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RESEARCH ARTICLE

Adaptive co-management, co-existence or just wildlife conservation? Case study of the human and Nile crocodile (*Crocodylus niloticus*) conflicts in Ngezi Dam, Mashonaland West, Zimbabwe

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Abstract

Increased human–wildlife conflicts in shared and partially closed conservation areas encompassing terrestrial and aquatic systems such as Ngezi Dam in Zimbabwe may arise from competing uses. This case study aimed to (i) estimate the abundance and distribution of Nile crocodiles (*Crocodylus niloticus*), (ii) identify potential human–crocodile conflict hotspots, (iii) assess the perceptions and attitudes of Ngezi Dam side communities towards crocodiles and their effects on rural livelihoods and (iv) examine the application of co-existence and adaptive co-management concepts in human–crocodile conflict resolution. A mixed-methods research approach integrating field surveys, focus group discussions and face-to-face interviews was used to collect data on crocodiles and human communities. A total of 54 and 57 Nile crocodiles were observed in 2017 and 2018, respectively, with no significant spatiotemporal differences ($p > 0.05$) in crocodile abundances. Crocodile hotspots (Getis-Ord >1.96) detected round the dam indicated potential human–crocodile-livestock conflicts. Most respondents (76%) showed a negative attitude towards crocodiles, which they indicated destroy livelihoods through injury, death and livestock depredation. The lopsided losses, for example human injuries and fatalities, loss of fishing equipment and livestock in human–crocodile conflicts drawn from this case study reflected a need to delicately recalibrate the contextualised optimisation and balanced implementation of conservation, co-management and human needs in shared landscapes. Astute crocodile conservation whilst offsetting human needs requires an inductive rather than deductive perspective lens. We propose a human–crocodile conflict contextual resolution framework (HCCCR), which prioritises interactive adaptive co-management in a specific context in shared conservation landscapes.

KEYWORDS
adaptive management, boundary spanning reserves, conservation, human-crocodile conflict, Nile crocodile

Résumé

L'augmentation des conflits entre les populations humaines et la faune sauvage dans les zones de conservation mixtes et partiellement fermées englobant des systèmes

terrestres et aquatiques comme le barrage de Ngezi au Zimbabwe peut résulter d'utilisations concurrentes. Cette étude de cas avait pour but (i) d'estimer l'abondance et la distribution des crocodiles du Nil (Crocodylus niloticus), (ii) d'identifier les points chauds potentiels du conflit homme-crocodile, (iii) d'évaluer les perceptions et les attitudes des communautés riveraines du barrage de Ngezi envers les crocodiles et leurs effets sur les moyens de subsistance ruraux et (iv) d'examiner l'application des concepts de coexistence et de cogestion adaptative dans la résolution des conflits humain-crocodile. Une approche de recherche à méthode mixte intégrant des enquêtes de terrain, des discussions de groupe et des entretiens en face à face a été utilisée pour collecter des données sur les crocodiles et les communautés humaines. Un total de 54 et 57 crocodiles du Nil ont été observés en 2017 et 2018, respectivement et les résultats ne montrent pas de variations spatio-temporelle significative ($p > 0,05$) en en ce qui concerne le nombre de crocodiles. Les points chauds pour les crocodiles (Getis-Ord>1,96) détectés autour du barrage indiquent des conflits potentiels entre l'humain, les crocodiles et le bétail. La plupart des répondants (76%) montrent une attitude négative envers les crocodiles, qui selon eux, attaquent, blessent et tuent leur bétails, détruisant ainsi leurs moyens de subsistance. Le bilan déséquilibrée, par exemple les blessures et les décès humains, la perte d'équipement de pêche et de bétail dans les conflits entre humains et crocodiles, mis en évidence par cette étude de cas montrent la nécessité de modifier avec prudence l'optimisation contextualisée et la mise en œuvre équilibrée de la conservation, de la cogestion et des besoins humains dans les territoires mixtes. Une conservation astucieuse des crocodiles capable de prendre en charge les besoins humains requiert une perspective inductive plutôt que déductive. Nous proposons un cadre de résolution contextuelle du conflit humain-crocodile (HCCCR), qui donne la priorité à la cogestion adaptative interactive dans un contexte spécifique de territoires de conservation partagés.

1 | INTRODUCTION

The Nile crocodile, *Crocodylus niloticus*, Laurenti 1768, is the largest in size among the five crocodile species in Africa, most widely distributed and adaptable to a wide range of wetland habitats within sub-Saharan Africa (Champions, 2010; Combrink, 2004; Nyirenda, 2015; Pooley, 1982; Revol, 1995). Nile crocodiles are aggressive opportunistic apex predators of fish, other reptiles, wetland birds and mammals (Combrink, 2004; CSG, 2009). As apex predators, they are vital in maintaining the integrity of freshwater ecosystems (Glen et al., 2007; Roff & Zacharias, 2001; Ross, 1998). The population of Nile crocodiles has widely fluctuated in Africa, with peak populations recorded before 1955, which drastically decreased from 1956 to 1978, due to overexploitation, habitat destruction, climate-induced water temperature changes and drawdowns (Aust et al., 2009; Fergusson, 2010; Hanks, 2001; Shacks, 2006).

Humans exploit crocodiles for meat and skins for leather, and teeth, eyes, gall bladder and claws for aphrodisiacs, traditional medicines and ritual purposes in parts of Western, Southern and Eastern Africa and Asia (CITES (Convention for the Trade in Endangered Species), 2010, 2021; Jablonicky, 2013; Zisadza-Gandiwa et al., 2013). Huge Asian-driven demand for crocodile products has resulted in the proliferation of crocodile farming (and a decline in wild crocodile populations due to human exploitation in Africa), which has inevitably increased human–crocodile conflicts (Leslie, 1997; McGregor, 2005; Musakwa et al., 2020; Pooley et al., 2019; Tchakatumba et al., 2019; Thorbjarnarson, 1996; Zisadza-Gandiwa et al., 2016). Nile crocodile populations only began recovering from the 1980s after intensive conservation and habitat restoration efforts (Branch, 1990; Jacobsen, 1991; Pooley, 2016; Pooley et al., 2019). The current IUCN classification status indicates that the Nile crocodile is not endangered (least concern status) despite some regional declines or extinctions (Ottley et al., 2008; CSG, 2009; Isberg et al., 2019; IUCN, 2021).

In Zimbabwe, the Nile crocodile is abundant and widespread in large permanent rivers and lakes with recorded sightings in Lake Kariba, Ngezi Dam and Lake Sebakwe among others (Fergusson, 2006, 2009; Lainez, 2008; ZPWMA, 2006, 2015). Regardless, populations of crocodiles have declined in the lower Zambezi, Limpopo and Runde and Save Rivers, and Sengwa River in the Midlands region

due to loss of breeding sites (Fergusson, 2010; Hutton & Woolhouse, 1989; ZPWMA, 2015), siltation, low water storage capacity in reservoirs and increased human–crocodile conflicts (Sai et al., 2016; Zisadza-Gandiwa et al., 2013). Hutton (1987) reported low populations of crocodiles in Ngezi Dam, a situation he attributed to high mortalities and limited natural recruitment. In a follow-up study, Fergusson (2010) observed increasing numbers of crocodiles attributed to an once-off release of crocodiles by a disgruntled evicted white crocodile farmer in the upper Mvuma area.

Crocodiles are prone to human persecution when they encroach into communities and attack humans and their livestock, a situation which is currently prevalent in Ngezi Dam in Zimbabwe (Fergusson, 2010). In Ngezi Dam (and other reservoirs elsewhere), crocodiles prey on economically important fish species and destroy valuable fishing equipment (mainly gill and seine nets) affecting fish catches and fishing-dependent livelihoods (Boyle, 2007; Games & Moreau, 1997; Graham & Beard, 1973; Santiapillai & de Silva, 2001; Wallace & Leslie, 2008). Human–crocodile conflicts in Ngezi Dam have created negative perceptions towards the species among communities living around the reservoir (Fergusson, 2010). This situation prevails in several reservoirs in the sub-Saharan African region (Anderson & Pariela, 2005; Marowa et al., 2021; McGregor, 2005; Nyirenda, 2015; Pooley et al., 2019). Regardless, there are few surveys of crocodiles with insufficient information on the abundance and distribution in wetland systems of Zimbabwe, such as Ngezi Dam, to inform conservation of the species and minimise human–crocodile conflicts (Chihona, 2014; Marowa et al., 2021).

The situation is compounded by the fact that past crocodile conservation programmes were developed by ecological experts without reference to local perceptions and attitudes (Blake & Loveridge, 1975). However, contemporary crocodile conservation efforts endeavour to integrate and provide economic benefits to local communities as part of adaptive co-management (Dzoma et al., 2008; CSG, 2009; Nyirenda, 2015). Adaptive co-management emphasises pluralism and communication; shared decision-making and authority; linkages within and among levels; actor autonomy; and, learning and adaptation along the way (Anderson & Pariela, 2005; Fergusson, 2009; Gandiwa et al., 2011; Nyirenda, 2015). Nevertheless, several authors, for example Duda and El-Ashry (2000); Duda (2003); Bressers (2004, 2005); Lamarque et al. (2009); de Boer and Bressers (2013) and Nyirenda (2015) suggested that adaptive co-management is complex and borders on interlinking the concepts of co-existence, conservation and conflict resolution for humans, livestock and crocodiles sharing partially closed conservation areas spanning water and terrestrial landscapes in local contexts in Africa.

For most developing countries, for example Zimbabwe, conservation authorities maintain strict regulations on wildlife conservation skewed towards conserving and preserving the crocodiles at the expense of humans (Musakwa et al., 2020; Sai et al., 2016; Zisadza-Gandiwa et al., 2016). Hence, there is blatant disregard of the perceived economic and conservation gains of adaptive co-management due to failure of mutually beneficial co-existence between crocodiles, humans and livestock in communities (Zisadza-Gandiwa et al., 2013, 2016). Thus, human–crocodile conflicts are inevitable and actually increasing in sub-Saharan Africa (Lamarque et al., 2009; Marowa et al., 2021; Nyirenda, 2015; Pooley et al., 2019; Thomas & Leslie, 2006). A revision of the co-existence, adaptive co-management and crocodile conservation measures is warranted, and this paper fills that gap. However, this can only be meaningful if there is clear evidence of the abundance and distribution of the crocodiles in water systems with a cogent understanding of the perceptions of dam side communities and wildlife authorities in context (Marowa et al., 2021).

1.1 | Aims of the study

This case study aimed to (i) estimate the abundance and distribution of Nile crocodiles, (ii) identify potential human–crocodile conflict hotspots, (iii) assess the perceptions and attitudes of Ngezi Dam side communities towards crocodiles and their effects on rural livelihoods, (iv) examine the application of co-existence and adaptive co-management concepts in human–crocodile conflict resolution.

2 | MATERIALS AND METHODS

2.1 | Study area

Ngezi Dam (Figure 1) was constructed in 1945 for irrigating farms and providing water for the Ngezi Mine. The dam is located in Ngezi Recreational Park (18°42'0" S and 30°22'60" E), Mashonaland West Province, Zimbabwe, and lies at an altitude of 1259 m, with a capacity of 26 megalitres. It is surrounded by predominantly rural communities that is Turf (8 km away) on the north-western boundary, Bumbe (7 km away) on the northern boundary, Manyoni (10 km away) and Silverstar (11 km away) on the east and southern boundaries, respectively (Figure 2). Mhondoro-Ngezi community has a population of 102,000–105,000 people, with animal husbandry and pastoralism, a significant livelihood activity, who exert pressure on the water resources in the Ngezi Dam increasing the potential for human-crocodile and livestock-crocodile conflicts in the shared reservoir. The dam also supports small-scale fisheries which utilise water and fisheries resources further increasing the potential for human-crocodile conflicts (Food and Agricultural Organization of the United Nations (FAO), 2013; ZINWA, 2017; ZPWMA, 2006, 2015).

2.2 | Determination of abundance and distribution of the Nile crocodiles in Ngezi Dam

The total count method was used to determine the population of the crocodiles in Ngezi Dam. Suffice to indicate that crocodile population estimates were only based on the actual sightings although estimates of crocodiles are sometimes carried out using a combination of actual sightings and indices and spoors and nests (Zisadza-Gandiwa

et al., 2013). Population estimates of crocodiles were taken from 30 sampling points, with six sampling points taken in each of the five distinct arms denoted as study sites A1–A5 (Figure 2). In each site, a motorised boat with a team of four people (one coxswain, two observers on both left and right sides and a recorder) was driven at an idling speed few metres from the shoreline. Surveys were done once during the day (0900 –1500 h) and once during the night (2000 h) two times per month for 6 months (July, September and October in 2017, and 2018) for maximum surveillance following methods by Leslie (1997). All observed crocodiles had their position logged in the GPS unit. For GPS recording, in case of crocodile/s sighting, the boat was driven at an idling speed towards the animal/s and the GPS location (within a radius of 5–10 m) of the sighting logged with maximum care to avoid disturbing the natural settings and frightening them off.

2.3 | Estimating body dimensions of crocodiles

Lengths for the sited crocodiles were estimated for age and size classification following methods by Shacks (2006) and Grajales-Gracia et al. (2012). The Nile crocodiles were classified into hatchling (total length TL ≤0.5 m), juvenile (TL <1 m), sub-adult (1.1 m < TL ≤ 2 m) and adult (TL >2 m) (Sai et al., 2016). We also estimated size classes during night spotlight counts in hatchlings (TL ≤0.5 m) and non-hatchlings (TL >0.5 m) and eyes only when size could not be estimated clearly. There was no catching, manipulation or anaesthetising of the crocodile population as this distorts normal movement (CSG, 2009; Garcia-Grajales et al., 2012).

2.4 | Assessment of perceptions and attitudes towards Nile crocodiles in Ngezi Dam communities

Questionnaires were administered to lakeside communities. The questionnaires focused on human–crocodile conflicts, styles of wildlife management and human–crocodile conflict resolution mechanisms. Five focus group discussions (FGDs) were made targeting clustered surrounding communities and each FGD comprised locals aged >25 years and who have lived in the area for more than 10 years. The management strategies and information on human–crocodile conflicts used by the Ngezi Recreational Park authorities were explored through key informant interviews on ZIMPARKS officials, local rural district authorities and village heads.

2.5 | Data analysis

2.5.1 | Abundance and distribution of crocodiles

Descriptive statistics were used to summarise crocodile data. Two non-parametric tests, Wilcoxon signed-rank test (spatial tests) and Chi square test (temporal assessment) of homogeneity, were used to compare the two related samples (in terms of spatial and temporal variation, respectively) of crocodiles for 2017 and 2018 so as to validate the results since the study period was short. Hotspot analysis of crocodile distribution was done using the Getis-Ord technique in ArcGIS 10.1 (Getis & Ord, 1992). This method used actual raw values as repeated measures of crocodile clustering in Ngezi Dam to calculate Getis Ord Gi* scores (*Z* scores). A significant cold spot has a $Z < -1.96$ and significant hotspot with a $Z > +1.96$ (Mitchell, 2005).

2.5.2 | Analyses of local perceptions and crocodile threats

Non-parametric Kruskal–Wallis ANOVA test was used to assess for differences in threats to human life, actual deaths and livestock depredation by crocodiles in Ngezi Dam. We used a total actor, causal, deductive theory of implementation (contextual theory of interaction) with the main thematic areas: motivation, access, dissemination and reception of information, and power of policy implementer, to predict the management strategies and the nature of their implementation (e.g. cooperation, co-existence, resistance, co-management and command and control) in the Ngezi Dam. We examined the responses from the face-to-face interviews, FGDs and key informants and rated the frequency of the responses for each thematic area to determine the matrix of interaction. Then based on a combination of interactions of the main themes, the principle nature of interaction was established from which management strategies were deduced following methods by Owens and Bressers (2013).

3 | RESULTS

3.1 | Abundance of crocodiles in Ngezi Dam

Fifty four and 57 crocodiles were observed during the period 2017 and 2018, respectively. The highest number of crocodiles was observed in October in both years (Table 1). The lowest numbers of crocodiles were observed in August in both years (Table 1). Monthly hierarchical ranking of frequency of occurrence of crocodiles was August > July > October. Both Chi square test of homogeneity (X^2 test, df = 2, $p = 0.446$) and Wilcoxon matched pairs test (Wilcoxon matched pairs test, $W = 3.5$, df = 2, $N = 111$, $p = 0.7745$) indicated no significant temporal and spatial differences, respectively, in crocodile abundances.

TABLE 1 Number of crocodiles observed in Ngezi Dam

Year	July	August	October
2017	16 (14.4)	11 (9.9)	27 (24.3)
2018	19 (17.1)	16 (14.4)	22 (19.8)
Total	35	27	49
Average	18	14	25

Frequencies of occurrence as % are shown in brackets

3.2 | Distribution of crocodiles in Ngezi Dam

Figure 2 shows the spatial distribution of crocodiles in the Ngezi Dam. Arm A showed the highest density of crocodiles in the dam. Arms B and E (Figure 2), located near the Silverstar and Turf settlements, indicated areas with a high probability of human–crocodile conflicts. However, hotspots and cold spots were generated across the whole Ngezi Dam. Red regions indicated hotspot (Getis –Ord, $Z > +1.96$) areas which range from 0 to 500 m where largest number of crocodiles were observed (Figure 3). Brown coloured regions indicated medium hotspots (Getis-Ord, $-1.96 < Z < +1.96$), which range from 500 to 1000 m. Grey coloured areas are cold spot regions (Getis-Ord, $Z < -1.96$), which range from 1000 to 1500 m (Figure 3).

3.3 | Demography of respondents in Ngezi Dam

A total of 151 households in the four communities were sampled. There were 55 females (36.4%) and 96 males (63.6%). Forty (26.5%) respondents were 26–35 years old, and only 2% ($n = 3$) of the respondents were over 75 years of age. About 20.5% ($n = 31$) of the respondents were educated up to the primary level, a larger proportion ($n = 88$; 58.3%) of the respondents had attained secondary education and 9.3% ($n = 14$) had attained university education. Forty two (27.8%) respondents were formally employed in the surrounding mining companies. Fishers constituted 17.9% ($n = 27$) of the sample whilst 30.5% ($n = 46$) of the respondents were involved in trinket selling.

3.4 | Perceptions of communities towards Ngezi Recreational Park, crocodiles and their effects

At least 71.5% ($n = 108$) of the respondents had access to natural resources in the Ngezi Recreational Park. Most respondents did not own sophisticated hunting equipment such as guns, tarp tents, and bows and arrows. Only 19.8% ($n = 30$) of the respondents owned fishing rods, gill and seine nets, and homemade snares. Although the communities have access to the Ngezi Recreational Park, only 47% ($n = 71$) have obtained wildlife-related training, project start-ups, basic wildlife awareness and conservation information from the park authorities. Some respondents ($n = 105$; 69.5%) acknowledged receiving benefits, mainly wild meat rations, disaster reaction support during floods and severe droughts and in disease outbreak periods and income, as they are employed on a temporary basis by Ngezi Recreational Park in different departments.

Most of the respondents ($n = 136$; 90.1%) have seen a crocodile in Ngezi Dam with an average of 15 crocodiles sighted per respondent. About 60.9% ($n = 92$) of the respondents believed that sightings of crocodiles had recently increased in Ngezi Dam. About 43.7% ($n = 66$) of the respondents believed that crocodiles are sacred animals, although only 11.3% ($n = 17$) perceived that a crocodile sighting is associated with bad luck and mysterious cultural beliefs. Most respondents ($n = 92$; 60.9%) strongly disagreed with the notion that people are responsible for the changes in the numbers of crocodiles in Ngezi Dam. About 35.1% ($n = 53$) of the respondents lost livestock to crocodiles which comprised cattle ($n = 28$; 18.5%), goats ($n = 6$; 4%), donkeys ($n = 3$; 2%) and sheep ($n = 1$; 0.7%). Most respondents ($n = 143$; 94.9%) acknowledged that human life has been lost to crocodiles in Ngezi Dam. In cases of crocodile attacks, most respondents ($n = 117$; 77.5%) reported to the authorities who included, ZIMPARKS officials ($n = 132$; 87.4%), Zimbabwe Republic Police (ZRP) officers ($n = 18$; 11.9%) and veterinary officers ($n = 1$; 0.7%).

Most respondents ($n = 117$; 77.4%) reported that the ZIMPARKS authorities dealt with the problem crocodiles. About 18.5% ($n = 28$) of the respondents reported that the responsible offices either came to the scene but did not see the culprit crocodile, or did not take action and in some cases, the authorities cited lack of vehicles to come and assess the situation, or they simply took a negative attitude and did not come to investigate and assist the victims. Most respondents ($n = 107$; 70.9%) acknowledged receiving training on human-wildlife conflicts and livestock–crocodile conflicts from the ZIMPARKS and ZRP officers. However, 53.6% ($n = 81$) of the respondents reported that ZIMPARKS and police officials did not have adequate manpower to control human-wildlife conflicts at Ngezi Dam. Communities surrounding the dam also indicated other drivers of human–wildlife conflict in the areas with key elements being baboons attacking crop fields, community's close proximity to the Park, fetching irrigation water for gardens in the dam, seine net fishing without permits, hippos grazing in nearby fields, damaged security fence allowing crocodiles to move longer distances from the dam attacking livestock in the process, people neglecting livestock, which tend to graze close the dam, and unemployment forcing people to poach fish and cultivate close to the dam.

3.5 | Human–crocodile conflict in Ngezi Dam

Available official ZIMPARKS statistics at Ngezi Recreational Park indicated that an average of 1.35 ≈ 2 human deaths due to crocodile attacks are reported in Ngezi Dam every year (Table 2). An average of 3.25 ≈ 4 threats or life-threatening crocodile attacks are

TABLE 2 Ngezi Dam Problem Animal Control (PAC) reports for 2011–2018 (ZIMPARKS, 2018)

Year	Threats to human life	Human deaths	Livestock killed
2011	2	0	2
2012	2	0	10
2013	4	1	5
2014	6	2	5
2015	3	1	11
2016	1	4	5
2017	1	1	13
2018	7	0	12
Mean ± SD	3.25 ± 2.25	1.37 ± 1.30	7.88 ± 4.09

reported per year to the Ngezi Dam authorities. Since 2011, an average of 7.88 ≈ 8 livestock/year was killed by crocodiles in Ngezi Dam (Table 2). Kruskal–Wallis ANOVA indicated no significant differences ($p > 0.05$) in crocodile threats to human life, the number of human deaths attributable to crocodiles and the number of livestock killed from 2011 up to date.

3.6 | Contextual interaction of proponents in wildlife management in Ngezi Dam

There is passive cooperation towards wildlife conservation on the part of the communities when they are denied full access to the resources in Ngezi Recreational Park (Table 3). Thus, ZIMPARKS authorities resort to enforcement management strategy in order to conserve the wildlife resources (Table 3). The fact that communities have reported increased crocodile sightings in the Ngezi Dam and the ZIMPARKS authorities have responded by issuing warnings to the villagers indicated a high level interaction and of information dissemination and active responses on the part of communities and the ZIMPARKS authorities. The authorities have co-opted villagers in some awareness teams although at times they enforce no entry zones. Thus, there is an element of enforcement but overall, there is adaptive co-management (Table 3). Communities indicated that ZIMPARKS officials have a generally good reactionary response to reports of crocodile attacks although at times they are hampered by lack of equipment and only target the problem animal leaving the villagers at the mercy of like species which force them to retaliate.

4 | DISCUSSION

4.1 | Abundance of crocodiles in Ngezi Dam

Abundance of the crocodiles has not changed from 2017 to 2018 in Ngezi Dam. Regardless, the total figures for the 2 years in this study were lower than the figures by Hutton (1987) and Fergusson (2010) who obtained monthly figures of >121 crocodiles per month in the same dam. Extrapolating the estimates using monthly averages, which were 19 crocodiles sighted, the dam has an approximate population of 228 crocodiles. Since the dam has a surface area of 5.73 km^2, it means there is a density of 0.02 crocodiles/km^2 or 2 crocodiles per hectare in Ngezi Dam. More so, the dam has a shoreline length approximately 32 km; thus, crocodiles occur at a density of 1.4 crocodiles/km on the banks. This figure is lower than that suggested by Hutton (1987) who obtained a density of 3.9 crocodiles/km along the shores.

We attributed the differences in the figures to the high use of total day surveys relative to night surveys, which could have underestimated the actual figures in the study. Crocodile abundance estimates were only based on the actual sightings yet estimates of crocodiles are sometimes carried out using a combination of actual sightings and indices (Zisadza-Gandiwa et al., 2013). Such indices,

TABLE 3 Contextual interaction permutations table for Ngezi Dam

Category	Motive of parks (M1)	Motive of villagers (M2)	Information of parks (IP1)	Information of villagers (PI2)	Balance of power- parks (BP1)	Balance of power-villagers (BP2)	Process interaction	Management Strategy
Access to park resources	Conservation; prevent poaching	Access to park resources; food in drought, seasonal jobs	Poor and no information dissemination	Lack of conservation information	Active-Positive	Neutral-Negative	Passive cooperation	Enforcement
Increased crocodile numbers	Preserving crocodile numbers	Increased sightings means danger	High dissemination	High informing probability	Active-Positive	Negative	Active cooperation	Enforcement/ Co-management
Response to attack reports	Good response to attack reports	Loss of livestock and human life	Poor reaction; low dissemination of course of action	High	Active	Negative	Forced cooperation	Reactionary
Training in wildlife conflict	Poor-lack of training equipment	High-loss of life and livelihoods	Good dissemination	Good reception	Neutral	Active-Neutral	Active cooperation	Co-existence/ Adaptive co-management
Other factors-no permits, poaching, damaged fence	Good response	High-hunger, jobless, mischief	Good dissemination	Good-passive resistance	Active	Negative	Forced cooperation	Enforcement

for example spoors and nests, could not be used due to conditions of the lake shores and banks, which are either rocky or covered by vegetation (Hutton, 1987). This might have resulted in underestimating of the actual crocodile populations in the dam. We however, do not rule out the fact that crocodile numbers may have actually decreased over the years in the dam due to persecution by humans, and changes in water levels, which may have forced downward migration of the crocodiles out of the dam (Calverley & Downs, 2014). Regardless, our crocodile density estimates compare relatively well with other studies in the region for example Sai et al. (2016), who recorded 2.28 crocodiles/km in the Kove and Sengwa Rivers. Nyirenda (2015) suggested a relatively high figure of >2 crocodiles/km in the Lower Zambezi River although most of the studies were carried out in lotic systems far different from lentic systems like Ngezi Dam.

The non-temporal significant differences in the crocodile populations in Ngezi Dam reflect the ecology of the species, which is highly territorial and status conscious and can stay in a suitable habitat for more than 3 years especially in the headwaters with small juveniles (Cott, 1961; Fergusson, 2010). The larger juveniles and sub-adults are mainly confined to the pelagic zones of dams (Hutton, 1987). In this study, large adults and small juveniles were more abundant in the littoral zones, a factor which could have contributed to the non-significant differences in abundances over 2017–2018. In small and unstable shallow reservoirs such as Ngezi Dam, Kushlan and Mazzotti (1989) suggested that recruitment of crocodiles is slow as the species starts reproducing at 10–12 years of age. This implies that significant population changes can be noticed after 6–12 years, partly explaining the non-significant temporal differences in the abundances of the crocodiles over the study period (Combrink, 2004; Vergne & Mathevon, 2008). The territoriality of the species, especially nesting females, means in undisturbed sites, nests may be used for more than one season. Thus, in cross over surveys, there is an element of recording the same numbers of crocodiles in same sites even at different times.

4.2 | Distribution of crocodiles in Ngezi Dam

There were almost uniform sightings in all the five arms of the dam with the lowest number of sightings recorded in arms A and D. Reasons for the observed distributions could be non-significant different variations in factors such as depth, food availability and human disturbance although this study did not assess such factors. Hutton (1987) attributed the almost uniform distribution of crocodiles in Ngezi Dam to the relative shallowness of the dam (depth <2 m), which force an even distribution of macrophytes and nutrients in turn determining an almost uniform fish prey availability. Suffice to indicate that recent fish surveys have shown a non-uniform distribution of fish with more fish recorded in the upper area where the main tributary Ngezi River, laden with high allochthonous sediment matter, enters the dam (Food and Agricultural Organization of the United Nations (FAO), 2013). Nonetheless, Fergusson (2010) attributed uniform distribution of crocodiles to the gently sloping lake shorelines, which offer suitable basking and nesting sites. We observed relatively more open drawdown zones in the upper arms where the Ngezi River enters and actually recorded big fully grown adults basking or hiding in the macrophytes. Where Ngezi River enters, there are murky, either brown tea coloured or clay black littoral sediments, which offer adequate camouflage.

The nutrient-rich upper area in the Ngezi Dam is considered as the spawning zone, has a high fish population, and thus crocodiles migrate to such zones (Thorbjarnarson, 1996; Marshall, 2011). Game species, for example water bucks, kudu, impala, scrub hare and wildebeest in Ngezi Recreational Park, are concentrated in areas adjacent to the medium and upper sections of the dam with low human presence (Hutton, 1987). These animals also attract crocodiles as they drink water in the dam. The less turbid waters, located in the lower section of the dam, are favoured by juvenile and sub-adult Nile crocodiles for hunting (Bishop et al., 2009; Wallace & Leslie, 2008), which can partially explain the fairly even distribution of the crocodiles in Ngezi Dam.

4.3 | Perceptions of local communities towards crocodiles in Ngezi Dam

Most respondents had negative attitudes towards crocodiles and given a chance, they would vouch for their removal from Ngezi Dam. Crocodiles attack humans, mainly in the low flow periods or when humans carry out water-based activities such as laundry, bathing and fishing, and also depredate livestock such as goats, donkeys and cattle, which have limited escape abilities (Marowa et al., 2021; Mishra et al., 2003; Musambachime, 1987). The combined impacts of crocodile attacks on humans and livestock induce human–crocodile conflicts (HCCs) in aquatic ecosystems (Gandiwa et al., 2011; Sai et al., 2016). These HCCs induce negative attitudes and perceptions towards the species (Chihona, 2014; Marowa et al., 2021).

The Ngezi community indicated that they are taught at a tender age the dangers of crocodiles with some citing spiritual and cultural witchcraft uses of the species (Chihona, 2014). What is clear is that the recent increase in human population growth, industries and agricultural development around Ngezi has made the crocodiles shift from their preferred prey species and has switched to domestic livestock and humans. In a contextual sense, the destruction of the protective fence around the Ngezi Recreational Park has led to the illegal encroachment by communities who poach firewood, fish and game species (ZPWMA, 2006, 2015). Livestock trek from villages to drink water from the unfenced sections of the dam and are exposed to attacks by crocodiles. This exposes a subtle point that the same communities supposed to be the custodians of natural resources have a tendency of destroying the protective infrastructure for the wildlife resources (Zisadza-Gandiwa et al., 2016). Such a tendency stems from the exclusion perception where communities view fences as barriers to accessing a common resource (Zisadza-Gandiwa et al., 2016). However, it also shows that each protected area has unique

contextual challenges (both within itself and in surrounding communities), which must be understood before applying any management strategy as this may even worsen HCC (Utete, 2020).

4.4 | Policy and managerial implications

A number of factors, for example inadequately trained and resourced Problem Animal Control units, poor enforcement of wildlife regulations and no compensation for injured humans and killed livestock, have been attributed for the failure of HCC mitigation strategies in Ngezi Dam. Typically, Zimbabwe, like most African countries, lacks a cogent Human–Wildlife Conflict Resolution Policy with clear pathways to resolving HCC and for other specific aquatic species such as hippos (Utete, 2020). Thus, in most cases, it is a reactionary and strict enforcement management strategy where the Problem Animal Control unit kills the problematic animal/s only and leaves out animals of the same species with the potential to cause HCC in future. There are no specific guidelines on HCC resolution policies in the current Parks and Wildlife Management Act, which has been amended almost eight times from 1975 through the use of reactionary Statutory Instruments, which tend to be temporary in nature.

From this case study, strict enforcement, reactionary and even co-existence management strategies have not curbed HCC. Adaptive co-management in a flexible and contextual interactive relationship between the wildlife officials and surrounding communities appears to be the easiest solution. What this means is that a Contextual Wildlife-Conflict Interactive Resolution Policy must be crafted and inserted as a stand-alone management tool in the proposed 2021 Wildlife Act, which must be divorced from the conflicted and vague 2013 Environmental Management Act [Chapter 20:27] jointly used with the 1975 Parks and Wildlife Management Act [20:04]. This Contextual Wildlife-Conflict Interactive Resolution Policy needs to be species specific and comprehensive enough not the 'injure one injure all' wildlife policies being used that lack transparency and accountability enough to resolve HCC. On a general platform, more species-specific case studies, although resource demanding, need to be instituted and then a cogent HWC policy must be crafted for both developing and developed countries especially in the sub-Sahara African region (Chihona, 2014; Marowa et al., 2021; Utete, 2020).

5 | CONCLUSION AND RECOMMENDATIONS

There is a uniform distribution of crocodiles in the Ngezi Dam, which implies that most sections of the dam are potential HCC hotspots. Coupled with the increased HCC incidences reported not only in Ngezi Dam but also in most protected conservation areas in Zimbabwe (Marowa et al., 2021), it implies a need to frame and calibrate a HCC policy. For this purpose, our study proposes a Human Crocodile Conflict Contextual Resolution Framework (HCCCR) as indicated in Figure 4. This conjoins three categories to the adaptable implementation action of the HCCCR management strategy. The first category is to document the contextual situation of the specific conservation area for example its location, surrounding land-use challenges and skills dynamics of surrounding communities and ZIMPARKS officials written in full for a proper understanding of the underlying causes of HCC. The second category seeks to craft a simple non-bureaucratic conflict resolution pathway with clear actor types and their roles and decision-making jurisdiction, and more importantly foster community care and engagement and transparent compensation mechanisms in order to initiate adaptive co-management. The third category seeks to create public awareness and stakeholder engagement and coordination for mitigating HCC especially with regards to solid legal and institutional back-up for contextual adaptive co-management driven by resource mobilisation to support the implementation of the HCCCR. It is important to note that the whole plan is interlinked with no stand-alone stage. This simple HCCCR plan is adaptable and flexible to be adopted for any species, which is involved in HWC. However, for a proper refinement and adoption at regional and international scale, more area-specific studies including long-term sustained surveys or censuses and local community awareness campaigns are needed.

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CONFLICT OF INTEREST

The authors declare no conflict of interest associated with this paper.

AUTHOR CONTRIBUTION

TC: Conceptualised, collected, analysed and wrote the paper. BU: Conceptualised, collected, analysed, wrote and finalised the paper.

DATA AVAILABILITY STATEMENT

There was no additional data associated with this study.

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