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Assessment of human–crocodile conflict in Mexico: patterns, trends and hotspots areas

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Abstract. An understanding of the factors, patterns of activities and seasonality per region that shape the response to the human–crocodile (HC) conflict in Mexico by humans is essential for prevention and mitigation of negative interactions. We compiled the publicly available data on incidents of crocodile attacks on the Gulf of Mexico and Mexican Pacific coast from January 2000 to the first days of January 2018. Of the recorded unprovoked crocodile attacks ($n = 149$) on humans in Mexico, 102 cases correspond to the Mexican Pacific coast and 47 to the Gulf of Mexico. The age of victims involved in the majority of the attacks ranged from 19 to 40 years old. Three municipalities of high risk (hotspots areas) were Puerto Vallarta, Lázaro Cárdenas and Pinotepa Nacional in the Mexican Pacific coast, whereas, in the Gulf of Mexico, only Bénito Juárez was of high risk. To mitigate this conflict, it is necessary that local authorities in the municipalities (mainly in those of high risk) establish public-safety programs with the goal of raising awareness of the risk of crocodile attacks on the basis of information status and distribution of the crocodile population, linked to the extent of HC conflicts, as a first step for better management and risk mitigation.

Additional keywords: crocodiles, management, wildlife conflict.

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Introduction

Because humans have defended themselves and their property from wild animals around the world, when wildlife activities intersect with those of humans, conflict can occur (Treves *et al.* 2006). Human–wildlife conflict is a growing issue worldwide (Woodroffe *et al.* 2005), and crocodilians are one of the major groups involved (Lamarque *et al.* 2009). In this case, crocodilians pose a threat to people, livestock or pets in local urban and rural communities (Aust *et al.* 2009; Gopi and Pandav 2009), and, in most cases, their attacks result in serious injuries or death of a victim (Fukuda *et al.* 2015); therefore, the crocodilian species are often viewed with fear (Wallace *et al.* 2011; Peña-Mondragón *et al.* 2013; García-Grajales and Buenrostro-Silva 2015*a*). Some of the causes that contribute to the increase of this conflict are human population growth (Fukuda *et al.* 2014); the transformation of undeveloped lands, coastal rivers, swamps and shorelines for urbanisation (Pooley 2015*a*; Redpath *et al.* 2015); and the encroachment by humans into crocodile habitats for tourism, recreation, agriculture, fishing or other purposes (Wallace *et al.* 2011; Fukuda *et al.* 2014).

In Mexico, there are three species of crocodilians: the American crocodile (*Crocodylus acutus*, Cuvier 1807), the Morelet's crocodile (*Crocodylus moreletii*, Duméril and Duméril 1951) and the spectacled caiman (*Caiman crocodilus chiapasius*, Bocourt 1876) and their general distribution is well known. The American crocodile has an extensive Neotropical range and appears on the Atlantic and Pacific coasts (Thorbjarnarson *et al.* 2006). It is sympatric with the other two species in Chiapas state, and sympatric only with the Morelet's crocodile in the coastal wetlands of the Atlantic and Caribbean lowlands (Cedeño *et al.* 2006).

Because of overexploitation and habitat loss in the past, crocodiles were protected by federal Mexican laws and classified as threatened (Casas-Andreu 1995), and several conservation actions were implemented, such as, for example, a permanent ban on hunting established in 1970 (Casas-Andreu 1995). However, conservation actions typically aim to increase depleted crocodilian populations, and the success of such conservation programs invariably leads to an increase in negative interactions between people and crocodilians (Fukuda *et al.* 2015).

Although Conover (2002) defined the interactions between human and wildlife as situations ocurring when an action by either humans or wildlife has an adverse effect on the other, later Young *et al.* (2010) suggested that human–wildlife conflicts should be split into their two components: human–wildlife impacts referring to the effects of wildlife on humans and their activities, and the underlying human–human conflicts referring to those defending pro-wildlife positions and those defending other positions.

With this background, this paper focuses on impacts (crocodile attacks) through an understanding of the factors, patterns of activities and seasonality per region in Mexico. Therefore, the aim of this work was to conduct an assessment of HC conflict in Mexico, so as to identify patterns, trends and hotspot areas and, hence, provide new insights into the social and biological context in which crocodile-conservation management programs could operate in Mexico.

Materials and methods

The study area comprised the entire territory of Mexico, between 14 and 32°N, 86 and 118°W, encompassing the natural historical distribution of *C. acutus*, *C. moreletti* and *C. c. chiapasius* (Fig. 1), where they inhabit a range of freshwater and saline water bodies, including beaches, floodplains, billabongs, lagoons, mangroves, rivers, swamps and waterholes (Álvarez del Toro 1974). Mexico shares land borders with the US (to the north) and Guatemala and Belize (to the south). The total area of Mexico is ~1 900 000 km^2 and is characterised by a great diversity of landscapes. The climate of Mexico is moulding by its tropical and subtropical latitude range from 15 to 32°N, which accounts for reasonably high temperatures. The country is located between a high pressure towards the north and the inter-tropical convergence zone that approaches the south of the country in summer. The mean annual temperature at low altitudes varies from 26°C in the far south-east to 25°C on the eastern coast. The seasonal variation in monthly mean temperature is very small (±1–2°C) in the southerly latitude on the Pacific coast, but increases northward and inland to ~±4–5°C in the northerly coastlands.

The Pacific coast of Mexico has 11 states along the shoreline, whereas the Gulf of Mexico has six states; therefore, for the purpose of this work, we divided the Mexican Pacific coast into the following three regions: (1) north-western coast (Baja California, Sonora, Sinaloa and Nayarit), (2) central coast (Jalisco, Colima and Michoacan) and (3) southern coast (Guerrero, Oaxaca and Chiapas), and the Gulf of Mexico into two regions, namely (4) Gulf of Mexico (Tamaulipas, Veracruz, Tabasco and Campeche) and (5) Peninsula de Yucatan (Yucatan and Quintana Roo).

Historical data

In this work, we compiled the publicly available data on incidents of crocodile attacks on the Gulf of Mexico and Pacific coast of Mexico from January 2000 to the first days of January 2018, and excluded data before 2000 from the analysis, owing to

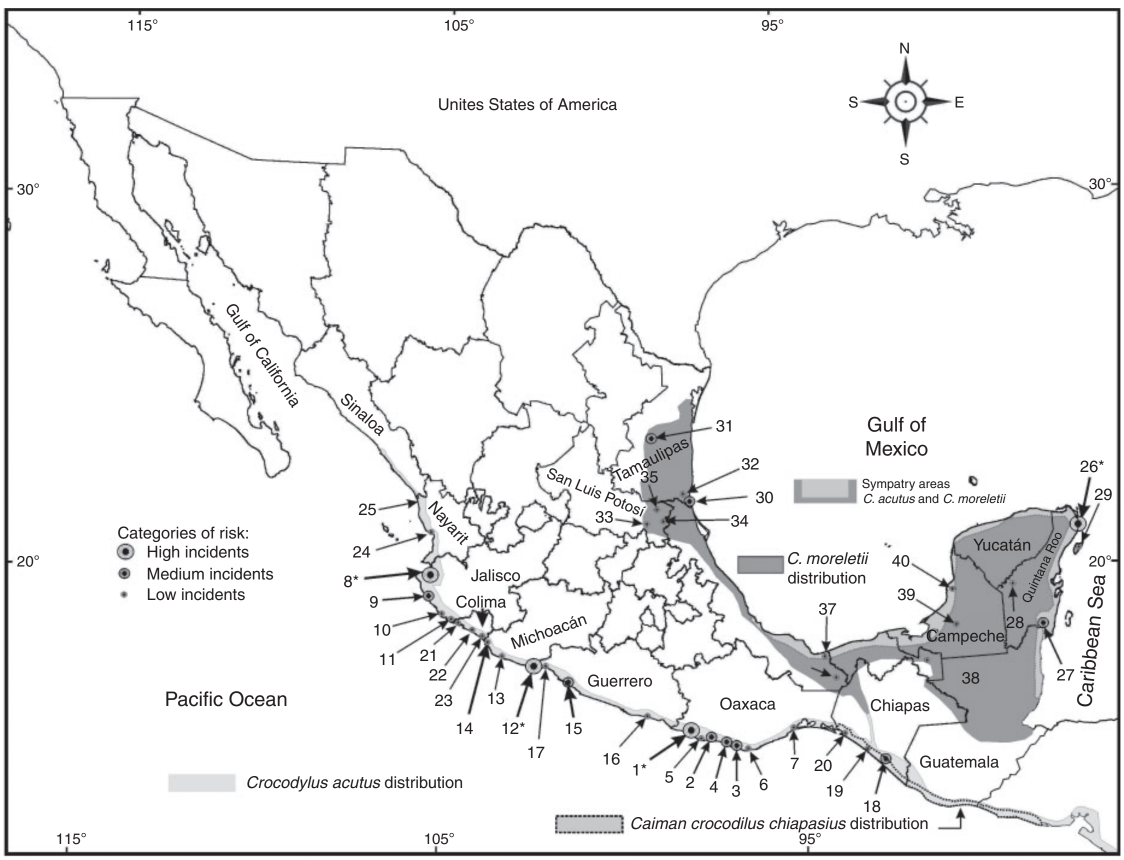

Fig. 1. Distribution of crocodilian species in Mexico, and hotspot areas in the human–crocodile conflict. The number codes correspond to those in Table 1. Asterisks represent the priority hotspot areas.

the difficulty of confirming information with media sources. For the analysis, our historic-data compilation of cases was obtained by various methods, including the following: (1) collating the internal reports and databases kept by government agencies (such as Protección Civil, Procuraduría Federal de Protección al Ambiente, and Secretaría de Medio y Recursos Naturales) and local police departments in some cases; (2) interviewing victims, witnesses, police officers or rangers involved in the incidents (the few that we were able to contact) by telephone line or email, when it was possible; (3) searching media sources, such as newspapers, magazines and websites (Crocodile Specialist Newsletter, Croc-Bite batabase) in the world wide web; (4) through personal communication of some researchers (those who agreed to provide information); and (5) personally experiencing crocodile attacks in Oaxaca state. Of the total incidents registered, we considered only the unprovoked attacks in the wild, and, therefore, we excluded the provoked attacks resulting from voluntary contact with crocodiles such as when catching crocodiles (e.g. handling crocodiles or collecting eggs), attacks that did not cause any injury, and suspected incidents such as victims going missing without witness or evidence as a crocodile attack and incidents that were not confirmed as evidence of crocodile attacks.

All incidents were entered into a database and classified by date, location of incident, sex, age, activity and origin of the affected, time of incident (daylight or nocturnal), presence of witnesses, type of crocodile habitat, region, political unit (municipalities) and type of attack (fatal or non-fatal). We grouped the age of victims in six categories (1–10 years, 11–18 years, 19–40 years, 41–60 years, >60 years) on the basis of the economically active ages in Mexico. Furthermore, with respect to non-fatal attacks, we classified the type of sequels as disabling (those that ended in the loss of tissue continuity to the extent of amputation or motor functionality, limiting or disabling physical daily activities) or non-disabling (those that did not represent the amputation or lack of motor function and allows them to continue with physical daily activities), when it was posible, and we excluded the psychological consequences from this work. We used the GPS coordinates of each attack as accurately as possible, using the most detailed information available, and using our geographic classification into the geoestatistic dataset of Instituto Nacional de Estadística y Geografía (2015), so as to generate a map.

Aditionally, we compiled information about reproductive periods of each of the species, from exclusively scientific papers, to compare it to the crocodile attacks registered in each. We used Microsoft Excel to compile the database and $\text{XLSTAT}_{\text{Ecology}}$ software (Addinsoft, Inc., Barcelona, Spain) for the statistical analysis and preparation of figures based on attack data. The Oriana software (Kovach Computing Services, Anglesey, UK) was used for the analysis of incidents through the years and timing of attacks, and Corel Draw X6 software (Corel Corporation, Ottawa, ON, Canada) was used to adjust the figures.

We examined the seasonal distribution of crocodile attacks by dividing the data into months (January–December) per state and by performing a Chi-Square test of both the Pacific coast of Mexico and Gulf of Mexico. We summarised the details of the victims (age, sex, local or visitor, day or night, activity, presence of witnesses) to identify patterns and trends. Aditionally, we grouped crocodile attacks into a 5-year period between 2000 and 2014, and into a smaller group from 2015 to 2018; then, we calculated the mean number of attacks (fatal and non-fatal) in each period in the Gulf of Mexico and on the Pacific coast and compared the means between periods using ANOVA. If we found a significant result, we fitted a linear regression to further examine the trend.

To explore potentially important areas (hotspots) for future HC conflict management in Mexico, we performed a spatial analysis, in which we identified the historical crocodile attacks per municipality in each state. We used a simple score to classify the municipalities into three categories of risk on the basis of the number of accumulated incidents, as follows: low (1–3 incidents), medium (4–9 incidents) and high (10–15 incidents). In the absence of a previous reference to the degree of risk by areas, we proposed this arbitrary criterion as a reference for our country on the basis of the maximum number of attacks in a single site.

In our work, we decided to exclude the analysis of humand trends and crocodilian population sizes. In the first case, because Mexico is the 11th most populated country in the world and is growing at a more rapid rate (1.4% rate of natural increase) than the global average (1.2%); however, there are vague data about communities near the water bodies. In contrast, there is scattered information about crocodilian population estimates.

Results

Between 2000 and 2018, 149 unprovoked crocodile attacks on humans were registered in Mexico, with 102 cases corresponding to the Pacific coast and 47 to the Gulf of Mexico coast. The total number of attack reports per annual period showed a marked increase ($n = 149$; regression analysis $R^2 = 0.82$, $P < 0.005$; Fig. 2). The mean number of crocodile attacks (fatal and non-fatal combined) was significantly different between the 5-year groups for the Pacific coast ($F_{1,99} = 72.65$, $P < 0.05$), but the mean number of crocodile attacks (fatal and non-fatal combined) was not different between the 5-year groups for the Gulf of Mexico ($F_{1,45} = 6.46$, $P > 0.05$; Fig. 3). The mean of non-fatal attacks in the Pacific coast showed a linear increase at a rate of 0.38 ($R^2 = 0.67$, $P < 0.01$) every 5 years, whereas the linear increase of the mean of fatal attacks was 0.15 ($R^2 = 0.35$, $P = 0.04$). The slope of the mean of non-fatal attacks in the Gulf of Mexico showed a linear increase at a rate of 0.23 ($R^2 = 0.32$, $P < 0.05$) in the past 5 years, whereas the linear increase of the mean of fatal attacks was 0.1 ($R^2 = 0.21$, $P = 0.05$).

There was no statistically significant variation among months in the number of crocodile attacks (fatal and non-fatal combined) for the Mexican Pacific coast ($\chi^2_{11} = 23.18$, $P = 0.19$) or for the Gulf of Mexico coast ($\chi^2_{11} = 12.19$, $P = 0.11$); however, it is possible to see a relationship between the number of attacks per month and the time of nesting of different species, as well as with the rainy season (Fig. 4).

Oaxaca, Jalisco and Michoacan in the Mexican Pacific coast represented 70.7% of the cases, whereas Quintana Roo and Tamaulipas in the Gulf of Mexico represented 74.5% of the cases (Fig. 5). With respect to the southern coast, Oaxaca was the state with the highest number of cases reported ($n = 33$), whereas Jalisco state had the highest number of cases ($n = 22$) in

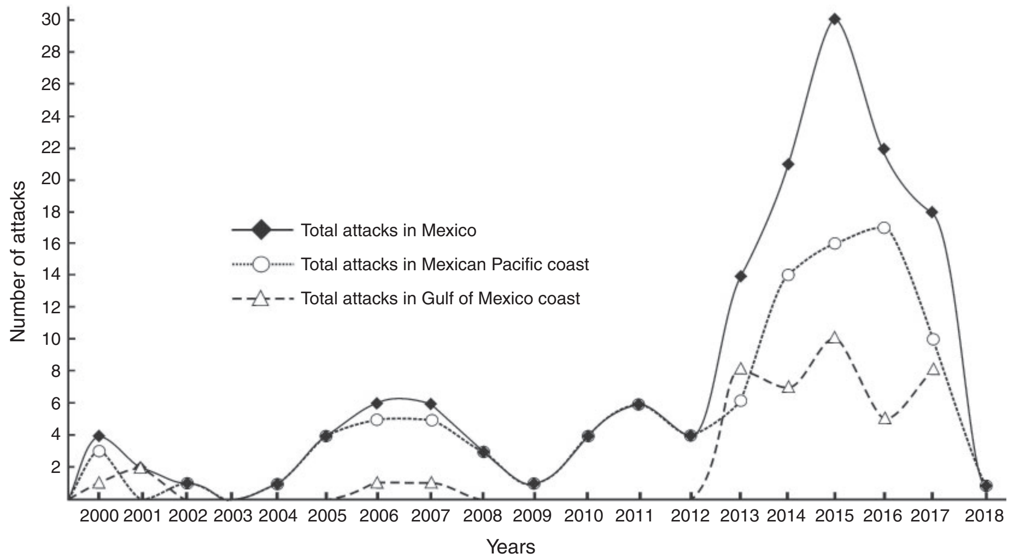

Fig. 2. Trends in the total number of attacks reported in Mexican Pacific and Gulf of Mexico coasts.

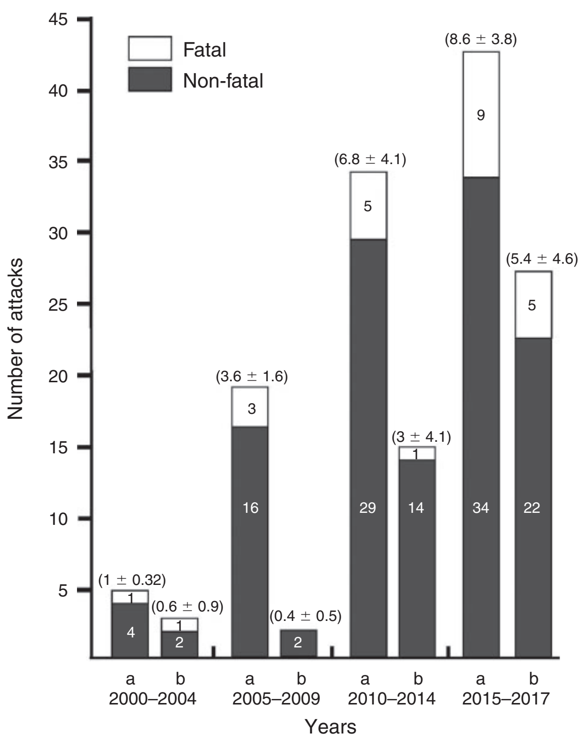

Fig. 3. The number of total attacks in Mexico divided into 5-year groups for (a) Mexican Pacific coast and (b) Gulf of Mexico coast. The annual number (mean ± s.e.) of total crocodile attacks is given in parentheses.

the central coast. In regard to the month in which the attacks occurred in the southern coast, May and September were the months with the highest number of crocodile attacks (5 cases each) in Oaxaca, and December was the month in which no attacks occurred (Fig. 6). For the central coast, in the case of Jalisco, April ($n = 5$) and September ($n = 4$) were the months with the highest number of crocodile attacks, and December, January and February were the months in which have no attcks occurred (Fig. 7). In Michoacan, October was the month with the greatest number of cases ($n = 4$) registered, and from November to March there were no attacks (Fig. 8). The months with the highest number of attacks in the Gulf of Mexico, in Quintana Roo, were April and September ($n = 4$ for each), and February was the month in wich no attacks occurred (Fig. 9). In Tamaulipas, July had the highest number of attacks ($n = 3$), and November, December and February were the months with no attacks occurring (Fig. 10).

The age of victims involved in the majority of the attacks ranged from 19 to 40 years old (32% for Mexican Pacific coast and 20% for Gulf of Mexico), followed by those from 41 to 60 years old (28% for Mexican Pacific coast and 14% for Gulf of Mexico). In both fatal and non-fatal attacks, male victims were more common than were female (89% for Mexican Pacific coast and 93.4% for Gulf of Mexico) and local people were much more commonly involved in the attacks than were visitors or tourists. In the state of Oaxaca, four of six cases of fatal attacks involved children.

With respect to the injuries resulting from a non-fatal attack, in the Mexican Pacific coast the highest proportion (52%) of victims showed non-disabling injuries, with only few cases (12%) showing amputation of a limb (disabling sequelae) and, in the other cases, there was no concrete information. For the Gulf of Mexico coast, only 10.6% reported non-disabling injuries and, for the rest of cases, there was no concrete information. For half of the attacks in the Mexican coast, there were witnesses; for the most cases (40.6%), the witnesses were of legal age (>18 years) but, in three of four fatal cases, the witnesses were under the legal Mexican age (<18 years). In the Gulf Mexico, there

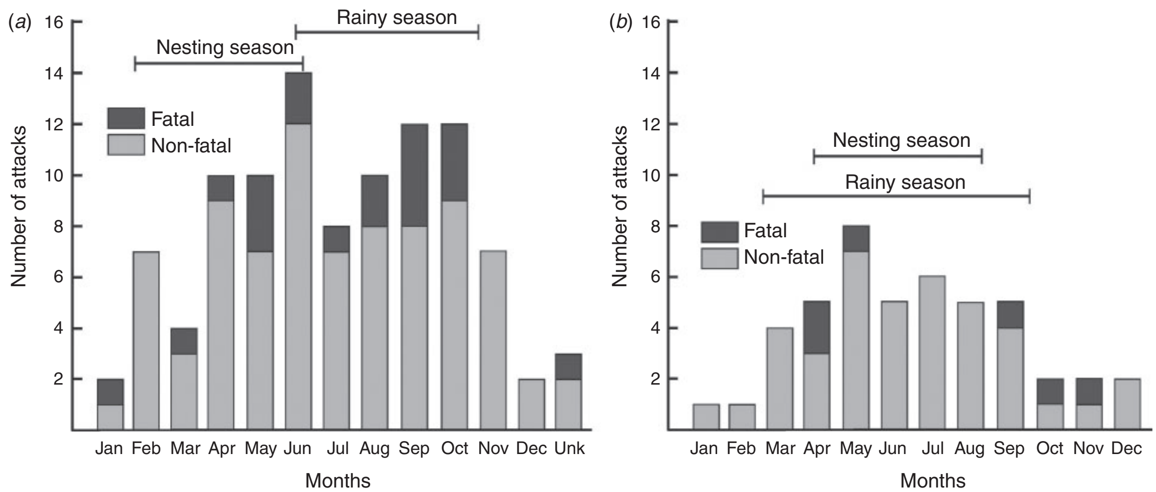

Fig. 4. The number of fatal and non-fatal attacks for (*a*) Mexican Pacific coast and (*b*) Gulf of Mexico coast by month and the possibly correlated seasons involved. Unk, unknown.

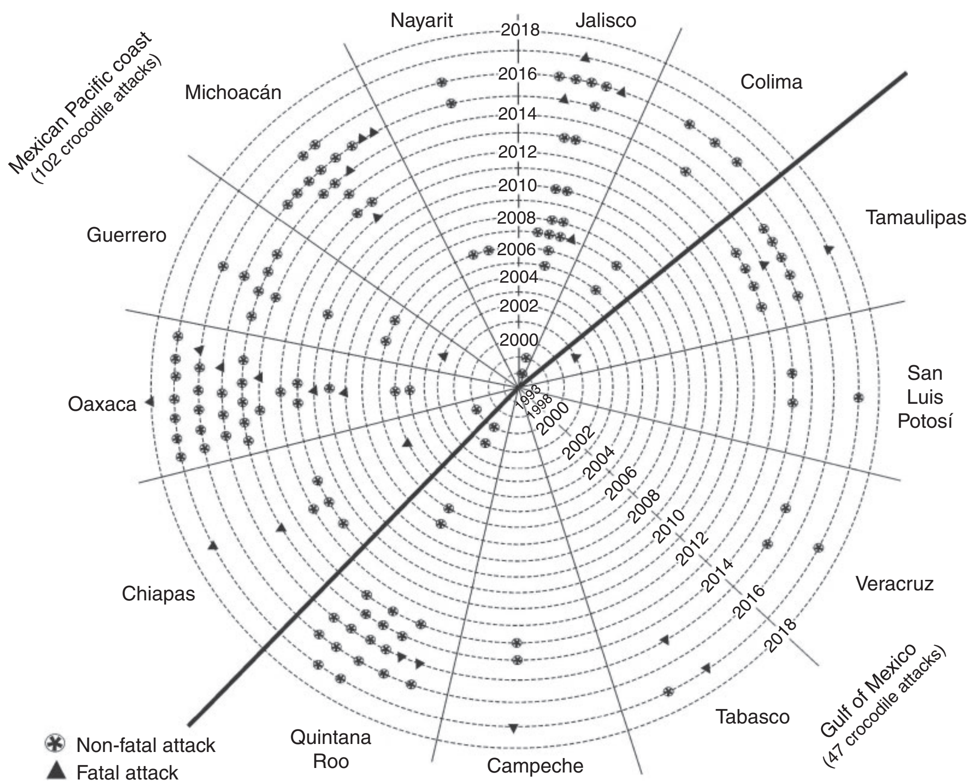

Fig. 5. Summary of crocodile attacks in Mexico per state, year and coast. Concentric dotted lines represent an annual cycle.

were witnesses for only 42.5% of the non-fatal cases, but there were no details about the age of the witnesses.

The most common activities at the time of fatal attacks in the Mexican Pacific coast were fishing (8%), playing (6%) and diving (2%), whereas those in the Gulf of Mexico were fishing (4.2%) and swimming (2.1%; Fig. 10). The most common activities at the time of non-fatal attacks in the Pacific coast were fishing (32%), swimming (11%), diving (8%) and playing

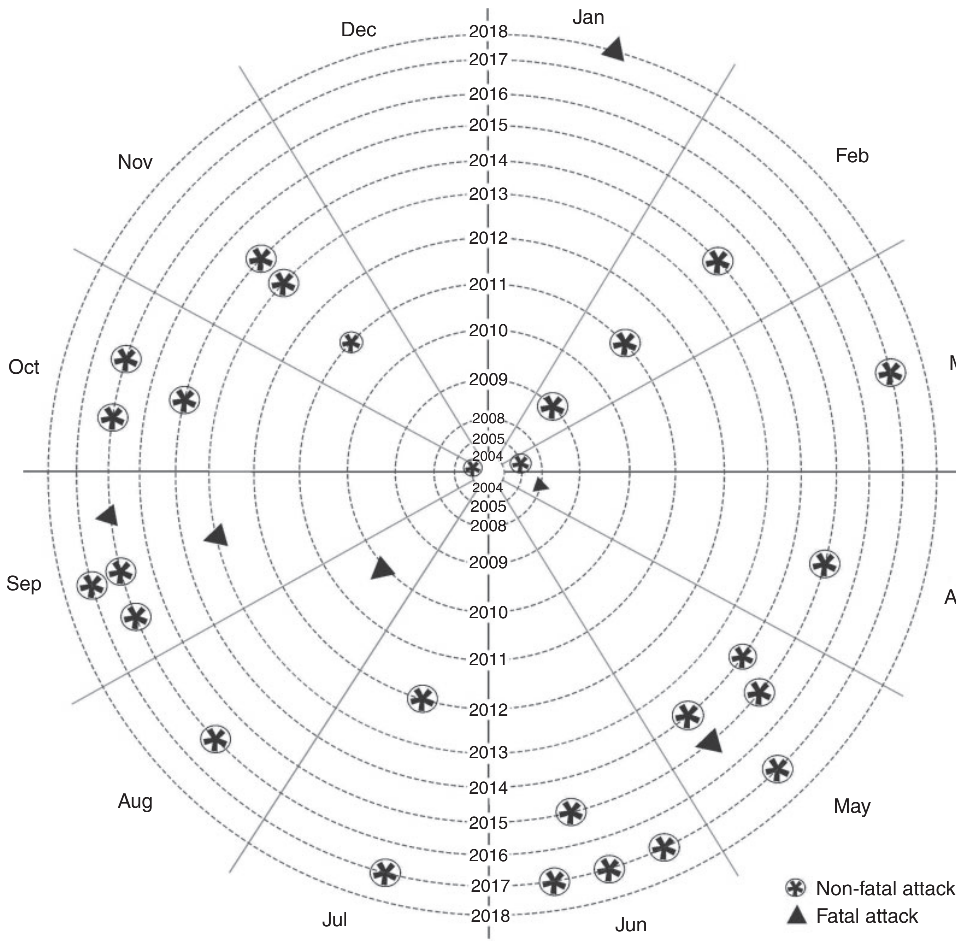

Fig. 6. Summary of crocodile attacks in the coast of Oaxaca per year and month. Concentric dotted lines represent an annual cycle.

(5%). Both fatal and non-fatal attacks ocurred more commonly in daytime (88% for Pacific coast and 40% for Gulf of Mexico).

The geographic analysis of the municipalities in the Mexican Pacific coast (Table 1) showed the following three regions as being high-risk areas (hotspot areas): Puerto Vallarta (Jalisco state), Lázaro Cárdenas (Michoacan state) and Pinotepa Nacional (Oaxaca state), whereas, in the Gulf of Mexico, there was only one municipality that was regarded as high risk, namely Bénito Juárez (Quintana Roo state; Fig. 11). Regarding the victims involved in fatal attacks, Lázaro Cárdenas (Michoacán state) was the municipality with the highest number of fatalities, followed by Pinotepa Nacional (Oaxaca state).

In our compilation of crocodile-attack cases, we identified the following three municipalities with a high frequency of attacks in the Mexican Pacific coast: Pinotepa Nacional (Oaxaca), Puerto Vallarta (Jalisco) and Lázaro Cárdenas (Michoacán), whereas, in the Gulf of Mexico, there was one location classified as a municipality of high risk, namely, Bénito Juárez (Quintana Roo).

Of the crocodile species involved, there is certainty of only one species being involved (*Crocodylus acutus*) in the Mexican Pacific coast. There is a discrepancy regarding the species involved in the Gulf of Mexico because the victims or witnesses failed to identify the species because of the sympatry between *Crocodylus acutus* and *C. morelettii*. So far, there have been no reports of attacks by spectacled caimans on humans in Chiapas.

Discussion

The occurrence of human–wildlife conflict has increased because of the growing human population and transformation of undeveloped lands and waterways (Madden 2004; Pooley 2015*b*), and this is particularly problematic for large predators (such as crocodiles) and those humans who live alongside them (Redpath *et al.* 2015) because both increasingly compete for limited space and resources (Madden 2004). In recent years, the number of human–crocodile attacks has been increasing in many parts of the world (Langley 2005; Pooley 2015*a*; Das and Jana 2018); however, there is an under-representation because numerous attacks by crocodilians go unreported, or are poorly documented, in many countries where crocodilians are distributed (Fukuda *et al.* 2015). Several assesments of these conflicts

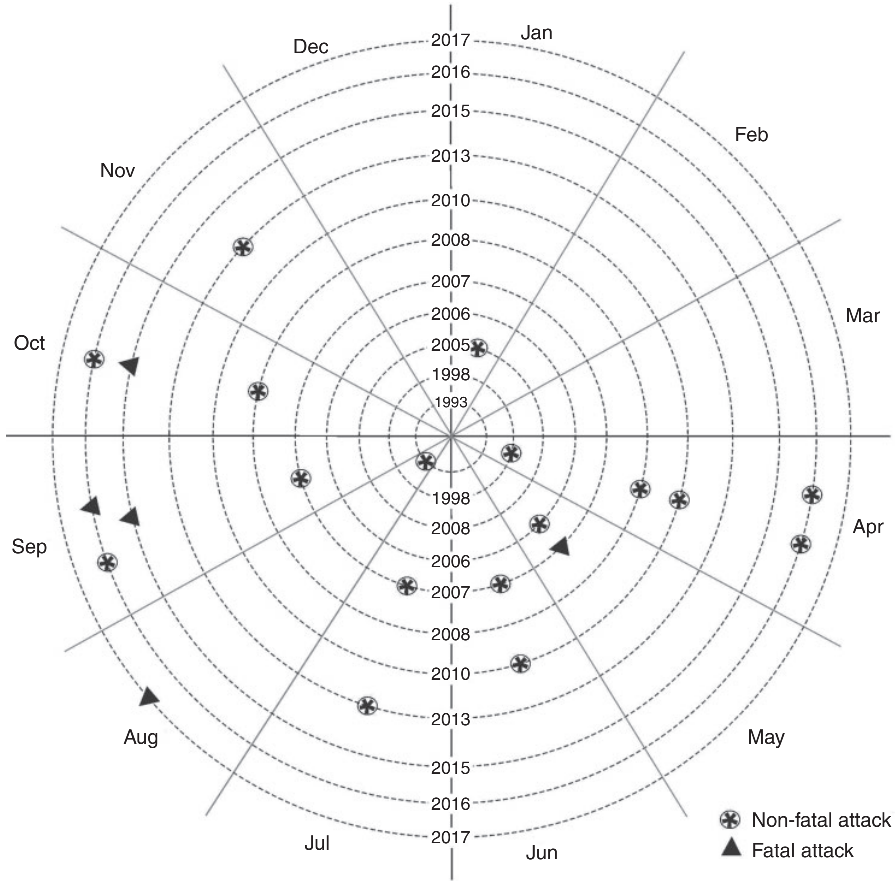

Fig. 7. Summary of crocodile attacks in the coast of Jalisco per year and month. Concentric dotted lines represent an annual cycle.

have been conducted in developed and developing nations, such as Australia (Caldicott *et al.* 2005; Fukuda *et al.* 2014; Campbell *et al.* 2015), Timor-Leste in the Lesser Sunda Archipelago (Sideleau *et al.* 2017), Mozambique (Dunham *et al.* 2010), Namibia and Zambia in Africa (Wallace *et al.* 2011; Pooley 2015*b*), and the USA (Langley 2005). In the countries of Latin America, there is scattered information for several countries of this region, but only in Costa Rica has there been some analysis of crocodile attacks (Barrantes 2010; Carrillo 2013; Carrillo and Porras 2016), and only information scattered has been collected throughout the CrocBITE worlwide crocodilian-attack database website (García-Grajales and Buenrostro-Silva 2018). In Mexico, a partial assessment was performed by Ponce-Campos (2014); however, a complete understanding of the factors that shape the response of HC conflict is necessary to promote efficient and essential measures for prevention and mitigation (Manfredo and Dayer 2004).

Our results showed a marked increase in attacks in recent years for both coasts; however, an unknown number of incidents are probably not reported by the common media as local news (Pooley 2015*a*). Moreover, the great increase in attacks, as has ocurred in Mexico, is considered a key factor that enhances this conflict (Sidelau and Britton 2013; Fukuda *et al.* 2014). Additionally, the context within which all of this is happening is related to the lack of economic alternatives in rural areas, and, therefore, people use dangerous fishing methods, such as net fishing (García-Grajales and Buenrostro Silva 2015*b*). In addition, difficulties with communication, especially in remote areas, may also contribute to the lack of reports of crocodile attacks.

The peaks periods for crocodile attacks (March–June and August–November) coincide with the species nesting season and with the beginning and end of the wet season for both coasts in Mexico, and these connections could be explained by three possible hypotheses: first, in the rainy season, crocodiles are widely dispersed as a result of an increase in the water level, and the possibility of negative interaction between humans and crocodiles increases as a result of this. Second, crocodiles are ectothermic and are more active (and, therefore, hungrier) during the hotter months of the year; therefore, the possibility of a negative interaction between the fisherman and the crocodile increases during this period. Third, although there is little evidence and there are differences of opinion, crocodiles are more dangerous during the breeding season because the large adult females guard their nests and fast until their hatchlings are ready to emerge (Pooley 2015*a*); therefore, they are intolerant to

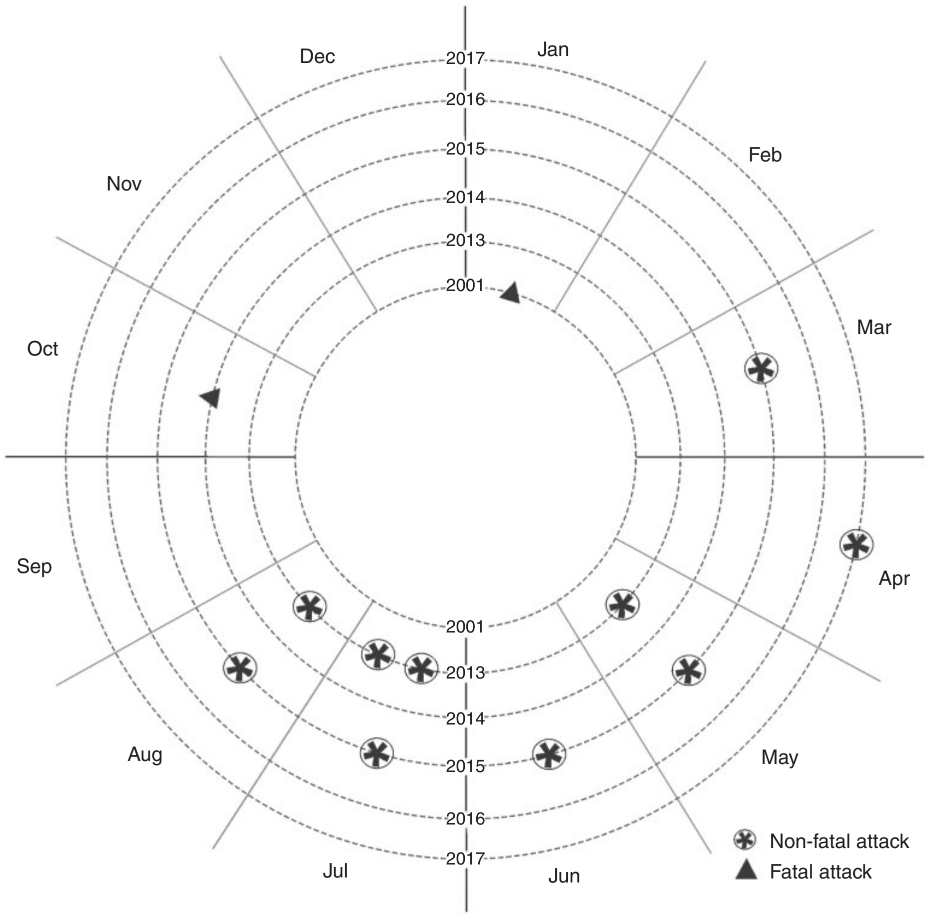

Fig. 8. Summary of crocodile attacks in the coast of Michoacán per year and month. Concentric dotted lines represent an annual cycle.

humans approaching their nesting areas, and, as a result, more aggresive towards humans (Lang 1992). In relation to this, Pooley (2015*a*) argued that the problem with these hypotheses is that they are overlapping, and it is necessary to gather more information that facilitates region-specific analyses.

In Mexico the prevalence of specified economic gender roles in rural areas favour males; more specifically, men of 19–40 years of age are the most likely to be engaged in high-risk jobs because they are the most economically active group. Therefore, these are the reasons why we find this group as the most vulnerable in HC conflicts. Moreover, fatal and non-fatal attacks happened more commonly in daytime, presumably because some activities such as fishing and swimming were more commonly conducted during daylight hours (Fukuda *et al.* 2014).

Despite the social, economic and ecological contexts in which HC conflicts occur in the different states of Mexico, one of the activities most commonly associated with attacks is fishing. Along both coasts, the methods used in fishing, such as fishing using nets (cast nets), diving with harpoons (spear guns), fishing in small canoes with the use of nets (gill-nets) and fishing from boats (handlines) put people at a high risk of an attack because many of these fishing methods are conducted along the coast in shallow or waist-deep water (Food and Agriculture Organisation of the United Nations 2015).

In the case of children, the attacks occurred on the banks of waterbodies, and, in some incidents with fishermen, the attacks occurred in shallow water, except in the cases of fishermen diving with harpoons. In Australia, the fatal attacks commonly occur in deeper water and, in contrast, non-fatal attacks commonly happen in shallow water or at the edge of water (Fukuda *et al.* 2014). In addition, when fatalities occur with younger victims ($<$10 years old), as was the case in Mexico, they trigger a negative reaction from local communities, and the death of an unquantified number of crocodiles ensues (García-Grajales 2013). In South Africa, the principal victims in crocodile attacks are boys while swimming (playing) and men while fishing (Pooley 2015*a*), which agrees with the results of the present work.

In both coasts, many rural communities in Mexico live on the margins of waterbodies and raise domestic animals without confinement, a situation that attracts crocodiles to feed (García-Grajales 2013). In addition to this, swimming in crocodile habitats clearly poses a high risk of attack and this represents

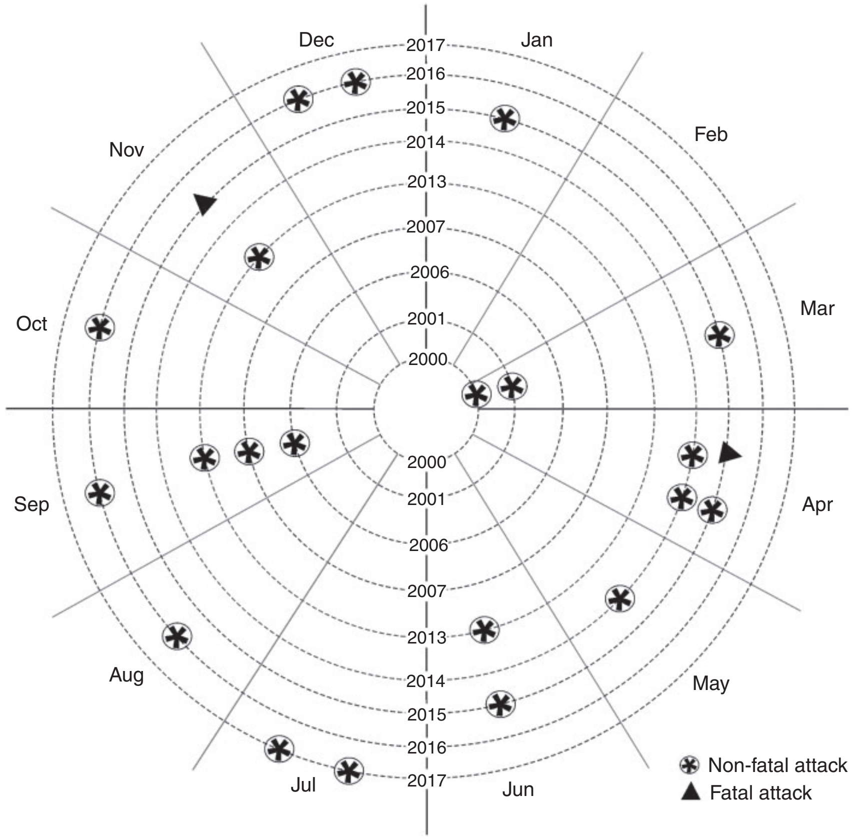

Fig. 9. Summary of crocodile attacks in the coast of Quintana per year and month. Concentric dotted lines represent an annual cycle.

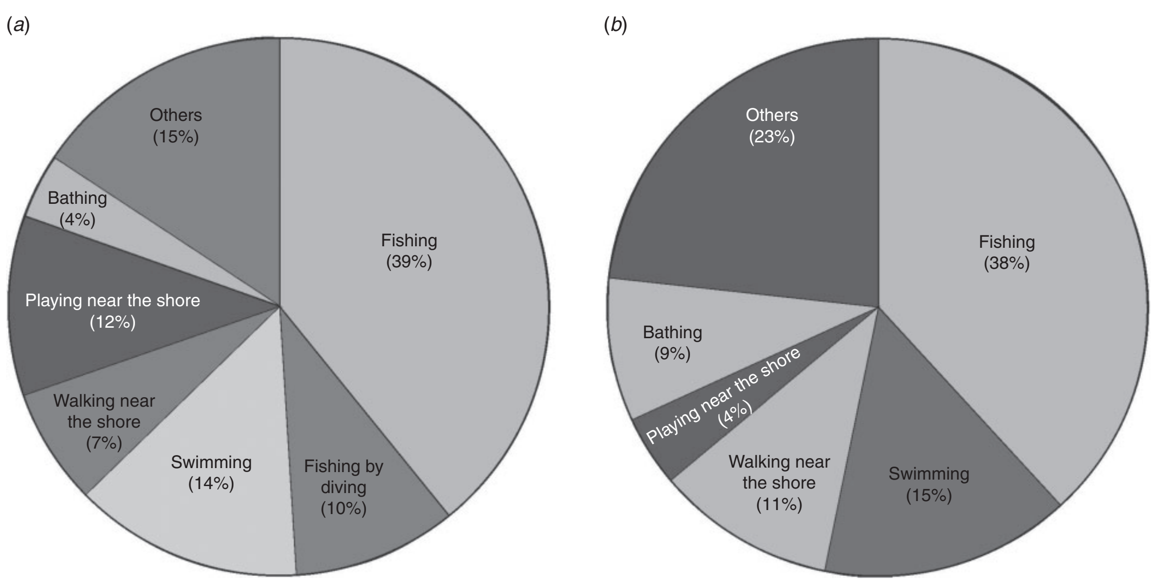

Fig. 10. Common activities at the time of fatal attacks in Mexico: (*a*) Mexican Pacific coast, (*b*) Gulf of Mexico coast.

Table 1. Classification risk (CR) score per municipality and crocodile-attack statistics of Mexico

The numbers in the code column correspond to locations shown in Fig. 1. Asterisks represent the priority hotspots areas

Region	State	Code	Municipality	CR	Total	Fatal	Non-fatal
Mexican Pacific coast	Oaxaca	1	Pinotepa Nacional	H*	13	4	9
		2	Villa de Tututepec	M	7	0	7
		3	Santa María Tonameca	M	5	1	4
		4	Santa María Colotepec	M	4	0	4
		5	Santa María Huazolotitlán	L	2	0	2
		6	San Pedro Pochutla	L	1	1	0
		7	Juchitán de Zaragoza	L	1	0	1
	Jalisco	8	Puerto Vallarta	H*	15	2	13
		9	Tomatlán	M	5	2	3
		10	La Huerta	L	1	0	1
		11	Cihuatlán	L	1	1	0
	Michoacán	12	Lázaro Cárdenas	H*	14	4	11
		13	Aquila	L	2	0	2
		14	Coahuayana	L	1	1	0
	Guerrero	15	Zihuatanejo	M	8	0	8
		16	San Marcos	L	3	0	3
		17	La Unión	L	1	1	0
	Chiapas	18	Huixtla	M	4	2	2
		19	Acapetahua	L	3	1	2
		20	Tonalá	L	1	0	1
	Colima	21	Manzanillo	L	2	0	2
		22	Armería	L	2	0	2
		23	Tecomán	L	2	0	2
	Nayarit	24	San Blas	L	3	0	3
		25	Tecuala	L	1	0	1
Gulf of Mexico coast	Quintana Roo	26	Benito Juárez	H*	13	1	12
		27	Othon P. Blanco	M	6	1	5
		28	José Ma. Morelos	L	3	0	3
		29	Cozumel	L	1	0	1
	Tamaulipas	30	Tampico	M	5	2	3
		31	Padilla	M	4	0	4
		32	Altamira	L	3	0	3
	San Luis Potosí	33	Aquismon	L	1	0	1
		34	San Vicente	L	1	0	1
		35	Tamuín	L	1	0	1
	Veracruz	36	Las Choapas	L	2	0	2
		37	Agua Dulce	L	1	0	1
	Tabasco	38	Balancán	L	3	2	1
	Campeche	39	Escárcega	L	2	1	1
		40	San Francisco de Campeche	L	1	0	1

the second activity related with HC conflicts, similar to what occurs in United Stated (Langley 2005, 2010), parts of Africa (Fergusson 2004) and Australia (Fukuda *et al.* 2014), where most victims were swimming. In addition, some cases in the Gulf of Mexico were related to the consumption of alcohol by victims, similar to what has been reported in Australia (Fukuda *et al.* 2014).

In Mexico, many details have been omitted at the time of collecting reports, such as the total length of the crocodile involved in the attack, the presence of witnesses, the age of the witnesses, the correct identification of the species involved, the presence of pets during the incident and the characteristics of the site where the incident occurred. One important aspect to consider more than the abundance of crocodilian populations is their length (Fukuda *et al.* 2015). For example, the probability of survival in a crocodile attack is related to the difference in body mass between the crocodile and the victim (Fukuda *et al.* 2015); thus, it is neccesary to know the total length of the crocodile involved. For example, an average-sized person weighing 75 kg would have a high probability of survival if they were attacked by a 300-cm crocodile in the water (diving, swimming or wading; Fukuda *et al.* 2015). This could happen with most fatal attacks in Mexico where victims were children with a small body size and weighing less than the crocodile involved. This type of information is essential for generating a more robust analysis of interactions. Recently, a strategy was created for preventing or reducing crocodile attacks on the basis of a national protocol and this will be published by the federal government; however, to create a correct strategy, it will be necessary to collect historical data and enter it in a standardised

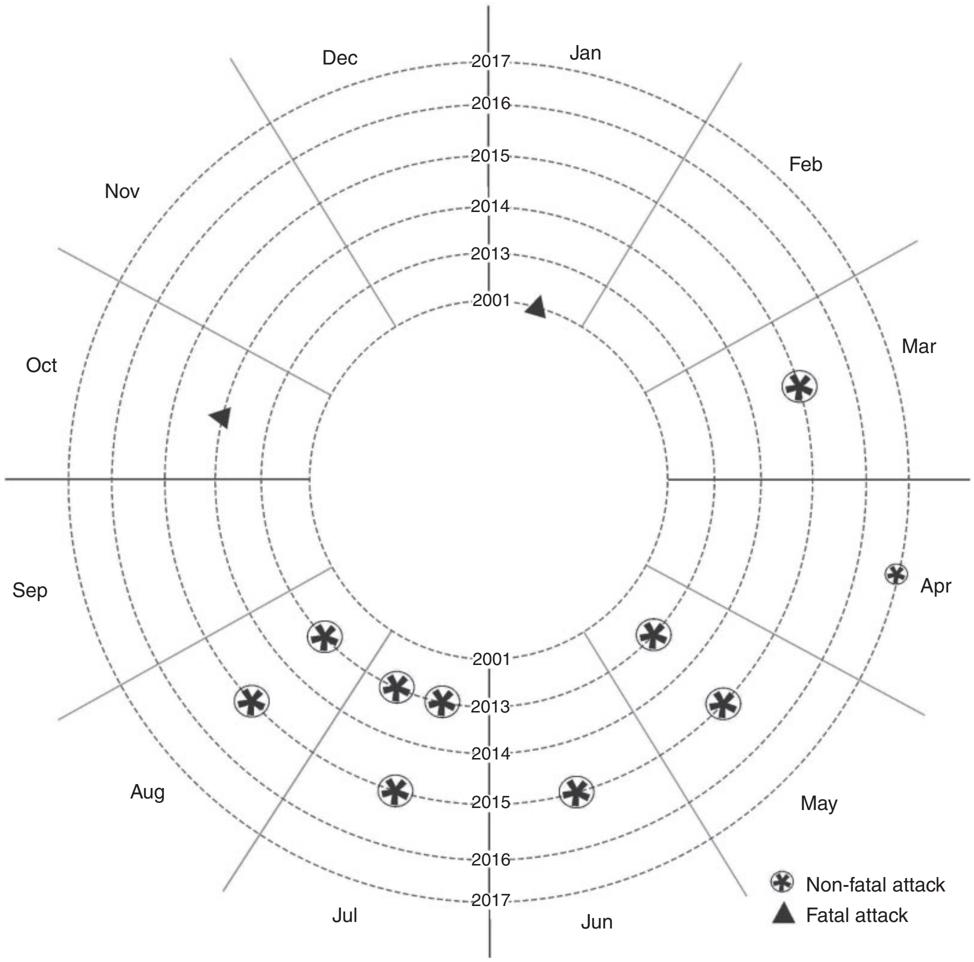

Fig. 11. Summary of crocodile attacks in the coast of Tamaulipas per year and month. Concentric dotted lines represent an annual cycle.

format in a freely available database, similar to the CrocBITE database but with the certainty of the information and the minimum variables necessary to understand the situation.

Pooley (2015*a*) explained that it is neccessary to gather sufficient data for a region and identify potential attack hotspots, along with and their history and trend of attacks, to provide recommendations to reduce HC conflicts. Herein, we have shown the critical hotspots among municipalities in Mexico and the trends for both coasts, so as to facilitate targeted mitigation.

The majority of coastal states in Mexico where the natural distribution of crocodiles occurs have presented at least one case of interaction between humans and crocodiles, except Sinaloa in the Mexican Pacific coast and Yucatán in the Gulf of Mexico. In Sinaloa, the likely reason for the absence of incidents is associated with a small population of crocodiles and low-quality habitats, and it represents the most northern part of the distribution of *Crocodylus acutus* (Thorbjarnarson *et al.* 2006). In the Yucatan Peninsula, the local perception of crocodiles is associated with a profound ethnic knowledge about the animal, which may be why there is no history of incidents in this area (Padilla and Perera-Trejo 2010). The hotspots identified in the Mexican Pacific coast correspond with the Crocodile Conservation Units established by Thorbjarnarson *et al.* (2006), where American crocodiles and their habitats have been adequately protected. With respect to *Caiman crocodilus chiapasius*, there are no reports of human interactions in Mexico, probably because caimans prefer nesting sites where humans rarely get to fish (pampas), and in Chiapas (principal distribution of this species) fishing is mainly undertaken on the estuary, where caimans are not nesting.

Similar to the proposal for the State of Oaxaca (García-Grajales and Buenrostro-Silva 2018), it will be neccesary to create new crocodile conflict networks in each state, composed of volunteers at academic institutions, state and federal wildlife service agencies, public and private fishing groups, lifeguards and individuals who respond to or provide professional advice on HC conflict events. This network will enable the compilation of information related to the human victims, such as gender, location and activity at the time of attack, as well as aid in facilitating targeted mitigation, long-term ecological analysis and social data on both crocodiles and humans.

This study has not provided new solutions; however, to issue specific recommendations to reduce the incidents of attacks by crocodiles, more information, such as that presented here, is required. Public education through a variety of media outlets (e.g. local television, radio, newspaper, and websites) will be the most effective means of informing the public about the potential danger of water-related activities in crocodile habitats (Fukuda *et al.* 2014). Finally, is necessary that local authorities in the municipalities (mainly those of high risk) establish public-safety programs with the goal of raising awareness of the risk of crocodile attacks on the basis of information on the status and distribution of crocodile population, linked to the extent of HC conflicts, as a first step for better management and risk mitigation.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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