after conservation and thus may explain the low yearly rate of crocodile attacks in the state.

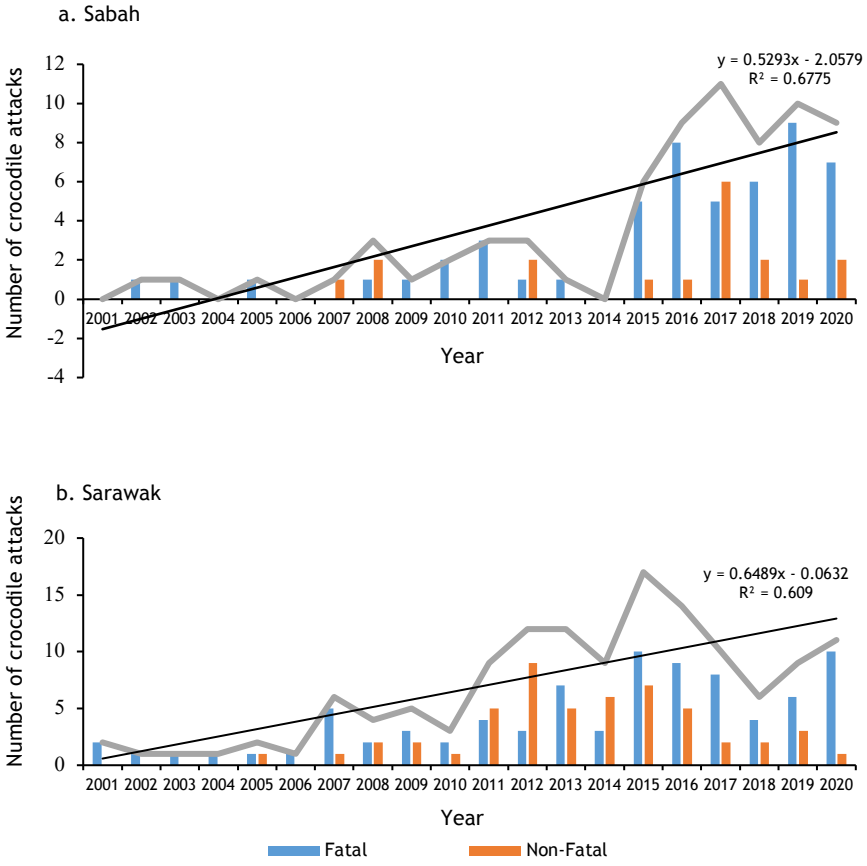


Figure 3. The estimated yearly number of crocodile attacks in Sabah (a) and Sarawak (b) from 2001 to 2020 includes the number of fatal, non-fatal, total and trends (i.e., linear) of attacks.

The increasing number of crocodile attacks due to growing population in the wild after conservation has been widely reported in many countries including India (Patro & Padhi, 2019), Australia (Fukuda et al., 2014) and Indonesia (Saragih et al., 2020). According to Webb et al., (2000), the recovery of crocodile populations after long-term protection will simultaneously increase the number of large-sized and aggressive individuals. This is also the case in Malaysian Borneo, for example, the ratio of large-sized adults (i.e. 34.9%) is high relative to juveniles and hatchling crocodiles throughout the state of Sarawak after long-term protection (Anonymous, 2015). It is believed that large-sized crocodiles may require larger prey and humans are well within the size range of prey that can be taken (Webb et al., 1982). The increasing number of large-sized adult crocodiles over time may also have increased the fatality rates of attack victims. According to Manolis & Webb, (2013), fatal cases are strongly related to the increasing proportion of larger crocodiles that can attack and overpower humans. In Australia, most attacks by large-sized crocodiles, i.e., over 4 m in length have resulted in the death of victims (Manolis & Webb, 2013). Recent information on the relative body size of the crocodile population in Malaysian Borneo is lacking. However, fatal attacks among large-sized crocodiles have been frequently reported where efforts to identify and hunt down the crocodiles are usually made after the attack.

Direct human competition with crocodiles for increasingly limited resources also contributed to the increase in crocodile attacks (Woodroffe, 2000; Treves & Karanth, 2003; Garcia-Grajales, 2013; Grajales & Silva, 2018). In Sarawak, many rivers are used daily for various purposes, especially by the local community and although their awareness level is high, safety issues among children are particularly a serious concern (Hassan & Abdul Gani, 2013). In addition, intensive use of mangrove areas and surrounding peat swamps for agricultural activities is likely to contribute to an increase in the number of fatal attacks, especially by saltwater crocodiles that naturally inhabit such ecosystems. The fatality rate due to saltwater crocodile attacks in Sarawak is nearly 61% (Tisen & Ahmad, 2010; Tisen et al., 2011; Ambu, 2011) while it is 36% in Sabah (Sabah Wildlife Department, 1992; Caldicott et al., 2005). These are much higher than in Australia (28.4%) (Manolis & Webb, 2013) and Sri Lanka (23.7%) (De Silva, 2010).

Monthly patterns of crocodile attacks

The monthly trend of crocodile attacks in the two states is different, especially the month that recorded the highest or lowest number of cases. In Sabah, the number of crocodile attacks was significantly high ($p < 0.05$) during March and April which range from 6 to 10 cases, followed by August and September with 7

to 9 cases (**Figure 4a**). The number of attacks is usually low in January, which is less than two cases compared to the other months. For the state of Sarawak, the number of attacks was significantly high ($p < 0.05$) during March and July with 20 and 17 cases, respectively (**Figure 4b**). The lowest number of attacks was recorded in December with 6 cases, while in other months, it varied from 8 to 11 cases. The results suggest that crocodile attacks occur all year round in Malaysian Borneo, however, a peak number is likely to occur during a particular time of year. In most countries, crocodile attacks take place throughout the year (Sideleau & Britton, 2014) with more attacks tending to occur during a particular period of the year which could have been associated with the reproductive cycle of the animals as well as environmental conditions that may influence their behaviour due to changes in the availability of food and habitat (Manolis et al., 2010; Grajales & Silva, 2018; Patro & Padhi, 2019).

Information on the reproduction cycle in particular the breeding season of crocodiles in Malaysia is rather limited, however, it has been reported that an increasing number of attacks are related to the aggression of the mother in nearby rivers when protecting hatchlings and yearlings (Hassan & Abdul Gani, 2013). In the Northern Territory of Australia, the peak season of crocodile attacks was from September to December coinciding with annual courtship and breeding (Manolis & Webb, 2013), however, fatal attacks occurred all year round (Sideleau & Britton, 2014; Fukuda et al., 2014; Fukuda et al., 2015). In both Sabah and Sarawak, the high number of attacks from March to July may coincide with the reproduction cycle during the dry season, however, further studies are needed to understand the breeding season of crocodiles.

In both Sabah and Sarawak, heavy rainfall during the monsoon season may contribute to the temporal variations of crocodile attacks due to changes in environmental conditions. The increase in food resources may coincide with the flooding of rivers following heavy rains during the monsoon, reducing the number of attacks on humans from October to December. On the other hand, during the driest inter-monsoon from January to March, the number of attacks may increase as crocodiles are more aggressive for limited food resources. Other factors, such as the seasonal peak of human activity in the nearby crocodile habitat, may also contribute to the high rate of attacks. In both states, artisanal fishing along the river usually occurs at certain times of the year when fishery resources such as shrimp are plentiful and are also expected to attract crocodiles. In Australia, the seasonal arrival of tourists along with other outdoor recreational activities during a particular time of year has been suggested to

contribute to potential crocodile attacks (Caldicott et al., 2005).

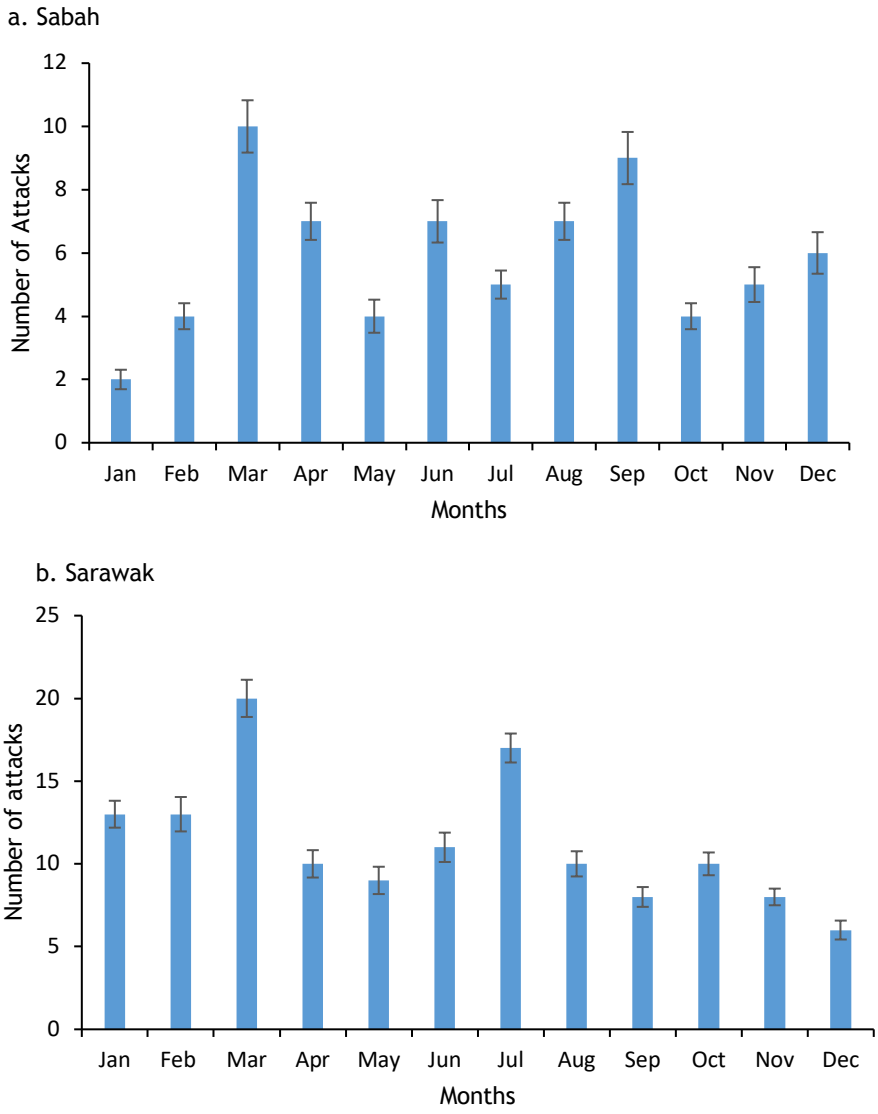


Figure 4. The monthly (January – December) number (mean ± SD) of crocodile attacks in Sabah (a) and Sarawak (b) from 2001 to 2020.

Gender and age group of attack victims

In Sabah, the yearly cases of crocodile attacks are significantly high among males than females (**Figure 5a**). Between 2001 and 2006, male victimss dominated the number of attacks, while females were only reported from 2008 to 2013 with a relatively small number (i.e., 1 case). However, the number of females increased to two cases from 2015 to 2020 in tandem with the increase in male victims which reached 11 cases in 2017. Similarly, in Sarawak, the number of attacks is dominated by male victims; from 2001 to 2010 only one female compared to seven males (**Figure 5b**). The significant increase in the number of female victims was from 2011 to 2018 with the highest being five in 2015 and is likely to be in tandem with the significant increase in male victims (i.e., 12 cases). The trend of an increase in the number of female victims that goes in tandem with the number of males has also been reported in other countries such as Australia (Caldicott et al., 2005; Manolis & Webb, 2013) and Indonesia (Sideleau & Britton, 2014; Sideleau et al., 2021). This shows that human-crocodile conflict can involve anyone regardless of gender when in a location at risk of a crocodile attack.

In Malaysian Borneo, the number of victims in the age group between 30 – 39 years was significantly ($p < 0.05$) higher than in the other age groups. In Sabah, the number of victims within this age group was the highest with 19 cases, followed by the age between 40 – 49 years with 14 cases and ages 20 – 29 with 9 cases (**Figure 6a**). Two victims aged between 0 and 9 years, and 4 victims aged 10 to 19 years were reported in the state, while those over 50 years old were also victims of attacks with 3 – 5 cases reported. In Sarawak, the number of victims between the ages of 30 and 39 years was 30 cases, this is followed by victims aged 40 to 49 and 20 to 29 years, with 24 cases each (**Figure 6b**). Unlike the trend of attacks in Sabah, the number of victims among teenagers and children is much higher in Sarawak. There are about 19 victims between the ages of 10 to 19 years, and three aged between 0 and 10 years have been recorded. In addition, the number of older people being attacked by crocodiles is also high in this state. There were a total of 14 victims in the age of 50 to 59 years, while 7 and 5 cases, respectively, for the ages of 60 to 69 years and 70 to 79 years. In general, the trend of crocodile attacks by age of the victim is similar to the trend reported elsewhere. Most common victims of crocodile attacks are between 30 to 39 years old and are likely to be carrying out their work activities (i.e., fishing) (Manolis & Webb, 2013) whereas children and senior individuals may be involved in water-related activities such as swimming (Fukuda et al., 2015).

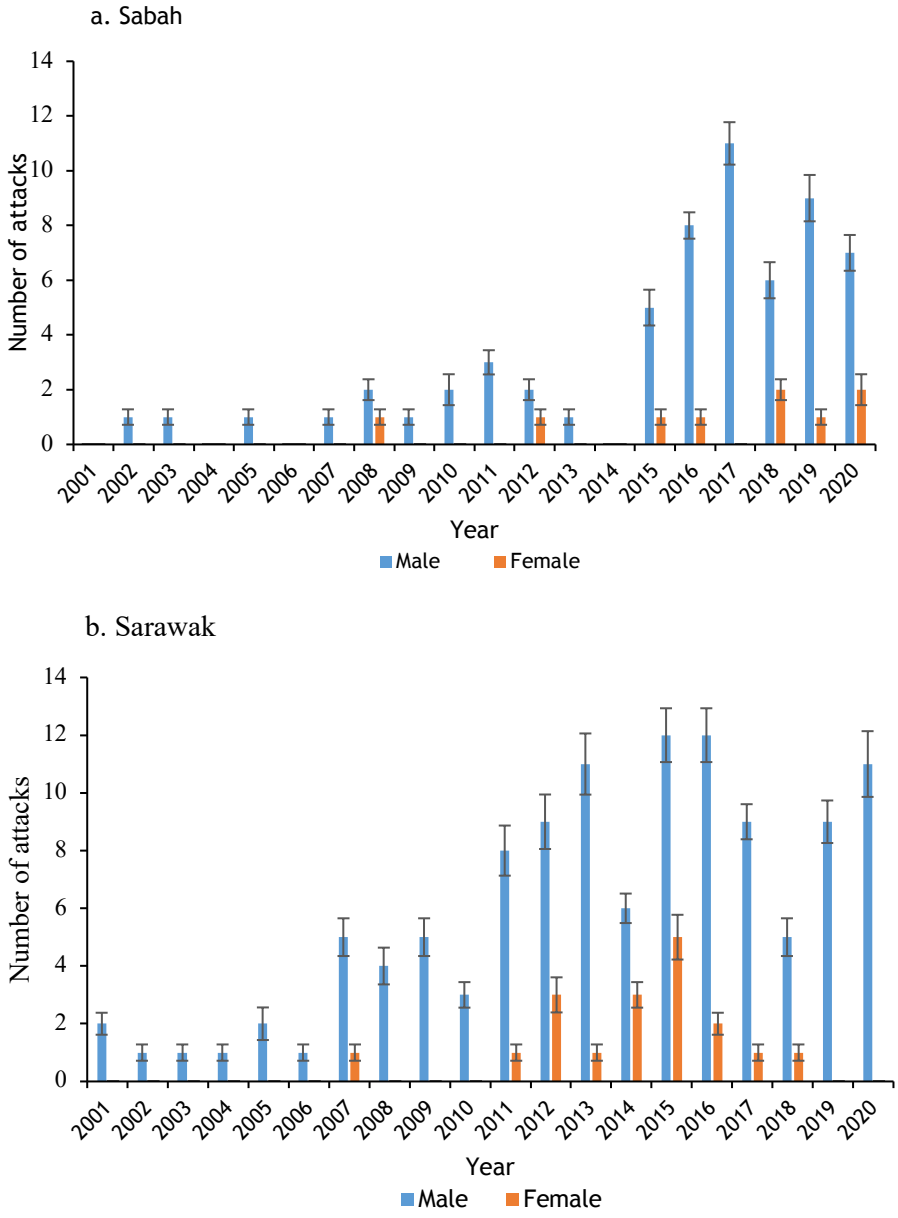


Figure 5. The yearly number (mean ± SD) of crocodile attack victims by gender in Sabah (a) and Sarawak (b) from 2001 to 2020.

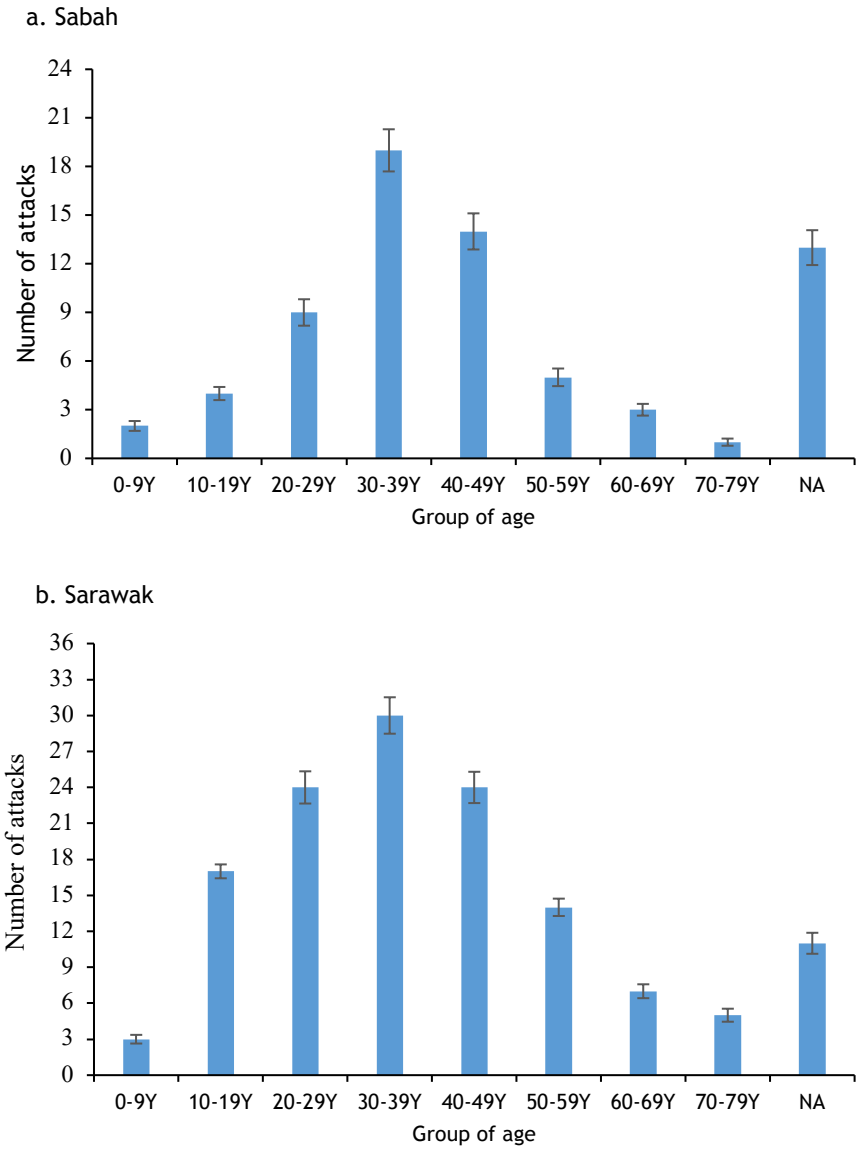


Figure 6. Total number (mean ± SD) of attacks by group age of victims in Sabah (a) and Sarawak (b) from 2001 to 2020.

Victim's activity during the attack

In Sabah, fishing activities before or during the crocodile attack involved 39 victims, which is significantly ($p < 0.05$) higher than other reported activities (**Figure 7a**). This is followed by swimming or bathing activities with a total of 14 victims. Other activities such as doing chores and even excreting, especially those carried out near the habitat of crocodiles, also make people vulnerable to attacks. The trend of victim activities before or during attacka in Sarawak is almost the same as in Sabah. In Sarawak, the number of victims who were involved in fishing was 56 cases, which is significantly ($p < 0.05$) higher than other activities (**Figure 7b**). This is followed by swimming or bathing activities with a total of 42 cases. Around the world, fishing and swimming are activities that involve a high number of crocodile attacks (e.g., Caldicott et al., 2005; Sideleau et al., 2017; Patro & Padhi, 2019; Khan et al., 2020) showing that such activities are risky to be carried out in areas inhabited by crocodiles. In contrast to the list of activities before the attack in Sabah, cases involving victims who were crossing the river and boarding a boat also occurred in Sarawak with at least 2 and 5 cases, respectively. This further indicates the severity of the human-crocodile conflict in Sarawak which relies heavily on the river system for various uses.

Several reasons have been suggested for the high number of attacks associated with water activities, in particular fishing and swimming. However, the crocodile's ability to be in the water without being noticed by the victim makes it a very efficient predator, especially saltwater crocodiles (Fukuda et al., 2015). According to Caldicott et al. (2005), victims were usually unaware of their presence in the water before the attack and took advantage of unbalanced prey in the water. Apart from these, the crocodile is capable of quiet, surreptitious movement before galloping and making a rapid movement toward its prey as an ambush predator (Grigg & Gans, 1993; Manolis & Webb, 2013). Surprisingly, activities such as boating as well as fishing from land are also at risk of being attacked by crocodiles. Such attacks may be subject to their body position before the attack and possibly the size of the boat used (Manolis & Webb, 2013; Fukuda et al., 2015) where small boats are at higher risk if attacked by a large size crocodile (Fukuda et al., 2015). Drowning is another cause of death for a crocodile attack victim based on the victim's body being relatively intact with no major trauma, thus the presence of an accompanying persons increases the survival of a victim (Cavanagh, 2004; Fukuda et al., 2015).

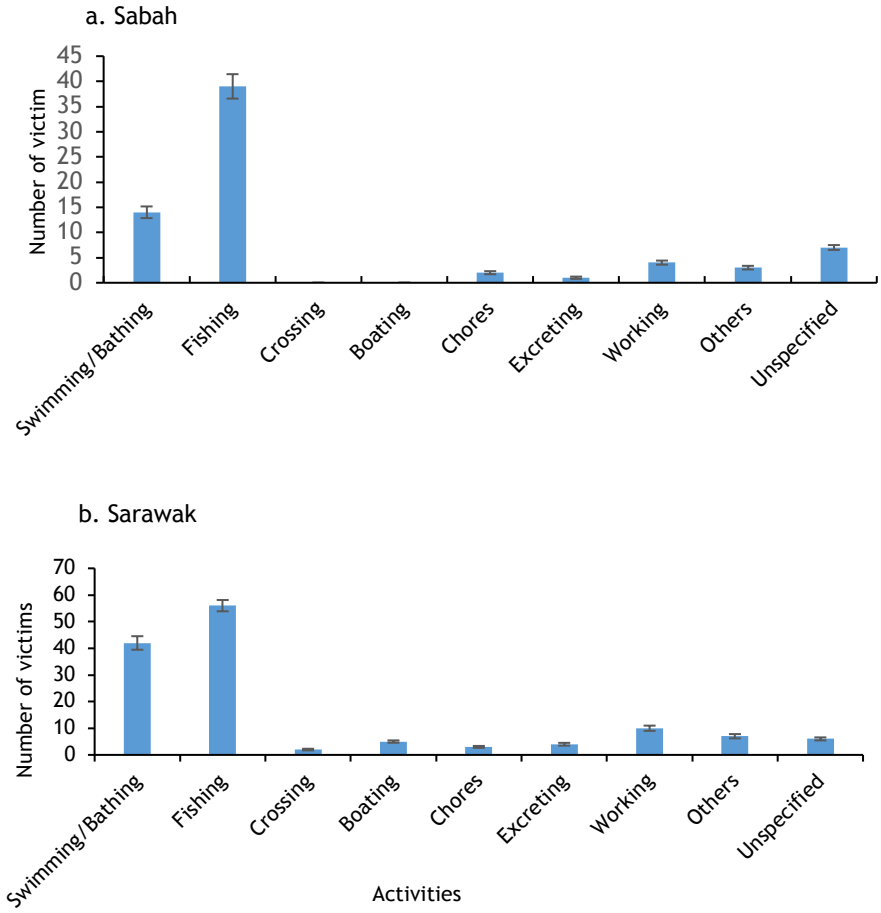


Figure 7. The number of victims and activities (mean ± SD) before the crocodile attacks in Sabah (a) and Sarawak (b) from 2001 to 2020.

Conclusion

The case of crocodile attacks in Malaysian Borneo shows an increasingly critical trend with an average of nearly 11 cases reported every year from 2001 until 2020. The number is higher in Sarawak than in Sabah, indicating a more worrying situation and this may be closely related to the higher population density of crocodiles inhabiting the river and estuary ecosystems which are also a source of livelihood for the local community. The fatality rate due to attacks continues to rise, indicating that the number of large size and dangerous crocodiles is increasing under conservation programmes that protect these animals in both

states. The number of attacks is usually high in the natural habitat of crocodiles with most of the victims being men between the ages of 30 and 39 years old and involved in fishing activities. The findings show that the human-crocodile conflict in both states of Malaysian Borneo requires an immediate solution that includes systematic conservation strategies such as controlling population numbers in selected areas to reduce the risk of attacks among the local community. More studies should be conducted to understand the current population status of crocodiles in risky areas to minimize conflicts with humans.

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