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Living with predators: a focus on the issues of human–crocodile conflict within the lower Zambezi valley

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Abstract

Context. Human–wildlife conflict is a global problem and increasing worldwide as people and wildlife compete for limited resources. Conflict between people and crocodiles, especially in Africa, is recognised as a serious problem. The people of the Chiawa Game Management Area are heavily dependent on the Zambezi River for several resources from potable water and irrigating fields to a source of food (subsistence and small-scale commercial fishing).

Aims. To assess the spatial and temporal scale of human–crocodile conflict (HCC) and identify associated factors, with a view to recommending mitigation measures.

Methods. A questionnaire survey and Zambia Wildlife Authority data were utilised to estimate the scale of HCC.

Key results. Between 2000 and 2009, there were 98 crocodile attacks on people, 62.2% were fatal. Most of the attacks occurred while canoe fishing (57.1%) and collecting water (29.6%). Crocodiles were disliked and seen as a 'problem' by the majority of the populace. Even though crocodiles are a charismatic mega-fauna species, being employed within the tourism industry had only a minor positive effect on people's attitudes. The area is an important location for crocodile egg and adult harvesting, although the local population gains no financial benefit. An increase in the number of boreholes in the villages was suggested by the local people as the primary mitigation measure, as well as the removal of crocodiles by various means.

Conclusions. Although people displayed an understanding of the risks of crocodile attack, very few actually employed mitigation techniques or utilised protective barriers when at the river. Increased water-access points (and their maintenance) in the villages would reduce people's dependency on the river. The negative attitude towards crocodiles is an issue that has to be addressed to allow successful implementation of long-term conservation strategies.

Implications. Understanding local people's attitudes towards wildlife is an important aspect within any conservation management plan.

Additional keywords: attack, attitudes, management, mitigation.

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Introduction

Human–wildlife conflict (HWC) is a global problem, occurring in many countries where human and wildlife requirements overlap. As wildlife and humans increasingly compete for limited space and resources, the severity and frequency of conflict increases (Madden 2004). The fate of many wildlife populations is dependent on coexistence with people. An understanding of the factors that shape the response to HWC by humans is essential for its prevention and mitigation (Manfredo and Dayer 2004). Conflict management has often focused on wildlife; however, alteration of human behaviour may be a more realistic option for long-term conservation plans (Baruch-Mordo *et al*. 2009). The evaluation of local people's tolerance thresholds and attitudes towards wildlife can have significant conservation implications (Manfredo and Dayer 2004; Romanach *et al*. 2007). If the fundamental issues of HWC are not addressed, conservation efforts lose stability and the support of local communities (Treves *et al*. 2006). Community involvement has been demonstrated to be a deciding factor in the success of management plans (Groom and Harris 2008). Such management plans, however, need to be adhered to by all parties so as to be successful (Infield and Namara 2001).

One of the animals associated with HWC is the crocodile, once heavily persecuted and harvested in the 1950s and 1960s (Cott 1961). Successful conservation methods have increased wild crocodile populations, which in turn has been accompanied by an increase in 'problem' crocodiles (Letnic and Connors 2006). The issues involved with human–crocodile conflict (HCC) are a

concern, especially in African countries where the Nile crocodile (*Crocodylus niloticus* Laurenti (1968)) is the cause of significant numbers of human and livestock fatalities (Aust *et al*. 2009; Dunham *et al*. 2010).

Crocodiles are keystone species and fulfil an important role within the aquatic ecosystem in which they occur (Mazzotti *et al*. 2009) and also have a significant economic value (Heykoop and Frechette 2001; Balmford *et al*. 2002). Although crocodile farms can ultimately be self-sufficient, they do require an initial wild stock if captive specimens are not available and crocodile ranching requires harvests of eggs from the wild population (Luxmoore 1992).

There are several factors involved with the Chiawa Game Management Area (GMA); it is a site of conservation importance, a location for people to settle and develop agriculture, a tourist destination, and a source of wild crocodile adults and eggs for the ranching industry. Developing a harmonious management plan that benefits all of the aforementioned participants as well as conserving the existing crocodile population requires accurate baseline data.

Some of the primary information for HCC analysis in the lower Zambezi is available as Zambia Wildlife Authority (ZAWA) keeps records of HWC incidents. There is no direct incentive to report wildlife attacks to ZAWA; therefore, it is not expected that all attacks would be reported. The magnitude of human–crocodile conflict is a challenge to quantify, because it is difficult to obtain comprehensive data especially concerning attacks resulting in no harm which are rarely reported (Fergusson 2004).

The main objectives of the study were to (1) estimate the scale of conflict, (2) investigate spatial and temporal aspects, (3) identify associated factors, (4) assess local attitudes towards crocodiles and (5) ascertain likely solutions to HCC.

An important pre-requisite for managing HWC in a specific locale is to understand the attitudes to wildlife and patterns of conflict. Involving people at the local level in surveys and realising attitudes can assist in future long-term conservation strategies (Dickman 2010). The priority is to ascertain whether the conflict is a serious problem endangering wildlife or a threat to people. Local people are directly involved with all forms of wildlife interactions and often decisions concerning both them and wildlife are realised by people far removed from the actual ‘problem areas’ and with limited understanding of the circumstances. The fundamental questions that require answering are ‘are the ‘problem’ wildlife really a problem’ and if so, what is the most practical compromise for the local community and the wildlife concerned. Quantifying the scale of the problem is one aspect and identifying the attitudes of the local community towards the wildlife concerned (e.g. prevention, mitigation) is important for long-term success.

Materials and methods

Study site

The Chiawa GMA is situated in the middle or lower Zambezi region of Zambia, hereafter referred to as the lower Zambezi, and is bordered by the Kafue River to the west and the Lower Zambezi National Park to the east (Fig. 1). The area has a distinct wet season from November to April, followed by a cool and dry season (May–July) and a hot and dry season (August–October). The Chiawa GMA is 2344 km^2 and is divided (perpendicular to the River) into two sections by a game-control fence. Although HCC can and has occurred in many areas across the lower Zambezi, the study examined only incidents within the western GMA because this has the largest human population adjacent to the Zambezi River. The eastern GMA ‘Sanctuary area’ acts as a buffer zone between the western area and the Lower Zambezi National Park to the east. A population of ~20 000 people reside in 15 villages that border the lower Zambezi Road that parallels the Zambezi River. The villages are spaced at regular intervals between the Kafue River and the game-control fence. The wildlife in the western GMA are at a lower density than those of the eastern GMA. However, several species of large wild animals persist and potentially pose human–wildlife conflict. These include baboon (*Papio ursinus*, *Papio cyncephalus*), buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*), hippopotamus (*Hippopotamus amphibious*), and Nile crocodile (*Crocodylus niloticus*). The Chiawa GMA is classified as an IUCN Category IV, defined as an area ‘to maintain, conserve and restore species habitat’ (IUCN 2010). It is also part of the African Wildlife Foundation (AWF) Heartlands program which encompasses key landscapes, including national parks, local villages, government and private lands (Muruthi 2005; AWF 2010). GMA’s in Zambia were principally established to act as buffer zones around National Parks, although they also support hunting and photographic safaris, as well as limited settlement for local communities who are allowed to practice agriculture (ZAWA 2010). The lower Zambezi valley is dominated by flood plains, with rural communities making use of the fertile soils and access to water to grow food crops. Fishing is the other means of subsistence and small-scale commercial operations. Water is available in most villages from a manually operated hand pump known as a borehole. Local villagers pay ZMK 5000–20 000 per household per month (~US$1–4) to the headman for maintenance of the borehole.

Questionnaire surveys

The questionnaire included both open-ended and fixed response questions. The study proposal and methodology were reviewed and approved by the Ethical Review Process of Imperial College London. The household was chosen as the sampling unit, with only one respondent used from each household. Interviews were conducted between April and August 2009. These were carried out with a permanent resident representative of the household, lasted 30 min and all respondents were above the age of 18 years. Translators were used when required and no incentives or rewards were offered to the respondents. A total of 14 enumerators (two ‘western’ research team members and 12 ‘western’ volunteers) conducted the interviews. So as to reduce interviewer bias, each enumerator was given prior training which included an explanation of the questionnaire and purpose of the survey, interview techniques and aspects of local culture. To reduce the possibility of any questions being misconstrued (Willgerodt 2003), all six translators that participated were interviewed and asked for feedback. Changes to the questionnaire were incorporated when necessary.

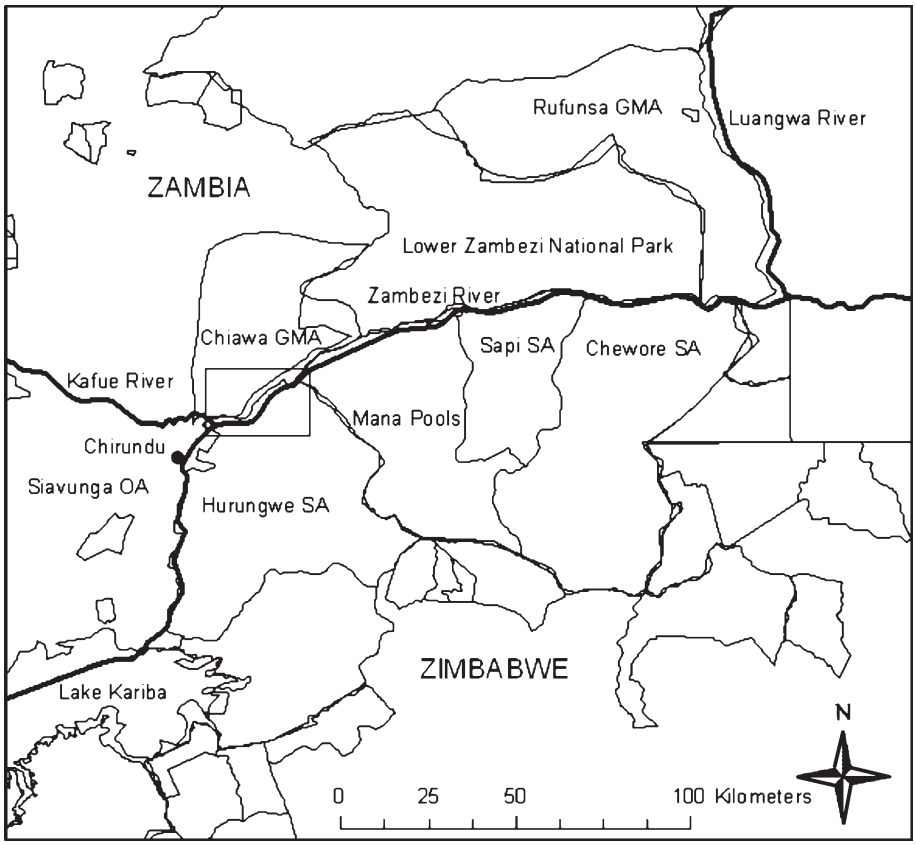

Fig. 1. The Lower Zambezi Valley. The study site is depicted by the rectangle in the western half of the Chiawa Game Management Area (GMA) in Zambia. Other abbreviations are safari area (SA) and open area (OA).

Statistical analysis

All statistical analyses were performed using R version 2.10.1. Respondents were asked for information concerning HCC. These crocodile-attack reports had to be disentangled because of the possibility of the same incident being reported by several different respondents. The data were cross-checked by correlating the name of the attack victim, age, sex, activity, location, date and severity of injury. ZAWA provided data detailing 44 crocodile attacks dating from 2000. The details regarding crocodile attacks (year, month, activity and outcome of incident) were assessed for accuracy by comparing the answers from respondents to the data of the identical incident recorded by ZAWA (assumed as being 'correct' because of it being reported immediately). This was then recorded as the percentage of respondents who gave the 'correct' answer.

The location of crocodile attacks (distance from the eastern Chiawa GMA gate) was used as an explanatory variable for the number of attacks, using regression analysis. Linear models were also used to examine the number of crocodile attacks as a response to the mean monthly temperature and rainfall. The year of attack was used as an explanatory variable to identify trends of attack rates through time. Seasonal variation in the pattern of attacks was examined with ANOVA using the wet season (November–April), cool and dry season (May–July) and hot and dry season (August–October).

Categorical data (sex, age, time period of residence, employment) were initially analysed with contingency tables using Pearson's chi-square test (χ^2) or Fishers exact test (if one or more of the expected values were below 5) to determine the homogeneity of proportions with regard to crocodile attacks. A generalised linear model with Poisson error structure was constructed for the number of crocodile-attack incidents that occurred. This was split into sex, the type of activity the victim was involved in before the incident (river-bank fishing, bathing, canoe fishing, crossing a footbridge, farming or water collection) and severity of the incident (fatal, injury or no injury). Saturated models were initially fitted which were then simplified to the minimum best-fit model, using an ANOVA with a chi-square test.

Linear models were used to ascertain the degree of correlation between the number of people in the village that collected water, as a function of the distance to the river and borehole reliability (to facilitate analysis, the respondents answers were assigned a numerical state from 1 = unreliable, to 4 = reliable). Similar analysis was conducted for the likelihood of a crocodile attack being reported using the incident outcome (1 = fatal, 2 = serious injury, 3 = minor injury, 4 = no injury) as the explanatory variable.

Demographic factors (age, sex, village rank, employment, employment within tourism, ownership of arable fields and/or livestock) were tested using Pearson's chi-square test (χ^2) as

explanatory variables to explain variation in attitude to crocodiles.

Results

In total, 398 people were interviewed in the 15 villages. This varied from 17.5% and 90% of the households of each village (mean = 41.1%). Only five people refused to participate and these cases were due to the potential respondent being too busy and there was no animosity towards the enumerator. There were more female (68%) than male (32%) respondents.

Scale of HCC

A third of respondents ($n = 126$) offered information detailing 85 individual crocodile attacks. An additional 41 attacks were obtained from ZAWA data, including 10 found on both sets of data. The crocodile-attack data given by respondents were assessed for reliability, as details of past events are often difficult to recall accurately (Odinot *et al*. 2009). Recollection of the outcome of the incident (78% of respondents recalled the correct outcome) and the activity being undertaken (74%) were similar to the ZAWA data. Most respondents (83.6%) were able to suggest a year when the incident occurred, but only 21.9% of respondents could also suggest a month or a period of the year (wet or dry season). It was decided to use the data from 2000 to 2009, omitting 28 attacks pre-1999, or of unknown date, from the analysis.

During the previous 10 years (2000–09 inclusive), crocodiles attacked 98 people. The questionnaire survey accounted for 57 attacks, ZAWA data 31 attacks and 10 attacks were identified by both. Females accounted for 36 of the victims and 62 were male. The mean age of the victim was 39.2 years. Most of the incidents were fatal (62.2%), 31.6% resulted in an injury, 4.1% in no harm and 2.1% had an unknown outcome.

Approximately half of the attacks (53.1%) identified from the questionnaire survey were reported to an organisation such as ZAWA or the police. There was a correlation between the severity of the attack and the likelihood of it being reported ($r^2 = 0.93$, $P = 0.02$, d.f. = 2); 31.6% of the fatal attacks were reported, 21.4% of the attacks resulted in a serious injury, 5.1% involved a minor injury and none of the attacks that resulted in no injury was reported.

Approximately half the households (45.8%) kept poultry (either ducks or chickens), 20.9% kept goats and 0.5% kept cattle. A quarter of the households (25.5%) that kept livestock experienced livestock depredation by a crocodile (70.4% goats and 27.7% dogs, 1.9% poultry); these incidents were infrequent, occurring from once a year to once in 10 years. Respondents witnessed 29.6% of the attacks, with the remainder being based on supposition. There were no reports of cattle being killed, with all being tended by a herd-boy.

Spatial and temporal aspects of HCC

Crocodile-attack incidents were consistent throughout the study site, showing no relationship to the distance (of the nearest village where the attack was recorded) from the eastern Chiawa GMA gate ($r^2 = 0.01$, $P = 0.36$, d.f. = 13). There was no direct evidence for temperature ($r^2 = 0.11$, $P = 0.30$, d.f. = 10), rainfall ($r^2 < 0.01$, $P = 0.90$, d.f. = 10) or season (ANOVA $F = 1.46_{2,9}$ $P = 0.28$) influencing the likelihood of an attack (Fig. 2). The combined number of attacks (survey and ZAWA data) decreased between the years 2000 ($n = 12$) and 2009 ($n = 7$) ($r^2 = 0.41$, $P = 0.05$, d.f. = 8), although no attacks were recorded by ZAWA during the recent years of 2006, 2007 and 2009.

Factors associated with HCC

There was a significant gender effect and activity effect within the model ($\chi^2 = 14.2$ $P < 0.01$, d.f. = 6). These ratios follow the sex biases for the various activities; of the canoe-fishing attacks, 90.3% involved men and of the water collection, 74.3% were women. The majority of attacks (57.1%) occurred while fishing from a canoe, which was an activity undertaken by a minority of the population (16.3%) (Fig. 3). The second-most dangerous activity was collecting water from the river (49.7% of households), accounting for 29.6% of the attacks. Most households (84.0%) had a borehole in a closer proximity than was the river, with the mean distance from a respondent's house to the nearest borehole being 411.3 m (range 10–5000 m) and that to the river 1368.1 m (range 100–6000 m). The reliability of the

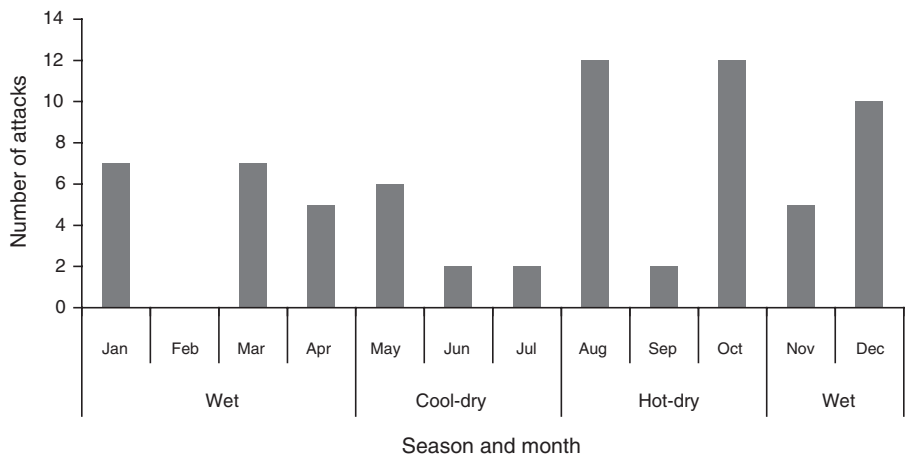

Fig. 2. Seasonal distribution of crocodile attacks that occurred in the Chiawa Game Management Area between 2000 and 2009 inclusive ($n = 98$).

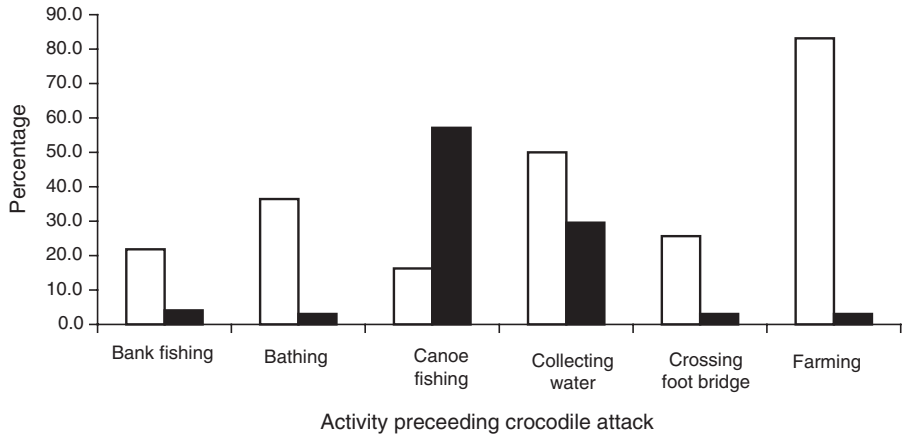

Fig. 3. Percentage of crocodile attacks ($n = 98$) between 2000 and 2009 (black bars) relative to the population involved in a particular activity (white bars, which exceed 100% because many households are involved with multiple activities) in the Chiawa Game Management Area.

borehole decreased with an increase in the number of households in the village per borehole ($r^2 = 0.57$, $P < 0.01$, d.f. = 13). As the reliability of the borehole decreased, the number of people that collected water from the river increased ($r^2 = 0.42$, $P = 0.02$, d.f. = 12). Increasing distance between the household and the river had a negative effect on the number of people collecting water from the river ($r^2 = 0.12$, $P = 0.03$, d.f. = 12).

Crocodile attacks were also recorded while individuals were engaged in agricultural activities (3.1% of the attacks). Most households were involved in some form of agricultural activity (83.2%), although the proportion of fields that actually border the river was not ascertained; therefore, the results may indicate this bias. A third (30.8%) of the households that cultivated crops had to cross a footbridge across a tributary of the Zambezi, which accounted for 3.1% of attacks. Approximately half (50.9%) was required to cross a footbridge during the rainy season and 49.1% all year round. The ZAWA data indicated that during the 10-year period, one crocodile was killed (during 2004) by ZAWA personnel.

Local attitudes towards HCC

Crocodiles were considered a problem by the majority of both women (92.9%) and men (89.1%). Only gender and employment within tourism had significant ($P < 0.05$) influences on some of the 'attitude towards crocodile' responses. The majority of households with both tourism and non-tourism employees regarded crocodiles as a problem, 80.4% and 97.3% respectively. However, of the 20 households that regarded crocodiles as either a benefit or a combined benefit and problem, 18 had a tourism employee. The main reason cited for crocodiles being a problem was that they were dangerous (94.8%). Of the remaining minority that believed that crocodiles were beneficial, 3.0% suggested that crocodiles were important for tourism or economic reasons, 0.7% that they were important for conservation reasons, 0.7% that they were avoidable, 0.5% that they were important because God created them and 0.2% that they were important for aesthetic reasons.

Removing some or all of the crocodiles from the river was preferred by the majority of both men (78.3%) and women (88.1%) as well as by the households that had an employed person (whether they were employed within tourism 75.5% or not 91.8%). This varied from selective culling or removal of large and/or problem animals to complete eradication. Gender influenced the response to the suggestion of a monetary recompense for living alongside crocodiles, with 25% of women willing to accept a form of payment, although the majority cited that 'a financial incentive is not comparable to the loss of human life'. Men were twice as likely (49.5%) as women to consider a financial incentive to allow crocodiles to remain.

The majority of people (62.7%) believed that crocodiles could attack at any time of the day. Most people (65.2%) regarded the rainy season as the most dangerous period during the year, as opposed to the dry season by 5.0%. Approximately a quarter (26.4%) of people believed the whole year to be dangerous. A large proportion of people (81.7%) did not take precautions to prevent crocodile attack, only 38 households (18.3%) utilised a river fence on a regular basis.

Possible solutions to HCC

Respondents were given a choice of four organisations that should be held responsible for public safety; the government was suggested by 40.0%, conservation non-governmental organisations (NGOs) by 23.7%, the local community by 11.4%, the headman by 10.6%, all of the previously mentioned by 1.3% and 13.1% did not know. When asked what the best mitigation solution would be to prevent crocodile attacks, approximately half of the respondents offered a comment ($n = 160$). Mitigation measures suggested were as follows: additional boreholes (57% of respondents), removal of crocodiles (29%), river fences (7%), building more and improved bridges (4%), developing fish farms (2%) and bathing pools (1%). Other suggestions (not actual mitigation techniques) included avoiding the river ($n = 5$), education ($n = 6$), God creating everything and protecting people ($n = 2$), ZAWA being more involved with communities experiencing 'problem crocodiles' ($n = 9$).

Discussion

Human–crocodile conflict in Africa is a significant problem, with many more fatalities reported than for other continents where crocodilians occur. People who live in areas where crocodiles occur run inherent risks when spending time at the river. Finding ways to save people's lives should be of paramount importance. Crocodiles are an ecologically and economically important species; therefore, it is important to resolve any negative relationships which may impede conservation or utilisation efforts. The present study identified the activities that precede crocodile attacks and quantified the attitudes of people towards crocodiles and mitigation methods. These data can be used as a framework for crocodile management, which should include public safety. The analysis revealed the complex nature of attitudes towards this charismatic species which is an efficient predator.

Scale of HCC

There was a discrepancy between the attack-incident data gathered using the questionnaire survey and the ZAWA data. It is possible that there was a lack of communication between the authorities to whom the crocodile incident was reported (e.g. Police, ZAWA patrol, village scout, village headman) and the ZAWA Chirundu office. Chirundu is ~16 km from the western edge of the GMA and therefore access for local people maybe an issue for the purpose of reporting a crocodile attack. The likelihood of reporting a crocodile attack increased with the severity of the incident. There were no attacks recorded by ZAWA that resulted in no harm being inflicted on the victim. Predators are more likely to return to an area where a previous attack has taken place (Treves *et al*. 2004). This highlights the importance of encouraging the local populace to report crocodile (and other animal) attacks to the relevant authorities. Livestock losses as a result of crocodile depredation were minimal, with goats being the main animal attacked, following the pattern of also being the predominant livestock. Crocodile attacks on humans appeared to outnumber those of livestock attacks. Any loss of human life is tragic and 9.8 attacks per year constitute 0.05% of the Chiawa GMA population. Human deaths that could have been avoided are deplorable and this figure represents only those people attacked by crocodiles. There are numerous other dangerous animals such as elephant in the area as well as the prevalence of life-threatening diseases such as HIV/AIDS and malaria. There is still a great deal of scope to realise the full extent of mitigatable fatalities.

Spatial and temporal aspects to HCC

It was thought that the rates of crocodile attack would increase towards the eastern section of the study site, which was close to the protected area and the increased number of crocodiles. However, the presence of large protected areas adjacent to (the Lower Zambezi National Park) and opposite (Hurungwe Safari Area) the study site may in fact have reduced the number of attacks because of an abundance of natural prey in areas of limited human density. These areas would also offer relatively undisturbed basking sites compared with the shoreline of the GMA.

Seasonal patterns of attacks by crocodiles on both livestock and people have been reported for Kenya and Namibia (Fergusson 2004) and for north-eastern Namibia, including a portion of the upper Zambezi River (Aust *et al*. 2009). During the dry season, it is assumed that more people (and livestock) would utilise the river to bathe and cool down. The warmer temperatures would allow crocodiles to be active during a greater portion of the day. These assumptions would lead to a hypothesis of an increase in attacks during the hot and dry months. The main peaks in the number of attacks did occur during 2 of the 3 months of the hot and dry season, whereas the third month had some of the lowest numbers of reported attacks. It is not known why September has some of the lowest numbers of reported attacks. The month and/or season were the most difficult aspect of the crocodile attack for respondents to recall accurately and this may be reflected in the results.

The number of crocodile attacks per year decreased from 2000 to 2009. More attacks were identified in recent years using the questionnaire survey. The ZAWA data had more attacks recorded for the earlier years, with few or no attacks reported during the past 3 years. The ZAWA data are reliant on 'reported' attacks, whereas the questionnaire survey revealed several attacks that were not reported. Only a small percentage of these were found within the ZAWA data. It is possible that the number of attacks is reducing each year, although the reasons are as yet unclear. One possible reason could be an increase in the number of boreholes, which would have reduced the number of people collecting water from the river.

Factors associated with HCC

The type of activity carried out at the river influenced the potential for a crocodile attack, with fishing from a canoe being recognised as the most dangerous because of the high incidence of attacks and the low proportion of the population involved. Fishing from a canoe has been recognised as a high-risk activity in other studies (McGregor 2005; Thomas 2006). Both fishing activities (canoe and bank) can place people in isolated areas and the associated activities of setting nets (wading in the river and along sandbars) and gutting fish (which can offer an olfactory cue to the crocodiles) may increase the risk of attack. If the individual is alone (as is often the case for fishermen), there is very little chance of the attack being either witnessed or for intervention from a third party. Not all of these incidents were visually confirmed and it should be noted that many of the canoes are often in a state of disrepair. It is not uncommon to see canoes being paddled and water being bailed out simultaneously. Very few of the local people can swim, and it is possible that some of these fatalities may be attributed to canoes capsizing or sinking from an encounter with a submerged obstacle or animal other than a crocodile (i.e. hippopotamus, *Hippopotamus amphibius*) and the individual drowning. The other activities in the order of potential risk of crocodile attack per year are collecting water, fishing from the bank, bathing and crossing foot bridges, which follow a pattern similar to the proportions of the local populace that are involved. The farming incidence of attack should be viewed as an underrepresentation; the actual river usage would depend on the location of the farm in regard to the river and irrigation method, neither of which was established.

Much of the literature concerning crocodile attacks reports the number of incidents in areas per year according to the preceding activity (Fergusson 2004; Caldicott *et al*. 2005) and some relates the data to human population size and proportion of the populace involved in that particular activity (Thomas 2006). This can be taken one step further by utilising the amount of effort per day for each activity. Some activities such as fishing from a canoe may consist of an entire day on the river, whereas collecting water may require only an hour at the most per day. Investigation into daily effort could yield informative results and elaborate on the ranking of activities in terms of the exposure to potential crocodile attack. This information becomes pertinent when assessing the activities for mitigation, especially when funding for conservation measures can be limited (Brockington and Scholfield 2010).

Local attitudes to crocodiles

On the whole, the majority of people viewed crocodiles as a problem, regardless of sex or employment within tourism. A higher proportion of women, however, was in favour of crocodile removal and a financial recompense was less likely to sway their point of view. Other studies have shown that women can express a higher degree of concern about potentially dangerous wildlife (Zinn and Pierce 2002). Men appear to have higher tolerance levels to crocodiles. The local tourism industry is biased to employing males and so there is a higher chance of males having a more sympathetic attitude towards wildlife because of previous experience. Tourism has been suggested as the solution to ensure positive human–wildlife relationships and, used in the correct way, can be beneficial, not only in raising awareness and tolerance levels for wildlife but in providing an economic incentive (Stronza and Pegas 2008). The interviews quantified whether the household had a tourism employee, not whether this was the respondent him/herself. We assume that because the family is benefiting from tourism they would be more predisposed to crocodiles; however, tourism have very little effect. It is possible that such 'tourism' respondents may be more predisposed to wildlife in general, but when singled out, the crocodile (because of its size and appearance) becomes a 'problem' animal. The type of tourism related job may also have an influence, possibly the 'front of house staff' (e.g. managers, lodge guides) acknowledge the bigger picture of an ecosystem and the relevance of different types of wildlife because of their training and experience. The 'back of house staff' (such as e.g. cleaners, kitchen staff) may not appreciate such nuances. Subtle differences such as these require further investigation because a general increase in the awareness of the wildlife issue may have a decisive impact on the attitudes of employees who may be unaware that their employment is dependent on the large and potentially dangerous species that they would like to be removed.

Only one household was involved with a crocodile ranch, directly benefiting from the presence of crocodiles. Considering that several Zambian crocodile farms and ranches harvest crocodile eggs and adults in this area, there is potential for community involvement. Conservation strategies have often benefited from local participation which includes financial benefits for the local population that live alongside the wildlife (Frost and Bond 2008; Groom and Harris 2008). There are no crocodile farms located in the Chiawa GMA and only a minority of people will directly benefit because adult crocodile capture and egg collection require small teams with specialist training and operate only for a few months of the year. Trophy hunting and the collection of wild crocodile eggs and specimens is regulated by ZAWA who set the quota and price. The Zambian crocodile management plan stipulates that 50% of the proceeds from trophy hunting will be distributed with the local communities '...to assist in creating a positive attitude towards crocodiles' (IUCN 2004). It also stipulates that 5% of wild-collected eggs, once hatched and reared to 1.2-m total length, should be repatriated to compensate for the initial off-take. An alternative strategy allows the crocodile farm to sell this percentage and pass the funds onto ZAWA for use in crocodile conservation (Chansa *et al*. 2005). These sentiments are admirable if followed through but it is not known if or how these funds would be distributed to local communities. Therefore, it is difficult to increase tolerance levels through direct economic incentives.

Possible solutions to HCC

The majority of people felt that it was the responsibility of the Government to ensure the safety of the people of Chiawa GMA. A considerable number of people suggested that NGO's should accept some of the responsibility. The reasons stated were that these were the interest groups that wanted conservation and therefore should take an active part in reducing the conflict between wildlife and people. Respondents believed that a crocodile attack could happen at any time of day and that the rate of attacks would peak during the wet season. Despite this knowledge, the majority of people did not use any form of mitigation while utilising the river.

The construction of more boreholes (and regular maintenance) in each village was the most widely suggested solution and would reduce substantially the proportion of the population that has to collect water from the River. Supplying every household with running water would be the ideal solution, but this is currently an unrealistic option in rural Zambia.

The removal of crocodiles was a widely suggested solution to reduce the number of attacks and has been cited as an effective technique in Australia (Nichols and Letnic 2008). The capture and relocation or removal of 'problem' crocodiles to a crocodile farm could have multiple benefits. The problem animal is humanely removed, the farm gains an extra breeding individual and ZAWA is seen to be following-up crocodile-attack reports. In conjunction with skilled capture teams, correctly identifying the 'problem animal' and not using as an excuse for excessive removals of large breeding females, capture and relocation poses a possible short-term solution. This will not necessarily reduce the potential for attack and, if not carried out correctly, could infuse a false sense of security for certain areas until another 'problem crocodile' takes up residency.

Unfortunately there is very little that can be done to mitigate the risk of crocodile attack on people who fish using a canoe, other than dissuading participation, which would require an alternative option. The use of better canoes is a possibility, but will require initial investment and continued maintenance. This may not deter a crocodile attack or accidental drowning as a result of collisions with submerged obstacles or encounters with other animals.

Mitigation measures to prevent or reduce crocodile attacks such as protective barriers at the river's edge have been cited (Thomas 2006) as a solution, yet this has not been validated empirically. Although it is common sense that physical barriers at the river's edge may reduce the number of attacks, there are also other factors that need to be considered. The barrier will require maintenance and corralling people into the same area may be problematic. This situation could change from a safe haven to a potentially high-risk area if the fence falls into a state of disrepair. There are only three protective barriers in the Chiawa GMA and these appear to be underutilised despite the potential benefits of using a mitigation measure that can be locally sourced, constructed and maintained. Only a small percentage of the respondents suggested the use of protective barriers as a mitigation aid.

The incidence of attacks while traversing a foot bridge could also presumably be reduced by a sturdier initial construction and building high enough to prevent the tributary flowing over the bridge at times of high water. Reducing livestock losses (at least from crocodiles) is possible by providing water for the animals in the village or using a shepherd to keep the animals away from the river and corralling them at night.

Although half of the respondents offered mitigation suggestions, a considerable number of people responded by saying that there was 'nothing that can be done to prevent crocodile attack'. This fatalistic attitude indicates a type of resignation to the possibility of an attack happening, accepting that living in the GMA brings with it inherent and unavoidable risks.

The present study has provided valuable data and insights to the human–crocodile relationships in the Chiawa GMA. Crocodiles are a problem and there is currently very little mitigation effort. More boreholes and on-going maintenance would reduce people's reliance on the river for water collection. A greater effort on follow-up, with the involvement of NGO's and/or crocodile farms to capture and remove 'problem' animals would be beneficial, and could increase the likelihood of the local populace reporting attacks. An improved system of reporting would be helpful, such as monthly visits by ZAWA to villages to document HWC. It is important to determine all the incident locations, regardless of the severity of the injury so that attack 'hot-spots' can be identified and appropriate action implemented. The ideal way to prevent HCC is to avoid the river. This is not possible in areas such as the Chiawa GMA, where people rely on the river for a multitude of activities from social pastimes to the necessity of collecting water. The underlying dislike of crocodiles by the local population should be carefully considered. Unless this is changed, future conservation or mitigation measures may not be as effective as anticipated. There appears to be a disregard for safety and minimal understanding of crocodile behaviour and the potential ecological and financial benefits. Conservation and ecological-education and -awareness campaigns would benefit local people and could have a positive influence on people's attitudes to wildlife.

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