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Human Dimensions of Wildlife

An International Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uhdw20

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To cite this article: Mercy-Gloria Ashepet, Farid Dahdouh-Guebas, Steve Redpath, Simon Pooley & Jean Huge (2023): The state and perceptions of human-crocodile interactions around Murchison falls conservation area, Uganda, Human Dimensions of Wildlife, DOI: 10.1080/10871209.2023.2212692

To link to this article: https://doi.org/10.1080/10871209.2023.2212692

HUMAN DIMENSIONS OF WILDLIFE
https://doi.org/10.1080/10871209.2023.2212692

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The state and perceptions of human-crocodile interactions around Murchison falls conservation area, Uganda

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ABSTRACT

Wildlife conflicts between people and large herbivores or mammalian carnivores are widely researched in Africa, but there is limited work on human-crocodile conflicts (HCC). In Uganda, conservation efforts have enabled the recovery of the Nile Crocodile (Crocodylus niloticus) population, yet the expanding human population and activities increasingly overlap with crocodile habitats resulting in negative interactions. This study used a combination of literature review, surveys, and the Nominal Group Technique to investigate the factors underpinning HCC around Murchison Falls Conservation Area. Results indicate that 115 attacks on humans occurred during 2012–2017, 84.3% of these being fatal. Also, 93.1% of the attacks occurred as victims were either fishing or collecting water. Construction of crocodile exclusion enclosures and translocation of problem crocodiles to protected areas were the most preferred mitigation measure. To reduce the prevalence of human injuries and offset local hostility toward crocodiles, conservation actors need to actively engage the affected communities.

KEYWORDS

Attacks; human-wildlife conflicts; Murchison falls National Park; Nile crocodile; nominal group technique; Uganda

Introduction

Human–wildlife conflicts (HWC) are a global conservation challenge (Redpath et al., 2013), emerging "when the presence or behavior of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife" (IUCN, 2020, p. 2). Human–wildlife conflicts occur in locations where human activities overlap with wildlife habitats or ranges (Anand & Radhakrishna, 2017; Aust et al., 2009; K. Wallace, 2011), particularly in communities neighboring protected areas (PAs) or those reliant on natural resources (RedpathRedpath et al., 2015). Communities living adjacent to aquatic environments in Africa have raised

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concerns over attacks from crocodiles (Lamarque et al., 2009). Crocodile attacks have devastating consequences because they can result in the loss of human life, injuries that culminate into disability, and predation upon valued livestock (Jeremiah, 2018). The Nile crocodile (*Crocodylus niloticus*), which is widely distributed across Africa, is believed to be responsible for more wildlife-caused fatalities of both humans and livestock than any other single wildlife species in several African countries (Lamarque et al., 2009). This situation has important implications for crocodilian conservation and human well-being (Amarasinghe et al., 2015; Sideleau et al., 2017; Fukuda et al., 2014). However, human-crocodile conflicts (HCC) have received relatively little scientific attention across Africa compared to human conflicts with lions or elephants (Pooley, 2015).

This paper sought to fill this knowledge gap by assessing the HCC situation in one of Uganda's most important conservation spaces, the Murchison Falls Conservation Area (MFCA). Following the end of the civil war, the exponential growth of the human population density around MFCA increased by approximately 16% between 1959 and 2014 (Hartter et al., 2016). Similarly, stability in this region, legal protection and successful conservation efforts have enabled the recovery of the once-depleted Nile crocodile population (Mudumba, 2011; Plumptre et al., 2015). According to the Uganda Wildlife Authority (UWA), MFCA currently supports the largest meta-population of Nile crocodiles in Uganda (Uganda Wildlife Authority, 2013). However, the success of the Nile crocodile conservation coupled with rapid human population growth and activities has come with an increase in HCC (Pooley et al., 2020; Thorbjarnarson & Shirley, 2011). For instance, crocodile attacks are rampantly reported along the shores of Lake Albert (UWA, 2013), while Thorbjarnarson and Shirley noted occurrences in Queen Elizabeth and Lake Mburo National Parks in 2011. Unfortunately, many attacks likely go unreported as is the case in many other developing countries (Sideleau & Britton, 2012; CrocBITE, 2013). However, the absence of properly documented information on crocodile attacks does not mean that HCC should be downplayed (Pooley, 2015). In addition to quantifying the scale of HCC, understanding human communities that live with and are affected by crocodiles is encouraged to promote and support their conservation (Aust et al., 2009; K. L. Wallace et al., 2011; Mudumba, 2011).

This study, therefore, not only unraveled the HCC situation in MFCA but also examined aspects of the human dimensions of crocodile conservation. In order to adequately respond to the study objectives, we collected data by: 1) analyzing crocodile attack records to establish the status and extent of negative interaction with crocodiles; 2) investigating the socio-economic status of the local communities around MFCA as well as their perceptions toward the Nile crocodile; 3) engaging MFCA and Mayuge communities to identify and prioritize mitigation measures using the consensus-building Nominal Group Technique (NGT); and 4) building a conflict profile to identify spatial-temporal trends and patterns of HCC. The information obtained will advance our understanding of the factors underpinning HCC and highlight the local peoples' views toward crocodiles, which is critical to inform and guide the development of HCC mitigation strategies (Pooley et al., 2019; B. M. Sideleau et al., 2017; Redpath & Sutherland, 2015).

Methods

Study Area

Murchison Falls Conservation Area is located at the northern end of the Albertine Rift Valley (2°12′ N, 31°49’ E) and is bordered by six densely populated districts as well as Lake Albert, an important lake in Uganda’s fisheries (Plumptre et al., 2015). The biodiversity hotspot is composed of three PAs, namely Murchison Falls National Park (MFNP), Karuma Wildlife Reserve (KWR), and Bugungu Wildlife Reserve (BWR). Together, these three form the largest (over 5000 sq. km), oldest, and most visited cluster of PAs in Uganda (Plumptre et al., 2015; UWA, 2013).

We selected four communities around MFCA (Figure 1) for this study after they were described as “high crocodile conflict areas” by officials of UWA’s problem-animal unit (Peter Ogwang, UWA, pers. comm., 2017). However, we also included two communities (Lwanika and Daguzi) along the shores of Lake Victoria in Mayuge because they have benefitted from UWA’s efforts to address HCC in the form of crocodile exclusion enclosures (CEE), referred to as protective barriers (Figure 2).

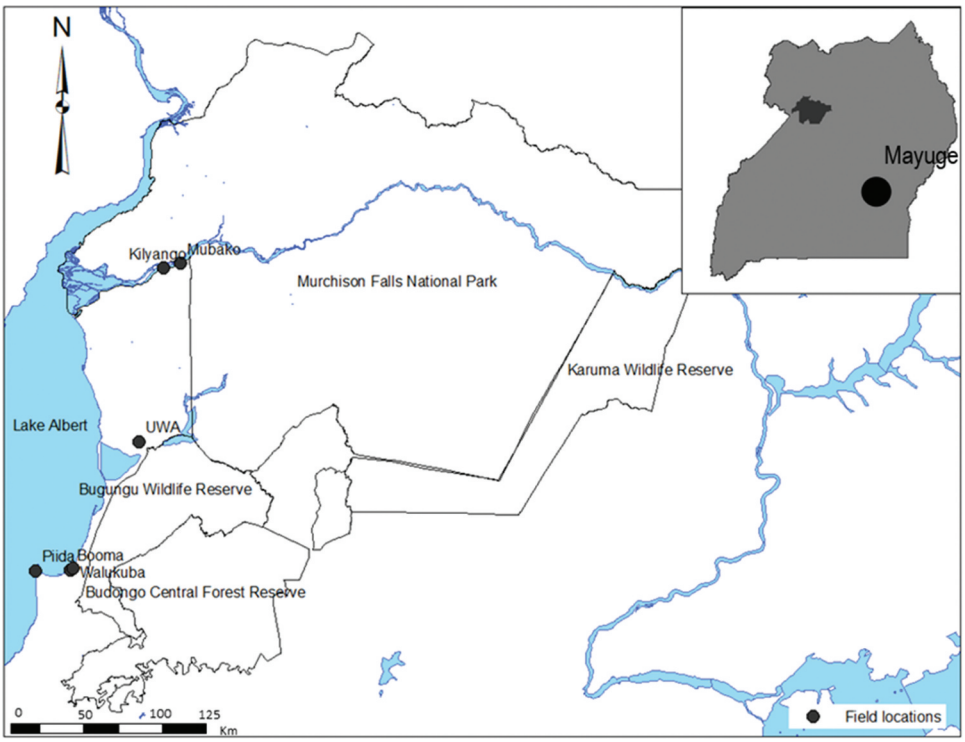

Figure 1. Map of Murchison Falls Conservation Area and an insert of Uganda showing the location of Mayuge District where the communities of Lwanika and Daguzi are situated.

Figure 2. Examples of crocodile exclusion enclosures: two dysfunctional and one functional. From left to right: a dry enclosure due to a drop in the water level in Lwanika followed by an enclosure that was destroyed by strong winds in Daguzi, and lastly a locally made enclosure in Mubaku, MFCA.

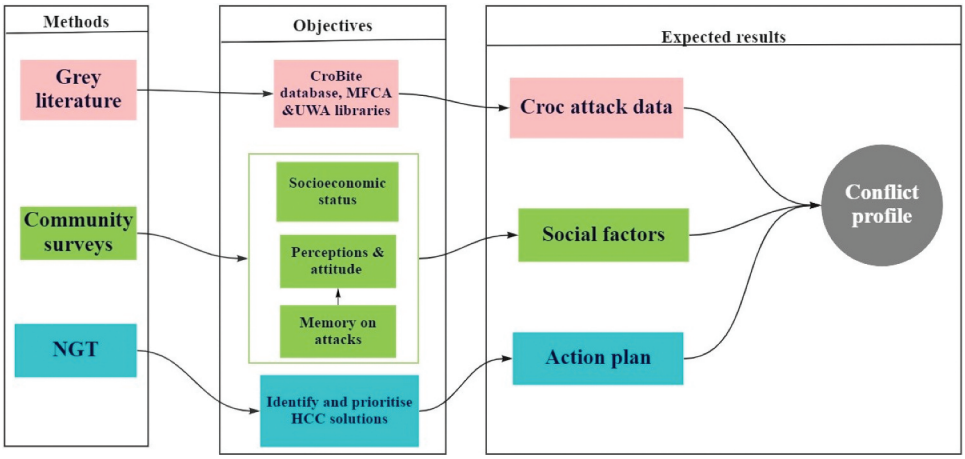

Figure 3. Conceptual scheme of the study showing the connections between the objectives, methods and expected results where NGT is Nominal Group Technique.

Data Collection

We applied a combination of methods to gather the data required to accomplish the aims above (Figure 3).

Records Search

To establish the status and extent of crocodile attacks, we searched for crocodile attack incidences occurring from 2012 to 2017 in MFCA by reviewing historical records. Crocodile attack records were obtained from CrocBite, an online database (http://www.crocodile-attack.info/) as well as the archives at the UWA headquarters and MFCA libraries. Information retrieved included the victim's name and age, location, outcome (fatal/non-fatal), date and time of the attack as well as the activity preceding the attack. Another variable, weather season, was formulated based on the date of attack

data (we categorized the months into either dry or wet according to Orlove et al. (2010)). We then merged the data and cross-checked it for double entries before further use. However, the records were likely an incomplete representation of reality as discussed by Sideleau and Britton (2012).

Community Surveys

We conducted semi-structured interviews to gather data on the socio-economic status of the communities around MFCA and their perceptions toward crocodiles (Appendix 1) between August and September 2017. Similar research conducted by De Silva (2008) and Wallace (2011) inspired our questionnaire content. The instrument comprises four sections: i) demographic information and socioeconomic status, ii) livelihood strategies and dependency on natural resources, iii) crocodile attack experiences, and iv) perceptions toward crocodiles. The interviews lasted about an hour, and we conducted them with assistance from the community conservation officer as well as three trained residents fluent in the local dialects. In all study sites, the Local Council one (LC1), the lowest administrative unit in Uganda, served as the community entry point and reference point. We followed systematic random sampling and interviewed the head of every third household starting from the reference point. However, contrary to the planning, we conducted community surveys in only three of the four communities in MFCA because the LC1 of Piida B denied coauthor MGA community entry.

Nominal Group Technique (NGT)

We used the Nominal Group Technique (NGT) to formulate and prioritize potential HCC mitigation measures. Typically, NGT is a structured group-based technique in which participants are first asked to individually reflect and generate ideas based on predetermined, structured questions asked by a facilitator (e.g., what are the research priorities in this specific area?). Subsequently, participants are asked to collectively prioritize the ideas and suggestions given by the group members (Huge et al., 2018; Maynard & Jacobson, 2017). By integrating both individual and group reflections, NGT minimizes negative group biases, such as dominance and halo effects, which are common in other group data collection techniques (Mukherjee et al., 2018). However, we adapted the NGT sessions by offering assistance to participants who could not write (Hutchings et al., 2013; Maynard & Jacobson, 2017).

Although community surveys were not possible in Piida B, we reached an agreement to hold an NGT session after coauthor MGA proved that she was just a student and thoroughly explained the study objectives to the LC1. In total, we conducted seven NGT sessions: five within MFCA and two in Mayuge district. In MFCA, we conducted four NGT sessions with community members of Booma, Mubaku, Piida B and Walukuba as well as one session with the wildlife rangers in BWR. The sessions in Mayuge district took place with the community members of Lwanika and Daguzi. Participant selection followed the snowball method through the LC1, and the sample included community members with varied socioeconomic statuses, such as fishermen, pastoralists, farmers, and police officers (Reed et al., 2009).

The stage of data collection followed four typical NGT stages as outlined in Huge et al. (2018):

Silent generation of ideas: The sessions had one open-ended question ("What do you think should be done to reduce human-crocodile conflicts in the area?"). Each participant reflected and wrote down all their ideas silently within 20 minutes. Group interaction at this stage was disallowed to avoid "production blocking." Only participants who could not write received writing assistance.

Sharing of ideas: After 20 minutes, each participant shared all their ideas without any modification, and the facilitator wrote them on a flip chart.

Group discussion: The participants clarified, elaborated, and screened the proposed ideas. Similar ideas were clustered, duplicate ideas deleted, and those deemed "inapplicable" excluded (for insistence, "poison all the crocodiles" as suggested in Piida B). This generated a list of distinct and clear ideas for all participants.

Voting and ranking: Finally, each participant silently voted for the five most preferred ideas and ranked them according to their judgment of importance. Ranking also occurred silently to reduce the bias that comes with social pressure during open ranking (Mukherjee et al., 2018). A score of 1–5 formed the criteria for ranking, with 5 representing the most preferred and 1 the least preferred idea. Finally, the facilitator tallied the results and immediately announced them to the participants.

The Human-Crocodile Conflict Profile

The conflict profile is a summary that describes the conditions, which shape the occurrence of conflicts. The profile contains information on all the affected (in this case crocodiles, humans, and livelihoods), a detailed description of the spatial-temporal factors, and the severity of the conflict matched with information on the socioeconomic status of the vulnerable communities (Barlow et al., 2010). This information aids in the quick identification of conflict trends and patterns, as well as (dis)enabling factors that can provide a basis on which to elaborate recommendations to address HCC (Barlow et al., 2010).

Ethical Standards

We obtained ethical clearance first from the Uganda Wildlife Authority, which provided a research permit (Appendix 2) for this study after reviewing the research protocols. In addition, we explained the scope and nature of the interview and NGT session to the respondents after which we sought informed consent verbally. Lastly, we collected the data anonymously, and the participants were informed that they could terminate the interview at any stage.

Data Analysis

We used descriptive statistics to summarize the data and contingency tables using Pearson's chi-square (χ^2) to assess whether the outcome of the crocodile attacks can be linked to gender, activity or weather season. Also, we developed Generalized Linear Models (GLM) using a binary logistic structure to determine the odds that a crocodile attack would be fatal. The outcome of the crocodile attacks (fatal = 1 and non-fatal = 0) formed the response variable while the independent explanatory variables included victim attributes (age, gender, region, activity, and weather season). We fitted saturated models from which the best-

fit model was automatically selected using Akaike's information criterion scores (AIC). We conducted all statistical analyses in R, version 3.5, at 95% confidence level.

Our study also considered the top five ideas (with the highest scores) from each NGT session as the most preferred solutions for HCC (McMillan et al., 2014). We then merged the top five results from each session to determine the overall preferred ideas (total scores). Next, we formulated themes reflecting priority solutions using the list of all top ideas following qualitative coding based on keywords and similarity of function (McMillan et al., 2014). Lastly, we computed total scores for each theme by adding individual scores of the ideas from each session.

Findings from the records search, survey and NGT provided data for the conflict profile also referred to as the action selection framework by Barlow et al. (2010). We estimated the conflict severity (number of people, livestock, and crocodiles affected) using the available recorded search data. The location of the conflict provided spatial information, while temporal information was extrapolated from the time of the attack data. Lastly, demographic data from the survey and ideas from the NGT sessions informed the social structure of the communities at risk.

Results

Status and Extent of Human-Crocodile Conflicts

To avoid overlap, we only considered records that contained sufficient information to clearly identify discrete attacks. The findings established a total of 115 recorded attacks between 2012 and 2017 in MFCA and Mayuge (Table 1), although more than half (63.5%) of these incidents occurred in MFCA. The majority (84.3%) of the cases were fatal, and the victims were primarily above 18 years (64%) while most victims reported were male (76.5%). Fishing (49.6%) and fetching water (43.5%) were the most reported activities

Table 1. Frequency of HCC in the study areas from 2012 to 2017 (source: CrocBite, UWA and MFCA archives).

		Number of cases per year						
Variable	Details	*2012 (n = 19)*	*2013 (n = 13*	*2014 (n = 17)*	*2015 (n = 25)*	*2016 (n = 25)*	*2017 (n = 17)*	*Proportion (%)*
Weather season	Dry	14	3	9	6	11	5	41.7
	Wet	5	10	8	19	14	11	58.3
Outcome	Fatal	17	10	17	19	19	15	84.3
	Non-fatal	2	3	0	6	6	1	15.7
Region	Mayuge	15	1	11	6	8	1	36.5
	MFCA	4	12	6	19	17	15	63.5
Time	AM	2	1	4			2	7.8
	PM	5	1		2	1	4	11.3
	No time	12	11	13	23	24	10	80.9
Activity	Fishing	12	7	9	12	10	7	49.6
	Fetching water	6	3	6	13	13	9	43.5
	Swimming	1	3	0	0	2	0	5.2
	Collecting firewood	0	0	2	0	0	0	1.7
Age	Adult	12	7	13	18	15	9	64.3
	Child	2	6	3	5	8	6	26.1
	No Age	5	0	1	2	2	1	9.6
Gender	Female	4	1	5	6	8	3	23.5
	Male	15	12	12	19	17	13	76.5

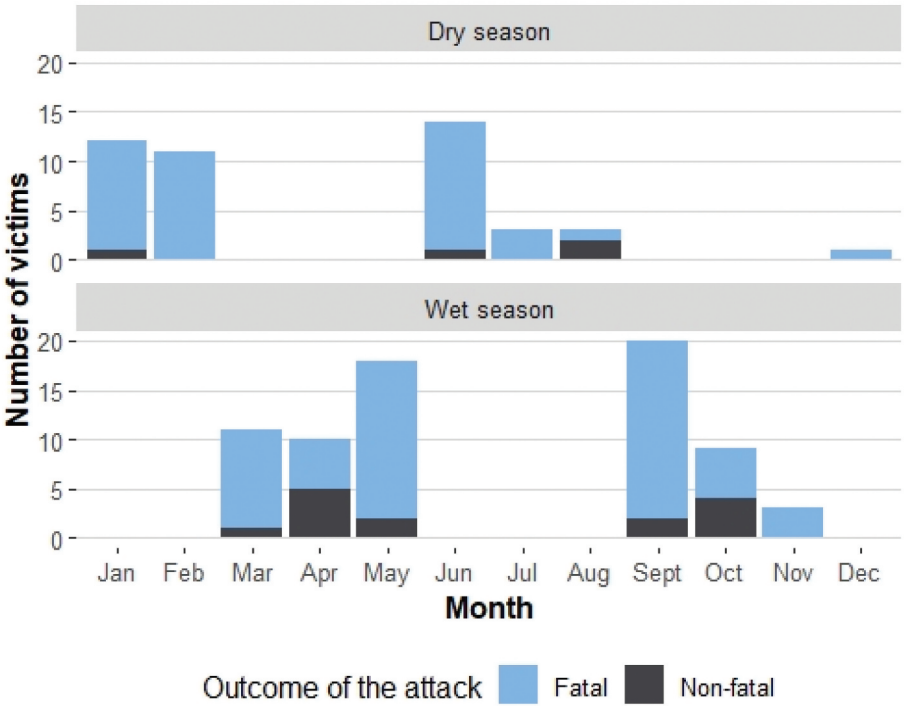

Figure 4. Total number of crocodile attacks recorded in each month of the year from 2012 to 2017.

preceding attack. In addition, UWA recorded the depredation of 57 cows and 33 goats by crocodiles, although the surveys reported more than double this number.

Most attacks occurred in May, June, and September (Figure 4). The number of attacks during the wet and dry seasons was not statistically different ($t = -1.401$, df = 9.9, $p = .19$). However, the outcome of the attack was associated with the weather season ($\chi 2 = 4.47$, df = 1, $p = .03$) but not with the gender of the victim ($\chi 2 = 0.55$, df = 1, $p = .46$) or the activity preceding attack ($\chi 2 = 0.53$, df = 1, $p = .46$). This is in agreement with the GLM results where only the weather season was included in the best-fit model (AIC = 101.3). Specifically, the wet weather season had a positive effect ($p = .01$) on the probability of the crocodile attack outcome being fatal (Table 2).

Socioeconomic Status of the Local Communities and Their Perceptions Towards the Nile Crocodile

We completed 111 surveys (Booma = 36, Walukuba = 29, Mubaku = 46) while nine households declined to participate. Most households (57.7%) consisted of more than five people and the majority (71.2%) of the respondents were male. Almost half of the respondents (48.6%) had no formal education, while agriculture was the major source of income for 58% of the respondents. Lakes and rivers are the main source of water for both domestic use (84.7%) and livestock (63.1%). The respondents indicated that this was due to the high cost (41.4%) of alternative water sources, and the short distance (19.8%) between the households

Table 2. Binary logistic models for all victim variables and fatal outcome as the response variable. model selection was automated based on AIC.

		Parameters		
Model		Df	Pr(>Chi)	AIC
I(outcome == "Fatal") ~ gender + age + region + activity + Season	activity	6	0.3707	108.8
	age	2	0.3644	
	gender	1	0.3625	
	Season	1	0.1845	
	region	1	0.1121	
I(outcome == "Fatal") ~ gender + age + region + Season	age	2	0.19096	103.3
	Season	1	0.24258	
	gender	1	0.19259	
	region	1	0.05506	
I(outcome == "Fatal") ~ gender + region + Season	gender	1	0.2722	102.6
	Season	1	0.1671	
	region	1	0.151	
I(outcome == "Fatal") ~ region + Season	region	1	0.2228	101.8
	Season	1	0.1614	
I(outcome == "Fatal") ~ Season	Season	1	0.1153	101.3
glm(formula = I(outcome == "Fatal") ~ Season, family = binomial(), data = crocattack)		Estimate	Pr(>|z|)	
	(Intercept)	2.3026	1.12E–05	
	SeasonWet	0.8986	0.0136	

and the water source. However, Mubaku differed slightly with almost half (47.8%) of the respondents citing a lack of alternative water sources due to broken boreholes.

Most respondents could recall attacks on humans (86.5%) and livestock (58.6%), the period (morning/afternoon) of the attack (79.3%), as well as activity preceding the attack (83.8%). Although there is a possible exaggeration, the respondents offered information on livestock depredation, reporting losses of approximately 495 chickens, 309 goats, and 289 cows. The surveys also revealed that crocodile attacks are usually reported to the police (27.9%) and neighbors (21.6%) rather than UWA (6.3%). The majority of the respondents perceived crocodiles as a problem, with just 10% mentioning tourism and education as benefits of crocodiles. Also, almost all (97.3%) of the respondents reported that they had never killed a crocodile due to fear of their size (41.4%) and lack of capacity or weapons to do so (37.8%). Only 6.3% of the respondents cited respect for the laws regulating wildlife as a hindering factor.

Priority Mitigation Measures

Each NGT session we held was composed of 7–8 participants, and we identified 14 unique ideas altogether. While the most preferred solution to mitigate HCC varied between the communities, the construction of CEE along the lake/river (overall score 146) was the most preferred solution in general (Table 3). This was followed by the relocation of problem crocodiles to PAs (139), and community sensitization (102). However, financial compensation for crocodile attack victims was notably the most preferred solution in Piida B unlike in other communities. On the other hand, top ideas from the UWA personnel mirrored the current HCC solutions implemented by the governing body such as constructing CEE and relocating problem crocodiles.

Table 3. List of preferred human-crocodile mitigation ideas from the Nominal Group Technique sessions.

	Scores from each session							
Ideas generated during the NGT sessions	Booma	Mubaku	Lwanika	Walukuba	Piida B	Daguzi	UWA	Total score
Construct protective fences in the lake for people to collect water	26	25	11	29	0	38	17	146
Capture and relocate problem crocodiles	39	0	29	14	23	9	25	139
Sensitization of the local community	22	12	17	23	0	9	19	102
Compensation of victims	0	19	0	11	33	0	10	73
Constructing boreholes	0	19	32	0	0	0	14	65
UWA should teach community members capture techniques	0	0	9	0	0	18	0	27
Allow the community to kill them	0	0	0	0	19	0	0	19
Introduce sustainable use programmes/other sources of income	0	16	0	0	0	0	0	16
UWA should kill all problem crocodiles	13	0	0	0	0	0	0	13
Establish a crocodile response unit in BWR	0	0	0	0	12	0	0	12
Monitor landing sites with problem crocodiles	11	0	0	0	0	0	0	11
Provide vermin guards who can act fast in case of a problem crocodile	0	0	0	8	0	0	0	8
Rangers should stay until the reported problem crocodile has been captured	0	0	0	0	7	0	0	7
Explore potential for tourism	0	0	0	0	0	13	0	13

Four themes emerged from all the ideas. The theme with the highest score (313) had ideas structured as exposure-reduction measures, which included the construction of boreholes or CEE, followed by strategies categorized as the problem-crocodile action (171) which included relocating or killing problem crocodiles. The third most common theme focused on financial incentives (102) such as providing economic support to the victims or compensation and the exploration of alternative income-generating opportunities. The final theme highlighted community engagement with ideas, such as skilling locals on the capture techniques of problem crocodiles as well as permission to kill problem crocodiles.

Conflict Profile

The action selection framework (Table 4) shows that approximately 16 fatal crocodile attacks on humans occur annually, mostly in the evening and during the wet months. More attacks on livestock according to the surveys compared to the information obtained during the literature search while crocodiles are rarely killed by the community members. Exposure and vulnerability are increased by poor fishing methods and the lack of alternative water sources. The time when most attacks occur (evening) coincides with a peak in risky activities, such as spreading fishing nets.

Discussion

Conservation efforts are often hampered by several factors, such as funding, political priorities, and scarcity of information. This study provides the much-needed benchmark information about human-crocodile interactions and the associated underlying factors; useful for crocodile conflict management in Uganda. The study indicated that engaging affected community members while developing mitigation actions has the advantage of reflecting community preferences and hence increasing community buy-in.

Table 4. Human-Crocodile Conflict profile for Murchison Falls Conservation Area (MFCA) based on the data gathered.

Pattern	Conflict description	Causality
Severity and spatial	• ~19 attacks on humans per year, most of which (~16) are fatal. • UWA recorded the predation of 57 cows and 33 goats by crocodiles in 6 years, while respondents reported 495 chickens, 309 goats, and 289 cows. • Only two crocodiles were reported to be killed by the community; poaching of crocodiles was not recorded. • Crocodiles are seen once in a while (low encounter rates) • 60 problem crocodiles were captured and relocated to MFNP and KWR during 2012–2017. • Presence of protective fences by community members - local materials and government - semi-permanent materials.	• ~84.7% of the people depend on the lake/river for water needs: this may increase exposure to crocodiles; • Unknown distribution of crocodiles, however, high density of crocodiles may lead to high encounter rates - 26 crocs were counted along the river in Mubaku during the study period. • The main reason for using the lake/river as the main source of water was the high cost of alternative water sources. • Crocodiles were killed in retaliation for previous human and livestock killings. • Non-functional protective fences; broken down or have poor water quality or weeds.
Temporal	• A high number of attacks in the evening (PM). • More croc attacks occurred in the wet months of the year (wet = 53%, dry = 46.9%).	• Human activity peaks in the evening coinciding with time for casting fishing nets and collecting water; Also crocodiles actively hunt during evening hours. • Increased human reliance on the "ever-available" water in the lakes/rivers.
Socio-demographic	• The majority of victims are men. • Most of the victims are adults. • Generally, no myths about croc attacks although some few respondents believe that these are related to witchcraft/curses. • Low knowledge of the potential benefits of crocodiles by most respondents (90%).	• Fishing is predominantly a "man's" job; poor fishing methods (net-fishing in shallow water without boats or use of small canoes). • Low literacy levels (almost half of the respondents have no formal education).

The records search revealed that most of the attacks were fatal, a trend also observed in Zambia (Wallace et al., 2011) and Mozambique (Dunham et al., 2010). However, this finding could highlight a lack of systematic reporting of crocodile attacks and HWC in general or a reporting bias resulting in fewer non-fatal cases reported (Pooley, 2015). Therefore, the situation on the ground could be different or worse than what was observed in the records search. Additionally, according to Sideleau et al. (2017), reporting is restricted by the severity of the injuries and the fear of repercussions. Indeed, attacks were said not to be reported if the victim was fishing in a protected fish breeding zone which is illegal - or if the victim only sustained injuries in our study (field notes). Furthermore, Sideleau and Britton (2012) noted that systematic reporting is constrained by "reporting effort" as most attacks occur in remote areas. While this may not hold for communities around MFCA, the nearest UWA station to Lwanika and Daguzi is in Mbale district, approximately 133.5 km away. Therefore, understanding the full scale of HCC calls for strategies to improve the quality of country-wide reporting.

Although the surveys reported high figures of crocodile attacks on livestock, the respondents seemed to regard this as a "blessing in disguise" because of a fear, as expressed by Piida B LC1, that crocodiles will pursue humans when livestock is depleted. Nonetheless, the loss of livestock has substantial economic implications and should be targeted by HCC mitigation plans. The way crocodile attacks are recorded needs addressing because accurately

recalling details of past events is often difficult (Wallace et al., 2011). In our study, we experienced difficulty obtaining detailed crocodile attack information (time of the attack, month, and age of the victim), although this is required to fully grasp the extent and implications of HCC. Data collection via citizen science could be explored to enhance reporting and data quality on negative human-crocodile interactions (Ostermann-Miyashita et al., 2021).

The high-risk activities (fishing and fetching water) observed in this study correspond with the survey results of a high dependency on water bodies to sustain households and livestock. Fishermen were frequently sighted using small canoes or net-fishing in waist-deep waters along the water bodies during this study. This behavior greatly increases exposure to crocodiles but does not fully explain the high number of fatal attacks. Although we noted a link between weather season and the outcome of crocodile attacks, the explanatory factors considered in this study were few, incomplete, and independently analyzed. Further research is therefore needed to establish why the probability of intense attacks increases in the wet months as well as to identify the other factors influencing HCC.

Conservation managers in the study area need to address HCC, as recurrent negative interactions between crocodiles and human fuel disagreements over crocodile management, which may lead to conservation conflicts (Redpath et al., 2013; IUCN 2020, p. 2). A typical example of this was witnessed in Piida B where the LC1 denied coauthor MGA community entry on two fronts. First, the LC1 mistakenly considered her one of the UWA personnel because she was accompanied by the community conservation officer. Secondly, this was a reaction to express frustration due to the lack of action from UWA following a recently reported crocodile attack. Indeed, not only does delayed response and the inadequate compensation create a difficult relationship between UWA and the communities, this also dissuades victims from reporting attacks (Peter Ogwang, UWA, pers. comm., 2017). Similarly, apart from their direct impacts on human life and livelihoods, crocodiles are resented by community members because wildlife legislation is perceived as indifferent to human populations (Jeremiah, 2018; Thorbjarnarson & Shirley, 2011). Indeed, the Daily Monitor reported that community members in Namayingo district felt that crocodiles were treated as "first-class citizens" ("Namayingo residents desert homes over crocodile attacks" 2021, Uganda Wildlife Authority, 2013). Finally, although the few crocodile killings could be linked to self-reporting biases, the reasons for not doing so suggest that the community members could engage in lethal management of crocodiles given the capacity to do so. We therefore believe that legislation alone will not suffice, and solutions require greater attention to the social, economic, ecological and physical factors of the communities at risk to mitigate disagreements.

The results of the NGT demonstrate the differences in priority measures and highlight the problem with a one size fits all approach. While the top mitigation priorities by UWA personnel (CEE and capture relocate) were consistent with the current HCC mitigation strategy, the effectiveness of CEE still needs to be verified (Wallace et al., 2011) as well as the cost–benefit implications of the different mitigation actions is recommended in general. During the study period, we noticed that the enclosures were, in most cases, in disrepair and required maintenance. For instance, the cage was dry in Lwanika because the water level in the lake had gone down drastically, while strong winds broke down the cage in Daguzi (Figure 2). Lack of a sense of ownership and low budget were commonly cited as the reasons for the non-

maintenance of the cages. The community members noted that they were not consulted during the construction of the cages by UWA and hence they are referred to as "UWA's cages" in several communities (field notes). Therefore, conservation actors, specifically UWA, should develop strategies to cultivate a sense of ownership about crocodile management that results in partnerships between the government and affected communities.

In addition, demand for financial compensation for the damaging HCC reports differed with some communities suggesting that compensation of the victims is not the best approach because a price cannot be put on human lives. In comparison, financial compensation was the most preferred mitigation measure in communities where tension with UWA exists, particularly Piida B. Fortunately, a compensation scheme for people negatively affected by wildlife has been recently approved (Uganda Wildlife Authority), but UWA still grapples with delayed/slow response to HCC. Furthermore, implementing exposure reduction ideas, such as alternative water sources (piped water or boreholes) could indeed alleviate HCC. However, the cost of water needs to be carefully considered given that respondents decried the cost (200 Ug.shs. or 0.047 EUR) of a 20-liter jerrycan of water, which is not practical for large households (field notes). In addition, conservation managers together with community members could explore the potential of sustainable-use programmes for crocodiles. This would not only improve the community's livelihoods but also incentivize peaceful coexistence and support for crocodile conservation (Wallace et al., 2011). Strategies such as crocodile egg harvesting may supplement livelihoods as they have elsewhere (Corey et al., 2017) but require further study.

Finally, the conflict profile provided a summary of the patterns, and trends as well as the underlying factors influencing HCC specifically the social-economic profile of the people at risk. However, the conflict profile was greatly limited by the data deficiencies especially that of livestock depredation by crocodiles. As such, conservation actors and researchers need to consider an in-depth survey of HCC to exhaustively identify and visualize the related risk factors (Barlow et al., 2010). In addition, data on the ecological factors of crocodiles may help to identify additional risk factors, which will enrich the conflict profile. Future research should ideally focus on the development of a framework of sustainable co-existence potential with crocodile habitat suitability assessment, which integrates human willingness-to-coexist with crocodiles (Vogel et al., 2023).

Limitations

While the findings provide useful HCC insights, the study was limited in that we did not evaluate all of the possible factors that could have a bearing on HCC. Also, the current study was conducted in communities described as high HCC zones, which could have influenced the results. Researchers might consider more factors and communities with low levels of conflict as an area for future research.

Acknowledgments

We would like to thank the Flemish University Council - Development Cooperation (VLIR-UOS) for funding the study for MGA. In Uganda, we thank all the UWA (Uganda Wildlife Authority) staff who

helped to acquire the research permits, conduct the fieldwork and support data collection. Lastly, the communities of Murchison Fall Conservation Area (MFCA) and Mayuge are highly appreciated for their collaboration and participation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Author contributions

Study design and fieldwork: MA, JH, FDG; data analysis and writing the article: MA, JH, FDG, SR & SP.

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