Humans and Nile crocodiles along the Kunene River, Namibia:

Population dynamics and socio-ecological interactions

by
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Declaration

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Abstract

Human crocodile conflict is widespread throughout Africa and occurs at higher frequencies than in most other parts of the world. In spite of this, data on the distribution and scale of the conflict remains limited with conservationists and policy makers often relying on limited data to make management decisions. To make informed choices on how to mitigate these conflicts, an understanding of both the human dimensions, such as the frequency and distribution of conflict, as well as the biological dimensions, such as the distribution and abundance of crocodiles, is required. In the context of the lower Kunene River of north-western Namibia, one aerial survey of crocodiles was undertaken in 2012, while no previous research on the nature of human crocodile interactions had been undertaken before this study. Considering the above, this study aimed to estimate, as accurately as possible, the distribution and abundance of Nile crocodiles along the lower Kunene River, with the intention of comparing the current population estimate to that of 2012. In addition, the study set out to produce the first comprehensive data set on the scale, drivers, and distribution of human crocodile conflict (HCC) along the river.

To estimate of the abundance and distribution of Nile crocodiles along the lower Kunene River, an aerial survey was undertaken over three days in April 2021. The data collected during the survey were plotted on a map and analysed using both the direct count and modelled estimate of the crocodile population. These results were compared to those of the 2012 survey. To understand the interactions between humans and crocodiles along the lower Kunene River, a social survey was undertaken during which a questionnaire was administered to 155 households living along the Namibian bank of the river. These social ecological data were collected over two months in early 2022 and interpreted using both spatial and statistical analysis.

Regarding the Nile crocodile population along the lower Kunene River, a population estimate of between 287 (0.81 crocodiles per km), and 597 (1.7 crocodiles per km) was determined. These results suggest a decrease in the crocodile population of between 28 and 49% from 2012 to 2021. Additionally, a demographic shift seems to be underway with the numbers of crocodiles under 2 m in length appearing to remain relatively stable between 2012 and 2021, whereas the number of crocodiles > 2 m have decreased dramatically. Importantly, human population density appeared to be negatively correlated with crocodile abundance suggesting that as the number of humans in an area increases, the number of crocodiles decreases.

The results of the social survey showed that the large majority (92%) of households actively engage in subsistence farming and place a great deal of importance on growing crops and rearing livestock. Community members living along the lower Kunene River appear to be heavily reliant on water from the river with at least two thirds of households using the river for drinking, washing, and bathing water. Reliable records of

33 crocodile attacks on humans between 2010 and March 2022 were obtained with men appearing to be at the highest risk of attack. Fishing was found to be the activity with the highest risk, and afternoon/ evening appeared to be the time with the highest risk of experiencing a crocodile attack. Additionally, there seemed to be an increased risk of attack as households performed more activities at the river, and for households who used the river as a primary source of water. Crocodile attacks on livestock appeared to be substantial with 55% of cattle owners and 78% of small stock owners reporting losses to crocodiles in 2021. Most (82%) livestock owners felt crocodiles were the animal responsible for the most damage to their herds, and most attacks appeared to occur in the hot and dry (*Okuni*) season. Watering livestock in the afternoon/ evening emerged as the time of day with the highest risk of attack while morning was the lowest, as was the case with attacks on humans. Households with a higher dependence on the river demonstrated a higher risk of experiencing attacks on livestock. The Nile crocodile population along the lower Kunene River showed a positive correlation with attacks on small stock, while the human population correlated positively with attacks on livestock and humans. Retaliation against crocodiles was not widely reported, although there were reports of crocodiles being killed with firearms, poison, snares, and hook and lines. Most respondents cited attacks on livestock as the motive behind retaliating against crocodiles. Perceptions of crocodiles were generally negative, and most respondents failed to offer solutions to the conflict between humans and crocodiles along the lower Kunene River.

Opsomming

Mens krokodil-konflik is algemeen en wydverspreid regoor landelike Afrika. Ten spyte hiervan is data oor die verspreiding en omvang van die konflik beperk, en natuurbewaarders steun dikwels op beperkte data om bestuursbesluite te neem. Om ingeligte keuses te maak oor hoe om hierdie konflik te verminder, is 'n begrip van die menslike dimensies, sowel as die biologiese bevindinge, nodig. In die konteks van die laer Kunene-rivier in noordwestelike Namibië is daar in 2012 een lugopname van krokodille geneem, terwyl geen vorige navorsing oor die aard van mens krokodil-interaksies voor hierdie studie onderneem is nie. Met bogenoemde in ag geneem, het hierdie studie ten doel gehad om die verspreiding van krokodille langs die laer Kunene so akkuraat as moontlik te skat, met die bedoeling om die huidige bevolkingsskatting te vergelyk met die van 2012. Daarbenewens het die studie ten doel gehad om die eerste omvattende databank oor die omvang, moontlike motiewe en verspreiding van mens krokodil-konflik langs die rivier te produseer.

Om 'n skatting van die getal en verspreiding van krokodille langs die laer Kunene te maak, is 'n lugopname oor drie dae in April 2021 onderneem. Die data wat tydens die opname ingesamel is gekaarteer en dan geanaliseer met behulp van beide die direkte telling en gemodelleerde skatting van die krokodilpopulasie. Hierdie resultate is vergelyk met die van die 2012-opname. Om die interaksies tussen mense en krokodille langs die laer Kunene te verstaan, is ook 'n sosiale opname onderneem waarin 'n vraelys aan 155 huishoudings wat langs die Namibiese oewer van die rivier woon, voorgehou is. Hierdie sosio-ekologiese data is oor twee maande vroeg in 2022 ingesamel en is deur middel van ruimtelike en statistiese analise geïnterpreteer.

Met betrekking tot die krokodilpopulasie langs die laer Kunene, is 'n bevolkingsskatting van tussen 287 (0.81 krokodille per km) en 597 (1.7 krokodille per km) bepaal. Hierdie resultate dui op 'n afname in die krokodilpopulasie van tussen 28 en 49% vanaf 2012 tot 2021. Daarbenewens blyk dit dat daar tans 'n demografiese verandering aan die gang is, met die aantal krokodille onder 2 m in lengte wat redelik stabiel bly tussen 2012 en 2021, terwyl die aantal krokodille >2 m drasties afgeneem het. Dit lyk asof die menslike bevolkingsdigtheid 'n negatiewe korrelasie met die getal krokodille toon, wat aandui dat die aantal krokodille afneem namate die aantal mense in 'n gebied toeneem.

Die resultate van die sosiale opname het getoon dat die groot meerderheid (92%) van die huishoudings aktief aan bestaansboerdery deelneem. Gemeenskapslede wat langs die laer Kunene woon, is sterk afhanklik van water uit die rivier, en minstens twee derdes van die huishoudings gebruik die rivier vir drinkwater, was, en bad. Betroubare rekords van 33 krokodilaanvalle op mense tussen 2010 en Maart 2022 is verkry, en dit blyk dat mans die grootste risiko vir aanvalle inhou. Hengel is die aktiwiteit met die hoogste risiko, en die middag-/aandure blyk die tye met die hoogste risiko van 'n krokodilaanval. Daar was ook 'n verhoogde risiko van aanvalle wanneer huishoudings meer aktiwiteite by die rivier uitgevoer het, en vir huishoudings wat die rivier

as hul primêre bron van water gebruik het. Krokodilaanvalle op vee blyk aansienlik te wees, met 55% van beesboere en 78% van kleinveeboere wat in 2021 verliese aan krokodille aangemeld het. Agt-en-tagtig persent van die vee-eienaars het gevoel dat krokodille die dier was wat die meeste skade aan hul kuddes aangerig het, en die meeste aanvalle blyk in die warm en droë (*Okuni*) seisoen voor te kom. Die middag-/aandure is die veedrinktyd met die hoogste risiko van aanvalle, terwyl dit in die oggend die laagste is. Soos met aanvalle op mense, het huishoudings wat meer afhanklik is van die rivier, 'n hoër risiko getoon om aanvalle op vee te ervaar. Die krokodilpopulasie langs die laer Kunene het 'n positiewe korrelasie met aanvalle op kleinvee getoon, terwyl die menslike bevolking 'n positiewe korrelasie met aanvalle op vee en mense getoon het. Vergelding teen krokodille is nie wydverspreid gerapporteer nie, maar daar was berugte van krokodille wat met gewere, gif, strikke en hoek- en lyn gevang is. Die meeste respondente het aangedui dat aanvalle op vee die motief was agter vergeldingsaksies teen krokodille. Persepsies van krokodille was oor die algemeen negatief, en die meeste respondente het nie oplossings vir die konflik tussen mense en krokodille langs die laer Kunene aangebied nie.

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Preface

This thesis is presented as a compilation of five chapters each of which deal with topics relevant to crocodiles and their interactions with humans along the lower Kunene River of northwestern Namibia. As the data chapters of the thesis (Chapter 3 and 4) are intended for publication these two chapters demonstrate a degree of repetition as the topic and study area is introduced in both chapters. Importantly, Chapter 4 (Humans and Nile crocodiles in the lower Kunene River region) should be seen as the primary data chapter of this thesis where Chapter 3 (Aerial Survey of Nile crocodiles in the lower Kunene River) serves as a comparative description of the current Nile crocodile population along the river. An outline of each chapter is provided below.

Chapter 1: General introduction and literature review.
This chapter deals with topics relevant to human wildlife interactions with a particular focus on human crocodile interactions. A review of socio-ecological research as well as crocodile counting methods are also included with a focus on aerial surveys of crocodiles and social surveys in general.

Chapter 2: Description of the study area, its local inhabitants and wildlife.
This chapter attempts to frame the study in the context of the lower Kunene River and the people and wildlife that live there.

Chapter 3: An analysis of the Nile crocodile population in the lower Kunene.
An estimate of the total Nile crocodile population and their distribution is made. These results are compared to the previous aerial survey undertaken in 2012. Importantly, all data analyses relating to the N-mixture model presented in this chapter were conducted by Dr Arnaud Lyet.

Chapter 4: An analysis of the scale, drivers, and distribution of human crocodile conflict in the study area.

Chapter 5: A synopsis of the primary findings of the study and management recommendations.

Appendices: Appendices including a copy of the questionnaire used during the social survey administered along the river and a summary presenting descriptive statistics for all questions asked in the social survey.

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List of abbreviations, acronyms, and common contractions

CAS	Complex Adaptive System
CBNRM	Community Based Natural Resource Management
CBRLM	Community Based Rangeland and Livestock Management
CITES	Convention on International Trade in Endangered Species
HCC	Human Crocodile Conflict
HWC	Human Wildlife Conflict
HWCTF	Human Wildlife Conflict Task Force
HWI	Human Wildlife Interaction
IUCN CSG	International Union for Conservation of Nature Crocodile Specialist Group
MEFT	Ministry of Environment Forestry and Tourism
SES	Socio Ecological System
UAV	Unmanned Aerial Vehicle
WVO	Wildlife Value Orientation
WWF	World Wide Fund for Nature

List of definitions

Alternative water source — A source of water other than the river such as a borehole, well, or spring.

Community Based Natural Resource Management — Legally recognized, geographically defined areas that have been formed by communities who have united to manage and benefit from wildlife and other natural resources (Weaver & Petersen, 2008; Barnes et al., 2002).

Complex Adaptive System — A system that is: 1) Characterised relationally, meaning that the system is typified by recurring patterns in the relationships between aspects of the system; 2) Adaptive, meaning that the system can change as spatial or temporal changes occur which could lead to a reorganisation of the system; and 3) Dynamic, meaning that the system can be enhanced or diminished by feedback loops which could lead to changes in the system (Preiser et al., 2018).

Cultural topography of wealth — The traditions and norms that mediate the exchange of wealth within a group of people (Ferguson, 1992).

Deep ecology — Rejection of the man-in-environment image in favour of the relational, total-field image. Organisms as knots in the biospherical net or field of intrinsic relations. An intrinsic relation between two things A and B is such that the relation belongs to the definitions or basic constitutions of A and B, so that without the relation, A and B are no longer the same things (Naess, 1973).

Ecosophy — A philosophy of ecological harmony or equilibrium. (Naess, 1973)

Human crocodile conflict — Instances of HWC that occur between humans and crocodiles.

Human wildlife coexistence — Dynamic but sustainable state in which humans and large carnivores co- adapt to living in shared landscapes where human interactions with carnivores are governed by effective institutions that ensure long-term carnivore population persistence, social legitimacy, and tolerable levels of risk (Carter & Linnell, 2016).

Human wildlife conflict — Struggles that emerge when the presence or behaviour of wildlife poses 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).

Okuni — The dry, hot season from August until January. During this time of the year livestock traditionally graze near the river in areas that hold surface water throughout the year.

Okurooro — The wet, cool season from February until July. During this time of the year, livestock traditionally graze further from the river in areas that only hold surface water during the wet season.

Political ecology — The study of the relationship between political, economic, social, and environmental matters (Thone, 1935).

Self-reflexivity — A self-awareness and an awareness of the relationship between the investigator and the research environment (Lamb & Huttlinger, 1989).

Semi nomadic pastoralism	Refers to livestock raised by holders who live a semi-nomadic life. Typically, the holder has a permanent residence to which he/she returns for several months of the year according to seasonal factors. For semi-nomadic and semi-pastoral systems, the holder establishes a semi-permanent home for several months or years and may cultivate crops as a supplementary food source. Herds are moved on transhumance to assure forage and water (FAO: World Programme for the Census of Agriculture, 2020)
Socio Ecological System	A complex adaptive system where the relationship between humans and their environment is seen as complex and interconnected (Biggs et al., 2022). A SES has strong connections and feedbacks between humans and their environment meaning that humans both effect and are affected by their environment to such a degree that you cannot separate one from the other (Berkes & Folke, 1998; Folke et al., 2010).
The lower Kunene River	The lower reaches of the Kunene River where it bisects the Namib desert and forms the border between Namibia and Angola for 353 km of its total length (Lyet et al., 2016; Meissner & Jacobs, 2016).
Wildlife Value Orientation	The pattern of direction and intensity among a set of basic beliefs regarding wildlife (Fulton et al., 1996).

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CHAPTER 1

Introduction and literature review

1.1 Human wildlife conflict and coexistence

1.1.1 Human wildlife interactions

Interactions between humans and wildlife have been a key feature of the human experience since the dawn of our species (Nyhus, 2016; Woodroffe et al., 2005). The relationship between humans and wildlife is depicted in some of the earliest artistic works, where images of human hands were painted alongside wildlife more than 45,000 years ago (Brumm et al., 2021), and form an important part of the creation stories of many cultures (Woodroffe et al., 2005). Frank et al. (2019) argues that human wildlife interactions stem from an anthropocentric worldview that separates humans “Us” from animals “Them”. Frank et al. (2019) further illustrates how this separation between humans and non-human species has strengthened as our ancestors changed from hunter gatherers who interacted both as predators and prey, to agriculturalists who domesticated wild animals and excluded wildlife from areas set aside for agriculture. Bhatia et al. (2019) argue that human responses to the impacts of wildlife exist on a spectrum ranging from “manifested intolerance” to “stewardship”. In this framework, “manifested intolerance” refers to cases where humans foster both negative attitudes and behaviours towards wildlife while “stewardship” refers to cases where humans foster both positive attitudes and behaviours towards wildlife. Frank. (2016) argues that human wildlife interactions exist on a continuum ranging from positive to neutral to negative, coined as the “conflict-to-coexistence continuum”. Interactions where humans promote the existence of wildlife such as agricultural land being set aside for conservation by landowners, fall on the positive extreme of the continuum and are considered examples of human wildlife coexistence. In contrast, interactions where humans actively persecute wildlife such as pest eradication programs fall on the negative end of the continuum and are examples of human wildlife conflict (Frank et al., 2019). Pooley et al. (2021) cautions that although the “conflict-to-coexistence continuum” is a useful concept for exploring human wildlife interactions, it is important to keep in mind that these interactions are multidimensional and dynamic where incidences of conflict does not denote the absence of coexistence and *vice versa*.

1.1.2 Human wildlife conflict

Human wildlife conflict (HWC) is one of the most studied forms of human wildlife interactions (Nyhus, 2016) and falls on the negative end of the “conflict-to-coexistence continuum” (Frank, 2016). HWC has been defined by multiple authors. Woodroffe et al. (2005) states that HWC occurs when the needs or behaviours of wildlife have a negative effect on humans or when humans have a negative effect on the needs of wildlife. Peterson et al. (2010) expands the definition by emphasizing that HWC often describes perceived conflict between people and animals rather than actual conflict. For the purpose of this thesis, I will use the definition agreed upon by the IUCN SSC Human-Wildlife Conflict Task Force: "struggles that emerge when the presence or behaviour of wildlife poses 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).

The causes and consequences of HWC are complex and far reaching. Meyer and Börner. (2022) argue that HWC can arise from a series of situations such as: 1) competition between humans and wildlife for non-cultivated resources, for example grazing, fish, and other resources harvested by humans from the natural environment (Meyer & Börner, 2022; Niamir-Fuller et al., 2012; Nyhus, 2016): 2) competition between humans and wildlife for cultivated resources such as crops and livestock (Meyer & Börner, 2022; Nyhus, 2016; Shaffer et al., 2019): and 3) negative interactions between humans and wildlife that relate to material property such as damage to water infrastructure or exclusion by fences (Meyer & Börner, 2022; Nyhus, 2016; Shaffer et al., 2019). Importantly, HWC can also arise as a result of underlying human on human conflict, such as conflicts surrounding resource use, management strategies or land allocation by competing human stakeholders (Nyhus, 2016; Peterson et al., 2010; Woodroffe et al., 2005).

Negative interactions between people and wildlife have a series of consequences for all species involved. Direct effects of HWC on humans includes loss of income, injury, or death (Aust et al., 2009), while indirect effects include more discrete impacts such as feelings of vulnerability and stress as well as opportunity costs (Barua et al., 2013; Khumalo & Yung, 2015). Effects of HWC on wildlife include exclusion from valuable resources as well as injury and death (Niamir-Fuller et al., 2012). More significant effects include the decreases in abundance of a particular species or in some cases extinction (Dirzo et al., 2014; Nyhus, 2016) which has been shown to have cascading effects on other species and ecosystem services (Ripple et al., 2014). Apart from the direct effects of HWC on humans and other non-human species, HWC has the potential to cause disillusionment in communities living alongside wildlife which can lead to a lack of support for conservation efforts as a whole (Aust et al., 2009).

1.1.3 Human wildlife coexistence

Human wildlife coexistence although poorly defined (IUCN SSC HWCTF, 2022), has been described as a "dynamic but sustainable state in which humans and large carnivores co-adapt to living in shared landscapes where human interactions with carnivores are governed by effective institutions that ensure long-term carnivore population persistence, social legitimacy, and tolerable levels of risk" (Carter & Linnell, 2016). Although this definition pertains specifically to large carnivores, I would argue that it is appropriate for use on other species living alongside humans. Scholars have also made the interesting distinction that identifying human wildlife coexistence as a conservation goal, denotes that humans in a particular landscape have chosen to share their land and resources with wildlife (IUCN SSC HWCTF, 2022).

The field of human wildlife coexistence has garnered considerable attention in the conservation community in recent years due to the recognition that: 1) a disproportionate amount of research on human wildlife interactions focused primarily on human wildlife conflict (König et al., 2020): 2) various other types of human wildlife interactions exist and are equally important especially when one strives towards a point of coexistence between humans and wildlife (Pooley et al., 2021) and: 3) by focusing primarily on conflict as a human wildlife interaction, researchers are likely reenforcing the notion of duality between humans and nature, where nature is purposefully detrimental to the needs of humans (Peterson et al., 2010).

In light of the above, many researchers have shifted their focus to understanding human wildlife coexistence (Glikman et al., 2021; IUCN SSC HWCTF, 2022; König et al., 2020; Pooley et al., 2021; Schroer, 2021; Treves & Santiago-Ávila, 2020). Glikman et al. (2021) illustrates that concepts such as tolerance and acceptance are integral to understanding coexistence, with coexistence being seen as the most positive form of interaction preceded by acceptance and tolerance, respectively. In this framework, communities living alongside wildlife either tolerate, accept, or coexist with wildlife with each point on the hierarchy representing a more positive form of human wildlife interaction (Glikman et al., 2021). Rather than insisting that this way of viewing coexistence is all encompassing, Glikman et al. (2021) offers an alternative view of coexistence, where coexistence is seen as an overlap between acceptance and tolerance. Furthermore, emphasis is placed on the idea that acceptance and tolerance are generally experienced at the individual level where coexistence is a broader category relating to multiple species existing within a shared social ecological system. While exploring the concept of coexistence, Bhatia, (2021) makes use of concepts from peace theory such as "positive peace" and "negative peace", (Galtung, 1964) to better understand coexistence. Bhatia, (2021) describes "positive coexistence" as situations where humans willingly coexist with wildlife and promote their presence in a shared habitat, where "negative coexistence" refers to situations where humans do not persecute wildlife but do not necessarily hold positive attitudes to conservation or wildlife.

Regarding research on human wildlife coexistence, Schroer, (2021) suggests that when studying coexistence, one should consider non-dualist or relational ways of thinking, rather than separating humans and their social interactions from wildlife and their social interactions. When one applies this framework, a concept more often used in the social sciences, it becomes clear that to understand human wildlife coexistence, one must consider the social, cultural, historical, and ecological dimensions of a system as they are interrelated and inseparable (Schroer, 2021). Pooley et al. (2022) further supports the use of a multidisciplinary approach to studying coexistence, noting the challenges faced by conservationists, usually trained in the biological sciences, who must make use of methods more commonly employed in the social sciences. Additionally, Pooley et al. (2022) recognises that it is easier to quantify human wildlife conflict, where for example, number of attacks on humans or livestock lost to depredation, can easily be counted compared to instances of coexistence, where for example, people chose not to retaliate against a certain damage causing animal. Although coexistence remains inadequately defined and its drivers poorly understood, there seems to be agreement around the complexity of the topic, as well as the importance of understanding it in a way that considers both the ecological and social dimensions of a system.

1.2 Human crocodile conflict and coexistence

1.2.1 Human crocodile conflict

Human crocodile conflict (HCC) refers to conflict that occurs between humans and crocodiles, as with other forms of human wildlife conflict, the effects are far reaching and have negative consequences for both humans and crocodiles (Eustace et al., 2022; Khan et al., 2020; Marowa & Matanzima, 2021; Matanzima et al., 2022). Nile crocodiles (*Crocodylus niloticus)* are widespread throughout Southern Africa and occur in a diversity of freshwater habitats such as lakes, rivers, and dams (Aust et al., 2009; Pooley, 2016a). Nile crocodiles are not only the crocodilian species responsible for the most attacks on humans when compared to other crocodilians but are thought to be responsible for the most attacks on humans when compared to all other wildlife (Pooley, 2016a; Sideleau & Britton, 2013). Although research on HCC in Africa remains porous, various scholars have studied the subject at different spatial and temporal levels. Chomba (2012) attributed 185 fatalities to crocodiles in Zambia between 2002 and 2010, Pooley et al. (2020) found records of 214 attacks in South Africa and eSwatini between 1949 and 2016, Eustace et al. (2022) estimated 575 attacks in Tanzania between 2010 and 2019, where Sideleau and Britton (2013) attributed 428 attacks to Nile crocodiles between 2008 and 2013. Although this list is by no means exhaustive, and all authors suggest that attacks are likely underreported, it shows the severity of HCC in southern Africa. Despite the disproportionate number of attacks on humans attributed to Nile crocodiles, data on HCC is still largely inadequate and the true number of attacks are likely higher than the current estimates (Sideleau & Britton, 2013).

HCC is driven by the dependence of both humans and crocodiles on water. Crocodiles rely on a variety of freshwater ecosystems to support their biological needs such as feeding and reproduction (Fergusson, 2010; Hutton, 1987; Kofron, 1989). In the same way, humans use water for drinking, washing, fishing, irrigation, and livestock rearing (Aust et al., 2009). This dependence on fresh water has led to an increasing number of people settling near water sources such as lakes and rivers, placing further pressure on freshwater ecosystems (Small & Cohen, 2004). In the context of rural Africa, many communities lack the facilities to provide alternative water sources away from rivers and lakes and consequently many communities are forced to fetch water directly from freshwater ecosystems leaving themselves and their livestock vulnerable to crocodile attacks (Aust et al., 2009; Thomas, 2006).

The effects of HCC on humans range from attacks that result in injury, death and/or psychological trauma (Aust et al., 2009; Matanzima et al., 2022). Attacks on livestock, damage to infrastructure such as fishing equipment, competition over shared resources such as water and fish, and opportunity costs particularly pertaining to herders who must keep livestock away from crocodile habitats are also widely reported (Eustace et al., 2022; Thomas, 2006). On the other hand, crocodiles are often killed, injured, or have their nests destroyed in retaliatory persecution (Aust et al., 2009; Shacks, 2006; Thomas, 2006). Crocodile nests are particularly vulnerable to excessive grazing by livestock and burning, a livestock management practice widely used to stimulate grass growth on riverbanks (Shacks, 2006). Other common forms of conflict include over harvesting of crocodiles or their eggs, crocodile entanglement and drowning in fishing nets, and damage to nests caused by human induced flooding (Kofron, 1989; Marowa & Matanzima, 2021; Thomas, 2006).

1.2.2 Human crocodile coexistence

Although instances of human crocodile coexistence are understudied (Pooley, 2022) and coexistence poorly defined (IUCN SSC HWCTF, 2022), the recent uptake of research on the topic has shed some light on the underlying drivers of human crocodile coexistence (Cavalier et al., 2022). In a comprehensive review of the literature surrounding human crocodile coexistence, Cavalier et al. (2022) concluded that human crocodile coexistence, or in some cases the lack thereof, is underpinned by human cognitions, human’s relationship with the physical environment, and the governance strategies implemented in a specific landscape.

Regarding the significance of human cognitions on coexistence, Cavalier et al. (2022) found evidence of coexistence driven by territorial cognitions, belief-based management protocols, and the potential for cognitive change over time. Territorial cognitions or place-based beliefs was shown to be a driver of coexistence where the potential to coexist with crocodiles was determined in part by how communities perceived their relationship with crocodiles (Cavalier et al., 2022). Examples of place-based beliefs driving coexistence are found in the Philippines where crocodiles play an important role in the creation story of the Maguindanao people thus inspiring tolerance and acceptance of crocodiles in a shared landscape (Van der Ploeg et al., 2011). Belief based management protocols refer to instances where the responses to interactions between humans and crocodiles are determined to varying degrees by underlying beliefs often shaped by mythology and folklore surrounding crocodiles (Cavalier et al., 2022). These underlying beliefs and the interactions they drive can either promote or impede coexistence between humans and crocodiles. Belief based management is illustrated by a shared ethical community paradigm (Cavalier et al., 2022) held by the Malagasy people of Madagascar who believe that killing a crocodile can set off a recurring pattern of crocodile attacks on humans and as such, this community refrains from retaliatory killings of crocodiles (Pooley, 2016a). Finally, the capacity for cognitive change over time has also been shown to have a significant effect on coexistence. This is demonstrated by a change over time in the human perceptions of crocodilians from negative to positive in communities in Australia and North America (Cohen, 2019).

The nature of a community's relationship with both the terrestrial and aquatic environment has also been shown to have a significant effect on coexistence potential (Cavalier et al., 2022). Both anthropological alterations to the terrestrial and / or aquatic environment as well as the adaptive capacity of communities, often dictated by their environment, drives coexistence (Cavalier et al., 2022). Alterations to the environment in India such as the construction of dams and land use change due to human settlements has been shown to decrease the potential for human crocodile coexistence as crocodile habitats are destroyed and encroached on by an ever-expanding human population (Rao & Gurjwar, 2013). The potential for communities to share an ecosystem with crocodiles is also driven by their capacity to adapt their lifestyles in a way that meets both the social and economic needs of a community while coexisting with crocodiles. Illustrating this point is the increased potential for conflict in rural subsistence communities, who often have economic and / or social barriers to adopting alternative methods of making a living and are thus constrained to economic activities such as fishing and livestock rearing in habitats shared by crocodiles (Aust et al., 2009).

Cavalier et al., (2022) noted the important effects that governance strategies as well as commodification schemes had on the potential for humans and crocodiles to coexist. In some cases, authoritarian, top-down decision making was shown to enhance the potential for conflict with conflict often arising between community members, government officials and conservationists (Pooley, 2016b). In contrast, allowing community members living with crocodiles to participate in decision making in a form of local governance was shown to promote coexistence between humans and crocodiles (Van der Ploeg & Van Weerd, 2004). Commodification of crocodiles either by consumptive means such as harvesting eggs, skins or meat or non-consumptive means such as eco-tourism has also been shown to drive human crocodile coexistence (Cavalier et al., 2022). Consumptive commodification (hunting) was shown to produce considerable economic benefits to stakeholders in Venezuela, however the lack of reinvestment in crocodile conservation likely undermined the sustainability of the practice (Thorbjarnarson & Velasco, 1999).

1.3 Socio ecological research

Research in the natural sciences has traditionally been the primary basis on which decisions regarding nature conservation have been made (Bennett et al., 2017). Despite the apparent dominance of the natural sciences in informing decision makers, conservation scholars have repeatedly expressed the importance of understanding the human dimensions of conservation and considering these when making decisions (Bennett et al., 2017). Aldo Leopold realised the importance of incorporating sociology into conservation as early as 1935 (Leopold, 1966) while Michael Soule described its importance in his seminal work on conservation biology (Soule, 1985).

Although the importance of considering humans in conservation frameworks was well recognised, conservation up until the end of the 20th century often adopted a top-down, biocentric approach where large tracts of land were set aside as protected areas with little consideration of the people who lived there (Brockington, 2004). As large areas uninhabited by humans became more scarce and with the recognition of the rights of indigenous peoples, a new anthropocentric model of conservation was adopted where humans were recognised as important stakeholders in conservation areas (Nuulimba & Taylor, 2015). The increased adoption of conservation frameworks that recognise the role that humans play in an environment, as well as the recognition that humans are not only the primary cause of environmental degradation but are severely affected by it and often determine the conservation outcomes, has highlighted the importance of considering anthropogenic factors in conservation policy (Sanborn & Jung, 2021). Although scholars still call for greater consideration of the human aspects of environmental management (Bennett et al., 2017; Pooley et al., 2017; Sanborn & Jung, 2021), social ecological research has been effectively used to inform conservation decisions in both terrestrial and aquatic environments, across multiple scales and land use types (Bennett et al., 2017).

Research on the social aspects of conservation make use of a variety of methods such as surveys, questionnaires, interviews, focus groups and participant observation to produce both qualitative and quantitative data (Bennett et al., 2017). These data have applications in various fields divided by (Bennett et al., 2017) into: 1) classic conservation social science fields, such as environmental anthropology and environmental sociology; 2) Applied conservation social science fields, such as conservation marketing and environmental and conservation education; and 3) Interdisciplinary conservation science fields such as political ecology and ecological economics.

Researchers studying the relationships between people and the environment have recently paid particular attention to concepts such as social ecological systems (SES) where the relationship between humans and their environment is seen as complex and interconnected (Biggs et al., 2022). In this framework, strong connections and feedbacks between humans and their environment means that humans both affect and are affected by their environment to such a degree that you cannot separate one from the other (Berkes & Folke, 1998; Folke et al., 2010). SES is further characterised as a complex adaptive system (CAS) (Biggs et al., 2022) where the system is; 1) characterised relationally, meaning that the system is typified by recurring patterns in the relationships between aspects of the system; 2) Adaptive, meaning that the system can change as spatial or temporal changes occur which could lead to a reorganisation of the system; and 3) Dynamic, meaning that the system can be enhanced or diminished by feedback loops which could lead to changes in the system (Preiser et al., 2018). Concepts such as "ecosophy", "deep ecology" (Naess, 1973), and "entanglement" (Hodder, 2014) align with those of SES and frame humans as part of a biophysical whole where they are shaped by their environment and shape their environment in turn.

Other important concepts to consider when studying social ecological interactions include the theories surrounding individual behaviour (Ajzen, 1991), wildlife value orientations (Fulton et al., 1996) and the cultural character (Manfredo & Dayer, 2004) of a specific person or group of people as these can inform researchers on how humans perceive wildlife and why they interact with their environment in the ways that they do (Manfredo & Dayer, 2004). Regarding the effects of specific actions on a group of people, scholars have used concepts such as political ecology (Thone, 1935), which examines how costs and benefits are borne (often unequally) by members of a society, as well as the cultural topography of wealth (Ferguson, 1992), which explores the traditions and norms that mediate the exchange of wealth within a group of people. Reflexivity has also emerged as an important concept to consider when conducting social research (Popoveniuc, 2014). Self-reflexivity refers to the consideration of the effect of a researcher's values and beliefs on the research she/he is engaged in and is defined as "a self-awareness and an awareness of the relationship between the investigator and the research environment" (Lamb & Huttlinger, 1989). In the same way, reflexivity of the respondents being interviewed must also be considered. As respondents become aware of the presence of a researcher, respondents are likely to draw conclusions about the beliefs held by a researcher or the nature of the research being undertaken. This consciousness likely results in the respondent responding to questions in a way that she/he thinks will achieve a specific goal, which if not considered by the researcher can lead to biases in the research (Popoveniuc, 2014). In this way, when a researcher fails to account for the effects that her/his values, beliefs and/or culture have on the research they are undertaking, conclusions are likely to be biased and misleading (Popoveniuc, 2014).

1.4 Counting crocodiles

A series of methods have been effectively used to conduct estimates of crocodile populations. Spotlight surveys (Messel et al., 1977) are undertaken by surveying the study area (a section of river in most cases) by boat at night and using a spotlight to identify and count crocodiles. Due to the reflective properties of a crocodile's eyes, these animals can be easily identified and counted using a spotlight at night (Bayliss et al., 1986; Grenard, 1991). Spotlight surveys are restricted to areas accessible by boat and several factors such as boat speed, observer proficiency, spotlight strength, vegetation, weather conditions, and crocodile behaviour are likely to bias results (Cherkiss, Mazotti & Rice, 2006; Hutton & Woolhouse, 1989). Despite the shortcomings of spotlight surveys, the relatively low cost and widespread use of this method has made it an attractive and effective way of estimating crocodile populations (Letnic & Connors, 2006).

Mark and recapture methods have also been a popular way to estimate crocodile populations (Murphy 1980; Bayliss et al. 1986). This method entails capturing and marking individuals of the study species and thereafter releasing them. After a certain period, individuals are captured again in the same study area using the same effort. On the second capture, the number of marked and unmarked individuals caught is related using a mathematical equation and this is used to estimate the total population in the study area (Lincoln, 1930; Petersen, 1896). This method makes a series of assumptions such as: 1) marking has no effect on individuals; 2) marked and unmarked individuals mix completely within a population; 3) the likelihood of catching marked and unmarked individuals is constant for both sexes and across size classes; and 4) capture occasions happen at discrete time intervals (Southwood & Henderson, 2003). Despite the failure of most crocodile populations to meet these assumptions, mark and recapture methods remain a relatively low cost and widely used method of estimating crocodile populations (Balaguera-Reina et al., 2015).

Aerial surveys have been used in various forms to estimate wildlife populations across multiple habitats (Samuel et al., 1987). Methods include total counts, where the entire study area is surveyed, block or quadrat counts, where a sample quadrat of the study area is surveyed and results are extrapolated for the rest of the study area, and strip counts, where line transects of the study area are surveyed and results are extrapolated for the rest of the study area (Cook & Jacobson, 1979; Pollock & Kendall, 1987). With regards to counting crocodiles, aerial surveys allow researchers to survey large areas rapidly (Bourquin, 2007). Using helicopters has been proven to be particularly advantageous due to the wider field of view, manoeuvrability, the ability to fly lower at slower speeds, and the capacity to access areas inaccessible by boats (Lyet et al., 2016). A series of factors influence the detectability of crocodiles during aerial surveys. Observer proficiency, flying speed and height can lead to undercounting the number of crocodiles in a system (Bourquin, 2007; Lyet et al., 2016), while vegetation, crocodile size, glare and time of year can make crocodiles more of less likely to be identified from the air (Bourquin, 2007; Lyet et al., 2016). These biases can be reduced by flying at a constant speed and height, and consistently using proficient observers (Lyet et al., 2016). Additionally, surveying in winter, when crocodiles spend the most time basking (Bayliss et al., 1986), and in the late morning and early afternoon to reduce the effects of glare can result in higher detection probabilities (Lyet et al., 2016). Importantly, while spotlight surveys and mark and recapture methods are generally used to estimate population trends by counting a sample of the system and its population (Bayliss et al., 1986), aerial surveys provide the unique opportunity to survey entire systems and make estimates on the total population size (Bourquin, 2007; Lyet et al., 2016). Recently, unmanned aerial vehicles (UAV) or drones have been used to carry out aerial surveys of crocodiles with very promising results (Aubert et al., 2022). The low cost, safety (Ogden, 2013), ability to fly at lower heights and speeds (Aubert et al., 2022), ease of use (Koh & Wich, 2012) and the reliance on photographic data (McEvoy et al., 2016) adds to the merits of this method. Despite the many benefits of this method, drones can only be flown a limited distance from the operator, and government regulations as well as a lack of equipment and skills has resulted in limited adoption of this method and wide scale use thereof is still lacking, although this is likely to change in the near future (Jiménez López & Mulero-Pázmány, 2019).

1.5 Introduction to the research problem

Despite the high occurrence of human crocodile conflict (HCC) in Africa and reports that crocodiles are responsible for more attacks on humans than any other species, the continent is still largely data deficient with a poor understanding of the scale, drivers and distribution of conflict and coexistence (Pooley et al., 2019). The lower 352 km of the Kunene River that forms the border between Angola and Namibia had an estimated Nile crocodile population of between 562 and 806 in 2012 (Lyet et al., 2016). Four out of the six conservancies bordering the river reported 499 problem animal incidents, referring to negative interactions between humans and wildlife, from the period of 2006 (earliest records) to 2017 (Registered Communal Conservancies, 2021), and the CrocBITE worldwide crocodilian attack database listed 8 crocodile attacks on humans in the area. Concerningly, studies on HCC conducted in other parts of Namibia found that existing estimates of losses due to HCC were significantly lower than those found by community surveys and that HCC could be undermining conservation efforts in the region (Aust et al., 2009). Furthermore, since the down listing of Nile crocodiles in Namibia from CITES Appendix I to CITES Appendix II in 2004, the potential to derive tangible economic benefits from coexistence with the species has increased. These benefits can be realised in the forms of non-consumptive commodification (tourism), and consumptive commodification (hunting and harvesting eggs) provided that the natural structure and function of crocodile populations are maintained (MET, 2014).

The current study was undertaken in response to the call by Namibia's Ministry of Environment, Forestry and Tourism's (MEFT) species management plan for the Nile crocodile, where a call was made for research to be undertaken on the ecological as well as the socio-economic aspects of crocodiles and HCC in Namibia and along the Kunene River in particular (MET, 2014).

> Section 2. c "Research should focus on answering questions relating to management. Kunene is a priority in terms of baseline ecological and biological data. Some important research questions include:…Regional and temporal movement patterns,…Population abundance including the development and/or refinement of boat, food, nest, and aerial survey methodologies" (MET, 2014).
>
> Section 4. d "Socio-economic review of HCC in Namibia to determine total cost and identify worst affected areas. This should include semi-structured interviews at the local level., Identify measures suitable for immediate deployment in the worst affected areas., Ecology and behaviour of crocodiles in human dominated landscapes." (MET, 2014).

Notably, much of the area was also listed as a "utilisation zone" under the same management plan, illustrating the potential for coexistence through commodification (MET, 2014).

Additionally, this study was undertaken in light of the call by the World Wide Fund for Nature (WWF) to explore the potential for income streams to community conservation other than hunting and tourism (Roe et al., 2020) as well as the International Union for Conservation of Nature Crocodile Specialist Group's (IUCN-CSG) recommendation to list studies dealing with HCC as "High priority" projects (Ferguson, 2010).

Finally, this study aimed to further the goals of Namibia's 5th National Development Plan with regards to; "Inclusive, equitable and sustainable economic growth, capable and healthy human resources, sustainable environment and good governance" (National planning Commission, 2017). This was realised by contributing towards a better understanding of; the extent, distribution and factors associated with human crocodile conflict and coexistence (see Chapter 4), the abundance and distribution of Nile crocodiles (see Chapter 3), and by collaborating with conservancies, MEFT, universities and Namibian research institutes to develop conflict management recommendations for the Kunene River (see Chapter 5 and see preface). The conflict management recommendations prioritised topics such as decreasing HCC, increasing the potential for sustainable economic development through coexistence, and the maintenance of a healthy ecosystem. Ultimately this study set out to further the cause of environmental sustainability and rural development in a way that developed local capacity and made use of international collaboration.

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CHAPTER 2

Study Area

2.1 The Kunene River

The focus of this study was the lower reaches of the Kunene River (Figure 2.1) (referred to as the lower Kunene River) where it bisects the Namib desert and forms the border between Namibia and Angola for 353 km of its total length (Lyet et al., 2016; Meissner & Jacobs, 2016). The Kunene River originates in the highlands of Angola and flows for 1050 km from the Sierra Encoco Mountains in Angola to the Atlantic Ocean (Midgely, 1966). The Kunene River catchment covers approximately 106 500 km^2 and is separated into three sections (Lyet et al., 2016; Midgely, 1966; Morant, 1966; Paterson, 2007). The upper and middle sections cover an estimated 92 400 km^2 and are situated in Angola, while the lower section drains into the Kunene River where it forms the border between Namibia and Angola with a catchment of approximately 14 216 km^2 (Lyet et al., 2016; Midgely, 1966; Morant, 1966; Paterson, 2007). The river is fed by a combination of natural springs (Irving & Ward, 1999) and rainfall ranging from 1 500 mm/year at its source in the Angolan Highlands, 350 mm/year at Ruacana, and 30 mm/year where it bisects the Namib Desert and terminates in the Atlantic Ocean (ERM South Africa, 2009; Hay et al.,1997; Wassenaar et al., 2021). Rain generally occurs from October to March with the heaviest rains occurring between February and March in the lower Kunene River region (ERM South Africa, 2009; Hay et al., 1997). The average temperatures range from 19 – 20°C at the coast to 21 – 22°C at Ruacana. During summer months, temperatures often exceed 40°C (ERM South Africa, 2009).

At Ruacana Dam (Ruacana Diversion Weir) the river has an altitude of approximately 904 m before falling to approximately 798 m below the Ruacana Falls (the eastern limit of the study area). The river then flows west past the Zebra Mountains into the Baynes Mountains. As the river enters the Baynes Mountains, it flows over the Epupa Falls to an altitude of 606 m and flows through the Baynes Gorge, past the Otjihipa Mountains to Otjinhungwa. At Otjinhungwa, the ephemeral Otjinjange River flows into the Kunene River through the Marienfluss Valley and continues its westward descent to the Atlantic Ocean passing through the Hartmann Mountains (Atlas of Namibia Team, 2022). Most of the lower Kunene River's flow is regulated by a series of dams and hydroelectric power stations in Angola and Namibia (ERM South Africa, 2009). The Ruacana Dam is the furthest downstream and has the greatest effect on the flow dynamics of the lower Kunene River with an average outflow of 160 m^3/s at the dam and an average annual discharge of 5.5 km^3 at the river mouth (Kunene River Awareness Kit, 2023). Importantly, the flow volumes of the lower Kunene River are highly variable with flow levels differing considerably both within and between years (ERM South Africa, 2009; Kunene River Awareness Kit, 2023).

The lower Kunene River forms the northern border of six community conservancies. Starting from the east, these conservancies are Uukolonkadhi – Ruacana, Kunene River, Okanguati, Epupa, Otjitanda, and Marienfluss conservancies (Figure 2.1). These conservancies have been formed on communal land where community based natural resource management (CBNRM) is used to derive benefits from wildlife. Conservancies in Namibia can be defined as "legally recognized, geographically defined areas that have been formed by communities who have united to manage and benefit from wildlife and other natural resources." (Weaver & Petersen, 2008; Barnes et al., 2002) and are founded on three fundamental ideas, that is: 1) communities should be empowered to manage their own resources; 2) communities should be allowed to utilize their natural resources to enact sustainable development; and 3) communities should be able to place economic value on their natural resources, as in doing so they are incentivized to protect them (Nuulimba & Taylor, 2015). In addition to forming the northern border of these conservancies, the lower Kunene River forms the southern border of the Iona National Park in Angola and the northern border of the Skeleton Coast National Park in Namibia (Figure 2.1). These two national parks make up the Skeleton Coast Iona Trans Frontier Conservation Area covering approximately 31 500 km^2 (De Cauwer & Wassenaar, 2020).

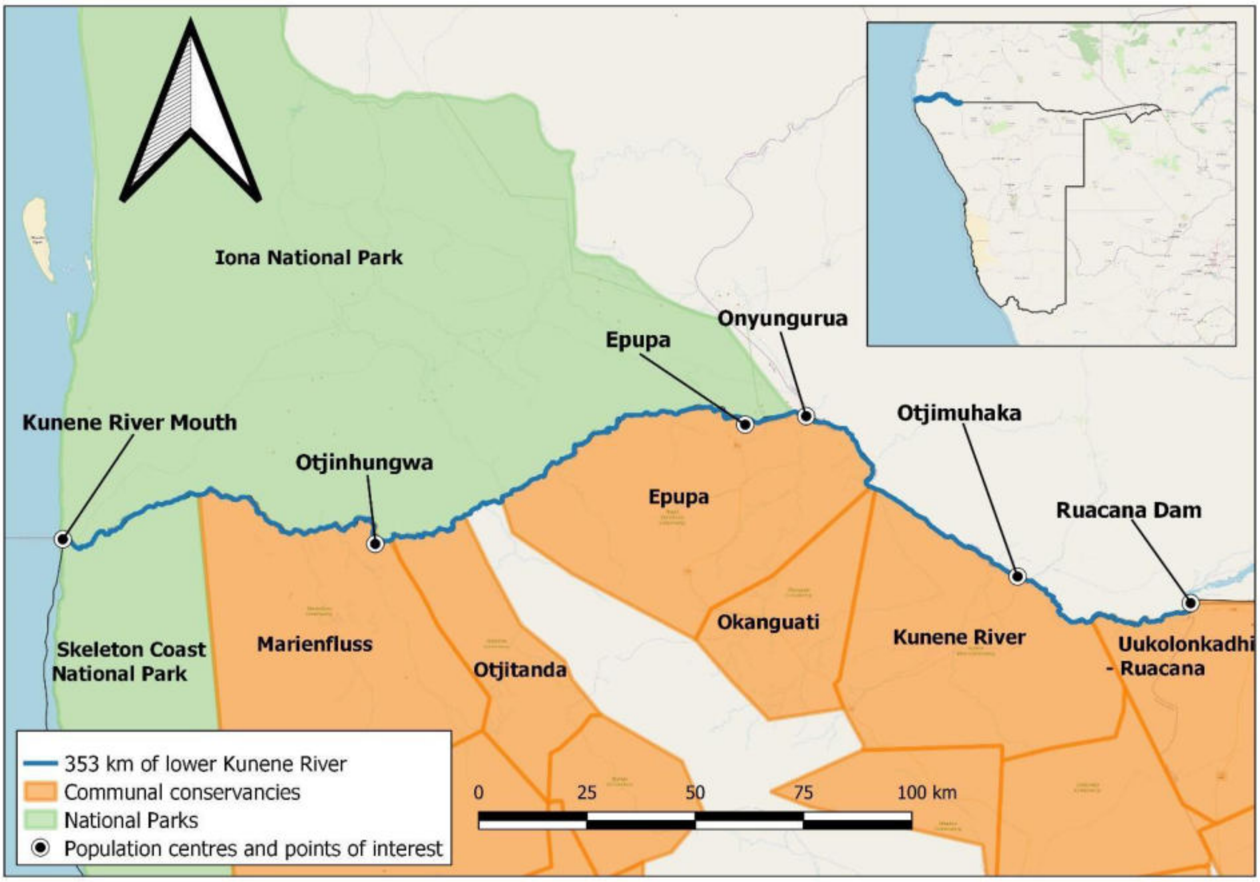

Figure 2.1: Map of the study area showing the lower 353 km of the Kunene River (in blue), the population centres and points of interest (labelled in black), the communal conservancies bordering the river (in orange), and the Skeleton Coast and Iona National Parks (in green).

2.2.1 Fauna and flora of the Kunene

The lower Kunene is comprised of various habitats hosting a diversity of species. Starting in the east, the river flows through the Western Highlands vegetation type in the Tree-and-Shrub Savanna biome (Atlas of Namibia Team, 2022). This area is characterised by mopane (*Colophospermum mopane), Catophractes alexandrii,* and various *Boscia* and *Commiphora* species interspersed with annual and perennial grasses (Figure 2.2). Near Otjinhungwa, the river passes through the Northwestern Escarpment and Inselbergs vegetation type in the Nama Karoo biome (Atlas of Namibia Team, 2022). This area forms the Western limit of the Kaokoveld Centre of Endemism (Craven, 2009) and is characterised by open shrublands and gravel plains which transform to grasslands after adequate rains (Figure 2.2). As the river nears the coast, it passes through the Northern Desert vegetation type in the Namib Desert biome (Atlas of Namibia Team, 2022). This vegetation type occurs between the coastline and 30 – 60 km inland and is dominated by gravel plains and dunes interspersed with desert adapted plants such as !Nara (*Acanthosicyos horridus*), and *Welwitschia mirabilis* (Figure 2.2). Although the lower Kunene River flows within steep gorges for much of its course (Hay et al., 1997), which do not support significant amounts of vegetation, the section between Ruacana Dam and Epupa is typified by riverine vegetation where a dominance of *Phragmites* reedbeds interspersed with dense stands of makalani palm (*Hyphaene petersiana*), as well as ana tree (*Faidherbia albida)*, lead wood (*Combretum imberbe)* and jackal berry (*Diospyros mespiliformis*). At the river mouth, the Kunene forms a coastal wetland dominated by *Phragmites* and *Sporobolus* swamps before flowing into the Atlantic Ocean (Paterson, 2007).

A series of terrestrial wildlife occur along the banks of the lower Kunene. Notable ungulates include black faced impala (*Aepyceros melampus petersi*), Hartmann's mountain zebra (*Equus zebra hartmannae*), Angolan giraffe *(Giraffa giraffa angolensis)*, kudu *(Tragelaphus strepsiceros)*, oryx *(Oryx gazella)*, and springbok *(Antidorcas marsupialis)*. Additionally, predators such as leopard *(Panthera pardus)*, cheetah (*Acinonyx jubatus*), brown hyena *(Hyaena brunnea)*, black backed jackal (*Lupulella mesomelas)* and caracal (*Caracal caracal)* are found throughout much of the study area (Wassenaar et al., 2021). An estimated 379 bird species occur along the lower Kunene River, 62 of which are listed as endangered or vulnerable on the IUCN Red list. Notable bird species associated with the riverine habitat on the banks of the lower Kunene include the cinderella waxbill (*Glaucestrilda thomensis*) and rufous-tailed palm thrush (*Cichladusa ruficauda*) (ERM South Africa, 2009; Simmons et al., 1999). The aquatic environment of the lower Kunene River hosts 69 freshwater fish species, five of which are endemic (Simmons et al., 1999). The Kunene River mouth contributes significantly to the biodiversity of the area and is Namibia's second richest coastal wetland hosting 72 bird species and forming the southern limit of distribution of Nile soft shelled terrapins (*Trionyx triunguis)* and green turtles (*Chelonia mydas*) on Africa's west coast (Simmons et al., 1999).

Figure 2.2: Vegetation types found in the lower Kunene River region. (A, B) Mopane (*Colophospermum mopane)* shrubland with ana trees (*Faidherbia albida)* growing on the riverbanks near Otjimuhaka. (C, D) Riverine habitat dominated by *Phragmites* reedbeds and stands of makalani palms (*Hyphaene petersiana*) near Epupa. (E, F) Gravel/grass plains interspersed with mopane (*Colophospermum mopane)* shrubs near Otjinhungwa. (G, H) *Phragmites* reedbeds and dunes near the river mouth. (Photos by J. le Roux).

2.2.2 Crocodiles

Nile crocodiles (*Crocodylus niloticus)* occur along the length of the lower Kunene River (Lyet et al., 2016) and are the focus animal in this study. Nile crocodiles are protected under Namibian law and are only allowed to be harvested through licensed trophy hunting, with the current quota being set at 25 trophies per year (Ordinance No. 4, 1975). Nile crocodiles are listed as a species of least concern on the IUCN Red list (Isberg et al., 2019) and CITES lists the species under Appendix 2, allowing the annual export of 1 600 crocodile trophies (skins) originating from trophy hunting and ranching in Namibia (CITES, 2023). The section of the lower Kunene River falling outside of the Skeleton Coast National Park (Figure 2.1) has been listed as a proposed "utilisation zone" where egg harvesting, sport hunting and problem animal control is permitted provided the natural structure and function of the species is maintained (MET, 2014).

Nile crocodiles are found throughout sub-Saharan Africa occurring in 26 countries on the continent (Fergusson, 2004; Isberg et al., 2019;). Crocodiles have traditionally been considered keystone species which play a disproportionate role in maintaining ecosystem structure and function (Craighead, 1968; Thorbjarnarson, 1992; Ross, 1998). Despite these claims regarding the importance of crocodiles in aquatic habitats, recent research has shown that many of these claims are unsubstantiated and that crocodiles have only been shown to act as indicators of ecosystem health (Somaweera et al., 2020).

Nile crocodiles are generally the largest predators in the freshwater ecosystems they inhabit with adults ranging from2.8 – 3.5 m in length although lengths of up to 5 m are also often recorded (Alexander & Marais, 2007). The life history of Nile crocodiles can be characterised by their extended life span over which development occurs slowly and reproduction occurs multiple times (Tucker, 1995). Nile crocodiles are oviparous reptiles laying their eggs (40 – 80) in cavities excavated by females and guarding these nests for an incubation period of approximately three months (Leslie, 1997). Eggs are particularly vulnerable to predation by predators such as the Nile monitor (*Varanus niloticus)* with predation rates of up to 50% of nests (Bourquin, 2007; Trutnau & Sommerland, 2006). In the same way, eggs are also particularly vulnerable to flooding which can be caused by fluctuating river levels caused by water releases from dams upstream of the nests (Trutnau & Sommerland, 2006). Once the eggs hatch crocodiles have diverse feeding habits with yearlings feeding primarily on insects and arachnids, juveniles diversify their diets to include amphibians, crustaceans, and fish, while adults feed primarily on fish but also prey on mammals including humans and domestic livestock (Thomas, 2006; Wallace & Leslie, 2008).

Although Nile crocodiles remain understudied in the Kunene River, a population estimate was made in 2016 using aerial survey data from 2012 (Lyet et al., 2016). This survey estimated the Nile crocodile population of the lower Kunene River to be 806 with a conservative estimate of 562 (Lyet et al., 2016). Lyet et al. (2016) estimated 2.29 crocodiles per km and concluded that the crocodile population could be considered "healthy" when compared to populations in other African rivers (Bourquin, 2007). Paterson (2007) reported crocodiles of 3 m and larger at the mouth of the Kunene River feeding on fish swimming into the river mouth from the ocean and noted anecdotal evidence of Nile crocodile tracks being found coming out of the ocean 10 km south of the mouth near Bosluis Bay. Other studies have suggested that due to the presence of crocodiles < 0.5 m in length at the river mouth, this area is likely used for breeding by Nile crocodiles (Carter & Bickerton, 1996; Griffin & Channing, 1991). A study recently conducted in the area concluded that communities living in the Epupa and Marienfluss conservancies of Namibia, as well as those living in Iona in Angola (Figure 2.1) perceived Nile crocodiles to be the most problematic wildlife in the area (Wassenaar et al., 2021). Notably, recent reports in the media have drawn the public's attention to an increase in Nile crocodile killings along the lower Kunene River with reports of 20 Nile crocodiles found dead in the study area between 2019 and 2020 (Guchu, 2020).

2.3 The people of the Kunene

The Namibian bank of the Kunene River is home to a diverse group of people most of whom belong to the ovaHimba, ovaZemba and ovaTjimba ethnic groups (Inman et al. 2020). These communities engage primarily in subsistence livestock farming and seasonal crop farming (Inman et al. 2020). Other inhabitants of the area include migrants from Angola and central Namibia, who appear to be primarily involved with subsistence agriculture (both livestock and crops) on the riverbanks or informally employed to manage livestock or small crop farms for employers living outside of the region. A series of lodges and small commercial farms are also found along the river where Namibians of multiple ethnic groups engage in formal employment in tourism and agricultural activities. Other formal employment opportunities exist in the population centres of Otjimuhaka, Onyungurua, Epupa, and Otjinhungwa (Figure 2.1) where a relatively small number of people work for the Namibian government as teachers, nurses, and police officers, as well as at the river mouth where a commercial diamond mine is situated.

Community Based Natural Resource Management (described in section 2.1 of this chapter) also plays an important role in the economics of the study area where community members are employed as conservancy committee members and community game guards. CBNRM is practiced along the Namibian bank of the river in the six communal conservancies mentioned above (Figure 2.1). These conservancies have an estimated human population of 37 118, 7 929, 2 393, 5 513, 612, and 340, respectively, with a total of 53 905 people living in Namibian conservancies bordering the lower Kunene River (NACSO Conservancies, 2023). The Epupa constituency, which covers the entire study area with its northern border formed by the lower Kunene River and its southern border approximately 112 km south of Epupa (Figure 2.1) had a population of 17 696 in 2011 (Namibian Statistics Agency, 2014).

The ovaHimba are the principal inhabitants of the study area (Bollig, 2006; Iiyambula, 2021; Wassenaar et al., 2021), and made up the majority of respondents of this study, sharing cultural and historic similarities with other predominant ethnic groups in the area such as the ovaZemba, and ovaTjimba. The ovaHimba and related groups practise a unique form of semi nomadic pastoralism where livestock and people move between a series of homesteads and mobile cattle camps in search of grazing (Bollig, 2006; Wassenaar et al., 2021) Decisions on when to move and where to graze are dictated by grazing quality, surface water availability and an intricate traditional grazing system (Bollig, 2013; Wassenaar et al., 2021). Traditionally, this grazing system clearly defined which households had rights to utilise specific pastures and permanent water sources (Wassenaar et al., 2021). Household and livestock numbers were small and grazing patterns were broadly separated into dry season (Okuni) grazing near permanent water sources and wet season (Okurooro) grazing where mobile cattle camps would be established in pastures further afield which only held surface water for a limited part of the year following adequate rains (Bollig, 2013; Wassenaar et al., 2021). This grazing system allowed for adequate rest periods in the wet season grazing areas where grazing was restricted to a few months each year allowing for the persistence of valuable perennial grass species (Bollig, 2013; Wassenaar et al., 2021). At the same time, well defined user rights and adherence to grazing laws meant that dry season grazing areas, near permanent water sources, were managed in a way that protected the seedbank of annual grasses ensuring their persistence and the sustainability of the system (Bollig, 2013; Wassenaar et al., 2021).

The traditional system of semi nomadic pastoralism employed in the study area utilised a high degree of mobility to mitigate the risks of farming in an arid, drought prone environment while maintaining system resilience by conserving adequate dry and wet season grazing comprised of perennial and annual grass species (Wassenaar et al., 2021). However, since the 1950's a series of external and internal pressures has largely disrupted this system. The 1950's heralded the beginning of the development of numerous boreholes and related road networks by the Apartheid government in the area, with 361 boreholes being drilled from 1960 to the end of the 1990's (Bollig, 2013). Prior to this period, livestock production was limited to areas where surface water was naturally available, but with the development of boreholes, areas that were previously reserved solely for wet season grazing or completely unutilized by livestock became viable settlement nuclei as water was available year-round (Bollig, 2013). This led to a dramatic increase in livestock numbers in the area with cattle numbers increasing from below 50 000 in the 1950's to ≈ 65 000 in the 1960's, ≈ 140 000 in the 1970's, to a high of ≈ 218 000 in 2006 with an annual average increase in cattle numbers of approximately 1 380 per year (Wassenaar et al., 2021). The shift in settlement patterns initiated by the development of boreholes, as well as the rapid increase in human and livestock populations led to a breakdown of the traditional grazing laws and the large-scale degradation of the environment driven by overgrazing (Bollig, 2013, 2020; Malan & Owen-Smith, 1974; Wassenaar et al., 2021). As semi-nomadic pastoralism became less viable as a subsistence strategy, communities started to practise a higher degree of sedentarization and agropastoralism where the cultivation of seasonal crops played a more important role in livelihood production (Bollig, 2020; Thuening, 2018). This shift towards a lower degree of mobility and a greater dependence on crops led to the expansion of settlements near permanent water sources such as the Kunene River.

Today, large sections of the Namibian banks of the lower Kunene are cultivated by subsistence farmers. These farmers rely on flooding caused by dam release, irrigation by hand or to a lesser degree by mechanised pumps to supply their crops with water. These communities and their associated herds of small and large stock place an ever-increasing amount of pressure on the river ecosystem and frequently come into conflict with crocodiles either in the form of livestock depredation or attacks on humans by crocodiles.

Aside from the obvious negative impacts of HCC when attacks on humans or livestock occur, it is important to think of the conflict in terms of the cultural character of the communities in question (Pooley et al., 2017; Redpath et al., 2013). In the case of the lower Kunene River, one must pay particular attention to the importance of livestock to the ovaHimba. Livestock and in particular cattle to the ovaHimba represent more than their economic worth and play an important role in the cultural identity of the communities in question (Bollig, 2020). Livestock is used as an invaluable source of milk, meat, leather, and are used as draft animals underpinning the subsistence lifestyle practised by many community members living along the banks of the lower Kunene (Bollig, 2020). However, apart from the obvious importance of livestock as a means of subsistence, livestock also play an important role in various celebrations, rituals, act as status symbols, link individuals to their ancestors, and act as a means of creating and maintaining exchange networks through a complex system of livestock loaning and matrilineal inheritance (Bollig & Schulte, 1999; Bollig, 2016, 2020). When one considers that livestock are valued for more than their economic worth, the degree of damage caused by livestock losses to Nile crocodiles are placed in context.

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CHAPTER 3

Aerial survey of crocodiles along the lower Kunene River

3.1 Introduction

An in-depth introduction to the topics dealt with in this thesis can be found in Chapter 1 and 2. Sections 1.1 (Human wildlife conflict and coexistence), 1.2 (Human crocodile conflict and coexistence), 1.4 (Counting crocodiles), 1.5 (Introduction to research problem), and 2.2.2 (Crocodiles) are of particular importance to the results presented in this chapter. Importantly, the principal aim of this chapter was to describe the current crocodile population in the river, while Chapter 4 (Humans and crocodiles in the lower Kunene River region) should be seen as the primary data chapter of this thesis. A brief introduction to the research presented in this chapter is offered below, however, these topics have been introduced in the sections mentioned above. Consequently, a degree of repetition was unavoidable.

Nile crocodiles (*Crocodylus niloticus*) are found throughout sub–Saharan Africa occurring in 26 countries on the continent (Fergusson, 2004; Isberg et al., 2019). Although Nile crocodiles are no longer considered keystone species, they play an important role as indicators of ecosystem health (Somaweera et al., 2020), and are generally the largest predators in the freshwater ecosystems they inhabit (Alexander & Marais, 2007). Adult Nile crocodiles range between 2.8 and 3.5 m in length, with lengths of up to 5 m often recorded in older individuals (Alexander & Marais, 2007). Crocodiles exhibit extended life span over which development occurs slowly and reproduction occurs multiple times (Tucker, 1995). These oviparous reptiles lay their eggs (40 – 80) in cavities excavated by females and guard these nests for an incubation period of approximately three months (Leslie, 1997). Nile crocodile eggs are vulnerable to predation by multiple species such as the Nile monitor (*Varanus niloticus)* with predation rates of up to 50% of nests (Bourquin, 2007; Trutnau & Sommerland, 2006). Eggs are also particularly vulnerable to human induced flooding which can be caused by water released from dams upstream of the nests (Trutnau & Sommerland, 2006), trampling by livestock, or intentional burning to stimulate grass growth on riverbanks (Shacks, 2006; Thomas, 2006). After hatching, Nile crocodiles go through a series of ontogenic shifts (Wallace & Leslie, 2008). Yearlings feed primarily on insects and arachnids, juveniles, diversify their diets to include amphibians, crustaceans, and fish, while adults feed primarily on fish but also prey on mammals including humans and domestic livestock (Thomas, 2006; Wallace & Leslie, 2008).

Nile crocodiles (*Crocodylus niloticus)* occur along the length of the lower Kunene River (Lyet et al., 2016) and are the focus animal of this study. Nile crocodiles are protected under Namibian law and are only allowed to be harvested through licensed trophy hunting, with the current quota being set at 25 trophies per year (Ordinance No. 4, 1975). Nile crocodiles are listed as a species of least concern on the IUCN Red list (Isberg et al., 2019) and CITES lists the species under Appendix 2 allowing the annual export of 1600 crocodile trophies (skins) originating from trophy hunting and ranching in Namibia (CITES, 2023). The section of the lower Kunene River falling outside of the Skeleton Coast National Park (Figure 3.1) has been listed as a proposed "utilisation zone" where egg harvesting, sport hunting and problem animal control is permitted provided the natural structure and function of the species is maintained (MET, 2014).

Although Nile crocodiles remain understudied along the lower Kunene River, a population estimate was made in 2016 using aerial survey data from 2012 (Lyet et al., 2016). This survey estimated the Nile crocodile population in the lower Kunene to be 806 with a conservative estimate of 562 (Lyet et al., 2016). Lyet et al. (2016) estimated 2.29 crocodiles per km and concluded that the Nile crocodile population could be considered "healthy" when compared to populations on other African rivers (Bourquin, 2007). Paterson. (2007) reported Nile crocodiles of 3 m and larger at the Kunene River mouth feeding on fish swimming into the river mouth from the ocean and noted anecdotal evidence of Nile crocodile tracks being found coming out of the ocean 10 km south of the mouth near Bosluis Bay. Other studies have suggested that due to the presence of crocodiles < 0.5 m in length at the river mouth, this area is likely used for breeding by Nile crocodiles (Carter & Bickerton, 1996; Griffin & Channing, 1991).

A study recently conducted in the area concluded that communities living in the Epupa and Marienfluss conservancies of Namibia as well as those living in Iona in Angola (Figure 3.1) perceived Nile crocodiles to be the most problematic wildlife in the area (Wassenaar et al., 2021). Notably, recent reports in the media have drawn the public's attention to an increase in Nile crocodile killings along the lower Kunene River with reports of 20 crocodiles found dead in the study area between 2019 and 2020 (Guchu, 2020). These findings do not come as a surprise as human crocodile conflict is widely reported throughout Africa and has negative consequences for both humans and crocodiles (Eustace et al., 2022; Khan et al., 2020; Matanzima et al., 2022).

Considering the HCC issues and crocodile carcasses reported along the river (Guchu, 2020; Wassenaar et al., 2021), MEFT in partnership with researchers from the University of Stellenbosch completed an aerial survey of the lower 353 km of the Kunene River in April 2021. Aerial surveys have been used in various forms to estimate wildlife populations across multiple habitats (Samuel et al., 1987). Methods include total counts, block or quadrat counts, and strip counts (Cook & Jacobson, 1979; Pollock & Kendall, 1987). With regards to counting crocodiles, aerial surveys allow researchers to survey large areas rapidly (Bourquin, 2007). Using helicopters has been proven to be particularly advantageous due to the wider field of view, manoeuvrability, the ability to fly lower at slower speeds, and the capacity to access areas inaccessible by boats (Lyet et al., 2016). A series of factors influence the detectability of crocodiles during aerial surveys. Observer proficiency, flying speed, and height can lead to undercounting the number of crocodiles in a system (Bourquin, 2007; Lyet et al., 2016), while vegetation, crocodile size, glare and time of year can make crocodiles more or less likely to be identified from the air (Bourquin, 2007; Lyet et al., 2016). In an effort to produce comparable results, the survey of the lower Kunene River, reported on in this chapter, was undertaken using a helicopter and observers following the methods used by Lyet et al., (2016), in the previous aerial crocodile survey of the river that took place in 2012.

The objective of this chapter is to document the distribution and density of Nile crocodiles along the lower Kunene River and to compare the current crocodile population estimate to the estimated population size in 2012. Additionally, this chapter investigates the effects of covariates such as river width, shore steepness, number of channels, and human population density on Nile crocodile population density along the lower Kunene River. All analyses relating to the N-mixture model was conducted by Dr Arnaud Lyet. In addition to modelling the Nile crocodile population along the lower Kunene for this thesis, Dr Lyet modelled the Nile crocodile population along the lower Kunene in 2012 (Lyet et al., 2016).

3.2 Methods

3.2.1 Study area

An in-depth description of the study area, the communities who live there and the dominant fauna and flora of the area can be found in Chapter 2 of this thesis. Section 2.2.2 (Crocodiles) is of particular importance to the results presented in this chapter. A brief description of the study area is presented below; however, this topic has been introduced in the sections mentioned above. Consequently, a degree of repetition was unavoidable.

The focus of this study was the lower reaches of the Kunene River (Figure 3.1) (referred to as the lower Kunene RIver) where it bisects the Namib desert and forms the border between Namibia and Angola for 353 km of its total length (Lyet et al., 2016; Meissner & Jacobs, 2016). Rainfall in the area ranges from 350mm/year at Ruacana, and 30 mm/year at the river mouth (ERM South Africa, 2009; Hay et al.,1997; Wassenaar et al., 2021), and average temperatures range from 19 – 20°C at the coast to 21 – 22°C at Ruacana, however, temperatures often exceed 40°C during summer months (ERM South Africa, 2009).

The lower Kunene River forms the northern border of six community conservancies. Starting from the east, these conservancies are Uukolonkadhi – Ruacana, Kunene River, Okanguati, Epupa, Otjitanda, and Marienfluss conservancies (Figure 3.1). These conservancies have been formed on communal land where

CBNRM is used to derive various benefits from wildlife. In addition to forming the northern border of these conservancies, the lower Kunene River forms the southern border of the Iona National Park in Angola and the northern border of the Skeleton Coast National Park in Namibia (Figure 3.1). These two national parks make up the Skeleton Coast Iona Trans Frontier Conservation Area covering roughly 31 500 km^2 (De Cauwer & Wassenaar, 2020).

An estimated 53 905 people live in the Namibian conservancies bordering on the lower Kunene River (NACSO Conservancies, 2023), while the Epupa constituency, which covers the entire study area had a population of roughly 17 696 in 2011 (Namibian Statistics Agency, 2014). Most people residing in the study area belong to the ovaHimba, ovaZemba and ovaTjimba ethnic groups and engage primarily in subsistence livestock farming and seasonal crop farming (Inman et al. 2020).

The lower Kunene River flows through various habitat types hosting a diversity of plant species. Starting in the east near Ruacana, the river flows first through the Western Highlands vegetation type in the Tree-and-Shrub Savanna biome, then the Northwestern Escarpment and Inselbergs vegetation type in the Nama Karoo biome, and finally, as the river nears the coast, it passes through the Northern Desert vegetation type in the Namib Desert biome (Atlas of Namibia Team, 2022).

The study area is home to a series of terrestrial and aquatic fauna such as black faced impala (*Aepyceros melampus petersi*), Hartmann's mountain zebra (*Equus zebra hartmannae*), Angolan giraffe *(Giraffa giraffa angolensis)*, kudu *(Tragelaphus strepsiceros)*, oryx *(Oryx gazella)*, and springbok *(Antidorcas marsupialis)*. Additionally, predators such as leopard *(Panthera pardus)*, cheetah (*Acinonyx jubatus*), black backed jackal (*Lupulella mesomelas)* and caracal (*Caracal caracal)* occur in the area (Wassenaar et al., 2021). An estimated 379 bird, and 69 fish species occur along the lower Kunene River (ERM South Africa, 2009; Simmons et al., 1999) and the area had an estimated Nile crocodile (*Crocodylus niloticus)* population of between 562 and 806 in 2012 (Lyet et al., 2016).

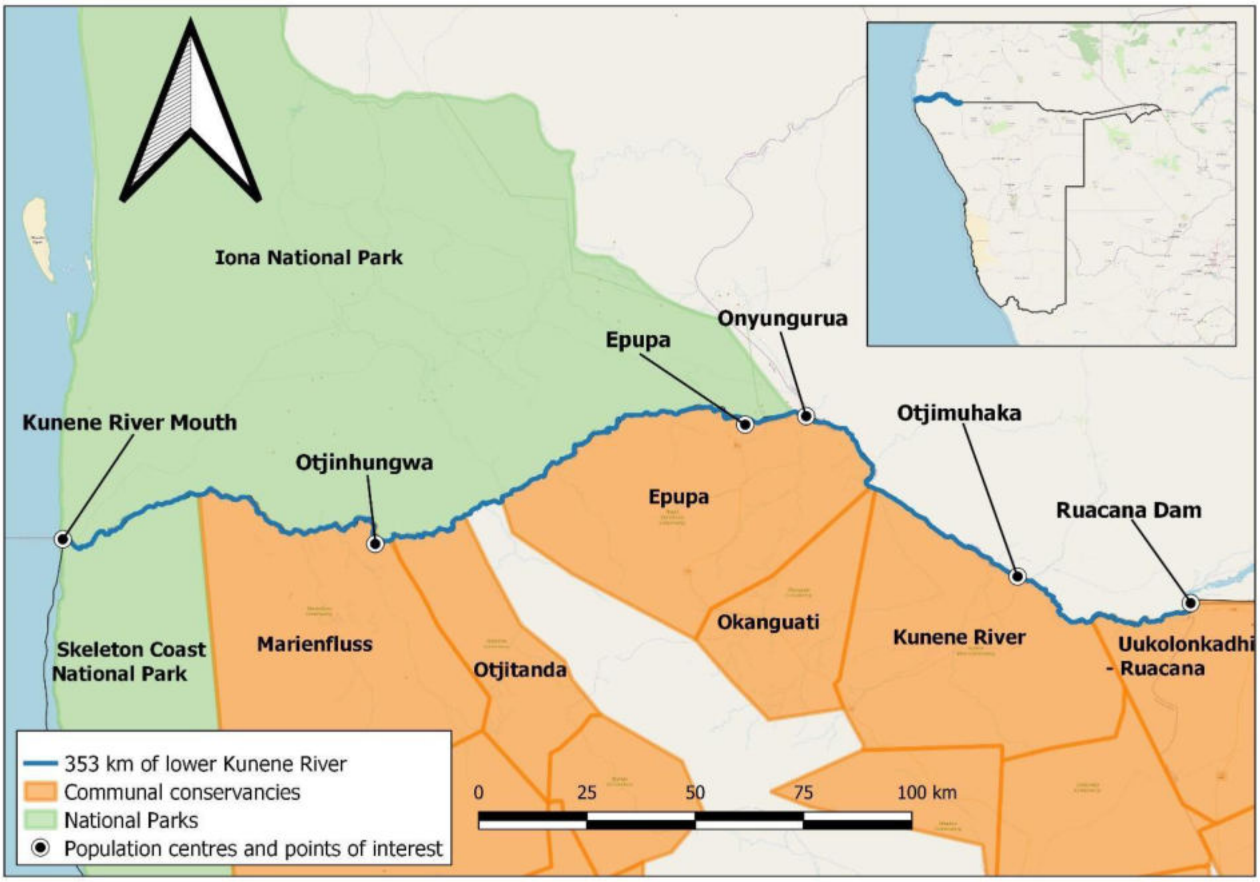

Figure 3.1: Map of the study area showing the lower 353 km of the Kunene River used as a transect for the aerial survey (in blue), the population centres and points of interest (labelled in black), the communal conservancies bordering the river (in orange), and the Skeleton Coast and Iona National Parks (in green).

3.2.2 Survey design and effort

The survey design was guided by the previous survey undertaken by MEFT in 2012 (Lyet et al., 2016), with the aim of generating comparable results. The river was divided into two sections, the western section between Epupa and the river mouth, and the eastern section between Ruacana Dam and Epupa (Figure 3.1). An AS 350 helicopter was used for the survey with a pilot, three observers and one data recorder. The helicopter was flown at 110 – 130 km/h at an approximate height of 73 – 82 meters above ground level. By using the same observers, all of whom had prior experience surveying wildlife, and by flying at a constant speed and height, biases were reduced. The western section of the river was flown once as an exploratory flight on the 23rd of April and once as a survey on the 26th of April 2021. The eastern part of the river was flown twice as surveys on the 24th and 25th of April 2021. Surveys were flown between late morning and early afternoon to reduce the effects of glare and to increase the likelihood of observing crocodiles basking in the sun (Lyet et al., 2016). For statistical analyses, every survey flight was considered a sampling occasion (SO) with SO1 occurring on the 26th, SO2 on the 24th and SO3 on the 25th of April 2021 (Figure 3.2).

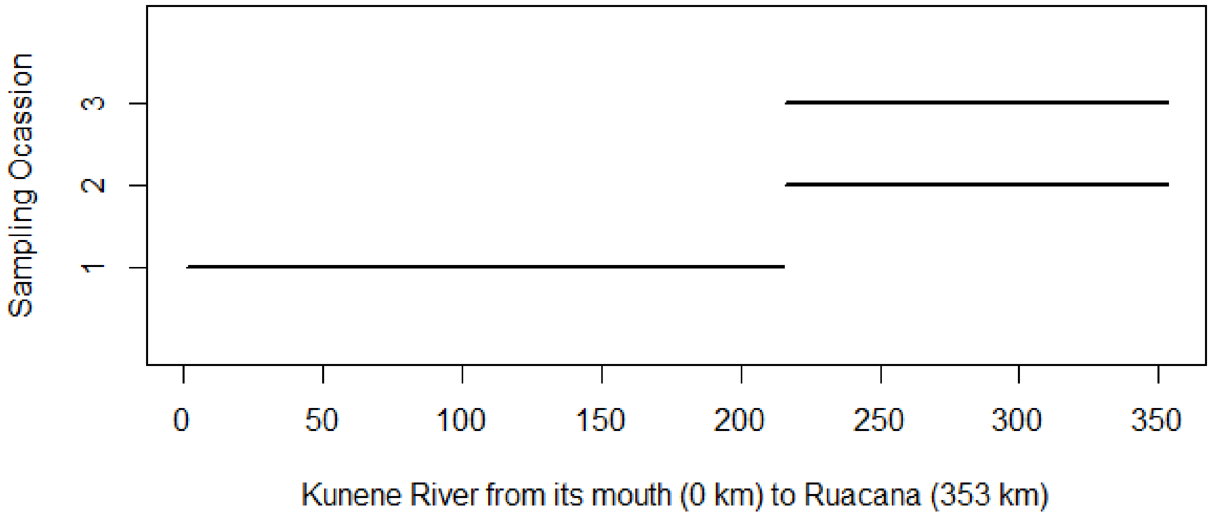

Figure 3.2: Survey design of the aerial count. Sampling occasion refers to areas surveyed in a single day. SO1 took place on 26/04/2021, SO2 on 24/04/21 and SO3 on 25/04/21.

As Nile crocodiles could move freely along most of the river, measures had to be put in place to reduce the effects of crocodile movements and maintain the assumptions of population closure, required for statistical analyses (Williams, Nichols & Conroy, 2002). Following the methods set out in Lyet et al. (2016), the issue of population closure was dealt with in two ways. Firstly, the river was divided into forty-four, non-overlapping, 8 km segments, referred to as sites, which were considered independent sampling units. The segment length (8 km) was determined using crocodile movement data collected on the Kavango River (Lyet et al., 2016). The data collected showed that Nile crocodiles seldomly move more than 8 km in a 24-hour period, thus by using 8 km segments we could assume that a minimal number of crocodiles would have moved into a different segment from one day to the next. In the same way, population closure was dealt with by minimising the time between consecutive surveys to no more than 24 hours passing between the first and second sampling occasion of a specific river segment. All 44, 8 km segments, were surveyed once and 18 segments were surveyed twice.

3.2.3 Recording data

For each sampling occasion, Nile crocodile observations were recorded noting the size class (1 – 2 m, 2.1 – 3 m, 3.1 – 4 m and >4 m) and location (latitude and longitude). Additionally, the flight path of the sampling occasion was recorded. The length of crocodiles was estimated visually using the same observers throughout the survey to minimise observer bias. All observations were assigned to their respective 8 km site for statistical analysis.

3.2.4 Direct count

The direct count results were calculated by summing the highest number of Nile crocodiles observed in an 8 km segment in a single sampling occasion (Lyet et al., 2016).

3.2.5 Covariates

To ensure that the results of the study were comparable to those of Lyet et al. (2016), four of the same environmental factors were selected as predictor variables. These predictor variables were selected by Lyet et al. (2016) based on their hypothesised effects on crocodile abundance (Table 3.1).

Table 3.1: Description of environmental factors used as covariates. Adapted from Lyet et al. (2016).

Factor	Description of factor	Source	Data type and unit
River width	River width. Measured manually at every kilometre on Google Earth and corresponds to the length of the perpendicular section of the river from one shore to the other after ground areas are excluded.	Google Earth, (Lyet et al., 2016).	Continuous, metre
Shore steepness	Shore steepness. Assessed visually every kilometre using Google Earth pro software 3D imagery and Play tour mode to fly along the Kunene River. Proxy for the accessibility to the river by large prey species.	Google Earth, (Lyet et al., 2016).	Categorical, index between 0 and 5, 0 corresponding to a flat shore
Number of channels	Index of river complexity. The number of channels was assessed visually at every 1 km segment on Google Earth software. Proxy for basking and nesting site availability.	Google Earth, (Lyet et al., 2016).	1, 2, 3, 4, and 5+ channels.
Human population density	Index of human population density. Assessed on an 8 × 10 km strip centred on the river course using ArcGIS software. Proxy for environmental disturbance and hunting pressure.	Atlas of Namibia, (Lyet et al., 2016).	Continuous, inhabitants per square kilometre

3.2.6 Description of model

An initial attempt was made to use the N-mixture model used by Lyet et al. (2016) to model the crocodile population along the lower Kunene River. However, the Markov Chain Monte Carlo (MCMC) chains (Gelman et al., 2004) did not converge well, indicating a lack of convergence of the model. In response to the failure to converge, a simplified N-mixture model, with fewer predictor variables was used to explain Nile crocodile abundance along the river. A description of the N-mixture model used is presented below:

Level 1:

The realised abundance of animals for size group g at site i is:

$N_{i,g} \sim \text{Poisson}(\lambda_{i,g})$

General Linear Model for level 1:

The mean $\lambda_{i,g}$ abundance at site i for group g is described by the following relation

$\log(\lambda_{i,g}) = \alpha_g + \alpha_{1,g}*\text{width}_i + \alpha_{2,g}*\text{shore}_i + \alpha_{3,g}*\text{channel}_i + \alpha_{5,g}*\text{den.H}_i$

Level 2:

The observed count for group g at site i and on survey j is:

$c_{i,j,g} \mid N_{i,g} \sim \text{Binomial}(N_{i,g}, P_{i,j,g})$

General Linear Model for level 2:

The detection probability at a site i for group g and survey j is described by the following relation

$\text{Logit}(P_{i,j,g}) = \beta_g + \text{rand}_{i,j,g}$

Level 2b (random survey effect):

$\text{rand}_{i,j,g} \sim \text{Normal}(0,\sigma)$

A Bayesian approach to estimate the model parameters was used with vague priors. Three MCMC's (Gelman et al., 2004) of the model were ran, each for 12 000 000 iterations after a burn-in of 2 000 000 and thinned by 10 000. The analyses were ran using the program R (R Core Team, 2023) using the software program JAGS (Plummer, 2003) to approximate posterior distributions for each of the parameters.

3.3 Results

3.3.1 Direct count

The direct count yielded a total of 287 Nile crocodiles with 186 in size class 1 (1 – 2 m), 66 in size class 2 (2.1 – 3 m), 27 in size class 3 (3.1 – 4 m) and 8 in size class 4 (>4 m) (Figure 3.3). Compared to the direct count of 2012 where 562 crocodiles were observed, the 2021 direct count showed a decrease of 275 individuals (49%) in the population from 2012 to 2021. The direct count of size class 1 shows a relatively stable population, with an increase of 21% from 2012 to 2021. In contrast, the direct count of size class 2, 3 and 4 shows a decrease of 67%, 79% and 90%, respectively. When comparing the proportions of crocodiles in a specific size class, the direct count data for 2021 placed 65% of the counted crocodiles in size class 1, 23% in size class 2, 9% in size class 3, and 3% in size class 4. In contrast, the direct count for 2012 placed 27% of counted crocodiles in size class 1, 35% in size class 2, 23% in size class 3, and 14% in size class 4. Importantly, these results should be seen as indicative of population trends rather than exact figures.

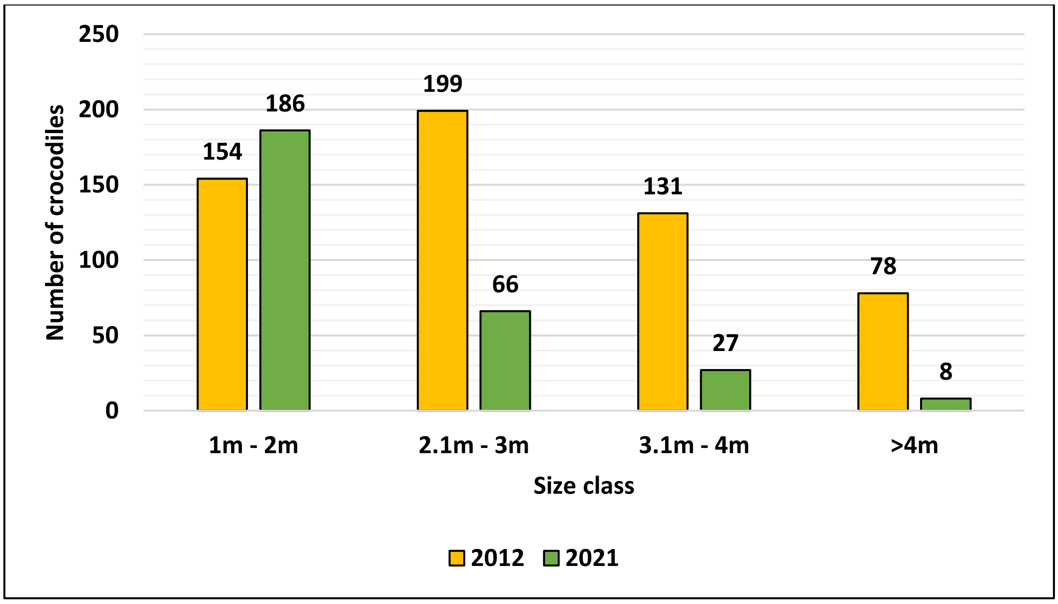

Figure 3.3: Number of Nile crocodiles observed in each size class along the lower 353 km of the lower Kunene River during aerial counts in 2012 (Lyet et al., 2016) (yellow bars) and 2021 (green bars). Importantly, these results should be seen as indicative of population trends rather than exact figures.

Visual inspection of the direct count distribution map (Figure 3.4) appears to show a relatively even distribution of Nile crocodiles of all size classes along the river with areas of particularly high density occurring downstream of Otjinhungwa and upstream of Epupa and Onyungurua. The relationship between crocodile population density and human population density is presented in Section 3.3.3 and discussed in Section 3.4 of this chapter.

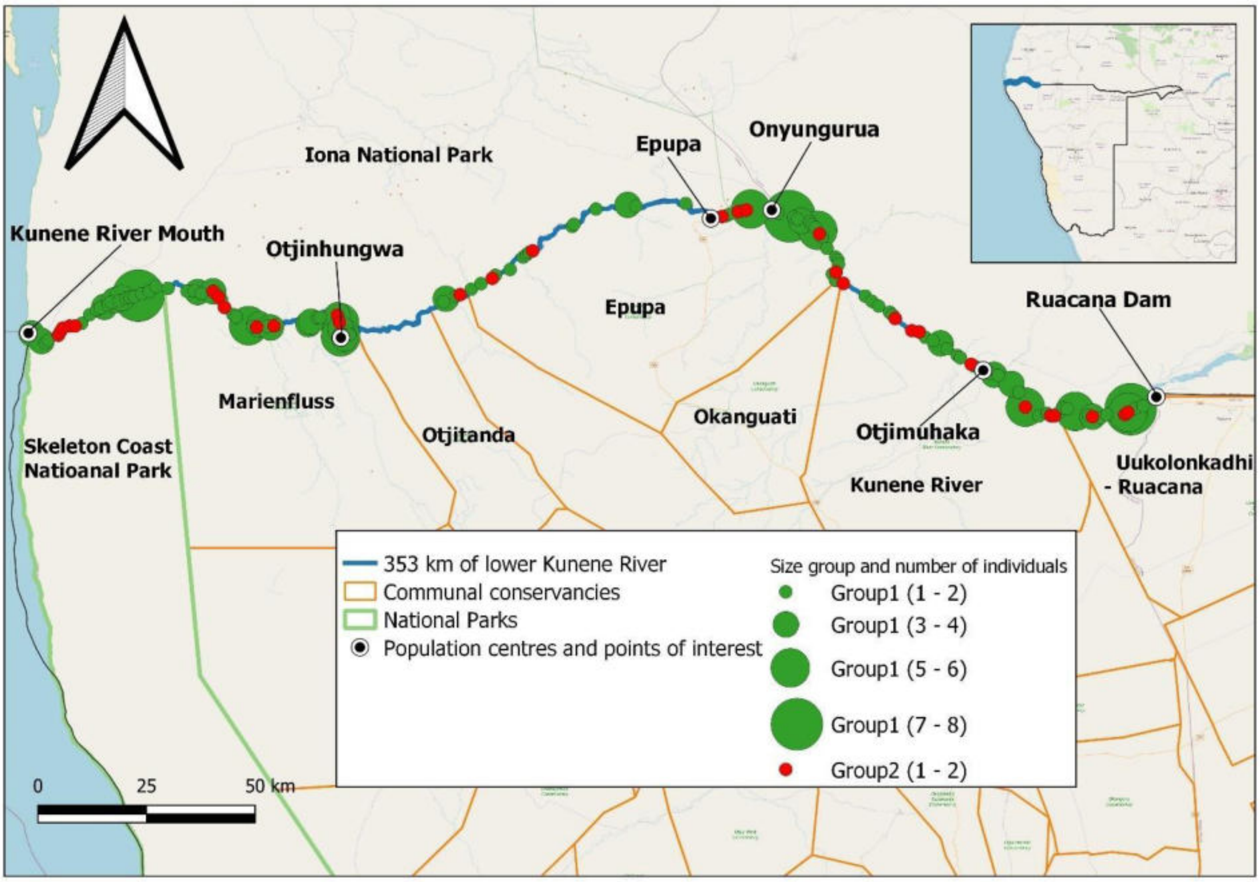

Figure 3.4: Nile crocodiles observed along the lower 353 km of the Kunene River during an aerial survey conducted in 2021. Crocodiles 3 m and under in size are represented by green circles and crocodiles over 3 m in size are represented by red circles. The size of a circle is proportional to the number of crocodiles observed. The lower Kunene River used as a transect for the aerial survey is shown in blue (insert included), the population centres and points of interest are labelled in black, the communal conservancies bordering the river, and the Skeleton Coast and Iona National Parks are shown as orange and green polygons respectively.

3.3.2 Model estimate

The model estimate yielded a total of 597 Nile crocodiles with 431 in size class 1 (1 – 2 m), 107 in size class 2 (2.1 – 3 m), 47 in size class 3 (3.1 – 4 m) and 12 in size class 4 (>4 m) (Table 3.2) Compared to the model estimate of 2012 where the population was estimated at 806 crocodiles, the 2021 direct count has shown a decrease of 209 individuals (26%) in the population from 2012 to 2021. Importantly, these results should be seen as indicative of population trends rather than exact figures.

Table 3.2: Comparison between model estimates of 2012 and 2021 for each size class with maximum and minimum estimates in brackets. Importantly, these results should be seen as indicative of population trends rather than exact figures.

Year	**1 – 2 m**	**2.1 – 3 m**	**3.1 – 4 m**	**> 4.1 m**	**Total**
2012	239 (189 -320)	340 (268-455)	149 (131-180)	78 (68-94)	806
2021	431 (279-800)	107 (77-166)	47 (34-73)	12 (9-19)	597

3.3.3 Model performance

Rhat values smaller than 1,05 showed that model parameters mixed sufficiently and converged (Tables 3.3 and 3.4). Additionally, the linear relationship between the actual and replicate data (Figure 3.5) shows that the replicate data correlated with the actual data and that the model produced was adequate for the data set.

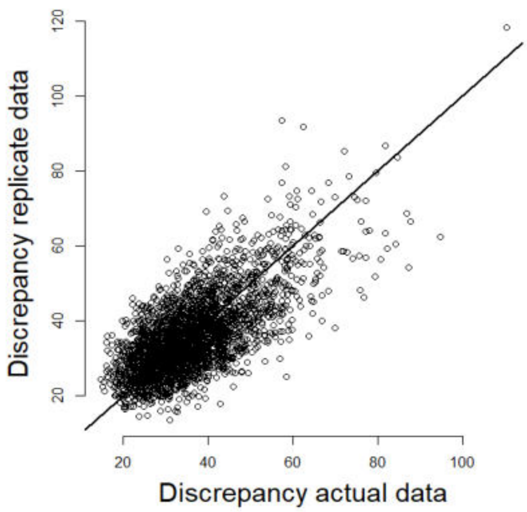

Figure 3.5: Actual and replicate data of an N-mixture model of the crocodile population along the lower Kunene River in 2021.

3.3.3 Covariate effects on local abundance

Crocodiles smaller than 2 metres in size:

The effects of covariates on local abundance were seen as significant when the credibility interval did not contain a zero value (Lyet et al., 2016). River width, shore steepness, and human population density appeared to have significant effects on the local abundance of Nile crocodiles smaller than 2 m in size. Local abundance of crocodiles smaller than 2 m in size seemed to increase significantly as river width increased (Table 3.3). In contrast, local abundance of crocodiles smaller than 2 m in size appeared to decrease significantly as shore steepness and human population density increased (Table 3.3).

Table 3.3: Summary of N-mixture analysis for Nile crocodiles between 1 and 2 m in size. The table shows the Bayesian posterior mean, standard deviation and 95% credibility interval for each parameter included in the model as described in the text. Rhat < 1.05 indicates that the chains have converged. Adapted from Lyet et al. 2016.

Parameter		**Mean**	**S.D.**	**2.50%**	**97.50%**	**Rhat**
α_1	River width	0.44	0.19	0.08	0.81	1.00 *
α_2	Shore steepness	-0.80	0.21	-1.22	-0.39	1.00 *
α_3	Number of channels	0.02	0.31	-0.56	0.65	1.00
α_5	Human population density	-0.61	0.20	-1.02	-0.23	1.00 *
β_1	Detection probability	-0.08	0.71	-1.55	1.25	1.00
sd.p	Random effect	1.93	0.48	1.04	2.86	1.00

*Represents significance at 95% credibility interval.

Crocodiles larger than 2 metres in size:

As with Nile crocodiles <2 m in size, shore steepness, and human population density appeared to have significant effects on the local abundance of crocodiles >2 m in size. Local abundance of crocodiles >2 m in size appeared to decrease significantly as both shore steepness and human population density increased (Table 3.4)

Table 3.4: Summary of N-mixture analysis for Nile crocodiles equal to or over 2.1 m in size. The table shows the Bayesian posterior mean, standard deviation and 95% credibility interval for each parameter included in the model as described in the text. Rhat < 1.05 indicates that the chains have converged. Adapted from Lyet et al. 2016.

Parameter		Mean	S.D.	2.50%	97.50%	Rhat
α_1	River width	0.09	0.22	-0.35	0.53	1.00
α_2	Shore steepness	-0.64	0.22	-1.08	-0.23	1.00 *
α_3	Number of channels	-0.11	0.31	-0.72	0.50	1.00
α_5	Human population density	-0.45	0.17	-0.78	-0.13	1.00 *
β_1	Detection probability	0.61	0.70	-0.77	1.95	1.00
sd.p	Random effect	1.92	0.48	1.04	2.86	1.00

*Represents significance at 95% credibility interval.

3.4 Discussion and conclusions

The Nile crocodile population along the lower 353 km of the Kunene River was estimated at 287 (0.81 crocodiles per km) based on the direct count, and 597 (1.7 crocodiles per km) based on the modelled results in 2021. In comparison, the aerial survey conducted in 2012 yielded an estimate of 562 crocodiles based on the direct count (1.60 crocodile per km), and 806 (2.29 crocodiles per km) based on the modelled results (Lyet et al., 2016). A 49% decrease in the crocodile population was found when comparing direct counts and 28% decrease when comparing modelled results. These results represent a concerning decrease in crocodile abundance along the river between 2012 and 2021. The overall decrease in crocodile population can likely be attributed to human crocodile conflict. Levels of HCC are likely high along the lower Kunene River as communities living in the Epupa and Marienfluss conservancies of Namibia, as well as those living in Iona in Angola perceived Nile crocodiles to be the most problematic wildlife in the area (Wassenaar et al., 2021). In the same way, the 20 Nile crocodiles found dead in the area between 2019 and 2020 provides further evidence for HCC driving the decrease in the crocodile population along the river (Guchu, 2020). An alternative explanation for the overall decrease in the crocodile population could be the discrepancies in methodology between the 2012 and 2021 survey. The 2012 survey was undertaken in two parts, with the section of the river west of Epupa being surveyed in April, and the section of the river east of Epupa being surveyed in August with a total of 10 sampling occasions (Lyet et al., 2016). In contrast, the 2021 survey was undertaken over 3 consecutive days in April with three sampling occasions. Damage to crocodile nests as a result of fluctuating water levels caused by dam releases upstream are not likely to be causing the overall decrease in the Nile crocodile population, as the population smaller than 2 m in size appears to be stable, suggesting relatively constant levels of survivorship in smaller crocodiles. A depleted fish population and consequent lack of prey could be driving the decrease in crocodiles along the lower Kunene River; however, this is not likely as fishing is not widely practised along the river as is shown in Chapter 4 (Section 4.3.1) of this thesis.

A demographic shift in the Nile crocodile population seems to be underway along the lower Kunene River. Crocodile numbers in size class 1 (1 – 2 m) increased by 21% from 2012 to 2021, while crocodiles in size class 2 (2.1 – 3 m), size class 3 (3.1 – 4 m), and size class 4 (>4 m) decreased by 67%, 79% and 90%, respectively. In 2012, most counted crocodiles were placed in size class 2 (35%), followed by size class 1 (27%), size class 3 (23%), and size class 4 (14%). In 2021, most counted crocodiles were placed in size class 1 (65%), size class 2 (23%), size class 3 (9%), and size class 4 (3%). As with the overall decrease in the crocodile population, the apparent demographic shift observed is likely being driven by HCC. Retaliatory killings are likely targeting crocodiles in larger size classes as these crocodiles are more conspicuous and consequently easier to locate and kill. Crocodiles also undergo an ontogenetic shift as they increase in size with yearlings feeding primarily on insects and arachnids, juveniles diversify their diets to include amphibians, crustaceans, and fish, while adults feed primarily on fish, but also prey on mammals including humans and domestic livestock (Thomas, 2006; Wallace & Leslie, 2008). As a result of the change in diets as crocodiles grow, larger crocodiles are more likely to come into conflict with communities living along the riverbanks of the lower Kunene River. If larger crocodiles are being targeted in retaliation, it could explain the increase in smaller crocodiles (<2 m). Larger crocodiles exclude and predate on smaller crocodiles (Hutton, 1989) consequently, the removal of large crocodiles from an area could be driving the short-term increase in smaller crocodiles. An alternative explanation for the increased number of crocodiles assigned to size class 1 in 2021 could be a systematic overestimation of crocodile size in a form of observer bias resulting in crocodiles smaller than 1 m in size being assigned to size class 1.

River width, shore steepness, and human population density appeared to have a significant effect on the local abundance of Nile crocodiles. Local abundance was positively correlated with river width; however, the relationship was only significant for crocodiles smaller than 2 m in size. Although previous studies have found positive correlations between river width and crocodile abundance, this trend generally has a greater effect on larger crocodiles which have been shown to prefer larger bodies of water (Aust, 2009; Lyet et al., 2016). The significant positive relationship between smaller crocodiles and river width shown in this study could be explained by the absence of large crocodiles in the system which could be allowing smaller crocodiles to exploit larger bodies of water (Hutton, 1989). The inability to show a significant positive relationship between larger crocodiles and river width could be attributed to the relatively small sample size of larger crocodiles. Both shore steepness and human population density appeared to show a negative relationship with a local abundance of crocodiles in all size classes. These results echo those of the aerial survey undertaken along the river in 2012 (Lyet et al., 2016). As shore steepness increases, the river becomes less accessible for terrestrial prey (Jarman, 1972), which could be driving the preference of crocodiles for areas with more gradual banks and consequently more opportunities to predate on terrestrial prey. Steeper banks are likely associated with faster river flow rates in areas such as the Baynes gorge downstream of Epupa. The increased flow rates could explain the absence of smaller crocodiles in these areas. The negative relationship between crocodile abundance and human population density was also observed in the 2012 aerial survey (Lyet et al., 2016), and can be attributed to crocodiles facing persecution and habitat disturbance as a result of human presence (Musambachime, 1987; McGregor, 2005).

The general decrease in the Nile crocodile population along the lower Kunene River comes as a source of concern as the river forms the northern boundary of 6 community conservancies and forms the border of national parks in Angola and Namibia (De Cauwer & Wassenaar, 2020). With a decrease in crocodile numbers, the conservancies and national parks will lose the potential to derive tangible economic benefits from crocodiles through tourism and hunting. However, the apparent stable population of crocodiles smaller than 2 m in size suggests that the population still has the potential to recover if crocodile conservation measures are put in place timeously. The primary driver of the decrease in crocodile population appears to be HCC and warrants an investigation into the scale, drivers, and distribution of the conflict. The following chapter (Chapter 4) explores HCC along the lower Kunene River, while Chapter 5, offers solutions to the conflict with an aim of decreasing HCC and increasing the potential for coexistence between humans and crocodiles on the lower Kunene River.

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CHAPTER 4

Humans and Nile crocodiles in the lower Kunene River region

4.1 Introduction

An in-depth introduction to the topics dealt with in this thesis can be found in Chapter 1. Sections 1.1 (Human wildlife conflict and coexistence), 1.2 (Human crocodile conflict and coexistence), 1.3 (Socio ecological research), and 1.5 (Introduction to research problem) are of particular importance to the results presented in this chapter. A brief introduction to the research presented in this chapter is offered below, however, these topics have been introduced in the sections mentioned above. Consequently, a degree of repetition was unavoidable.

Human wildlife conflict (HWC), defined by the IUCN SSC Human-Wildlife Conflict Task Force as “struggles that emerge when the presence or behaviour of wildlife poses 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), is prevalent across the world in areas where the needs of humans and wildlife overlap (Wallace et al., 2011). The conflict between wildlife and humans generally arises over competed, shared resources such as water, grazing, or space (Anthony et al., 2010; Marker & Dickman, 2002). This competition and the consequent conflict caused by it threatens the means of livelihood production and safety of people and communities (Barua et al., 2013; Inskip & Zimmermann, 2009; Kiffner et al., 2015). The consequences of HWC are far reaching and range from direct economic effects that result from loss of property (Aust et al., 2009) to more discrete hidden impacts. The hidden impacts of HWC include psychological stress and vulnerability (Khumalo & Yung, 2015) as well as significant opportunity costs (Barua et al., 2013). HWC has been shown to influence the attitudes of communities affected by it, and as such if conservationists can change patterns in HWC, they can likely change the attitudes of communities living alongside wildlife (Bennett, 2016).

In the context of African rivers, HWC often arises between humans and Nile crocodiles (*Crocodylus niloticus).* Human crocodile conflict (HCC) is widespread throughout Africa and has negative consequences for both humans and crocodiles (Eustace et al., 2022; Khan et al., 2020; Matanzima et al., 2022). Nile crocodiles occur across southern Africa and inhabit a diversity of freshwater habitats such as lakes, rivers, and dams (Aust et al., 2009; Pooley, 2016a). Nile crocodiles are the crocodilian species responsible for the most attacks on humans when compared to other crocodilians and are also thought to be responsible for the most attacks on humans when compared to all other wildlife (Pooley, 2016a; Sideleau & Britton, 2013). Despite the disproportionate number of attacks on humans attributed to Nile crocodiles, data on HCC is still largely inadequate and the true number of attacks are likely higher than the current estimates (Sideleau & Britton, 2013). Human crocodile conflict is driven by the dependence of both humans and crocodiles on water. Nile crocodiles rely on a variety of freshwater ecosystems to support their biological needs such as feeding and reproduction (Fergusson, 2010; Hutton, 1987; Kofron, 1989). In the same way, humans use water for drinking, washing, fishing, irrigation, and livestock rearing (Aust et al., 2009). In the context of rural Africa, many communities lack the facilities to provide alternative water sources away from rivers and lakes and consequently many communities are forced to fetch water directly from freshwater ecosystems leaving themselves and their livestock vulnerable to crocodile attacks (Aust et al., 2009; Thomas, 2006).

As with other forms of HWC, the effects of HCC on humans range from attacks that result in injury, death and/or psychological trauma (Aust et al., 2009; Matanzima et al., 2022), attacks on livestock, damage to infrastructure such as fishing equipment, competition over resources such as water and fish, and opportunity costs (Eustace et al., 2022; Thomas, 2006). For crocodiles, the effects are similarly dire where crocodiles are often killed, injured, or have their nests destroyed in retaliatory persecution (Aust et al., 2009; Shacks, 2006; Thomas, 2006). In the same way, crocodiles often face indirect threats from humans such as the destruction of nests because of livestock management practices, crocodile entanglement and suffocation in fishing nets, and damage to nests caused by human induced flooding (Kofron, 1989; Marowa & Matanzima, 2021; Shacks, 2006; Thomas, 2006).

The nature of a community's relationship with both the terrestrial and aquatic environment has been shown to be a significant driver of HWC and coexistence (Cavalier et al., 2022) where humans are often not only the primary cause of HWC, but are severely affected by it, and often determine the outcomes of the conflict (Sanborn & Jung, 2021). In line with this, scholars have called for an increased understanding of the human dimensions of HWC with an aim of identifying the underlying patterns of HWC and coexistence (Pooley et al., 2017) as this has been shown to effectively inform conservation decisions in both terrestrial and aquatic environments (Bennett et al., 2017).

This chapter sets out to understand the nature of the conflict between humans and Nile crocodiles along the lower Kunene River with the aim of identifying underlying drivers and patterns of conflict in the study area. This chapter focuses on the patterns of Nile crocodile attacks on humans and livestock, as well as the retaliatory killing of crocodiles, perceptions on wildlife, and the solutions to HCC as suggested by community members living along the banks of the river.

4.2 Methods

4.2.1 Study area

An in-depth description of the study area, the communities who live there, and the dominant fauna and flora of the area can be found in Chapter 2 of this thesis. Sections 2.2.2 (Crocodiles), and 2.3 (The people of the Kunene) are of particular importance to the results presented in this chapter. A brief description of the study area is presented below; however, these topics have been introduced in the sections mentioned above. Consequently, a degree of repetition was unavoidable.

The focus of this study was the lower reaches of the Kunene River (Figure 4.1) (referred to as the lower Kunene River) where it bisects the Namib desert and forms the border between Namibia and Angola for 353 km of its total length (Lyet et al., 2016; Meissner & Jacobs, 2016). Rainfall in the area ranges from 350 mm/year at Ruacana, and 30 mm/year at the river mouth (ERM South Africa, 2009; Hay et al.,1997; Wassenaar et al., 2021), and average temperatures range from 19 – 20°C at the coast to 21 – 22°C at Ruacana, however, temperatures often exceed 40°C during summer months (ERM South Africa, 2009).

The lower Kunene River forms the northern border of six community conservancies. Starting from the east, these conservancies are Uukolonkadhi – Ruacana, Kunene River, Okanguati, Epupa, Otjitanda, and Marienfluss conservancies (Figure 4.1). These conservancies have been formed on communal land where community based natural resource management (CBNRM) is used to derive benefits from wildlife. In addition to forming the northern border of these conservancies, the lower Kunene River forms the southern border of the Iona National Park in Angola and the northern border of the Skeleton Coast National Park in Namibia (Figure 4.1). These two national parks make up the Skeleton Coast Iona Trans Frontier Conservation Area covering roughly 31 500 km^2 (De Cauwer & Wassenaar, 2020).

An estimated 53 905 people live in the Namibian conservancies bordering on the lower Kunene River (NACSO Conservancies, 2023), while the Epupa constituency, which covers the entire study area had a population of roughly 17 696 in 2011 (Namibian Statistics Agency, 2014). Most people residing in the study area belong to the ovaHimba, ovaZemba and ovaTjimba ethnic groups and engage primarily in subsistence livestock farming and seasonal crop farming (Inman et al. 2020).

The lower Kunene River flows through various habitat types hosting a diversity of plant species. Starting in the east near Ruacana, the river flows first through the Western Highlands vegetation type in the Tree-and-Shrub Savanna biome, then the Northwestern Escarpment and Inselbergs vegetation type in the Nama Karoo biome, and finally, as the river nears the coast, it passes through the Northern Desert vegetation type in the Namib Desert biome (Atlas of Namibia Team, 2022).

The study area is home to a series of terrestrial and aquatic fauna such as black faced impala (*Aepyceros melampus petersi*), Hartmann's mountain zebra (*Equus zebra hartmannae*), Angolan giraffe *(Giraffa giraffa angolensis)*, kudu *(Tragelaphus strepsiceros)*, oryx *(Oryx gazella)*, and springbok *(Antidorcas marsupialis)*. Additionally, predators such as leopard *(Panthera pardus)*, cheetah (*Acinonyx jubatus*), black backed jackal (*Lupulella mesomelas)* and caracal (*Caracal caracal)* occur in the area (Wassenaar et al., 2021). An estimated 379 bird, and 69 fish species occur along the lower Kunene River (ERM South Africa, 2009; Simmons et al., 1999) which had an estimated Nile crocodile (*Crocodylus niloticus)* population of between 806 and 562 in 2012 (Lyet et al., 2016).

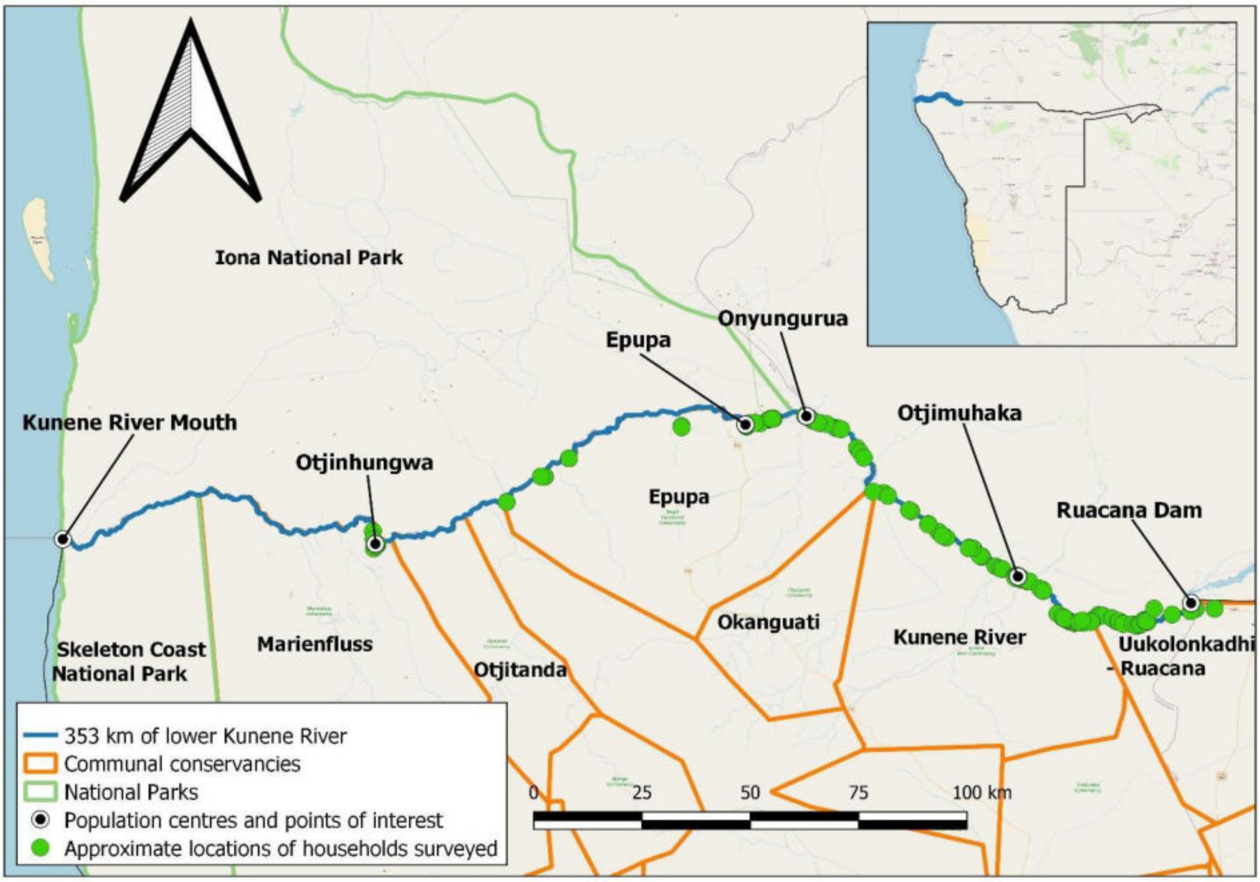

Figure 4.1: Map of the study area showing the lower 353 km of the Kunene River (in blue, insert included), the population centres and points of interest (labelled in black), the communal conservancies bordering the river (orange polygons), the Skeleton Coast and Iona National Parks (green polygons), and the approximate locations of households surveyed (green points) n = 155.

4.2.2 Development of questionnaire

Data were collected by means of an extensive social survey that was undertaken in the lower Kunene River region. The questionnaire administered during the social survey comprised of 177 questions (Appendix 1). The questionnaire consisted primarily of closed ended, quantitative questions, however, some questions were open ended and qualitative allowing for respondents to discuss their answers and give reasons for their views. The questionnaire included sections on socio economics and livelihood production, river and water usage, livestock management, attitudes towards wildlife in general, and crocodiles in particular, attacks on livestock, attacks on humans, retaliation, and possible solutions to the conflict between humans and Nile crocodiles. The questionnaire followed a logical, non-leading order and was developed using aspects of other questionnaires aimed at trying to understand HWC in Southern Africa. In particular, the questionnaire was developed using aspects of the questionnaires developed by, and with permission from; Marina Tavolaro in her PhD thesis, titled: "Understanding community based natural resource management (CBNRM) in Namibian communal conservancies", Dr Patrick Aust (Aust et al., 2009), and Dr Kevin Wallace (Wallace et al., 2011).

4.2.3 Data collection

Data were collected by posing the questionnaire to the head of a household. Tracks following the river course were used as transects for locating households such as the D3700 which follows the course of the river from Ruacana to Epupa. The section of the river between Epupa and Otjinhungwa has very little vehicle access consequently, this area was surveyed on foot. Data collection for this section involved traversing approximately 115 km of the length of the river on foot for nine days. During this section, researchers travelled from household to household administering questionnaires and carried all food and equipment in rucksacks. Due to the logistical challenges involved with surveying sparsely populated, remote communities, households were selected by a combination of convenience and snowball sampling (Goodman, 1961). One hundred and fifty-five households were surveyed in total, with 18 households surveyed in the population centre of Otjimuhaka, six in Onyungurua, 15 in Epupa, and seven in Ontjinhungwa (Figure 4.1). In line with snowball sampling methods (Goodman, 1961), respondents were asked where we could find their nearest neighbour as a means of locating the next household to survey. Despite making a conscious effort to sample as many households as possible, due to logistical constraints, there was an undeniable bias towards households that were more accessible and situated close to roads (Reddy & Dávalos, 2003).

Interviews generally followed a format of reaching a household, exchanging a customary greeting, and then introducing myself as a researcher from Stellenbosch University in South Africa interested in studying the interactions between people and crocodiles along the lower Kunene River. Permission was then asked to conduct an interview with the head of the household. In some cases, the head of the household was absent, in which case I interviewed a senior member of the household who could speak on behalf of the household. In most cases the interview involved not only the head of the household but a multigenerational group of people from both genders. Questions regarding crop management or household water use were often answered by women in the household, where questions on small stock management were often answered by boys. The knowledge of specific age and gender groups (men, women, boys, or girls) on specific activities (fetching water, watering crops, herding, or fishing) seemed to be based on customary roles assigned to specific groups. During the introduction of the project as well as the administration of the questionnaire I was accompanied by a translator, Mr Uuezirua Mbinge, who worked with me for the entire duration of the social survey. During the nine days spent walking from Epupa to Otjinhugwa, Mr Kauroorua Tjavara also accompanied us as a local guide and cultural interpreter. Both Mr Mbinge, and Mr Tjavara were not affiliated with any of the conservancies or government organisations working in the area and were briefed on the importance of posing questions in a non-leading manner. Time was taken to clearly explain each question to mitigate translation bias'. However, the differences in language and culture between the primary researcher, and respondents meant that a degree of translation bias was to be expected (Temple & Young, 2003). As a result of the extensive nature of the survey, interviews often lasted up to two hours. Respondents were informed that they could decline from participating in the study or from answering any questions within the survey and were not renumerated for their time. None of the respondents refused to participate in the survey, however many respondents abstained from answering specific sections. Sections dealing with sensitive topics such as the retaliatory killing of crocodiles were abstained from by most respondents. In total a period of approximately two months was spent interviewing households in the lower Kunene region from 15 March to 20 May 2022.

4.2.4 Data analysis

Data collected during the social survey were analysed by an array of means. Descriptive statistics were calculated for all questions asked. This chapter focuses specifically on topics such as socio economics and river use, Nile crocodile attacks on humans, crocodile attacks on livestock, the relationship between crocodile population density and attacks on humans and livestock, retaliatory killings of crocodiles, perceptions of crocodiles, and potential solutions to the conflict between humans and crocodiles. Descriptive statistics for specific topics are presented both in text and in contingency tables in the relevant results sections. Spatial data, such as attack and survey locations, are presented using maps (QGIS Development Team, 2023). Tests for normality were conducted using Shapiro-Wilk tests while correlation testing was done using Spearman's rank correlation, and Exact multinomial tests for goodness of fit. Post hoc analyses were done using exact binomial tests with Bonferroni adjustments. All statistical analyses were conducted using the statistical programme R (R Core Team, 2023).

4.3 Results

4.3.1 Socio economics, and river use

To place the study in the context of the communities living along the banks of the lower Kunene River, a brief description of the socio-economic characteristics of the respondents was undertaken. Most respondents were male (59%), with an average household size of 10 (μ = 10, σ = 15, n = 154). An average of one person earned money in a household through employment, sales, or government grants (μ = 1, σ = 1, n = 154) with an average monthly income of N$ 1 678 (μ = 1 678, σ = 2 614, n = 151). Virtually all households (92%) engaged in some sort of subsistence agriculture, producing food for their own consumption and/or to sell (n=155). Most households owned livestock (73%), all of whom owned small stock and 39% of whom owned cattle as well. The majority of households (98%) felt that livestock were either very (82%) or somewhat (16%) important (n=155). Most households grew crops (84%), while 95% of households felt that growing crops was either very (65%) or somewhat (30%) important (n = 153).

With regards to river use, 48% of households fished in the river, 89% of cattle and small stock owners took their livestock to drink at the river. Thirty eight percent of households who planted crops, watered their crops from the river. Most households used the river for drinking water (75%), washing clothes (77%), and bathing/swimming (75%). Men were thought to spend the most time at the river (79%), followed by women (38%), boys (17%), and girls (6%) (Table 4.1; Figure 4.2)

Table 4.1: River use for 155 households interviewed on the lower Kunene River between March and May 2022.

Question posed to respondent	Number of respondents, respondents who answered question, respondents who abstained, and number of responses.	Results	Proportion of respondents who answered question (%)
Does anyone in your household fish?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Yes = 74 No = 80	Yes = 48 No = 52
Do your cattle drink at the river?	Respondents = 44 (Only those respondents who answered “a) Cattle” to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Yes = 35 No = 5 Sometimes = 4	Yes = 80 No = 11 Sometimes = 9

Do your small stock drink from the river?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Yes = 89 No = 13 Sometimes = 11	Yes = 79 No = 12 Sometimes = 10
Do you water your crops from the river?	Respondents = 130 (Only those respondents who answered "Yes" to question 2.31) Respondents who answered question = 130 Respondents who abstained = 0 Number of responses = 130	Yes = 46 No = 80 Sometimes = 4	Yes = 35 No = 62 Sometimes = 3
Where does your household fetch your drinking water?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 157 (some respondents gave multiple answers)	a) River = 116 b) Borehole = 7 c) Well = 0 d) Spring = 10 e) Home = 22 f) Other = 2	a) River = 75 b) Borehole = 5 c) Well = 0 d) Spring = 6 e) Home = 14 f) Other = 1
Where does your household fetch your water for washing your clothes??	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 156 (some respondents gave multiple answers)	a) River = 119 b) Borehole = 7 c) Well = 0 d) Spring = 11 e) Home = 19 f) Other = 0	a) River = 77 b) Borehole = 5 c) Well = 0 d) Spring = 7 e) Home = 12 f) Other = 0
Where do you get your water to bathe/swim?	Respondents = 151 Respondents who answered question = 151 Respondents who abstained = 4 Number of responses = 151	a) River = 114 b) Borehole = 5 c) Well = 0 d) Spring = 10 e) Home = 20 f) Other = 2	a) River = 75 b) Borehole = 3 c) Well = 0 d) Spring = 7 e) Home = 13 f) Other = 1
In total, who spends the most time at the river?	Respondents = 155 Respondents who answered question = 147 Respondents who abstained = 8 Number of responses = 147	a) men = 57 b) women = 56 c) boys = 25 d) girls = 9	a) men = 39 b) women = 38 c) boys = 17 d) girls = 6
What do you use more, the river or an alternative water source?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	River = 121 Alternative water source = 33	River = 79 Alternative water source = 21

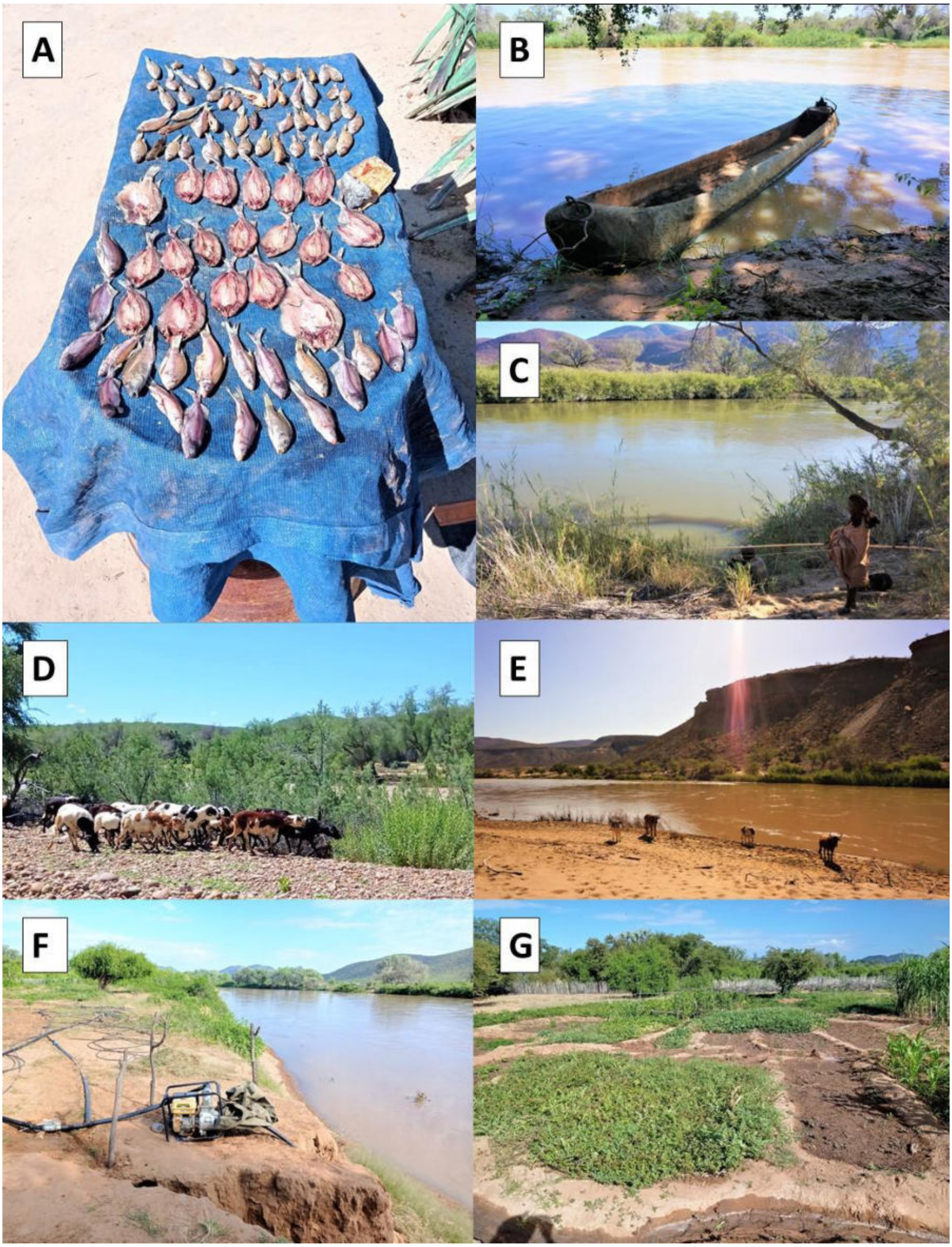

Figure 4.2: The relationship between people and the river along the lower section of the Kunene River. (A) fish drying downstream of Ruacana dam, (B) one of the few wooden dugout canoes encountered along the lower Kunene, (C) community members fishing with hook and line, (D, E) livestock drinking at the river, (F) one of the few water pumps encountered along the river, (G) subsistence farm using a flood irrigation system. (© J. le Roux).

4.3.2 Crocodile attacks on people

4.3.2.1 Scale of the conflict

Respondents were asked if anyone in their household had been attacked by a Nile crocodile, 29% of households gave details of crocodile attacks on household members. When asked if they knew of anyone else who was attacked (i.e., not within their household), 94% of households gave details of crocodile attacks that occurred along the lower Kunene River (n=155). The information on crocodile attacks on humans was disentangled and cross checked with information given by multiple households about the same attack. A subset of data was created for all attacks that occurred between 2010 and March 2022, about which detailed, and reliable information on the attacks was obtained from respondents. Detailed information on 33 attacks was obtained for the period between 2010 and March 2022 (n=155). The outcome of the 33 attacks was analysed, with 43% of attacks resulting in death of the victim, 36% resulting in a disability such as the amputation of a limb, and 21% of attacks resulting in a non-debilitating injury (Figure 4.3).

Figure 4.3: Injuries sustained by Nile crocodile attack victims along the lower Kunene River (© J. Le Roux).

To quantify perceived trends in Nile crocodile attacks on humans, respondents were asked whether they thought that crocodile attacks on humans had increased, stayed the same or decreased from 2010 to March 2022. Most respondents (57%) felt that crocodile attacks on humans had increased, 18% felt that they had stayed the same and 26% felt that they had decreased (n=148).

Respondents were asked to give reasons for the perceived trend (increased, decreased, or stayed the same; n= 148). Ten percent of respondents felt that Nile crocodile attacks on humans had decreased because people were more careful at the river, 5% thought that crocodile attacks on humans had decreased because more people were using alternative water sources such as boreholes, natural springs, taps installed by the government or pumping water away from the river, 1% thought that crocodile attacks on humans had decreased because the crocodile population was decreasing, and 9% thought that crocodile attacks on humans had decreased but they did not know what was driving the perceived decrease in attacks on humans (Table 4.2).

Some respondents (16%) thought that crocodile attacks on humans had increased because more people were using the river, 15% thought that crocodile attacks on humans had increased because the crocodile population was increasing, 15% thought that crocodile attacks on humans had increased because crocodiles were attacking more people, and 15% thought that crocodile attacks on humans had increased but they did not know what was driving the perceived increase in these attacks (Table 4.2).

Table 4.2: Perceived trend in Nile crocodile attacks on humans (increased, decreased, or stayed the same) and reasons given for this trend from 2010 – March 2022 along the lower Kunene River (percentages exceed 100 as some respondents gave multiple responses; n = 148).

Perceived trend	Reason given for trend	Percentage of respondents
Crocodile attacks on humans have decreased	People are more careful. These respondents cited reasons such as: People are more vigilant; People are going to the river less often; People are not swimming in the river; People are making crocodile proof harbours.	10% of total; 30% of decreased
	People are using alternative water sources. These respondents cited reasons such as: Alternative water points are being established; people are moving to areas where there are alternative water points.	5% of total; 18% of decreased
	Crocodile population is decreasing. These respondents cited reasons such as: There are less crocodiles; Hunters are killing dangerous crocodiles.	1% of total; 5% of decreased
	Don’t know	9% of total; 37% of decreased
Crocodile attacks on humans have stayed the same		18% of total; 100% of stayed the same

Crocodile attacks on humans have increased	More people are using the river. These respondents cited reasons such as: More people are settling near the river to plant crops; People are using the river more frequently for activities such as bathing, swimming, fishing and herding; Drought is forcing people to utilise the river for their livestock, and increasing the dependency on fish as a source of sustenance; More people are crossing the river to and from Angola; More people are using the river for recreational purposes and drinking alcohol at the river.	16% of total; 27% of increased
	Crocodile population in increasing. Respondents cited reasons such as: Crocodiles are breeding more; Crocodiles are being protected by authorities such as the government, conservancies, and NGOs.	15% of total; 26% of increased
	Crocodiles are catching more people. Respondents cited reasons such as: There is a lack of fish in the river resulting in more crocodile attacks on humans; Crocodiles have developed a taste for human meat.	15% of total; 26% of increased
	Don't know	15% of total; 26% of increased

Respondents were asked whether they (the attack victim or their household) had received compensation from the government or conservancy for Nile crocodile attacks on humans that occurred between 2010 and March 2022. Most respondents (67%) did not receive any compensation, 18% did receive compensation, and 15% did not know if anyone had received compensation for the attack (n=33). Respondents were asked to give reasons and comments on the compensation outcome (compensation, no compensation, or do not know; n= 33). A minority (6%) of respondents felt that they had received full compensation for the attack, 6% felt that although they had received compensation, they had not received adequate financial compensation for the attack, and 6% felt that although they had received financial compensation for the attack, the crocodile responsible for the attack should have been eradicated. Twenty four percent of respondents did not receive compensation because they did not report the attack, 18% did not know why they had not received compensation, 15% reported the attack but the injury was not deemed serious enough by authorities to warrant compensation, and 9% of respondents did not receive compensation because they did not report the attack as they did not have official documentation for residing in Namibia (Table 4.3).

Table 4.3: Compensation outcomes and comments given on the outcomes for 33 Nile crocodile attacks on humans that occurred between 2010 – March 2022 along the lower Kunene River.

Compensation outcome	Comments given on outcome of compensation	Percentage of respondents
Compensation received	Received full compensation.	6% of total; 33% of compensation received

	Received compensation but felt that it was not enough.	6% of total; 33% of compensation received
	Received compensation but felt that the crocodile should have been eradicated.	6% of total; 33% of compensation received
No compensation received	Did not report attack.	24% of total; 36% of no compensation received
	Reported attack but does not know why they did not receive compensation.	18% of total; 27% of no compensation received
	Reported attack but injury was not deemed serious enough by authorities to warrant compensation.	15% of total; 23% of no compensation received
	Did not report attack because they do not have official documentation for residing in Namibia.	9% of total; 14% of no compensation received
Do not know if they received compensation		15% of total; 100% of do not know

To further illustrate the scale of the conflict, households were asked whether they worry about Nile crocodile attacks when members of their household go to the river, 95% of households did worry about crocodile attacks while 5% did not (n=155). Detailed analyses on how the activities performed by attack victims as well as their sex, age and other factors influenced the likelihood of attack is presented in Section 4.3.2.3 of this chapter.

4.3.2.2 Conflict in relation to time and place

Approximate locations of the 33 Nile crocodile attacks on humans that occurred between 2010 and March 2022 were plotted on a map (Figure 4.4). Most attacks occurred within the Kunene River Conservancy (41%) followed by the Uukolonkadhi – Ruacana Conservancy (22%), Epupa Conservancy (19%), Marienfluss Conservancy (9%), and Okanguati Conservancy (6%). No attacks were recorded for the Otjitanda Conservancy and 3% of attacks occurred in areas outside of conservancies (Figure 4.4).

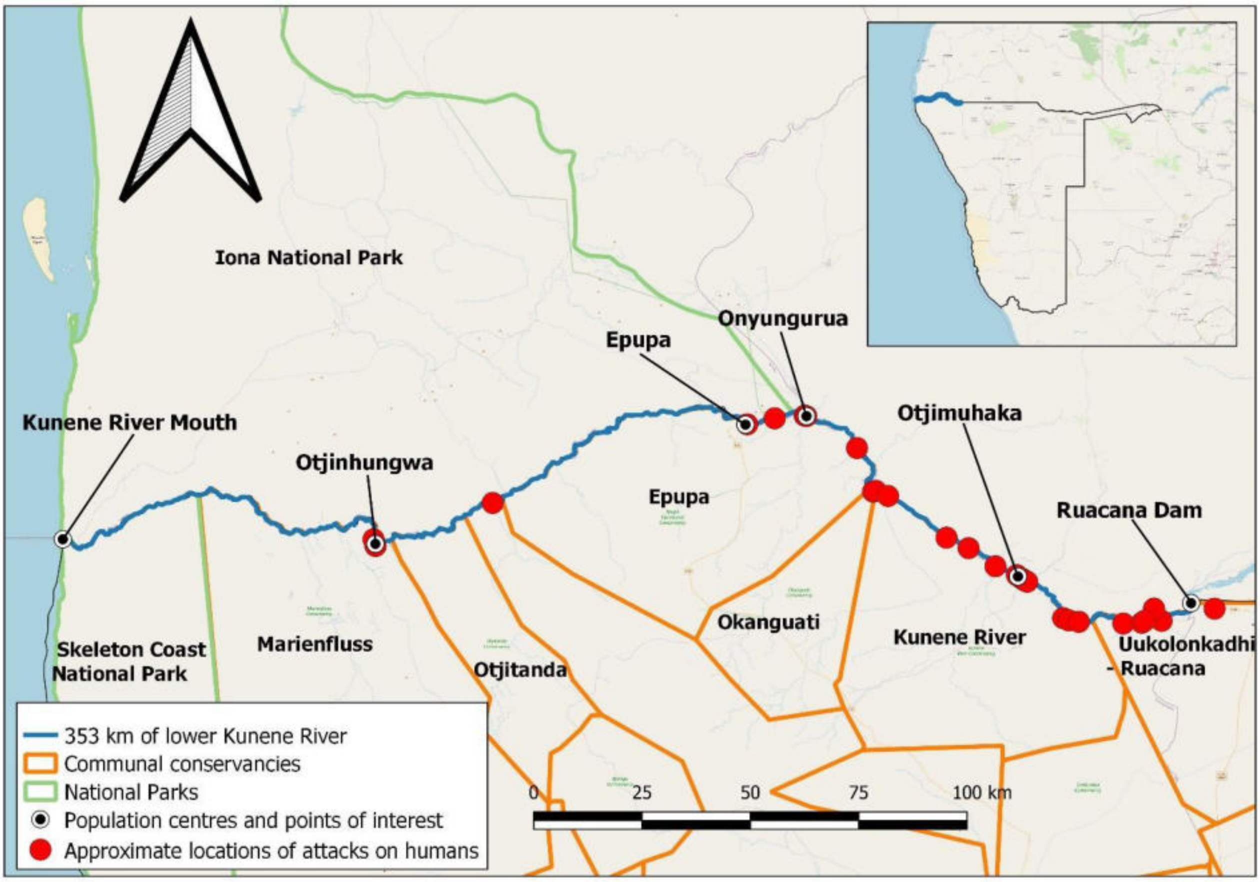

Figure 4.4: Map of the study area showing the lower 353 km of the Kunene River (in blue), the population centres and points of interest (labelled in black), the communal conservancies bordering the river (in orange), and the Skeleton Coast and Iona National Parks (in green). Approximate locations of 33 Nile crocodile attacks on humans that occurred between 2010 and March 2022 were gathered from 155 households and are plotted in red.

Most attacks occurred in 2018 (7 attacks), followed by 2015, 2017, and 2020 (5 attacks per year), 2011 (3 attacks), 2021 (2 attacks), 2010, 2012, 2013, 2014, 2019, 2022 (1 attack per year), and 2016 (0 attacks) (Figure 4.5) Spearman's rank correlation showed that there was a positive correlation between year and attacks per year suggesting that the number of attacks per year are increasing, however these results were not significant ($r(11) = 0.22$, $p = 0.468$).

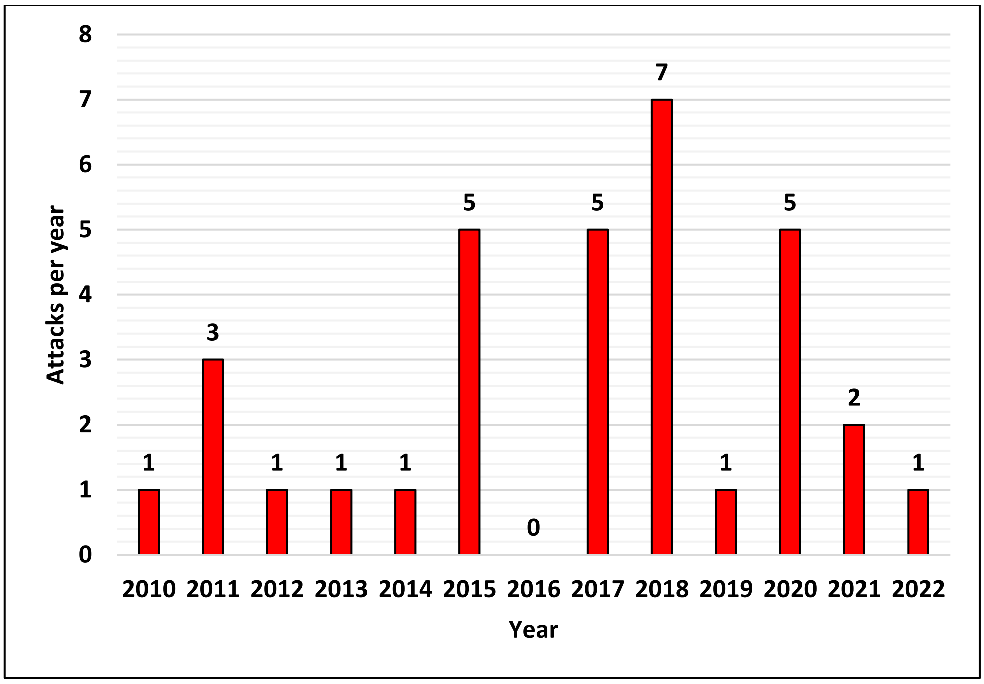

Figure 4.5: Number of Nile crocodile attacks on humans per year along the lower Kunene River between 2010 and March 2022. This information represents details of 33 attacks gathered from 155 households.

Information on the month of attack could only be recalled for 15 of the 33 attacks that occurred between 2010 and March 2022. Most attacks occurred in April (5 attacks), followed by January (3 attacks), February, March, June, July, August, November, December (1 attack per month), no attacks were recorded for May or September (Figure 4.6). Spearman's rank correlation showed that there was a positive correlation between the number of attacks that occurred per month and mean monthly rainfall, suggesting that more attacks happen in months with higher rainfall, however these results were not significant ($r(10) = 0.44$, $p = 0.152$). In the same way, Spearman's rank correlation showed that there was a positive correlation between the number of attacks that occurred per month and mean monthly minimum temperature suggesting that more attacks happen in months with higher minimum temperatures, however these results were also not significant ($r(10) = 0.29$, $p = 0.358$).

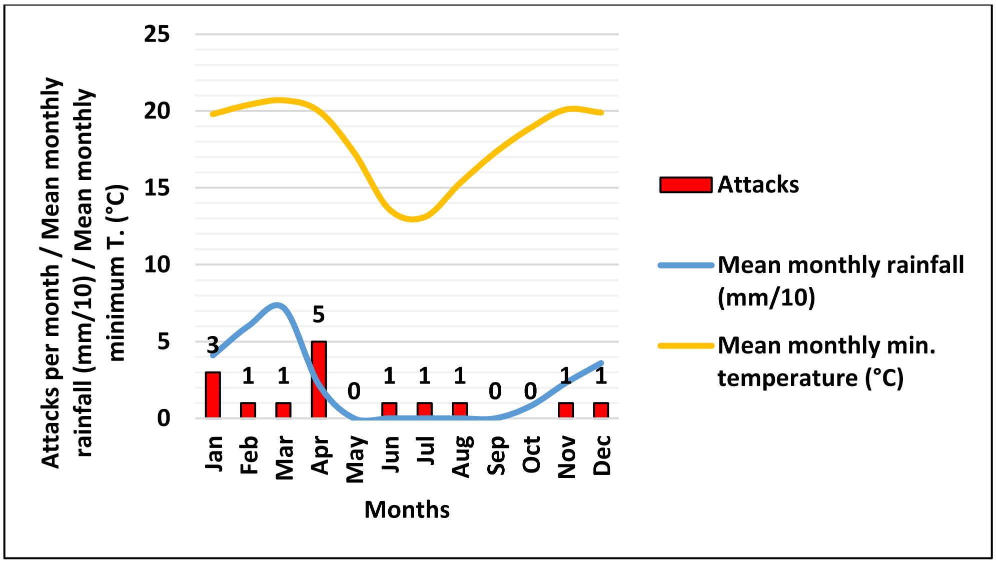

Figure 4.6: Number of Nile crocodile attacks on humans per month along the lower Kunene River between 2010 and March 2022, mean monthly rainfall (mm), and mean monthly minimum temperature (°C) (Climate-Data.org, 2023). This information represents details of 15 attacks gathered from 155 households.

Time of attack (morning, midday, afternoon/evening) could be established for 30 of the 33 Nile crocodile attacks on humans. These were compared to river use times for; all households (n=155), and households that did not experience an attack in the specified period (n=125, Figure 4.7). An exact multinomial test for goodness of fit showed that attack times were not randomly distributed ($p < 0.001$). Most attacks occurred in the afternoon/evening (63%) followed by morning (33%), and midday (3%).

When one considers risk of attack (the number of attacks relative to the number of households using the river at a specific time), afternoon/evening is considered the time with the highest risk of attack (63% of attacks occur at a time when 47% of households use the river), followed by morning (33% of attacks occur at a time when 40% of households use the river), and midday (3% of attacks occur at a time when 13% of households use the river) (Figure 4.7).

An exact multinomial test for goodness of fit showed that there was no significant difference between the distribution of attack times and the times at which households used the river for; all households ($p = 0.134$), and households that did not experience an attack ($p = 0.132$). These results suggest that the number of Nile crocodile attacks on humans that occur at a specific time is proportional to the number of households that use the river at that time, and that river use time does not significantly increase or decrease the likelihood of experiencing an attack.

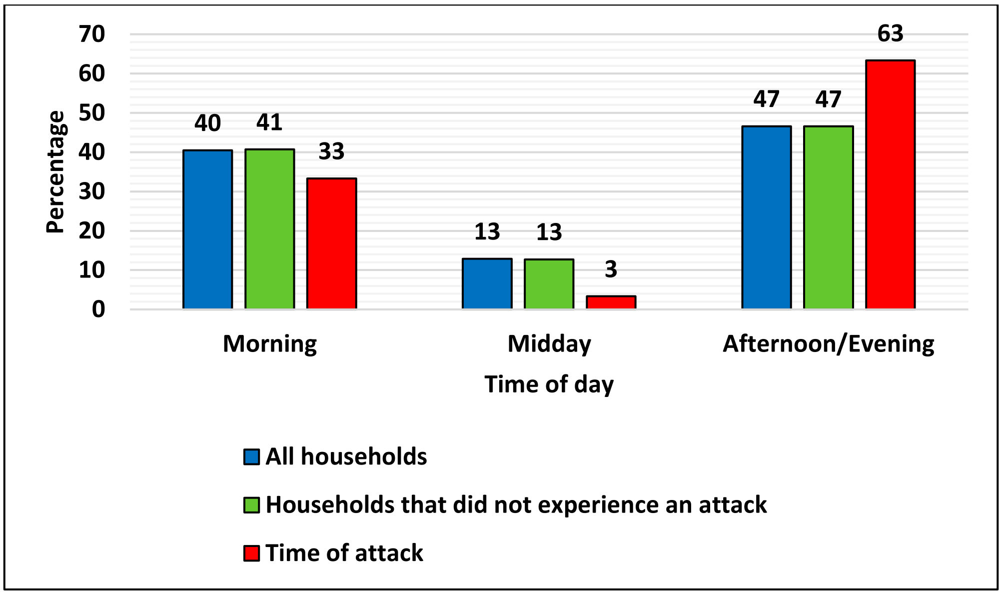

Figure 4.7: Time of attack for 30 Nile crocodile attacks on humans that occurred along the lower Kunene River between 2010 and March 2022 compared to river use times for; all households (n = 155), and households that did not experience an attack in the specified time (n = 125).

4.3.2.3 Factors associated with the conflict.

An analysis of the 33 attacks that occurred between 2010 and March 2022, showed that 52% of attack victims were men (≥ 18 years old), 6% were women (≥ 18 years old), 24% were boys (≤ 17 years old) and 18% were girls (≤ 17 years old). Most attacks occurred while victims were collecting water at the river (33%), followed by bathing or swimming (24%), fishing (21%), herding (9%). Twelve percent of victims were involved with activities such as crossing the river to or from Angola or were alone during the attack, and if no reliable information was available on the activity that they were undertaking preceding the attack, these activities were listed as other (Table 4.4).

Table 4.4 Contingency table showing the relationship between activity at time of attack, age, and sex of Nile crocodile attack victims for attacks that occurred between 2010 and March 2022 along the lower Kunene River. This information represents details of 15 attacks gathered from 155 households.

Activity	Men ≥ 18	Women ≥ 18	Boys ≤ 17	Girls ≤ 17	Total
Fetching water	4 (24% of men; 36% of fetching water)	0 (0% of women; 0% of fetching water)	3 (38% of boys; 27% of fetching water)	4 (67% of girls; 36% of fetching water)	11 (33% of total)
Bathing/Swimming	5 (29% of men; 63% of bathing / swimming)	0 (0% of women; 0% of bathing / swimming)	2 (25% of boys; 25% of bathing / swimming)	1 (17% of girls; 13% of bathing / swimming)	8 (24% of total)
Fishing	5 (29% of men; 71% of fishing)	1 (50% of women; 14% of fishing)	0 (0% of boys; 0% of fishing)	1 (17% of girls; 14% of fishing)	7 (21% of total)
Herding	0 (0% of men; 0% of herding)	1 (50% of women; 33% of herding)	2 (25% of boys; 67% of herding)	0 (0% of girls; 0% of herding)	3 (9% of total)
Other	3 (18% of men; 75% of other)	0 (0% of women; 0% of other)	1 (13% of boys; 25% of other)	0 (0% of girls; 0% of other)	4 (12% of total)
Total	17 (52 % of total)	2 (6% of total)	8 (24% of total)	6 (18% of total)	33

Age, gender, and crocodile attacks:

Age and gender group (men, women, boys, or girls) of the 33 Nile crocodile attack victims were compared to the age and gender groups that spent the most time at the river for; all households (n=147) and households that did not experience an attack in the specified period (n=118, Figure 4.8). An exact multinomial test for goodness of fit showed that attacks were not randomly distributed among age and gender groups ($p = 0.003$). Most attack victims were men (52%) followed by boys (24%), girls (18%), and women (6%).

When one considers risk of attack (the number of attacks relative to the age and gender group that spends the most time at the river), men are at the highest risk of attack (men comprised 52% of attack victims while 39% of households indicated that men spend the most time at the river), followed by girls (girls comprised 18% of attack victims while 6% of households indicated that girls spend the most time at the river), boys (boys comprised 24% of attack victims while 17% of households indicated that boys spend the most time at the river), and women (women comprised 6% of attack victims while 38% of households indicated that women spend the most time at the river) (Figure 4.8).

An exact multinomial test for goodness of fit showed that there was a significant difference between the distribution of attack victim age and gender group and the age and gender group that spends the most time at the river for; all households ($p < 0.001$) and for households that did not experience an attack ($p < 0.001$). This suggests that the number of attack victims in each age and gender group is not proportional to the age and gender group that spends the most time at the river. A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $p < 0.0125$) to determine which age and gender groups demonstrated a significant difference between attack victim age and gender group, and the age and gender groups that spent the most time at the river for all households. The results of the tests did not show significant differences in proportions for men ($p = 0.154$), boys ($p = 0.251$), or girls ($p = 0.014$). However, women showed a significant difference ($p < 0.001$). These results suggest that age and gender do not significantly influence the likelihood of attack except in the case of women who appear to be significantly less likely to experience a Nile crocodile attack relative to the amount of time that they spend at the river.

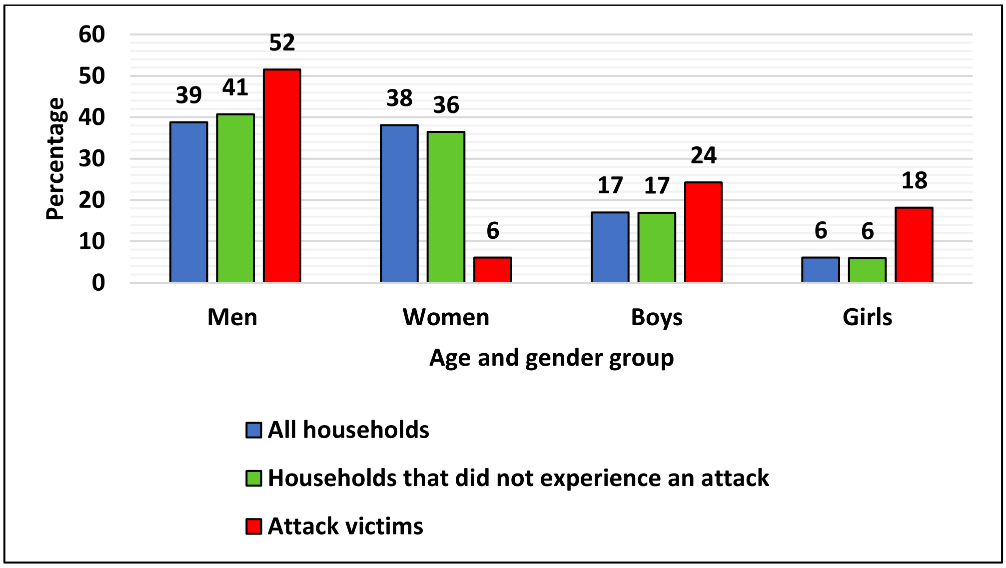

Figure 4.8: Age and gender group for 33 Nile crocodile attacks on humans that occurred along the lower Kunene River between 2010 and March 2022 compared to the age and gender group that spends the most time at the river for; all households (n = 147), and households that did not experience an attack in the specified time (n = 118).

Type of activities performed at the river, and crocodile attacks:

Activity during attack (fetching water; bathing/swimming; fishing; herding) could be established for 29 of the 33 Nile crocodile attacks on humans and these were compared to the number of households that take part in an activity for; all households (n=155), and households that did not experience an attack in the specified period (n=125, Figure 4.9). An exact multinomial test for goodness of fit showed that activity during attack followed a random distribution ($p = 0.189$). Most attacks occurred while victims were fetching water (38%) followed by Bathing/swimming (28%), Fishing (24%), and Herding (10%).

When one considers risk of attack (the number of attacks relative to the number of households that take part in an activity), fishing is considered the activity with the highest risk of attack (24% of attacks occurred during an activity performed by 16% of households), followed by fetching water (38% of attacks occurred during an activity performed by 31% of households), Bathing/swimming (28% of attacks occurred during an activity performed by 25% of households), and herding (10% of attacks occurred during an activity performed by 28% of households) (Figure 4.9).

An exact multinomial test for goodness of fit showed that there was no significant difference between the distribution of activity during attack and the number of households that take part in each activity for; all households ($p = 0.136$) and for households that did not experience an attack ($p = 0.064$). This suggests that the number of attacks per activity is proportional to the number of households that take part in the activity and that the type of activity a household performs at the river does not significantly influence the likelihood of experiencing an attack.

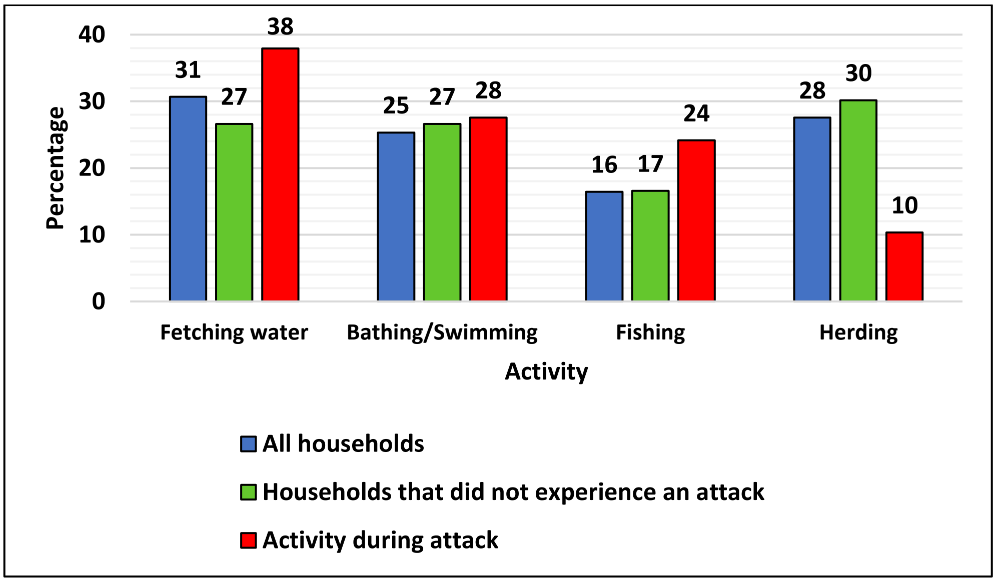

Figure 4.9: Activity during attack for 29 Nile crocodile attacks on humans that occurred along the lower Kunene River between 2010 and March 2022 compared to the number of households that take part in an activity for; all households (n = 155), and households that did not experience an attack in the specified time (n = 125).

Number of activities performed at the river and crocodile attacks:

The number of activities performed at the river (1, 2, 3, 4, 5 or 6) could be established for 30 households that experienced Nile crocodile attacks on humans between 2010 and March 2022. These were compared to the number of activities performed at the river for; all households (n=155), and households that did not experience an attack in the specified period (n=125, Figure 4.10). An exact multinomial test for goodness of fit showed that households that experienced attacks on humans were not randomly distributed among the number of activities that they took part in at the river ($p < 0.001$). Most households that experienced an attack took part in 5 activities at the river (43%), followed by 4 activities (27%), 2 activities (10%), 6 activities (7%), 1 activity (7%), 3 activities (3%), and 0 activities at the river (3%).

When one considers risk of attack (the number of households that experienced an attack relative to the number of households that take part in a specific number of activities), taking part in 5 activities at the river is considered to have the highest risk of attack (43% of households that experienced an attack take part in 5 activities at the river, while 29% of all households take part in 5 activities at the river), followed by 6 activities at the river (7% of households that experienced an attack take part in 6 activities at the river while 6% of all households take part in 6 activities at the river), 2 activities performed at the river (10% of households that experienced an attack take part in 2 activities at the river while 10% of all households take part in 2 activities at the river), 4 activities performed at the river (27% of households that experienced an attack take part in 4 activities at the river while 31% of all households take part in 4 activities at the river), 0 activities performed at the river (3% of households that experienced an attack take part in 0 activities at the river while 5% of all households take part in 0 activities at the river), 3 activities performed at the river (3% of households that experienced an attack take part in 3 activities at the river while 8% of all households take part in 3 activities at the river), and 1 activity performed at the river (7% of households that experienced an attack take part in 1 activity at the river while 12% of all households take part in 1 activity at the river) (Figure 4.10).

Although only 35% of all households took part in 5 or 6 activities at the river, these two activity classes made up 50% of households that experienced attacks. The disproportionate number of attacks attributed to these two classes, as well as the higher risk attributed to them, suggests that as a household performs more activities at the river, the likelihood of experiencing an attack increases (Figure 4.10).

An exact multinomial test for goodness of fit showed that there was no significant difference between the distribution of households that experienced an attack when compared to all households ($p = 0.751$) and households that did not experience an attack ($p = 0.456$). This suggests that the number of attacks per number of activity class is proportionate to the number of households in that class, and that the number of activities performed at the river does not significantly increase the likelihood of experiencing an attack.

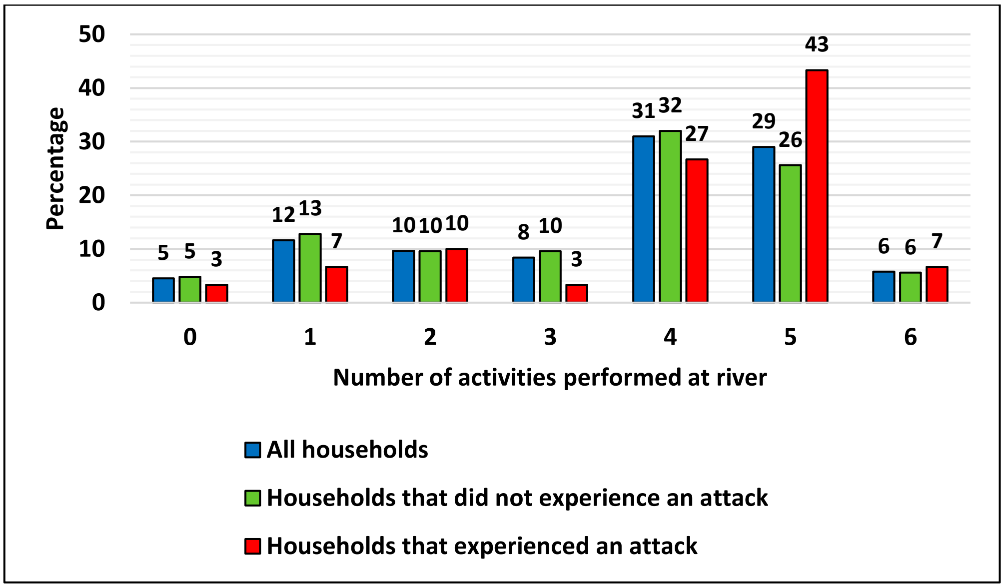

Figure 4.10: Number of activities performed at the river for 30 households that experienced Nile crocodile attacks on humans along the lower Kunene River between 2010 and March 2022, compared to the number of activities performed at the river for; all households (n = 155), and households that did not experience an attack in the specified time (n = 125).

Primary source of water and crocodile attacks:

The primary water source (river, or alternative water source) could be established for 29 households that experienced Nile crocodile attacks on humans between 2010 and March 2022. These were compared to the primary water sources for; all households (n=154), and households that did not experience an attack in the specified period (n=125, Figure 4.11). An exact multinomial test for goodness of fit showed that households that experienced attacks were not randomly distributed between primary water source classes ($p < 0.001$). Most crocodile attacks occurred in households where the river was their primary water source (83%), compared to 17% of attacks that occurred in households where an alternative water source, such as a borehole, spring, or government provided tap was the primary water source.

When one considers risk of attack, (the number of attacks relative to the number of households using a water source), households that used the river as a primary water source appeared to be at the highest risk of attack (comprised 83% of attacks while 79% of households used the river as a primary water source), while households who primarily used an alternative water source appeared to be at lower risk (comprised 17% of attacks while 21% of households used an alternative as a primary water source). The inverse of this trend was observed when one compared households that did not experience attacks to all households, further supporting the narrative that using the river as a primary source of water increases the risk of experiencing an attack (Figure 4.11).

An exact multinomial test for goodness of fit showed that there was no significant difference between the primary source of water used by households that experienced attacks when compared to all households ($p = 0.821$), and households that did not experience an attack ($p = 0.658$). This suggests that the number of attacks per primary water source class is proportional to the number of households in that class, and that using the river as a primary water source does not significantly increase the likelihood of experiencing an attack.

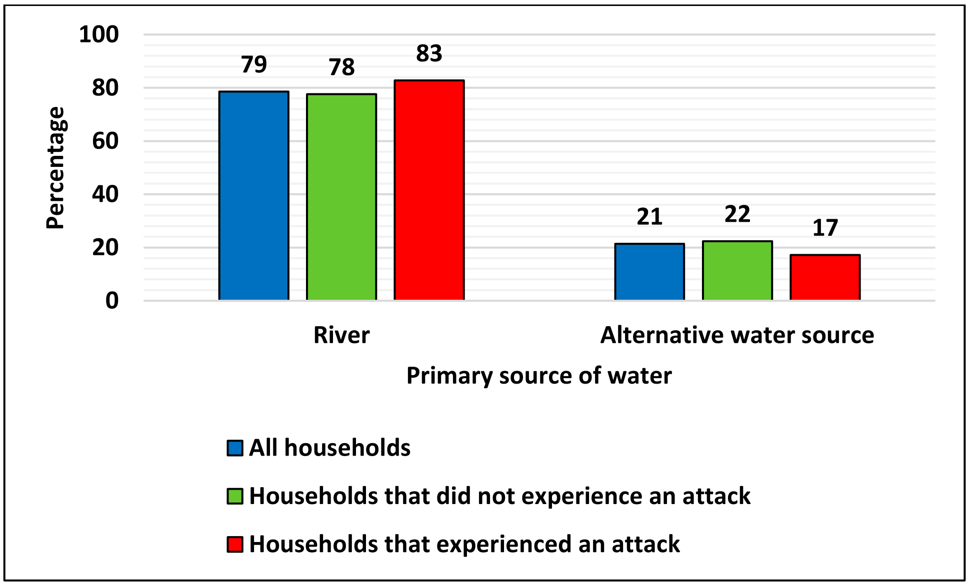

Figure 4.11: Primary water source used by 29 households that experienced Nile crocodile attacks on humans along the lower Kunene River between 2010 and March 2022, compared to the primary water source for; all households (n = 154), and households that did not experience an attack in the specified time (n = 125).

4.3.3 Crocodile attacks on livestock

4.3.3.1 Scale of the conflict

Respondents were asked whether they had lost any livestock to Nile crocodiles. Most cattle owners (55%) lost cattle to crocodiles in 2021 ($\mu = 2$, $\sigma = 3$, $n = 44$), while 84% of cattle owners lost cattle to crocodiles in the past (2021, and the years preceding it). The majority of small stock owners (78%) lost small stock to crocodiles in 2021 ($\mu = 9$, $\sigma = 9$, $n = 113$), while 93% of small stock owners had lost small stock to crocodiles in the past (2021, and the years preceding it). Livestock owners who had lost livestock to crocodiles in the past were asked whether adult or young animals were attacked more frequently. Eighty four percent of respondents who had lost cattle to crocodiles felt that adult animals were attacked more often (n = 44), while 84% of respondents who had lost small stock to crocodiles felt that adult animals were attacked more often (n = 105). Cattle owners had lost an average of 2 cattle to crocodiles in 2021 ($\mu = 2$, $\sigma = 3$, n = 44), approximately 9% of the average cattle herd size ($\mu = 23$, $\sigma = 32$, n = 44), while small stock owners had lost an average of 9 small stock to crocodiles in 2021 ($\mu = 9$, $\sigma = 9$, n = 113), approximately 12% of the average small stock herd size ($\mu = 77$, $\sigma = 86$, n = 113).

To understand perceived trends in Nile crocodile attacks on livestock, respondents were asked whether they thought that crocodile attacks on livestock had increased, stayed the same or decreased from 2010 to March 2022. Most respondents (75%) felt that crocodile attacks on livestock had increased, 10% felt that they had stayed the same, 12% felt that they had decreased, and 3% did not know (n = 155).

Respondents were asked to give reasons for the perceived trend (increased, decreased, stayed the same, or did not know; n= 155). Some respondents (3%) felt that crocodile attacks on livestock had decreased because the crocodile population had decreased, 2% felt that crocodile attacks on livestock had decreased because the livestock numbers had decreased, 2% did not know why attacks on livestock had decreased, 1% felt that livestock attacks had decreased because more alternative water points were made available to the community, and 1% thought that attacks on livestock had decreased because less people were settling close to the river (Table 4.5).

Twenty eight percent of respondents felt that Nile crocodile attacks on livestock had increased because the crocodile population had increased, 18% felt that attacks on livestock had increased because crocodiles were hungry, 15% did not know why they perceived an increase in attacks on livestock, 10% thought that an increase in livestock numbers was driving the increase in attacks on livestock, and 3% cited other reasons for the perceived increase in attacks on livestock (Table 4.5).

Table 4.5: Perceived trend in Nile crocodile attacks on livestock (increased, decreased, stayed the same, or do not know) and reasons given for trend from 2010 – March 2022 along the lower Kunene River (percentages exceed 100 as some respondents gave multiple responses; n = 155).

Perceived trend	Reason given for trend	Percentage of respondents
Crocodile attacks on livestock have decreased	Crocodile population has decreased. These respondents cited reasons such as: Crocodiles are killed by trophy hunters and authorities.	3% of total; 27% of decreased
	Livestock numbers have decreased.	2% of total; 20% of decreased
	Don't know.	2% of total; 20% of decreased

	More alternative water sources have been made available to livestock owners.	1% of total; 13% of decreased
	Less people are settling near the river	1% of total; 7% of decreased
Crocodile attacks on livestock have stayed the same		10% of total; 100% of stayed the same
Crocodile attacks on livestock have increased	Crocodile population has increased. These respondents cited reasons such as: Crocodiles are being protected by authorities such as the government, conservancies, and NGOs, there are fewer trophy hunters than in the past, floods bring crocodiles from upstream.	28% of total; 38% of increased
	Crocodiles are hungry. Respondents cited reasons such as: The natural food of crocodiles such as fish and wildlife have been depleted and this is resulting in crocodiles increasing their dependence on livestock as a source of nutrition.	18% of total; 24% of increased
	Don't know.	15% of total; 21% of increased
	Livestock number have increased. Respondents cited reasons such as: Drought forces people and livestock to settle near the river, where there is reliable water and grazing.	10% of total; 13% of increased
	Other. Respondents cited reasons such as: Crocodiles are developing a preference for catching livestock, people are no longer following the advice of traditional healers, herders are no longer doing their jobs well, flooding makes livestock more accessible and makes it difficult to protect livestock while drinking.	3% of total; 3% of increased
Don't know		3% of total; 100% of don't know

Wildlife was thought to be responsible for the most cumulative livestock loses (49%), followed by drought (42%), disease (8%), and theft (1%). Most losses of cattle were attributed to drought (73%), followed by wildlife (25%), disease (1%), and theft (0%). Most losses in small stock were attributed to wildlife (53%), followed by drought (37%), disease (10%) and theft (0%) (Figure 4.12).

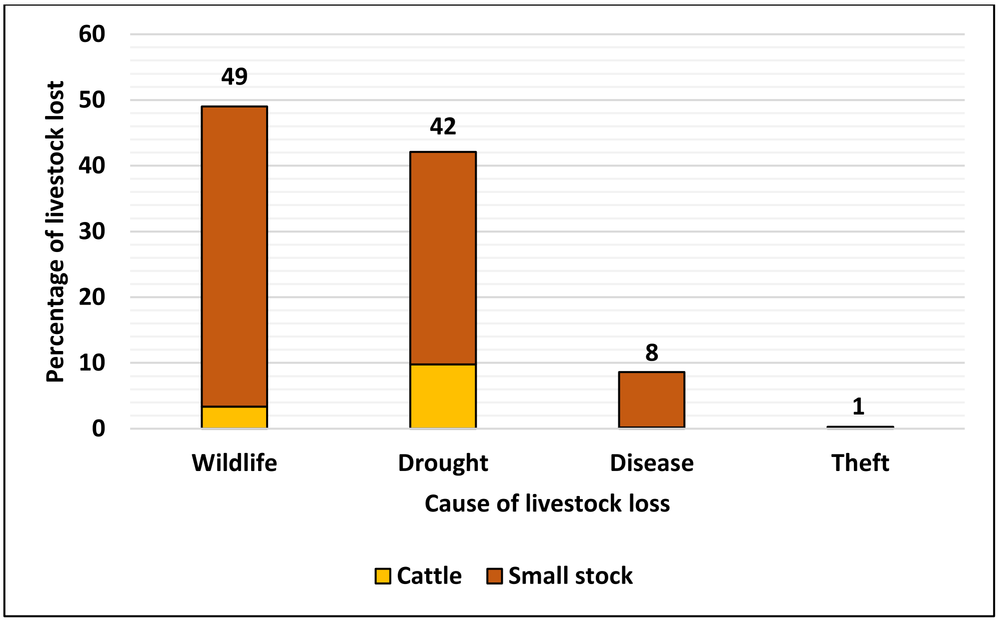

Figure 4.12: Perceived causes of livestock losses on the lower Kunene River in 2021. This graph reflects information gathered from 155 households, 113 of which owned small stock and 44 of which owned cattle in 2021.

After establishing that wildlife was thought to be responsible for the most cumulative losses of livestock (49%), an investigation into the specific species thought to be responsible for depredation on livestock was undertaken. Nile crocodiles were thought to be responsible for the most cumulative livestock losses (82%), followed by caracal *Caracal caracal* (8%), leopard *Panthera pardus pardus* (5%), cheetah *Acinonyx jubatus* (4%) and Black backed jackal *Lupulella mesomelas* (1%). Most losses of cattle were attributed to crocodiles (99%), followed by leopard (1%), caracal, cheetah, and jackal (0% attributed to each species). Most losses of small stock were attributed to crocodiles (81%), followed by caracal (9%), leopard (6%), cheetah (4%), and jackal (1%) (Figure 4.13).

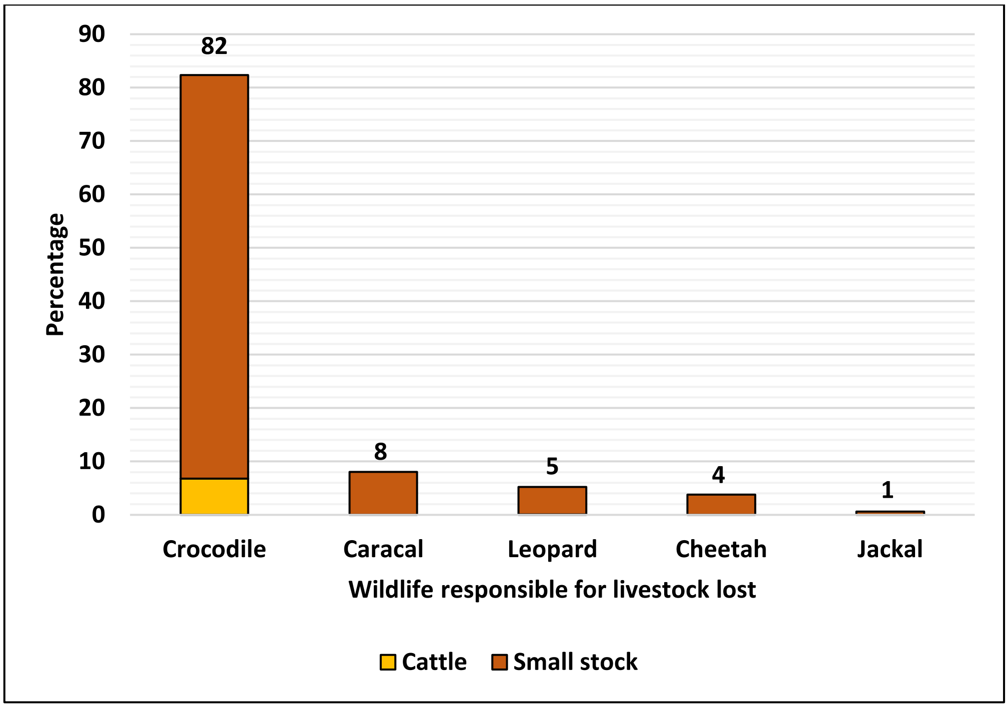

Figure 4.13: Wildlife thought to be responsible for livestock losses along the lower Kunene River in 2021. This graph reflects information gathered from 155 households, 113 of which owned small stock and 44 of which owned cattle in 2021.

Livestock owners were asked if they had ever received compensation from the conservancy or government for livestock losses attributed to Nile crocodiles, and to comment on the outcomes of the compensation. Nearly half of the respondents (49%) did not receive compensation because they had not reported the attacks to authorities, 2% of respondents did not receive compensation because authorities could not confirm that the losses were caused by wildlife, 47% of respondents had reported the attacks but were still waiting for compensation, 3% of respondents had received compensation for all of the livestock lost to crocodiles, and 1% of respondents had received compensation for some but not all of their livestock lost to crocodiles (n= 101). To further illustrate the scale of the conflict between humans and crocodiles along the lower Kunene River, livestock owners were asked if they thought that they would experience attacks on their livestock by crocodiles in the future. Ninety five percent of respondents thought that they would experience depredation by crocodiles in the future, 3% thought that they would not, and 2% did not know if they would experience livestock depredation by crocodiles in the future (n = 101).

4.3.3.2 Conflict in relation to time and place

Approximate locations of 91 households that experienced Nile crocodile attacks on livestock in 2021 were plotted on a map (Figure 4.14). Most attacks on livestock occurred within the Kunene River Conservancy (58%) followed by the Epupa Conservancy (19%), Uukolonkadhi – Ruacana Conservancy (16%), Marienfluss

Conservancy (6%), and Okanguati Conservancy (1%). No attacks were recorded for the Otjitanda Conservancy and no attacks occurred in areas outside of conservancies (Figure 4.14).

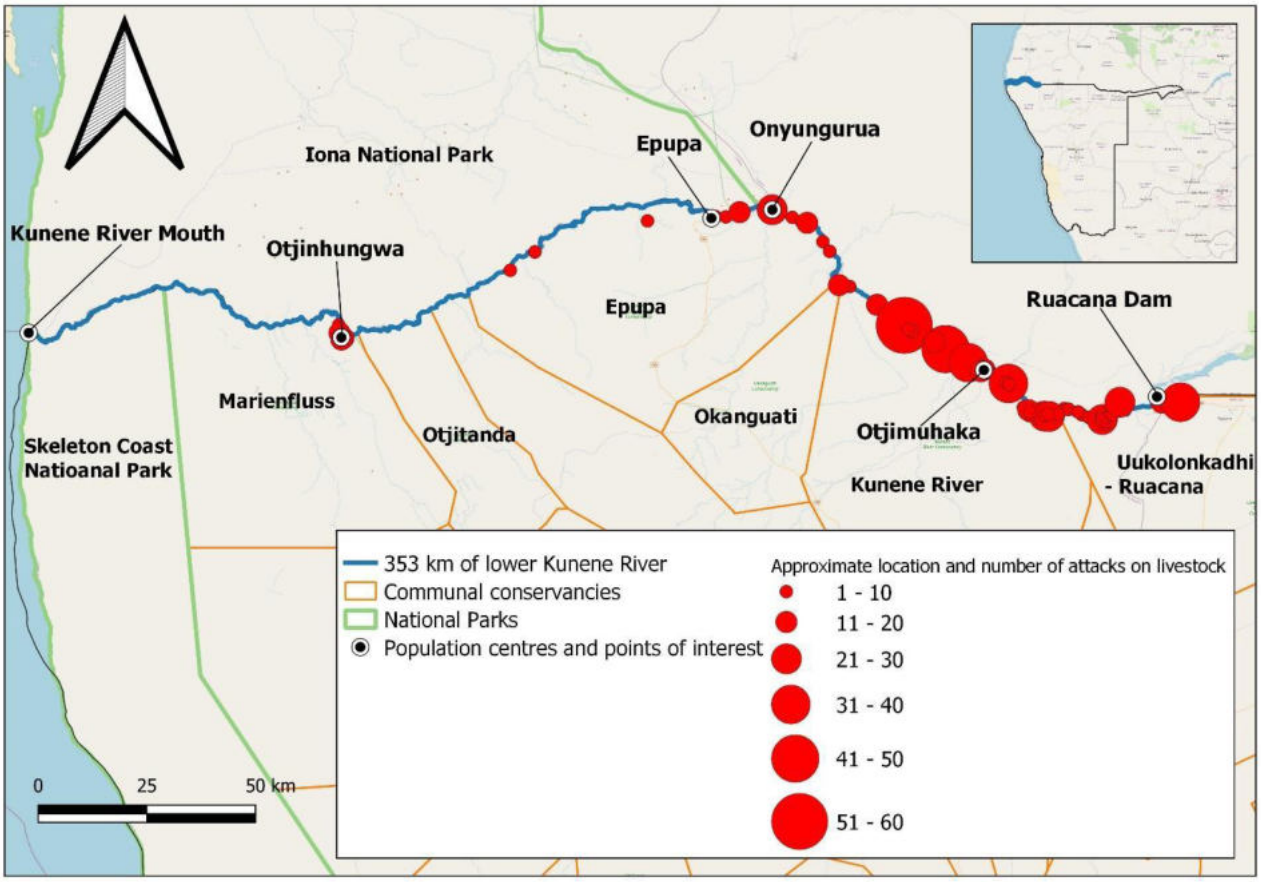

Figure 4.14: Map of the study area showing the lower 353 km of the Kunene River (in blue), the population centres and points of interest (labelled in black), the communal conservancies bordering on the river (in orange), and the Skeleton Coast and Iona National Parks (in green). Approximate locations of 91 households that experienced Nile crocodile attacks on livestock, as well as the number of attacks experienced by each household in 2021 is plotted in red.

To determine seasonality of attacks, respondents were asked at what time of year do most attacks on livestock occur. Eighty six percent of cattle owners who had lost cattle to Nile crocodiles felt that most attacks occurred in the hot and dry season (Okuni) that ran from August to January, while 14% felt that most crocodile attacks on cattle occurred in the cool wet season (Okurooro) that ran from February to July (n = 37). In the same way, 94% of small stock owners who had lost small stock to crocodiles felt that most attacks occurred during Okuni, while 7% felt that most crocodile attacks on small stock occurred during Okurooro (n=105, Figure 4.15).

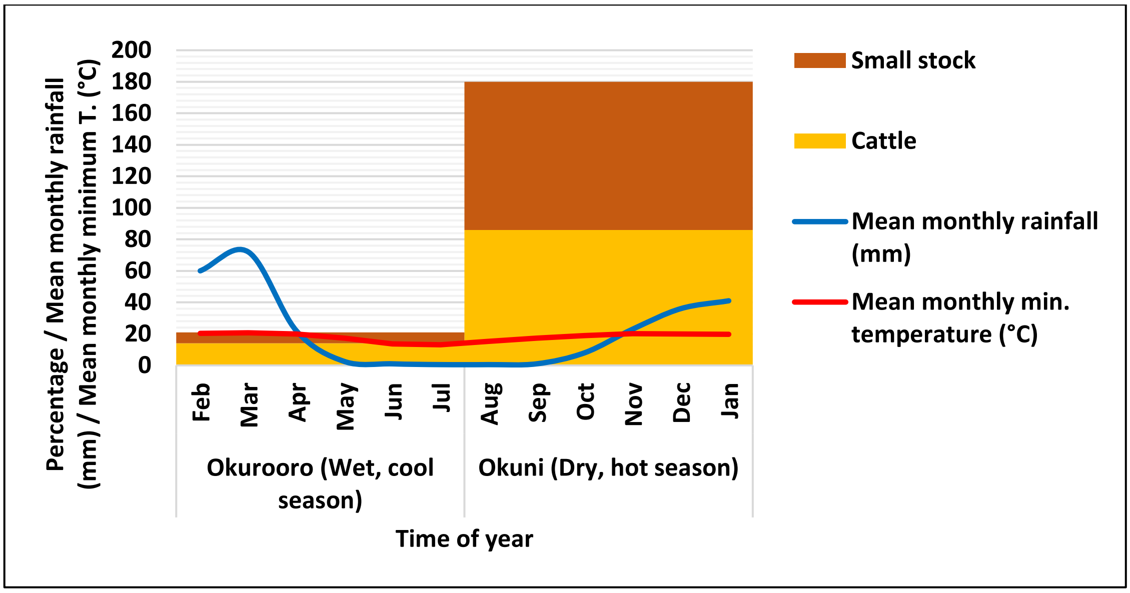

Figure 4.15: Season in which most Nile crocodile attacks on livestock are thought to occur along the lower Kunene River, mean monthly rainfall (mm), and mean monthly minimum temperature (°C) (Climate-Data.org, 2023). Respondents were asked at what time of the year do most attacks on livestock occur for cattle (n = 37) and for small stock (n = 105).

Cattle attack times (morning, midday, afternoon/evening) could be established for 37 cattle owners who had lost cattle to Nile crocodiles in the past. These were then compared to cattle drinking times for; all cattle owners (n = 44), and cattle owners who did not lose cattle to crocodiles in 2021 (n=20, Figure 4.16). An exact multinomial test for goodness of fit showed that attack times were not randomly distributed ($p < 0.001$). Most attacks occurred in the afternoon/evening (73%) followed by morning (19%), and midday (8%).

When one considers risk of attack (the number of attacks relative to the number of households that take their cattle to drink at a specific time), afternoon/evening is considered the time with the highest risk of attack (73% of attacks occurred at a time when 46% of cattle drink), followed by midday (8% of attacks occurred at a time when 19% of cattle drink), and morning (19% of attacks occurred at a time when 34% of cattle drink) (Figure 4.16).

An exact multinomial test for goodness of fit showed that there was a significant difference between the distribution of cattle attack times and cattle drinking times for all households ($p = 0.006$). However, there was no significant difference between cattle attack times and cattle drinking times for households that did not lose cattle to Nile crocodiles ($p = 0.059$). The significant difference between cattle attack times and cattle drinking times for all households, suggests that the number of attacks that occur at a specific time is not proportional to the number of cattle drinking at that time. A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $p < .0167$) to determine which time of day demonstrated a significant difference between attack time and cattle drinking time for all households. The results of the test did not show significant differences in proportions for morning ($p = 0.056$), or midday ($p = 0.096$). However, the proportions of attacks that occurred in the afternoon/evening differed significantly from the proportion of cattle that drank during that time ($p = 0.001$). These results suggest that drinking time does not significantly influence the likelihood of attack except in the afternoon/evening when it appears to be significantly more dangerous for cattle to drink as 73% of attacks occurred at a time when 46% of cattle drink.

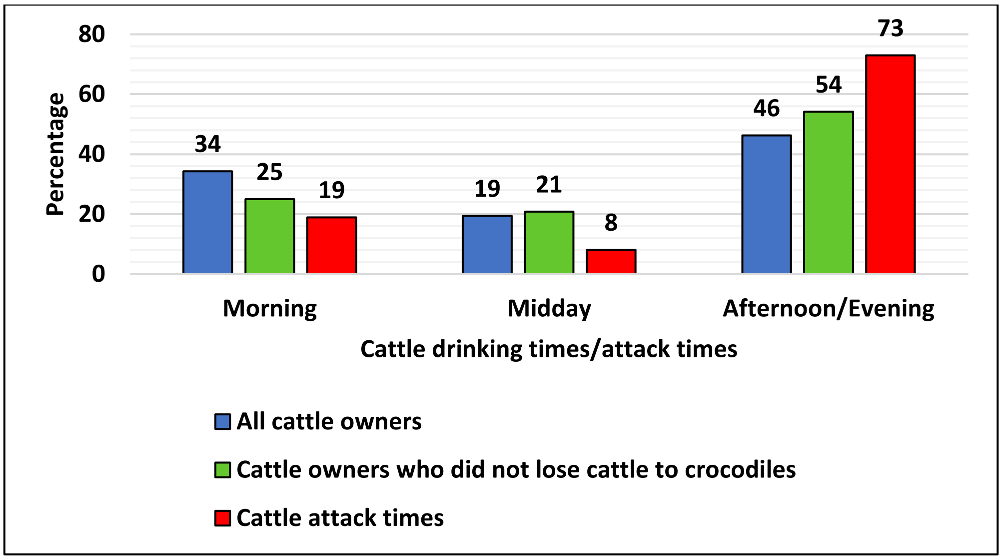

Figure 4.16: Cattle attack times for 37 cattle owners who have lost cattle to Nile crocodiles along the lower Kunene River compared to cattle drinking times for; all cattle owners (n = 44), and cattle owners who did not lose cattle to crocodiles in 2021 (n = 20).

Small stock attack times (morning, midday, or afternoon/evening) could be established for 105 small stock owners who had lost small stock to Nile crocodiles in the past, these were compared to small stock drinking times for; all small stock owners (n = 113), and small stock owners who did not lose small stock to crocodiles in 2021 (n=25, Figure 5.16). An exact multinomial test for goodness of fit showed that attack times were not randomly distributed ($p < 0.001$). Most attacks occurred in the afternoon/evening (86%) followed by morning (9%), and midday (5%).

When one considers risk of attack (the number of attacks relative to the number of households that take their small stock to drink at a specific time), afternoon/evening is considered the time with the highest risk of attack (86% of attacks occurred at a time when 69% of small stock drink), followed by midday (5% of attacks occurred at a time when 10% of small stock drink), and morning (9% of attacks occurred at a time when 21% of small stock drink) (Figure 4.17).

An exact multinomial test for goodness of fit showed that there was a significant difference between the distribution of small stock attack times and small stock drinking times for all households ($p = <0.001$) and for households that did not experience an attack ($p = <0.001$). The significant difference between small stock attack times and small stock drinking times suggests that the number of attacks that occur at a specific time is not proportional to the number of small stock drinking at that time.

A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $p < 0.0167$) to determine which time of day demonstrated a significant difference between attack time and small stock drinking time for; all small stock owners, and small stock owners who did not lose small stock to Nile crocodiles. The results of the test did not show a significant difference between the proportions for midday ($p = 0.039$). However, the proportions of attacks that occurred in the morning ($p < 0.001$) and in the afternoon/evening ($p < 0.001$) differed significantly from the proportion of small stock that drank during that time. In the same way, the post hoc analysis comparing the distribution of attack times and small stock drinking times for small stock owners that did not experience an attack showed a significant difference for morning ($p < 0.001$) and afternoon/evening ($p < 0.001$) but not for midday ($p = 1.000$).

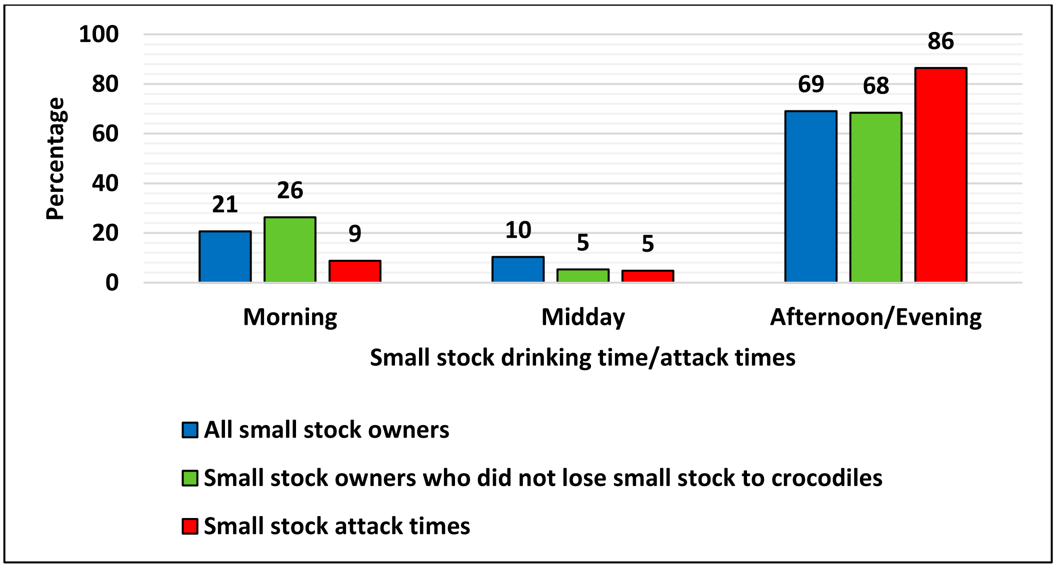

Figure 4.17: Small stock attack times for 105 small stock owners who have lost small stock to Nile crocodiles along the lower Kunene River compared to small stock drinking times for; all small stock owners (n = 113), and small stock owners who did not lose small stock to crocodiles in 2021 (n = 25).

These results suggest that it is significantly less dangerous for small stock to drink in the morning as 9% of attacks occur in the morning, while 21% of small stock drink at that time. In the same way, it is significantly more dangerous for small stock to drink in the afternoon/evening as 86% of attacks occur at a time when 69% of small stock drink.

4.3.3.3 Factors associated with the conflict.

Primary water source for livestock and crocodile attacks:

Cattle:

The primary water source for cattle (river, or alternative water source) could be established for 24 cattle owners who lost cattle to Nile crocodiles in 2021, and these were compared to the primary water sources for; all cattle owners (n = 44), and cattle owners who did not lose any cattle to crocodiles in 2021 (n=20, Figure 4.18). An exact multinomial test for goodness of fit showed that cattle owners that experienced attacks were not randomly distributed between primary water source classes ($p < 0.001$). Most cattle owners who lost cattle to crocodiles let their cattle drink from the river (92%), while 8% let their cattle drink from alternative water sources such as boreholes or springs.

When one considers risk of attack (the number of cattle owners who lost cattle to crocodiles relative to the number of cattle owners who use a specific water source), using the river as a primary water source is considered to have a higher risk of attack (92% of cattle owners who lost cattle to crocodiles used a primary water source used by 89% of all cattle owners), while using an alternative water source is considered to have a lower risk of attack (8% of cattle owners who lost cattle to crocodiles used a primary water source used by 11% of all cattle owners). The inverse of this trend is observed when one compares cattle owners that did not lose cattle to Nile crocodiles to all cattle owners, further supporting the narrative that using the river as a primary source of water for cattle increases the risk of experiencing an attack (Figure 4.18).

An exact multinomial test for goodness of fit showed that there was no significant difference between the primary source of water used by cattle owners who lost cattle to Nile crocodiles when compared to all cattle owners ($p = 1.000$) and cattle owners who did not lose cattle to crocodiles ($p = 0.566$). This suggests that the number of attacks per primary water source class is proportional to the number of cattle owners in that class and that where cattle owners allow their livestock to drink does not significantly increase the likelihood of attack.

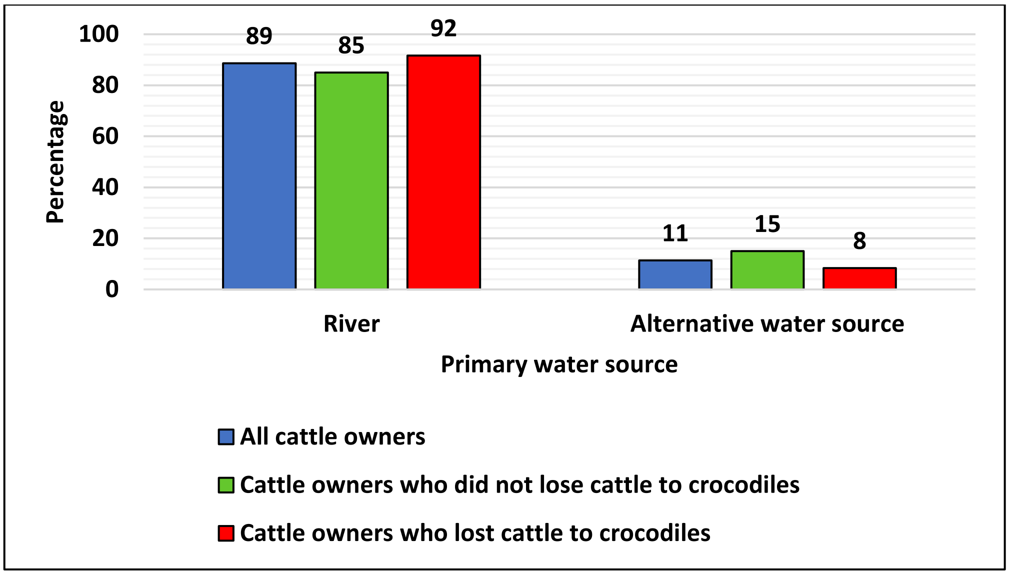

Figure 4.18: Primary water source for cattle used by 24 cattle owners who lost cattle to Nile crocodiles in 2021 along the lower Kunene River compared to the primary water source class for cattle used by; all cattle owners (n = 44), and cattle owners who did not lose cattle to crocodiles in 2021 (n = 20).

Small stock:

The primary water source for small stock (river, or alternative water source) could be established for 88 small stock owners who lost small stock to Nile crocodiles in 2021, and these were compared to the primary water sources for; all small stock owners (n = 113), and small stock owners who did not lose any small stock to crocodiles in 2021 (n=25, Figure 4.19). An exact multinomial test for goodness of fit showed that small stock owners that experienced attacks are not randomly distributed between primary water source ($p < 0.001$). Most small stock owners who lost small stock to crocodiles let their small stock drink from the river (93%), while 7% let their small stock drink from alternative water sources such as boreholes or springs.

When one considers risk of attack (the number of small stock owners who lost small stock to crocodiles relative to the number of small stock owners who use a specific water source), using the river as a primary water source is considered to have a higher risk of attack (93% of small stock owners who lost small stock to crocodiles use a primary water source used by 88% of all small stock owners) while using an alternative water source is considered to have a lower risk of attack (7% of small stock owners who lost small stock to crocodiles use a primary water source used by 12% of all small stock owners). The inverse of this trend is observed when one compares small stock owners that did not lose small stock to Nile crocodiles to all small stock owners further supporting the narrative that using the river as a primary source of water for small stock increases the risk of experiencing an attack (Figure 4.19).

An exact multinomial test for goodness of fit showed that there was no significant difference between the primary source of water used by small stock owners who lost small stock to Nile crocodiles when compared to all small stock owners ($p = 0.239$). When comparing small stock owners who lost small stock to crocodiles to those that did not, a significant difference in distribution among water source used by small stock was found ($p < 0.001$).

A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $p < 0.025$) to further investigate the difference in distributions among primary water source use for small stock owners who lost small stock to Nile crocodiles and those that did not. The results of the test showed a significant difference between proportions of small stock owners who lost small stock to crocodiles and those that did not ($p < 0 .001$). These results suggest that there is a significant difference in water source use when comparing small stock owners who lost small stock to crocodiles and those who did not.

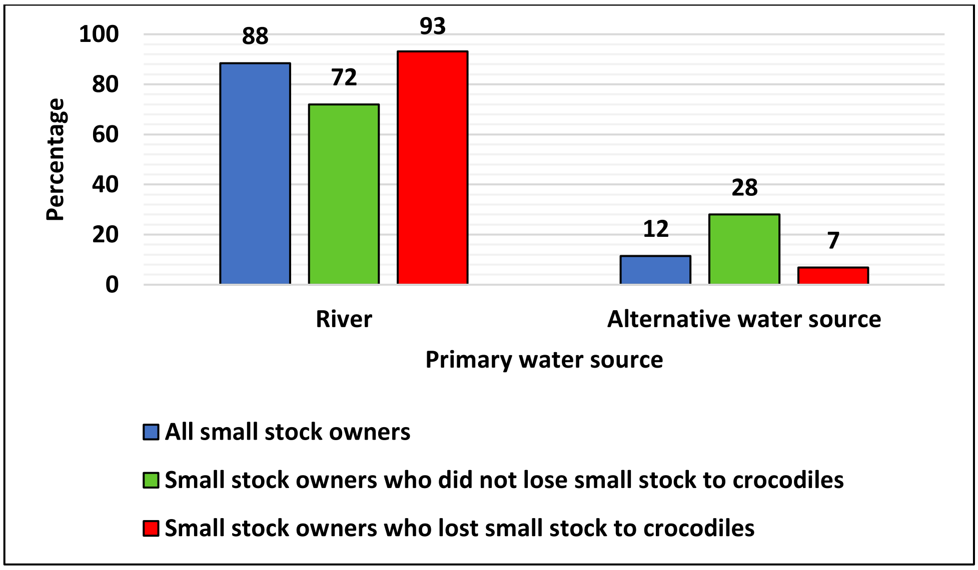

Figure 4.19: Primary water source for small stock used by 88 small stock owners who lost small stock to Nile crocodiles in 2021 along the lower Kunene River compared to the primary water source class for small stock used by; all small stock owners (n = 113), and small stock owners who did not lose small stock to crocodiles in 2021 (n = 25).

A greater proportion of small stock owners who lost small stock to Nile crocodiles used the river as a primary water source when compared to those that did not lose small stock to crocodiles (93% and 72% respectively), while a lower proportion of small stock owners who lost small stock to crocodiles used an alternative as a primary water source when compared to those that did not lose small stock to crocodiles (7% and 28% respectively). These results suggest that using the river as a primary water source for small stock significantly increases the likelihood of attack while using an alternative water source significantly decreases the likelihood of attack.

Herder use and crocodile attacks:

Cattle:

Herder use (herder, or no herder) could be established for 22 cattle owners who lost cattle to Nile crocodiles in 2021, and these were compared to herder use for; all cattle owners (n = 39), and cattle owners who did not lose any cattle to crocodiles in 2021 (n=17, Figure 4.20). An exact multinomial test for goodness of fit showed that cattle owners that experienced attacks are randomly distributed between herder use classes (herder, or no herder; $p = 0.286$). Most cattle owners who lost cattle to crocodiles use a herder (64%), while 36% do not use a herder.

When one considers risk of attack (the number of cattle owners who lost cattle to crocodiles relative to the number of cattle owners who either use a herder or do not), using a herder is considered to have a higher risk of attack (64% of cattle owners who lost cattle to crocodiles use a herder while 51% of all cattle owners use a herder), while not using a herder is considered to have a lower risk of attack (36% of cattle owners who lost cattle to crocodiles do not use a herder, while 49% of all cattle owners do not use a herder). The inverse of this trend is observed when one compares cattle owners that did not lose cattle to crocodiles to all cattle owners, further supporting the narrative that cattle owners who use a herder are at higher risk of experiencing an attack (Figure 4.20).

An exact multinomial test for goodness of fit showed that there was no significant difference in herder use when comparing cattle owners who lost cattle to Nile crocodiles to all cattle owners ($p = 0.290$). When comparing cattle owners who lost cattle to crocodiles to those that did not, a significant difference in herder use was found ($p = 0.007$).

A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $P < 0.025$) to further investigate the difference in distributions among herder use for cattle owners who lost cattle to Nile crocodiles and those that did not. The results of the test showed a significant difference between the proportion of cattle owners who lost cattle to crocodiles and those that did not ($p = 0.007$). These results suggest that there is a significant difference in herder use when comparing cattle owners who lost cattle to crocodiles and those who did not. A greater proportion of cattle owners who lost cattle to crocodiles used a herder when compared to those that did not lose cattle to crocodiles (64% and 35% respectively), while a lower proportion of cattle owners who lost cattle to crocodiles did not use a herder when compared to those that did not lose cattle to crocodiles (36% and 65% respectively). These results suggest that using a herder does not significantly decrease the likelihood of attack, on the contrary, cattle owners who use a herder appear to have a higher likelihood of losing cattle to crocodiles.

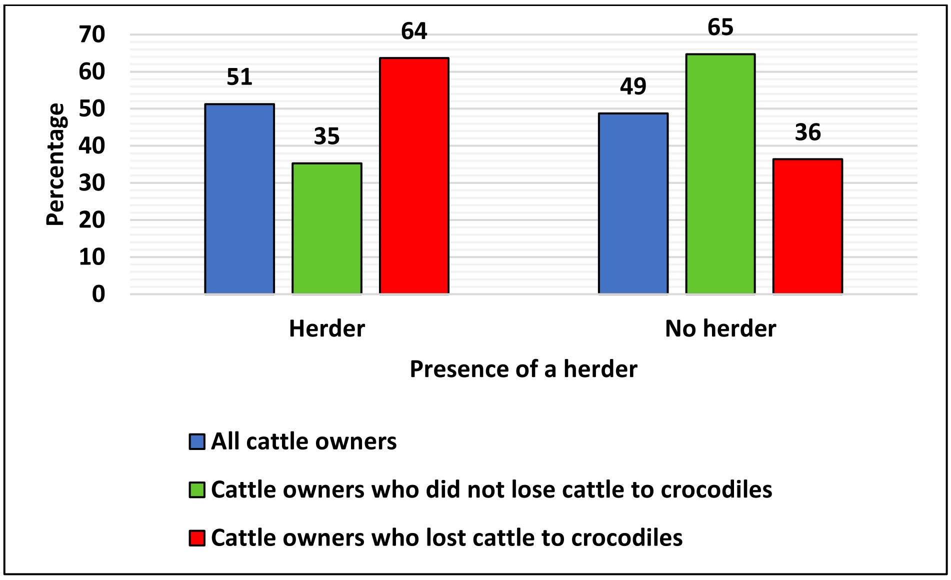

Figure 4.20: Herder use for 22 cattle owners who lost cattle to Nile crocodiles in 2021 along the lower Kunene River compared to herder use for; all cattle owners (n = 39), and cattle owners who did not lose cattle to crocodiles in 2021 (n = 17).

Small stock:

Herder use (herder, or no herder) could be established for 82 small stock owners who lost small stock to Nile crocodiles in 2021, these were compared to herder use for; all small stock owners (n = 100), and small stock owners who did not lose any small stock to crocodiles in 2021 (n=18, Figure 4.21). An exact multinomial test for goodness of fit showed that small stock owners that experienced attacks are not randomly distributed between herder use classes (herder, or no herder; p <0 .001). Most small stock owners who lost small stock to crocodiles use a herder (94%), while 6% do not use a herder.

When one considers risk of attack (the number of small stock owners who lost small stock to crocodiles relative to the number of small stock owners who either use a herder or do not), using a herder is considered to have a higher risk of attack (94% of small stock owners who lost small stock to crocodiles use a herder, while 93% of all small stock owners use a herder) while not using a herder is considered to have a lower risk of attack (6% of small stock owners who lost small stock to Nile crocodiles do not use a herder, while 7% of all small stock owners do not use a herder). The inverse of this trend is observed when one compares small stock owners that did not lose small stock to crocodiles to all small stock owners, further supporting the narrative that small stock owners who use a herder are at a higher risk of experiencing an attack (Figure 4.21).

An exact multinomial test for goodness of fit showed that there was no significant difference in herder use when comparing small stock owners who lost small stock to Nile crocodiles to all small stock owners (p = 1.000) and small stock owners who did not lose any small stock to crocodiles (p = 0.215). This suggests that the number of attacks per herder use class, is proportional to the number of small stock owners in that class, and that whether small stock owners use herders on not does not significantly affect the likelihood of attack.

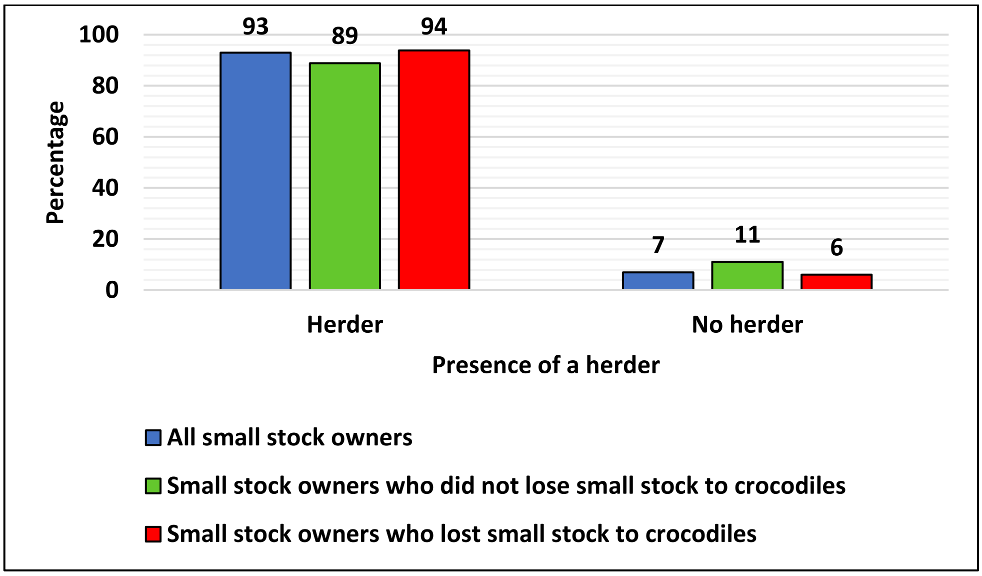

Figure 4.21: Herder use for 82 small stock owners who lost small stock to Nile crocodiles in 2021 along the lower Kunene River compared to herder use for; all small stock owners (n = 100), and small stock owners who did not lose small stock to crocodiles in 2021 (n = 18).

4.3.4 Crocodile population density and attacks on humans and livestock

To further understand the interactions between humans and Nile crocodiles on the lower Kunene River, an analysis of the relationship between crocodile population density, human population density, and attacks on livestock was undertaken. Values were calculated for 8km sections of the river, with section 1 starting at the river mouth and section 44 ending below Ruacana Dam wall (Figure 4.22). This analysis compared crocodile population density determined by the aerial count presented in Chapter 3, with human population density (2011 national census data), human attack data for all attacks that occurred between 2010 and March 2022, and attacks on livestock data for all attacks that occurred in 2021.

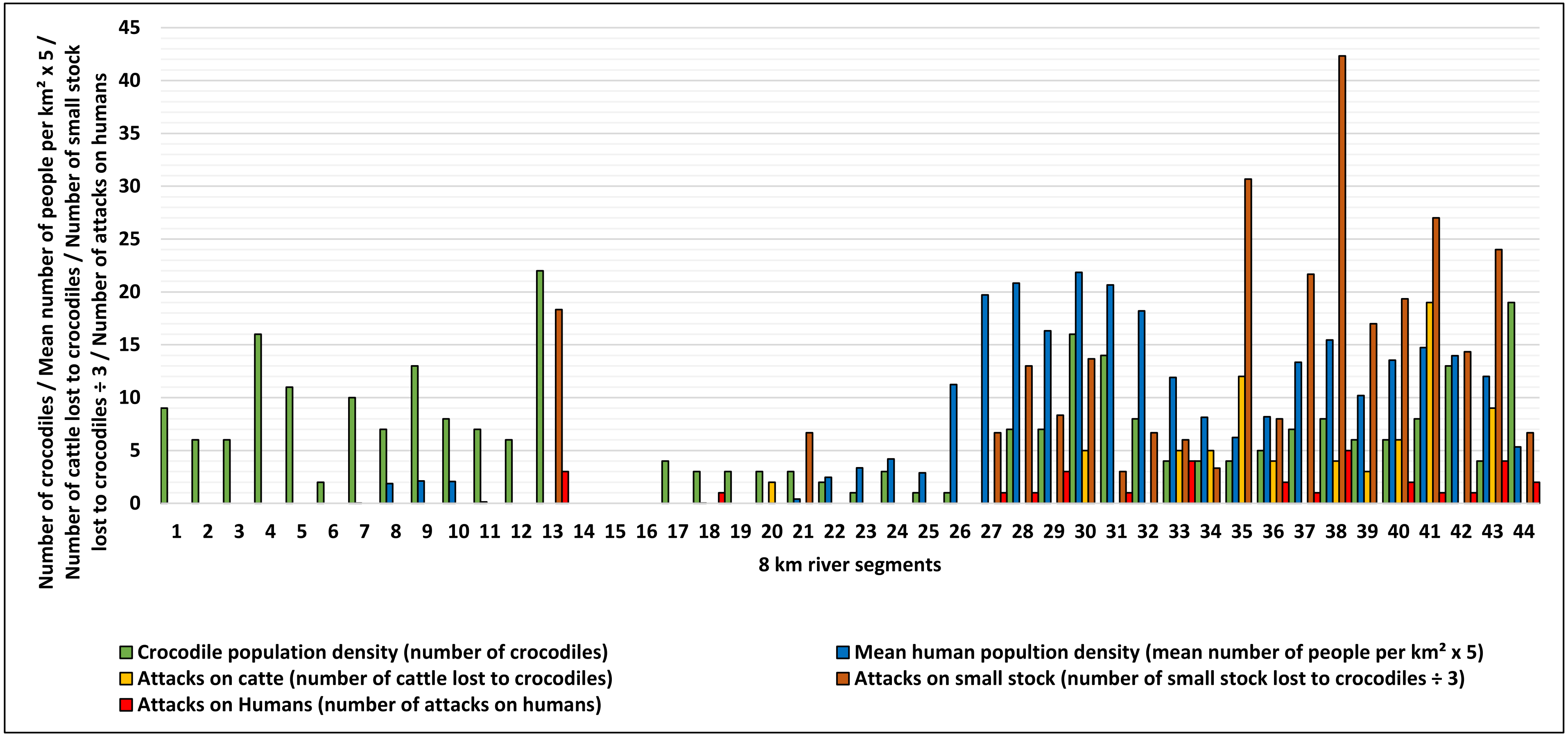

Figure 4.22: Nile crocodile population density (2021 direct count), mean human population density (2011 estimate), number of cattle and small stock lost to crocodiles in 2021, number of attacks on humans from 2010 to March 2022 for 8km river segments. Segment 1 is the river mouth and segment 44 ends below Ruacana Dam wall.

Figure 4.22 (dark blue) illustrates how low human population density is in the lower reaches of the river where it passes through the Namib desert, Hartmann, Otjihipa, and Baynes Mountains (section 1 – 26). This area is also characterised by a lack of attacks on humans and livestock due to the low number of communities in this area. Further upstream, human population density and associated attacks on humans and livestock are notably higher as the river passes through the population centres of Epupa, Onyungurura, and Otjimuhaka Figure 4.22, (section 26 – 44).

Nile crocodile population density was compared to human population density, attacks on cattle, attacks on small stock, and attacks on humans (Table 4.6). Spearman's rank correlation showed that there was a significant positive correlation between crocodile population density and attacks on small stock [r (42) = 0.32, p = 0.035]. These results suggest that areas with higher crocodile population densities experience a significantly higher number of attacks on small stock (Table 4.6).

In the same way, human population density was compared to Nile crocodile population density, attacks on cattle, attacks on small stock, and attacks on humans (Table 4.6). Spearman's rank correlation showed that there was a significant positive correlation between human population density and: attacks on cattle [r (42) = 0.41, p = 0.006], attacks on small stock [r (42) = 0.71, p <0.001], and attacks on humans [r (42) = 0.54, p <0.001] (Table 4.6). These results suggest that areas with higher human population densities experience significantly higher numbers of attacks on cattle, small stock, and humans.

Table 4.6: Summary of Spearman's rank correlation results comparing Nile crocodile, and human population density with attacks on humans, cattle, and small stock for forty-four 8km sections of the lower Kunene River.

Variable	**Crocodile population density**			**Human population density**		
	Degrees of freedom	**Spearman's rank correlation**	***P* value**	**Degrees of freedom**	**Spearman's rank correlation**	***P* value**
Crocodile population density				**42**	**0.208**	**0.176**
Human population density	**42**	**0.208**	**0.176**			
Attacks on cattle	**42**	**0.029**	**0.853**	**42**	**0.411**	**0.006***
Attacks on small stock	**42**	**0.319**	**0.035***	**42**	**0.714**	**<0.001***
Attacks on humans	**42**	**0.258**	**0.091**	**42**	**0.543**	**<0.001***

***Represents significance at 95% confidence level**

4.3.5 Retaliation

In light of the series of Nile crocodile killings that took place on the lower Kunene River with reports of 20 crocodiles found dead between 2019 and 2020 (Guchu, 2020), a section of the questionnaire was devoted to further understanding the killing of crocodiles and in particular, retaliatory killings along the lower Kunene River (Figure 4.23). Respondents were asked if crocodiles were ever killed in their area, with 79% stating that crocodiles were never killed in their area, 15% stating that crocodiles were killed on occasion in their area and 5% responding that they did not know (n = 155). In the same way, respondents were asked if they had heard of the crocodiles that were allegedly killed in 2019 and 2020. Thirty two percent of respondents had heard of the crocodiles that were killed, while 68% had not (n = 152). When asked about trends in humans killing crocodiles, 4% felt that humans killing crocodiles had increased from 2010 to March 2022, 35% felt that it had stayed the same, 28% felt it had decreased, and 33% did not know (n = 152).

Figure 4.23: Crocodiles found dead along the lower Kunene between Epupa and Ruacana dam. Photographs were posted on a WhatsApp group for stakeholders in the area with a focus on human crocodile conflict. Photos were taken between 2019 and 2021. (Photos used with permission from J. Van Tonder).

Regarding the Nile crocodiles found dead in 2019 and 2020, respondents were asked who was responsible for killing them, why they were killed, and how they were killed. Notably, most respondents (n = 106) abstained from answering these questions. When asked who was responsible for the crocodile deaths, 39% of respondents (n = 49) stated that the conservancy had killed the crocodiles, 27% did not know who had killed the crocodiles, 22% felt that community members living on the Angolan bank of the river had killed the crocodiles, and 20% felt that community members living on the Namibian bank of the river had killed the crocodiles. When asked why the crocodiles had been killed, 47% of respondents (n = 49) felt that the crocodiles had been killed because they had attacked livestock, 31% did not know why the crocodiles had been killed, 24% felt that the crocodiles had been killed by trophy hunters within the conservancy, 8% felt that they had been killed for attacking people, 8% felt that they had been killed to harvest their body parts for illegal trade in wildlife products, and 4% felt that the crocodiles had died from sickness. When asked how the crocodiles had been killed, 65% of respondents stated that the crocodiles had been shot, 33% stated that they had been poisoned, 18% of respondents did not know how they had been killed, 8% felt that they had been snared or caught with a hook and line, and 4% felt that they had died from sickness (n = 49).

4.3.6 Perceptions on wildlife and crocodiles

To gauge the perceived benefits from wildlife in general, and Nile crocodiles in particular, respondents (n = 152) were asked if living with wildlife and crocodiles benefitted their household. When asked if living with wildlife benefitted their household, 76% of respondents felt that they did not benefit from living with wildlife, 2% of respondents felt neutral, and 22% of respondents felt that they did benefit from living with wildlife (Figure 4.24). When asked about benefits from living with crocodiles, 86% of respondents (n = 152) felt that they did not benefit from living with crocodiles, 1% of respondents felt neutral, and 13% of respondents felt that they did benefit from living with crocodiles (Figure 4.24).

An exact multinomial test for goodness of fit showed that there was a significant difference between the perceptions of benefits from living with wildlife when compared to the perceptions of benefits from living with Nile crocodiles ($p = 0.012$). A post hoc exact binomial test was performed with Bonferroni adjustments (result significant at $p < 0.017$) to further investigate the difference in perceptions on benefits from wildlife and crocodiles. Distributions differed significantly for disagree ($p = 0.003$), and agree ($p = 0.006$), but not for neutral ($p = 0.774$). These results suggest that significantly more respondents feel that they do not benefit from living with crocodiles when compared to other wildlife, and significantly less respondents feel that they benefit from crocodiles when compared to other wildlife.

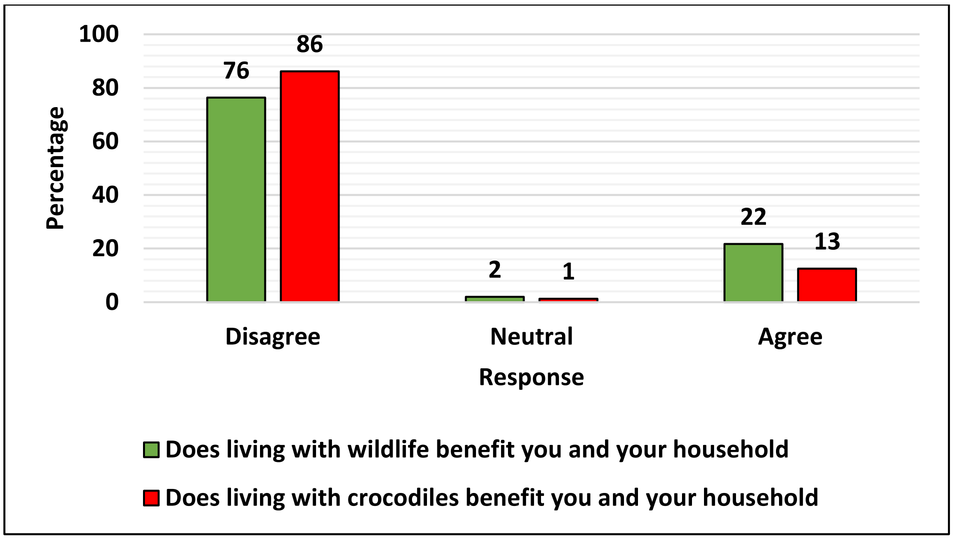

Figure 4.24: Perception on benefits from living with wildlife and Nile crocodiles along the lower Kunene River in 2022 (n= 152).

To gauge the perceptions on happiness derived from living with wildlife in general and Nile crocodiles in particular, respondents were asked if they would be happier if there were no wildlife living in the area, and in a subsequent question, if there were no crocodiles living in the area. When asked if they would be happier if no wildlife lived in the area, 75% of respondents felt that they would not be happier, 5% of respondents felt neutral, and 20% of respondents felt that they would be happier if there were no wildlife in the area (n = 153). When asked if they would be happier if no crocodiles lived in the area (n = 155), 30% of respondents felt that they would not be happier, 1% of respondents felt neutral, and 69% of respondents felt that they would be happier if there were no crocodiles in the area (Figure 4.25).

An exact multinomial test for goodness of fit showed that there was a significant difference between the perceptions on happiness from living with wildlife when compared to living with Nile crocodiles ($p < 0.001$). A post hoc exact binomial test was performed with Bonferroni adjustment (result significant at $p < 0.017$) to further investigate the difference in perceptions on happiness derived from wildlife and crocodiles. Distributions differed significantly for disagree ($p < 0.001$), and agree ($p < 0.001$), but not for neutral ($p = 0.052$). These results suggest that significantly more respondents feel that they would be happier if there were no crocodiles living in the area when compared to wildlife, and significantly less respondents feel that they would be happier if crocodiles remained in the area when compared to other wildlife.

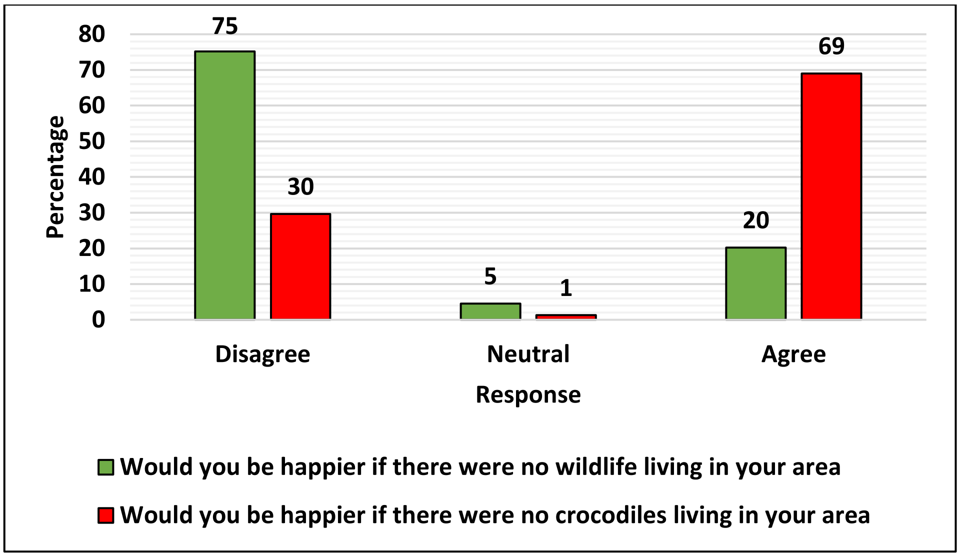

Figure 4.25: Perceptions on happiness derived from living with wildlife (n = 153) and Nile crocodiles (n = 155) along the lower Kunene River in 2022.

4.3.7 Solutions

In an effort to mitigate the conflict between humans and Nile crocodiles along the lower Kunene RIver, respondents were asked to provide possible solutions to the problem as well as who they thought should be responsible for mitigating the conflict. Most respondents did not have any suggestions on how to solve the problem (71%). Eighteen percent of respondents felt that providing alternative water points for people and livestock would reduce the conflict, 7% suggested exterminating the crocodiles in the area, 6% suggested the construction of crocodile proof harbours where communities and livestock could safely access the river, 3% suggested educating the community on how to act near the river and the importance of staying away from the river, 2% felt that if the authorities were to pay compensation for crocodile attacks or compensate communities for living alongside crocodiles, it would solve the problem, 2% felt that the provision of gardens away from the river would solve the problem as this would keep people away from the river and decrease dependence on fishing and grazing livestock on the river banks, 1% felt that providing official river crossings in safe areas would solve the problem as this would prevent community members from swimming across the river or using unsafe crafts to cross the river, and 1% felt that there was no solution to the problem (percentages add up to > 100% as some respondents gave multiple answers; n = 129).

When asked who should be responsible for mitigating the conflict between humans and Nile crocodiles, most respondents felt that the government should be responsible for mitigating the conflict (53%), 50% of respondents felt that the particular conservancy should be responsible, 17% felt that the local community should be responsible, 14% felt that the Ministry of Environment, Forestry, and Tourism (MEFT) should be responsible, 9% felt that their own household should be responsible, and 2% felt that the traditional authority should be responsible (percentages add up to > 100% as some respondents gave multiple answers; n = 129).

4.4 Discussions and conclusions

4.4.1 Socio economics and river use

The socio-economic review of the study area highlighted the importance of subsistence farming on the lower Kunene River. Most respondents (92%) engaged in some form of subsistence agriculture, while households are generally large, with relatively low monthly incomes. The reliance on subsistence agriculture and importance of livestock in the area is further illustrated by the 73% of households that own livestock, and 84% of households that plant crops. These agricultural activities were seen as important by virtually all respondents.

In the same way, an analysis of river use showed the importance of the river to communities living on its banks. Most livestock owners took their animals to the river to drink, while many households fished in the river or used water from the river to irrigate their crops. At least 75% of households used the river as a primary source of water for drinking, washing clothes, and bathing/swimming.

4.4.2 Scale of the conflict

Attacks on humans:

When one considers that 29% of households offered details on Nile crocodile attacks that happened to members of their household, and 94% of households offered details on attacks that occurred to community members not within their household, it becomes apparent that crocodile attacks on humans affect most people living along the lower Kunene River. Although only 33 attacks were recorded for the period between 2010 and March 2022, which is comparatively low when compared to other southern African rivers (Aust et al., 2009; Thomas, 2006; Wallace et al., 2011), the fact that 95% of households worry about crocodile attacks when members of their household go to the river, and 57% of households feel that attacks on humans are increasing, shows that the effects of these attacks are still far reaching. These results correspond with those of other studies on HWC which showed that HWC does not only affect the safety of communities living alongside wildlife (Barua et al., 2013; Inskip & Zimmermann, 2009; Kiffner et al., 2015), but also cause feelings of stress and vulnerability (Khumalo & Yung, 2015).

Concerningly, most respondents (67%) did not receive compensation for Nile crocodile attacks on humans. When one investigates the reasons given for why compensation was not received, it becomes apparent that most attacks are not reported and when an attack is reported, there seems to be a lack of communication between the attack victims and the authorities. The lack of reporting is likely due to the remote nature of the lower Kunene River as well as a lack of capacity demonstrated by both community members and authorities to respond to attacks. Community members likely do not have the financial means to travel to population centres to make reports, this is combined with the costs of abandoning agricultural and familial responsibilities, and a cultural and language barrier between authorities and community members. The problem is further exacerbated by community members who do not have official documentation for residing in Namibia and are likely severely marginalised because of this. Successful reporting is further hindered by the lack of capacity demonstrated by authorities who often receive attack reports late (days if not weeks or months after attacks) and then have logistical and funding barriers to investigating the attack. Authorities in the area often have very large areas in which they work and are thinly spread across the landscape. Authorities are further hindered by constraints in transport, where some conservancies do not have vehicles, and some attacks happen in areas only accessible by walking in for multiple days.

Attacks on livestock:

Most livestock owners lost livestock to Nile crocodiles in 2021, while virtually all livestock owners have lost livestock to crocodiles in the past (years preceding 2021) and expect to lose livestock to crocodiles in the future. These results, as well as the fact that 49% of all livestock losses are attributed to wildlife, while 82% of livestock lost to wildlife are attributed to crocodiles, demonstrates the severity of the conflict between livestock owners and crocodiles along the lower Kunene River. The scale of the conflict is further demonstrated when one considers that cattle owners lost an average of two head of cattle to crocodiles in 2021 or 9% of the average cattle herd size. Although this number may appear small, in the cultural context where bride wealth payments are often made using two or three cattle (Bollig, 2020), an average loss of two cattle in 2021 can be considered significant. These results do not come as a surprise, when one considers the significant losses of livestock attributed to crocodiles along other rivers in southern Africa (Aust et al., 2009; Thomas, 2006; Wallace et al., 2011).

Most livestock owners did not receive compensation for livestock lost to Nile crocodiles (98%), while the majority of those that did receive compensation felt that they had only received compensation for some of their animals. As was the case with human attacks, the failure of farmers to receive compensation seemed to be driven by a failure to report crocodile attacks on livestock, combined with a failure of authorities to respond to HWC reports. There appears to be a pattern arising where farmers report HWC incidences but are not compensated fully or timeously, if at all. The lack of adequate compensation leads to a disillusionment in the compensation scheme and authorities in general. Farmers then stop reporting HWC incidences and consequently HWC rises as the costs thereof are no longer offset by the government. In the absence of reports, authorities fail to comprehend, and respond to the scale of the conflict in a particular area. The failure to report HWC incidences has also been demonstrated by other studies conducted along the lower Kunene River, who similarly concluded that the lack of reporting is likely due to reporting fatigue in community members who have become disillusioned by the delay between reporting HWC and receiving compensation (Iiyambula, 2021).

4.4.3 Conflict in relation to time and place

Attacks on humans:

Unsurprisingly, most attacks occurred within the Kunene River Conservancy, the conservancy covering the longest section of the river. A detailed discussion on the relationship between human and Nile crocodile population density and attacks on livestock and humans is presented in section 4.4.5 of this chapter.

Other studies have identified temporal patterns in crocodile attacks on humans such as a general positive correlation between temperature, rainfall, and crocodile attacks attributed to increased activity levels in warmer months when crocodiles have higher nutritional requirements (Aust et al., 2009; Manolis & Webb, 2013; Pooley et al., 2019), and are more aggressive due to breeding (Pooley et al., 1992). However, there was no significant trend in the number of attacks per year or month identified in this study. There seemed to be a marginal increase in attacks per year between 2010 and March 2022, echoing the perceptions of most households that Nile crocodile attacks on humans are increasing. The increase in crocodile attacks on humans per year could be explained by an increase in the human population, as well as an increased adoption of sedentary farming practices resulting in more community members settling near the river (Bollig, 2020; Thuening, 2018). These conclusions are supported by community members who cited an increase in people using the river as the reason for a perceived increase in crocodile attacks on humans, and the dependence on the river discussed in section 4.4.1 of this chapter.

An analysis of time of attack (morning, midday, afternoon/evening) did not yield any significant results however, afternoon/evening appeared to be the time with highest risk of attack, followed by morning and midday. The higher levels of risk associated with afternoon/evening could be attributed to the biophysiological traits of crocodiles who are more active and have higher nutritional needs later in the day (Manolis & Webb, 2013), making them more likely to attack in the afternoon/evening. Another factor that likely contributed to more attacks being recorded during this time is the unequal time frames into which attacks were separated. While midday generally refers to a short period of time around noon, afternoon/evening can be interpreted as any time between noon until after sunset. This unequal division of time frames likely led to a bias in results.

Throughout the analysis of conflict in relation to time and place results seldomly showed statistical significance. The absence of statistical significance is likely due to the small sample size used in this analysis as well as the inability of many attack victims to accurately recall the month and year of attack, a problem encountered by other studies dealing with HCC in southern Africa (Wallace et al., 2011).

Attacks on livestock:

As was the case with attacks on humans, most Nile crocodile attacks on livestock occurred in the Kunene River Conservancy, the conservancy covering the longest section of the river. A detailed discussion on the relationship between human and crocodile population density and attacks on livestock and humans is presented in section 4.4.5 of this chapter.

An analysis of the time of year in which livestock owners thought most livestock attacks occurred, showed a clear discrepancy between the Okuni and Okurooro seasons. These seasons do roughly correspond to climate, with Okuni being seen as the hot, dry season and Okurooro as the cool, wet season, The differences between these seasons were explained to me by Mr Uuezirua Mbinge, and Mr Kauroorua Tjavara who accompanied me in the roles of translator, and cultural interpreter respectively. Okurooro, was considered the wet, cool season (running from February until July), because it was the time in which thunderstorms occurred and the associated clouds would cast shade on the landscape. Despite temperatures remaining relatively high throughout the year, the shade caused by rain clouds, as well as the drop in humidity following a storm would give some semblance of *coolness.* On the other hand, Okuni, described as the dry, hot season (running from August until January) was associated with an absence of clouds and rains, leaving the arid landscape scorched by the sun's rays. As was described by both Mr Mbinge and Mr Tjavara, the primary distinction between these two terms refers to grazing practices. During Okurooro, livestock can be grazed further afield in areas that hold surface water for only part of the year. During this time, rains falling at the end of Okuni, and beginning of Okurooro support grass growth in these pastures and ensures the availability of surface water by replenishing springs. At the end of Okurooro, and beginning of Okuni, when the outlying pastures and surface water has been depleted, livestock are moved to areas nearer to permanent water such as the lower Kunene River. This period is known as Okuni, the river ensures the availability of surface water for livestock while the vegetation growing on the riverbanks such as the pods of *Faidherbia albida* are a reliable source of fodder for livestock during the dry season. In this way a high degree of mobility is used to mitigate the risk of drought by conserving the valuable grazing resource (Bollig, 2013; Wassenaar et al., 2021). The grazing laws described above are still followed by many community members living on the lower Kunene River however, more community members are adopting a sedentary form of agropastoralism (Bollig, 2020; Thuening, 2018), where crops are cultivated near permanent water, and livestock are grazed in the same area year-round. In the context of the Kunene River, this means that livestock are present on the riverbanks throughout the year, but then increase dramatically during Okuni. This fluctuation in livestock numbers is illustrated by the data collected that showed that 86% of Nile crocodile attacks on cattle and 94% of crocodile attacks on small stock are thought to occur during Okuni, when livestock are grazed near the river.

Most livestock owners felt that Nile crocodile attacks on livestock had increased, with the increase being attributed to a growing crocodile population. Data were not available to analyse the trends in livestock lost over the long term, however, Chapter 3 of this thesis demonstrates that the crocodile population along the river has decreased, contrary to the beliefs of most community members. Other reasons given for the perceived increase in crocodile attacks on livestock such as "crocodiles are hungry", and "livestock numbers have increased" are likely a significant driver of crocodile attacks on livestock. The large-scale degradation of the grazing resources attributed to severe overgrazing by livestock (Bollig, 2013, 2020; Malan & Owen-Smith, 1974; Wassenaar et al., 2021), and an increase in cattle numbers (Wassenaar et al., 2021) in the region have resulted in a cultural shift in livelihood production. Communities have shifted away from a traditional semi nomadic form of pastoralism described in the preceding paragraph to a more sedentary form of agropastoralism (Bollig, 2020; Thuening, 2018). The increase in cattle numbers and decrease in rangeland quality has likely had an adverse effect on the natural terrestrial prey of crocodiles such as grazing ungulates who compete with cattle for resources. This decrease in natural prey could be driving a shift in the diet of crocodiles from wildlife to livestock. In the same way, the breakdown of the grazing resource and increased dependence on sedentary agropastoralism is likely forcing more community members to settle near the river where livestock have reliable access to water and fodder. As the number of livestock owners who use the river increase, the number of attacks on livestock are also likely to increase.

An analysis of time of attack (morning, midday, afternoon/evening), for all livestock, showed that it was significantly more dangerous for livestock to drink in the afternoon/ evening. In the same way, it was shown that morning was the safest time for livestock to drink at the river. These results correspond with those of Thomas., (2006) who concluded that most attacks in the Okavango Delta occur during the day, while the majority of those that occur during the day, occur in the afternoon. As with time of attacks for humans, the higher levels of risk associated with afternoon/evening and lower levels of risk associated with morning, could be attributed to the biophysiological traits of crocodiles. Crocodiles are more active and have higher nutritional needs at higher temperatures (Manolis & Webb, 2013), making them more likely to attack in the afternoon/evening, after spending the day basking in the sun, and less likely to attack in the morning when temperatures are lower.

4.4.4 Factors associated with the conflict

Attacks on humans:

Men made up the highest proportion of Nile crocodile attack victims followed by boys, girls, and women. When considering risk of attack, men seemed to be at the highest risk of attack followed by girls, and boys. Interestingly, women seemed to be significantly less likely of experiencing an attack when compared to all other age and gender groups. These results correspond with those of other studies on HCC in southern Africa that identified men as the age and gender group being attacked by crocodiles most frequently (Pooley et al., 2019; Thomas, 2006; Wallace et al., 2011). In the case of the lower Kunene River, there seems to be a cultural tendency of men going to the river either alone or in groups to wash for extended periods of time. The increased exposure to the river and consequently crocodiles is likely driving the disproportionate number of men falling victim to crocodile attacks.

Most attacks occurred while fetching water, followed by bathing/swimming, fishing, and herding. When considering risk of attack, fishing is considered the activity with the highest risk of attack, followed by fetching water, bathing/swimming, and herding. Other studies in southern Africa also found fishing to be an activity that exposed community members to a particularly high risk of Nile crocodile attack (Pooley et al., 2019; Thomas, 2006; Wallace et al., 2011). A series of factors could be contributing to the disproportionate number of attacks that occur while fishing. Firstly, fishing generally involves long periods of time spent near the river often in isolation. In the same way, activities associated with fishing such as wading and gutting fish further increases the risk of attack (Wallace et al., 2011).

Although statistical significance could not be shown, there was a trend of increased risk of attack as households performed more activities at the river. In the same way, there seemed to be an increased risk of attack for households that used the river as a primary source of water rather than an alternative source such as a borehole, spring, or tap. These results come as no surprise as increased exposure to the river increases exposure to Nile crocodiles and in turn increases the likelihood of experiencing a crocodile attack.

Attacks on livestock:

As was the case with Nile crocodile attacks on humans, livestock owners who used the river as a primary source of water for their livestock seemed to be at higher risk of experiencing attacks on livestock when compared to those who used alternative water sources such as boreholes or springs. In particular, small stock demonstrated this trend with small stock that drank at the river being significantly more likely of being attacked by crocodiles. As with attacks on humans, the greater risk of attack for livestock associated with using the river as a primary source of water is likely driven by increased exposure to crocodiles and consequently increased risk of attack.

Interestingly, using a herder was not shown to decrease the likelihood of attack, on the contrary, in the case of cattle, using a herder seemed to significantly increase the likelihood of attack. It was hypothesised that using a herder would mean that livestock are actively kept away from the river while they grazed and were watched over by the herder when they went to drink, thus decreasing the risk of attack. The failure to accept this hypothesis could be explained by a lack of competency demonstrated by the herders, many of whom are young children, or more likely by the possibility that livestock herds that are particularly vulnerable to attack due to other factors such as accessibility to the river or Nile crocodile density in a particular area also have herders. These herders likely mitigate some but not all attacks on livestock.

4.4.5 Crocodile population density and attacks on humans and livestock

Nile crocodile population density seemed to be highest between Epupa and the river mouth, where human population density was the lowest. This can be explained by a lack of HCC in these areas and the consequent absence of retaliatory killings of crocodiles. The National Park status of Iona to the north and Skeleton Coast to the south could also mean an increased abundance of natural prey for these crocodile populations, which could be leading to an increase in the crocodile population. The crocodile population size demonstrated a significant positive correlation with attacks on small stock. This could be explained by the comparatively higher population of small stock when compared to humans and cattle. The higher density of small stock could be driving an increased occurrence of attacks of crocodiles on small stock.

Human population density appeared to be higher between Epupa and the Ruacana Dam wall. The higher human population density is likely driven by higher rainfall in these areas making the climate more suitable for agriculture, as well as the availability of infrastructure. When compared to other sections of the lower Kunene River, the area between Epupa and Ruacana Dam wall is also comparatively more accessible with the D3700 road running along the bank of the river, and the population centres of Epupa, Onyungurua, and Otjimuhaka offering educational and economic opportunities as well as healthcare facilities. There was a significant positive correlation between human population density, attacks on cattle, attacks on small stock and attacks on humans. These results seem to suggest that rather than Nile crocodile population density, human population density is driving the conflict between humans and crocodiles. Humans and their associated livestock and agriculture activities are placing pressure on the lower Kunene River and competing with a declining crocodile population for resources. The increased density of humans, and likely their associated livestock are driving the attacks of crocodiles on humans and livestock.

4.4.6 Retaliation

Most respondents abstained from answering questions on retaliation, and many of those that did answer the questions stated that they did not know who was responsible for the retaliation, why it had occurred or how the Nile crocodiles had been killed. These results are telling of the nature of the questions asked which untangles a potentially incriminating and sensitive topic, the killing of crocodiles by humans. Due to the nature of the topic under discussion, some degree of social desirability (Ibbett et al., 2021), and non-response (Krumpal, 2013; Tourangeau & Yan, 2007) bias is to be expected. Most respondents who answered the question stated that the conservancy was responsible for killing crocodiles, that the crocodiles had been shot, and that they had been shot for trophy hunting. These responses likely demonstrate the desire of respondents to give socially acceptable answers. In the context of the lower Kunene River, crocodile hunts (the lawful way in which most crocodiles are killed) generally involve a trophy hunter coming into the area. The hunter is normally accompanied by a professional hunter with a hunting concession in the area, a conservancy representative, and the crocodile is shot before the trophy is harvested and meat is shared with the community. Most responses to questions dealing with retaliation alluded to a situation like the one described above, which is likely the only legal means of killing a crocodile that most community members have reference to.

Other answers given by respondents likely offer more details on the nature of retaliatory killings on the river. Retaliation is likely coming from community members on both the Namibian and Angolan banks of the river in response to Nile crocodile depredation on livestock and to a lesser degree attacks on humans, and for the harvest of crocodile body parts. Most crocodiles seem to be either shot or poisoned. These results correspond with the opinions of various stakeholders along the river who felt that crocodiles were being poisoned by commercial farmers who had established themselves on the Angolan bank of the river. The alleged poisonings were thought to be in response to attacks on livestock suffered by these farmers.

4.4.7 Perceptions on wildlife and crocodiles

The perceptions on wildlife and Nile crocodiles were assessed by asking respondents questions relating to benefits and happiness. The large majority of respondents felt that they did not benefit from living with wildlife or crocodiles. In addition to the general negative sentiment towards benefits derived from wildlife and crocodiles, significantly more respondents felt that they did not benefit from crocodiles, illustrating a particularly negative perception towards benefits derived from crocodiles. In the same way, most respondents felt that they would be happier if there were no crocodiles living in their area, further supporting a negative sentiment towards the species. The acknowledgment of benefits derived from wildlife drives attitudes towards conservation (Muyengwa, 2015; Rust & Marker, 2013) and when communities do not derive benefits from wildlife, they are more likely to foster negative attitudes towards wildlife (Störmer et al., 2019). In light of the above, the general lack of benefits perceived by communities along the lower Kunene River is likely resulting in negative perceptions on both wildlife and crocodiles, in particular. High levels of HWC illustrated in section 4.4.2 of this chapter are likely also causing a negative sentiment towards wildlife as this has been the case in other areas where HWC is prevalent (Kansky et al., 2014; Mogomotsi et al., 2020).

Interestingly, when asked if they would be happier if no wildlife lived in their area, most respondents felt that they would not. This result suggests that despite the perceived absence of benefits derived from wildlife, respondents still placed a value on the presence of wildlife and derived happiness from sharing their landscape with them. These results can likely be attributed to aesthetic or cultural values placed on wildlife and their presence in an area (Störmer et al., 2019). These positive sentiments shown towards wildlife could also be attributed to more abstract concepts such as "ecosophy", "deep ecology" (Naess, 1973), and "entanglement" (Hodder, 2014), which suggest a non-dualist relationship between humans and their environment where one cannot be separated from the other (Berkes & Folke, 1998; Folke et al., 2010). Despite the drivers of perceptions, one trend seems to remain clear, communities along the lower Kunene River generally foster negative attitudes towards crocodiles.

4.4.8 Solutions

Most respondents did not have any suggestions on how to solve the conflict between humans and Nile crocodiles along the lower Kunene River. The lack of solutions suggested by community members could be attributed to a fatalistic view on the conflict, where crocodiles and their associated conflict is accepted as part of the reality of living in the area (Wallace et al., 2011). In the same way, these results could be telling of world views that accept the crocodiles as part of the shared social and ecological landscape where it is accepted that attacks by crocodiles are natural and should be expected (Berkes & Folke, 1998; Folke et al., 2010).

The respondents that did offer solutions to the conflict, seemed to favour the provision of alternative water points, the extermination of Nile crocodiles, the construction of barriers separating crocodiles from humans, education, compensation, and the provision of gardens away from the river. These solutions all appear to be logical and will likely decrease the conflict between humans and crocodiles (Aust et al., 2009; Thomas, 2006; Wallace et al., 2011).

Most respondents seemed to feel that the government or other conservation authorities such as the MEFT or conservancies should be responsible for implementing mitigation methods, while the minority felt that the onus lay with the local community, or household itself. These results correspond with those of Wallace et al., (2011) who found that community members in rural Zambia expected the government to take responsibility for mitigation measures. A detailed discussion of possible solutions to human crocodile conflict along the lower Kunene River is presented in Chapter 5 of this thesis.

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CHAPTER 5

Conclusions and management recommendations

5.1 Conclusions

Human crocodile conflict is widespread throughout Africa and occurs at higher frequencies than in most other parts of the world (Eustace et al., 2022; Khan et al., 2020; Matanzima et al., 2022). In spite of this, data on the distribution and scale of the conflict remains porous with conservationists and policy makers often relying on limited data to make management decisions (Pooley et al., 2019). To make informed choices on how to mitigate these conflicts, an understanding of both the human dimensions, such as the frequency and distribution of conflict, as well as the biological dimensions, such as the distribution and abundance of crocodiles, is required (Schroer, 2021). In the context of the lower Kunene River, one aerial survey of Nile crocodiles was undertaken in 2012 (Lyet et al., 2016), while no previous research on the nature of human crocodile interactions had been undertaken before this study. In light of the above, this study aimed to estimate the distribution and abundance of crocodiles along the lower Kunene River, with the intention of comparing the current population estimate to that of 2012. In addition, the study set out to produce the first comprehensive data set on the scale, drivers, and distribution of HCC along the river.

To determine the abundance and distribution of Nile crocodiles along the lower Kunene River, an aerial survey was undertaken over three days in April 2021. The data collected during the survey was plotted on a map and analysed using both the direct count, and modelled estimate of the crocodile population. These results were compared to those of the 2012 survey (Lyet et al., 2016). To understand the interactions between humans and crocodiles along the lower Kunene River, a social survey was undertaken during which a questionnaire was administered to 155 households living on the Namibian bank of the river. These socio-ecological data were collected over two months in early 2022 and disentangled using both spatial and statistical analyses.

Regarding the Nile crocodile population in the study area, a population estimate of between 287 (0.81 crocodiles per km), and 597 (1.7 crocodiles per km) was made. These results suggest a decrease in the crocodile population of between 28 and 49% from 2012 to 2021. Additionally, a demographic shift seems to be underway with the numbers of crocodiles under 2 m appearing to remain relatively stable between 2012 and 2021, whereas the number of crocodiles >2 m in length have decreased dramatically. Importantly, human population density appeared to be negatively correlated with crocodile abundance suggesting that as the number of humans in an area increases the number of crocodiles decreases.

The results of the social survey showed that the large majority (92%) of households actively engage in subsistence farming and place a great deal of importance on growing crops and rearing livestock. Community members living along the lower Kunene River appear to be heavily reliant on water from the river with at least two thirds of households using the river for drinking, washing, and bathing water. Reliable records of 33 Nile crocodile attacks on humans were obtained with adult men appearing to be at the highest risk of attack. Fishing was found to be the activity with the highest risk, and afternoon/ evening appeared to be the time with the highest risk of experiencing a crocodile attack. Additionally, there seemed to be an increased risk of attack as households performed more activities at the river, and for households who used the river as a primary source of water. Crocodile attacks on livestock appeared to be substantial with 55% of cattle owners and 78% of small stock owners reporting losses to crocodiles in 2021. Eighty two percent of livestock owners felt crocodiles were the animal responsible for the most damage to their herds, and most attacks appeared to occur in the hot and dry (Okuni) season. Watering livestock in the afternoon/ evening emerged as the time of day with the highest risk of attack while morning was the lowest. As was the case with attacks on humans, households with a higher dependence on the river demonstrated a higher risk of experiencing attacks on livestock. The crocodile population along the lower Kunene River demonstrated a positive correlation with attacks on small stock, while the human population correlated positively with attacks on livestock and humans. Retaliation against crocodiles was not widely reported, although there were reports of crocodiles being killed with guns, poison, snares, and hook and lines. Most respondents cited attacks on livestock as the motive behind retaliating against crocodiles. Perceptions of crocodiles were generally negative, and most respondents failed to offer solutions to the conflict between humans and crocodiles along the lower Kunene River.

The results of this study come as a source of concern, with clear evidence that the Nile crocodile population in the study area is decreasing and that humans seemingly have an adverse effect on the abundance of crocodiles. In the same way, crocodiles appear to be having negative effects on the communities living on the banks of the lower Kunene River. Crocodiles are not only posing a direct threat to the safety of community members but are also taking a significant toll on the livestock of a human population that are heavily reliant on subsistence agriculture, and place immense cultural value on their livestock (Bollig & Schulte, 1999; Bollig, 2016, 2020). The conflict between humans and crocodiles appears to be driving negative perceptions of crocodiles and is also driving at least some retaliation.

The interactions between humans and Nile crocodiles in the study area can be characterised as a socio-ecological system where the relationship between humans and crocodiles are complex and interconnected (Biggs et al., 2022). In this system, humans appear to be affecting the crocodile population while the crocodile population appears to be affecting humans. Similarly, humans and crocodiles in the region appear to be thoroughly entangled (Hodder, 2014) and living in a state of negative coexistence (Bhatia, 2021). It appears to be that most respondents do not actively conserve and appreciate crocodiles, but rather tolerate crocodiles while holding negative perceptions regarding their presence. Considering the above, solutions to the conflict must consider both the human and crocodile aspects of the system in question. In the following section, a series of management recommendations are presented for mitigating the conflict and increasing the potential for coexistence between humans and crocodiles along the lower Kunene River. These mitigation measures aim to change the frequency and type of interactions that occur between humans and crocodiles with the aim of conserving the crocodile population, preventing negative interactions between humans and crocodiles and optimising benefits derived by communities from crocodiles.

5.2 Management recommendations

5.2.1 Education:

Educating community members about the dangers of Nile crocodiles and the risk of attack at specific times of day and when performing certain activities, would go a long way in decreasing the conflict. Signs should be erected along the river and in public spaces near the river such as schools, clinics and community centres warning people about the presence and dangers of crocodiles as well as the measures they can put in place to protect themselves. People should be taught the importance of being vigilant at the river and a system should be encouraged where some people remain vigilant and stand watch while others collect water. Community members should also be encouraged to collect water using containers and then move to a safe distance away from the river to wash rather than wash directly in the river. In this regard, the provision of water containers and washing tubs could be a low cost and effective manner of reducing conflict. Importantly, community members should be encouraged to avoid the river in the afternoon/ evening as this is the time with the highest risk of attack for both humans and livestock. In the same way, an effort should be made to educate people on the role that crocodiles play in freshwater ecosystems and the importance of conserving them. Tourism operators should make a conscious effort to showcase the beauty of the natural environment to the community members who share their landscape with crocodiles. Ideally, tourism operators should take local leaders and school groups on activities that develop appreciation for crocodiles such as guided walks or boat tours where crocodiles can be viewed from a safe distance. These activities could be easily incorporated with information on best practices for staying safe in an area where crocodiles occur. In these ways, education could be one of the most affordable measures to effectively reduce the conflict along the river.

5.2.2 Alternative water points:

The primary cause of conflict appears to be competition between humans and Nile crocodiles for the shared freshwater resource. A decrease in the dependence of community members and livestock on the river will likely lead to a decrease in the conflict between humans and crocodiles. Alternative water points should be provided for both humans and livestock to decrease time spent at the river. In the long-term, the aim should be to provide taps for individual households, however, a lower cost and likely more achievable goal would be to provide taps for groups of households shared by the community in a specific area. In the same way, drinking troughs should be provided for livestock to prevent them from drinking directly from the river where they are vulnerable to attack. Community water points and livestock drinking troughs should be provided to areas with the highest human densities first, as these areas have been shown to be predictors of both attacks on humans and attacks on livestock as detailed in Chapter 4 of this thesis. Specifically, an effort should be made to provide adequate and reliable water points for both humans and livestock in the population centres of Otjimuhaka, Onyungurua, Epupa, and Otjinhungwa. The construction of these water points should be paired with training and capacity building in the community to ensure that communities have the technical and financial capabilities to maintain the water points over the long term. Other studies have advocated for the construction of crocodile proof harbours where humans and livestock can safely access the river (Thomas, 2006). Crocodile proof harbours offer a low-cost method of decreasing conflict. Despite the apparent benefits of crocodile proof harbours, these harbours can be damaged during flooding and can dry up when the river is low. If harbours are put in place, maintenance and careful placement would be essential.

5.2.3 Community gardens:

Community gardens should be established away from the river with access to reliable water for irrigation. The current cultivation practices along the river often lead to community members clearing and cultivating areas bordering directly on the river and watering the gardens by hand from the river. These practices do not only disturb the habitat and potential nesting sites of crocodiles but also expose individuals to the risk of attack while fetching water for irrigation. By establishing community gardens with irrigation away from the river, negative interactions between humans and crocodiles will be reduced while providing an opportunity for sustainable economic development along the river.

5.2.4 Response to HCC:

In the case of Nile crocodile attacks on people or livestock, relative authorities such as the conservancy and MEFT staff should be empowered to respond to these incidents in a timely manner. Incident reports and consequent investigations should be made as soon as possible to allow authorities to accurately verify attacks. Crocodiles deemed too dangerous to remain in the area should be shot or translocated. One option for translocation would be to move problem crocodiles to below the Epupa Falls where the human population density is lower. The falls act as a physical barrier, preventing crocodiles from moving upstream and as such, translocation to downstream of the falls would likely be effective. In the same way compensation for attacks on humans or livestock should be paid out sooner. When eradicating or translocating crocodiles, community members should be actively involved to ensure that the crocodiles responsible for the losses are targeted.

5.2.5 Benefits derived from crocodiles:

An effort should be made to increase the benefits derived by community members from Nile crocodiles. Tourism operators should market walking and boat tours where crocodiles can be safely appreciated. These tourism operators should employ members of the local community to act as guides, managers, and camp staff to increase the economic importance of crocodiles in the area. Importantly, community members should be educated on the role that crocodiles play in the creation of these benefits. The current state of the crocodile population along the lower Kunene River does not warrant consumptive use of crocodiles such as trophy hunting, and egg harvesting, but perhaps in the future these methods could be employed to further derive benefits from crocodiles.

5.2.6 Community based rangeland and livestock management:

The establishment of a community-based rangeland and livestock management (CBRLM) system (Volkmann, 2011), would likely decrease HCC, improve the condition of the grazing resource, and increase direct economic benefits to the communities in question. In this system, community groups in an area will collectively make decisions on where and when to graze livestock while pooling resources to ensure the wellbeing of their livestock. Ideally, a system like this will build on the traditional semi nomadic grazing system developed in the area explained in detail in Chapter 2 of this thesis. A CBRLM system along the banks of the lower Kunene River could adjust stocking rates based on rangeland health and practise a form of rotational grazing to preserve the grazing resource. Livestock could be herded collectively during the day and kraaled in protective enclosures at night. These measures would ensure that livestock do not wander unattended to the river where they would be vulnerable to Nile crocodile attack. Livestock drinking times could be strictly managed to ensure that they drink in the mornings when attacks are less likely. In the same way resources could be pooled to create safe drinking areas for livestock either by pumping water away from the river to troughs or by constructing and maintaining crocodile proof harbours. An additional benefit of improved grazing management would be the increased health of the grazing resource in wet season grazing areas. Ensuring the health of the grazing resource in areas further from the river would allow livestock owners to continue practising their semi nomadic system of grazing where livestock are grazed far from the river in the wet season and near the river in the dry season. This semi nomadic grazing system has been linked to a marked decrease in attacks on livestock in the wet season when herds are kept further afield as shown in Chapter 4 of this thesis. The implementation of such a system will prevent conflict between humans and crocodiles, lead to improved economic outcomes, and will preserve the cultural heritage of the area by ensuring the persistence of the traditional semi nomadic grazing system.

5.2.7 Crocodile hunting along the lower Kunene River:

Given the dramatic decrease in the Nile crocodile population in the study area detailed in Chapter 3, it is advised that trophy hunting of crocodiles is prohibited for the short term. Hunting of crocodiles should be restricted to known problem crocodiles that have a history of attacking people or livestock. The stable population of crocodiles less than 2m in size suggests that a temporary ban on hunting combined with improved conservation measures will likely result in the recovery of the population of larger crocodiles. The recovery in numbers of larger crocodiles will ensure that breeding continues and that the benefits derived from trophy hunting are maximised in the long term as larger crocodiles are generally more sought after by trophy hunters. It is recommended that hunting crocodiles is halted until another survey of the crocodile population can be undertaken. In light of this, a third aerial survey is recommended for 2026 followed by subsequent surveys at 5-10 year intervals. These surveys will allow for a more accurate estimate of crocodile population trends along the river and consequently more sustainable decisions on crocodile hunting quotas. Although these recommendations will likely be met with resistance from stakeholders, they are made with the long-term sustainability of the crocodile population and associated benefits in mind. Importantly, these measures should be seen as temporary, with the aim of growing the crocodile population with the goal or re-establishing extractive use of the resource in the future. As mentioned above, problem crocodiles should still be actively translocated or exterminated to prevent further loss of human lives along the river. If these measures are not put in place, they will likely lead to disillusionment of community members and hunting outfitters in the area.

This list of suggested mitigation measures is by no means exhaustive and numerous novel methods would likely also be effective. Considering the results presented in this thesis, action is required from authorities, stakeholders, and members of the local communities. Failure to act in a timeous manner will likely lead to an increase in HCC, a decrease in the Nile crocodile population and the loss of unrealised benefits derived from crocodiles. Any measures taken to improve the relationship between humans and crocodiles should be implemented with extensive input from the local community. Failing to actively involve the community would likely lead to more negative interactions between humans and crocodiles and to the failure of the mitigation measures as a whole. Importantly, if conservationists and community members act quickly, there is the potential to preserve the crocodile population along the lower Kunene River while deriving social and economic benefits from the species. In this way, humans and crocodiles can coexist in the landscape in a way that promotes sustainable development and preserves both the cultural and natural heritage of the area.

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Appendices

6.1 Appendix 1: Questionnaire used to collect socio ecological data along the lower Kunene River

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Informed Voluntary Consent to Participate in Research Study

Project Title: The state of crocodiles on the Kunene River, Namibia: Population dynamics and socio-ecological interactions

Invitation to participate, and benefits: You are invited to participate in a research study conducted with community members living on the banks of the Kunene River. This study aims to explore both the ecological and social aspects of crocodiles and their interactions with humans on the lower Kunene River. The study aims to determine the state of crocodile populations on the lower Kunene River while simultaneously assessing the impacts of HCC on communities living on the banks of the Kunene River. The findings of this study will be used to recommend measures that can be taken to ensure the conservation of a healthy crocodile population while mitigating HCC. The study will aim to produce a master's thesis, one or more publishable scientific articles, as well as a species management plan for Nile crocodiles on the Kunene River for the Namibian Ministry of Environment Forestry and Tourism. I believe that your experience would be a valuable source of information.

Procedures: During this study, you will be asked to answer questions about the impacts of living alongside crocodiles, farm management and mitigating crocodile impacts on your livelihood.

Risks: There are no potentially harmful risks related to your participation in this study.

Feedback: You will receive feedback about the results of this research in the manner of a conservancy meeting at the end of the research.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Confidentiality and anonymity will be maintained as pseudonyms will be used.

What signing this form means: By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way.

I agree to participate in this research (tick one box) ☐ Yes ☐ No _________ (Initials)

________________________________ ___________________________________ ________

Name of Participant	Signature of Participant	Date
______________________________	_________________________________	________
Name of Researcher	Signature of Researcher	Date

This questionaire was developed using aspects of the of the questionaires developed by and with permission from Marina Tavolaro in her PhD thesis titled Understanding CBNRM in Namibia, Aust et al., 2009, and Wallace et al., 2011. Additional input was given by Simon Pooley.

Question posed to respondent	**Answers**
Section 1: Personal details	
1.1) Questionnaire ID	
1.2) Name	
1.3) Date	
1.4) Do you agree to participate in this research?	Yes No
1.5) Signature	
1.6) Location	
1.7) Sex	Female Male
1.8) Age	
1.9) How many people live in your household?	
1.10) Are you a conservancy member?	Yes No
Section 2: Livelihoods	
2.1) How many adults in your household earned money in the past year (from employment or sales)?	
2.2) How much money (on average) from wages, sales and government grants comes into your household each month? (N$)	
2.3) In the past year, did your household produce food?	a) for your own consumption only b) for your own consumption and to sell c) Only to sell it d) Do not produce any food
2.4) Does anyone in your household fish?	Yes No
2.5) How important is fish to your household?	a) Not important b) Neutral c) Somewhat important d) Very important
2.6) Why (fish)?	
2.7) Who fishes the most?	a) men b) women c) boys d) girls
2.8) How often do they fish?	a) Daily b) More than once a week

	c) Once a week d) Every month e) Less than once a month
2.9) How do they fish?	a) lines b) nets c) poison d) fish traps
2.10) Where do they fish from most of the time?	a) Bank b) Wading c) Canoe
2.11) Does anyone in your household own livestock?	Yes No
2.12) How important is livestock to your household?	a) Not important b) Neutral c) Somewhat important d) Very important
2.13) Why (Livestock)?	
2.14) What sort of livestock do you own?	a) Cattle b) Small stock (goats/sheep)
2.15) What was the largest number of cattle you had in 2021?	
2.16) Are your cattle?	a) Herded b) Alone c) Bit of both
2.17) Do your cattle drink at the river?	Yes No Sometimes
2.18) Do your cattle drink with a herder?	Yes No Sometimes
2.19) Who herds the cattle most of the time?	a) men b) women c) boys d) girls
2.20) How often do your cattle drink from the river?	a) More than once a day b) Daily c) More than once a week d) Weekly e) Don't know
2.21) Do your cattle drink at certain times?	a) Morning b) Midday c) Afternoon d) Don't know
2.22) Do your cattle drink from the same place?	Yes No Sometimes Don't know
2.23) What was the largest number of small stock (goats and sheep) you had in the past year?	
2.24) Are your small stock?	a) Herded b) Alone c) Bit of both
2.25) Do your small stock drink from the river?	Yes No Sometimes

2.26) Do your small stock drink with a herder?	Yes No Sometimes
2.27) Who herds the small stock most of the time?	a) men b) women c) boys d) girls
2.28) How often do your small stock drink from the river?	a) More than once a day b) Daily c) More than once a week d) Weekly e) Don't know
2.29) Do your small stock drink at certain times?	a) Morning b) Midday c) Afternoon d) Don't know
2.30) Do your small stock drink from the same place?	Yes No Sometimes Don't know
2.31) Does anyone in your household grow crops?	Yes No
2.32) How important is growing crops to your household?	a) Not important b) Neutral c) Somewhat important d) Very important
2.33) Why?	
2.34) Do you water your crops from the river?	Yes No Sometimes
2.35) Do you water your crops by hand or with a pump?	a) by hand b) with a pump c) both
2.36) Who fetches water from the river for watering the fields/gardens the most?	a) men b) women c) boys d) girls
Section 3: River and water usage	
3.1) Where does your household fetch your drinking water?	a) River b) Borehole c) Well d) Spring e) Home f) Other
3.2) Who fetches the water from the river the most?	a) men b) women c) boys d) girls
3.3) How often do they fetch water from the river?	a) More than once a day b) Daily c) More than once a week d) Weekly e) Don't know
3.4) At what time of day do they fetch water from the river?	a) Morning

	b) Midday c) Afternoon d) Don’t know
3.5) Do they fetch water from the river at the same place?	Yes No Sometimes
3.6) Where does your household fetch your water for washing your clothes??	a) River b) Borehole c) Well d) Spring e) Home f) Other
3.7) Who fetches water from the river for washing your clothes?	a) men b) women c) boys d) girls
3.8) How often do you fetch water from the river to wash clothes?	a) More than once a day b) Daily c) More than once a week d) Weekly e) Monthly
3.9) At what time of day do they fetch water from the river for washing clothes?	a) Morning b) Midday c) Afternoon d) Don’t know
3.10) Do they fetch water for the washing at the same place at the river?	Yes No Sometimes
3.11) Where do you get your water to bathe/swim?	a) River b) Borehole c) Well d) Spring e) Home f) Other
3.12) Who bathes/swims in the river the most?	a) men b) women c) boys d) girls
3.13) How often do they bathe/swim in the river?	a) More than once a day b) Daily c) More than once a week d) Weekly e) Monthly
3.14) At what time of day do they bathe/swim in the river?	a) Morning b) Midday c) Afternoon d) Don’t know
3.15) Do you bathe/swim at the river at the same place?	Yes No Sometimes
3.16) In total, who spends the most time at the river?	a) men b) women c) boys d) girls

3.17) What is closer, the river or an alternative water source?	River Alternative water source
3.18) What do you use more, the river or an alternative water source?	River Alternative water source
3.19) How often does your alternative water source break forcing you to use the river?	a) Never b) Sometimes c) Often
Section 4: Attitudes to wildlife	
4.1) Which wildlife does your household benefit from?	
4.2) Why (Wildlife benefits)?	
4.3) Which wildlife does your household not benefit from?	
4.4) Why (wildlife not benefit)?	
4.5) Do you think wildlife should be protected (not allowed to be hunted or killed)?	Yes No
4.6) Are you happy that you live with wildlife?	Yes No
4.7) Does living with wildlife benefit you and your household?	a) strongly disagree b) disagree c) neutral d) agree e) strongly agree
4.8) Does living in a conservancy benefit you and your household?	a) strongly disagree b) disagree c) neutral d) agree e) strongly agree
4.9) Would you be happier if there was no wildlife in your area?	a) strongly disagree b) disagree c) neutral d) agree e) strongly agree
Section 5: Attitudes to crocodiles	
5.1) Are there crocodiles living in the area?	Yes No
5.2) Since 2010, have crocodiles living in the area	a) increased b) stayed the same c) decreased d) don't know
5.3) Why (crocodile population trends)?	
5.4) Do you think crocodiles should be protected (Not allowed to be hunted or killed)?	Yes No
5.5) Are you happy that you live with crocodiles?	Yes No
5.6) Does living with crocodiles benefit you and your household?	a) strongly disagree b) disagree c) neutral d) agree e) strongly agree
5.7) Can you list some benefits of living with crocodiles for your household?	
5.8) Can you list some problems of living with crocodiles for your household?	

5.9) Are there spiritual/ traditional beliefs on crocodiles in your area?	Yes No
5.10) Describe these beliefs/give an example	
5.11) Are there traditional/spiritual uses for crocodiles or their body parts?	Yes No
5.12) Describe these uses/give an example	
5.13) Would you be happier if there were no crocodiles in your area?	a) strongly disagree b) disagree c) neutral d) agree e) strongly agree
5.14) If there was a way to make money from crocodiles, would you like crocodiles to remain in the area?	Yes No Don't know
5.15) Is it a good thing that crocodiles are on the hunting quota?	Yes No Don't know
5.16) Should more crocodiles be put on the hunting quota?	Yes No Don't know
Section 6: Crocodile attacks on livestock (Cattle)	
6.1) Since 2010, has crocodiles attacking livestock?	a) increased b) stayed the same c) decreased d) don't know
6.2) Why (Crocodile attack trends)?	
6.3) Did you lose any cattle in 2021?	Yes No
6.4) How many cattle did you lose to disease?	
6.5) How many cattle did you lose to drought?	
6.6) How many cattle did you lose to theft?	
6.7) How many cattle did you lose to wildlife?	
6.8) How many cattle did you lose to other?	
6.9) How many cattle did you lose to lion?	
6.10) How many cattle did you lose to leopard?	
6.11) How many cattle did you lose to cheetah?	
6.12) How many cattle did you lose to spotted hyena?	
6.13) How many cattle did you lose to wild dog?	
6.14) How many cattle did you lose to jackal?	
6.15) How many cattle did you lose to caracal?	
6.16) How many cattle did you lose to crocodile?	
6.17) Have you ever lost cattle to crocodiles at any time in the past?	Yes No
6.18) Regarding crocodile attacks on your cattle, which animals are attacked most?	a) young b) adults
6.19) Regarding crocodile attacks on your cattle, when were most of the attacks?	a) Morning b) Midday c) Afternoon d) Evening

	e) Don't know
6.20) Regarding crocodile attacks on your cattle, at what time of year did most of the attacks happen?	a) Summer b) Winter
6.21) Regarding crocodile attacks on your cattle, what were they doing when they were attacked	a) Drinking b) Grazing c) Grazing in the river d) Other e) Don't know
6.22) Regarding most of the crocodile attacks on your cattle, was there a herder with them when they were attacked?	Yes No
Section 7: Crocodile attacks on livestock (Small stock)	
7.1) Did you lose any small stock (sheep/goats) in 2021?	Yes No
7.2) How many small stock did you lose to disease?	
7.3) How many small stock did you lose to drought?	
7.4) How many small stock did you lose to theft?	
7.5) How many small stock did you lose to wildlife?	
7.6) How many small stock did you lose to other?	
7.7) How many small stock did you lose to lion?	
7.8) How many small stock did you lose to leopard?	
7.9) How many small stock did you lose to cheetah?	
7.10) How many small stock did you lose to spotted hyena?	
7.11) How many small stock did you lose to wild dog?	
7.12) How many small stock did you lose to jackal?	
7.13) How many small stock did you lose to caracal?	
7.14) How many small stock did you lose to crocodile?	
7.15) Have you ever lost small stock to crocodiles in the past?	Yes No
7.16) Regarding crocodile attacks on your small stock, which animals are attacked most?	a) young b) adults
7.17) Regarding crocodile attacks on your small stock, when were most of the attacks?	a) Morning b) Midday c) Afternoon d) Evening e) Don't know
7.18) Regarding crocodile attacks on your small stock, at what time of year did most of the attacks happen?	a) Summer b) Winter
7.19) Regarding crocodile attacks on your small stock, what were they doing when they were attacked?	a) Drinking b) Grazing c) Grazing in the river d) Other e) Don't know
7.20) Regarding most crocodile attacks on your small stock, was there a herder with them when they were attacked?	Yes No Don't know
7.21) Do you normally take action against the crocodile/s that attacked your livestock?	Yes No
7.22) What action do you take?	
7.23) By Whom?	
7.24) Why do you take this action?	

7.25) When last did you take any action following a crocodile attack?	
7.26) Did you receive any offset/compensation for the losses caused by crocodiles?	a) No because I did not report the killings b) No because the deaths could not be confirmed as wildlife related c) No still waiting d) Yes, I got offsets for the animal(s) killed e) Yes, but not for all of the animals killed
7.27) Do you think you will experience more crocodile attacks on your livestock in the future?	Yes No Don't know
Section 8: Crocodile attacks on Humans	
8.1) Since 2010, has crocodiles attacking humans:	a) increased b) stayed the same c) decreased e) don't know
8.2) Why (Human attack trends)?	
8.3) Has anyone in your household been attacked by a crocodile?	Yes No
8.4) How many?	
8.5) What was their name?	
8.6) What was their sex?	a) male b) female
8.7) What was their age?	
8.8) Where did the attack take place?	
8.9) When did the attack take place (Date)?	
8.10) What time of the day did the attack take place?	a) Morning b) Midday c) Afternoon d) Evening e) Don't know
8.11) What were they doing when they were attacked?	a) fetching water b) washing clothes c) bathing/swimming d) fishing e) herding f) other g) don't know
8.12) Severity of attack	a) Killed b) Injured (disability) c) Injured (minor) d) No injury e) Don't know
8.13) Any other details	
8.14) Was the attack reported?	Yes No Don't know
8.15) Was any action taken?	Yes No Don't know

8.16) By whom?	
8.17) Describe action taken	
8.18) Do you worry about crocodile attacks when members of your household go to the river?	Yes No
8.19) Do you know of anyone else who was attacked by a crocodile on the Kunene	Yes No
8.20) What was their name? (Someone else)	
8.21) What was their sex? (Someone else)	a) male b) female
8.22) What was their age? (Someone else)	
8.24) When did the attack take place (Date)? (Someone else)	
8.25) What time of the day did the attack take place? (Someone else)	a) Morning b) Midday c) Afternoon d) Evening e) Don't know
8.26) What were they doing when they were attacked? (Someone else)	a) fetching water b) washing clothes c) bathing/swimming d) fishing e) herding f) other g) don't know
8.27) Severity of attack (Someone else)	a) Killed b) Injured (disability) c) Injured (minor) d) No injury e) Don't know
8.28) Any other details (Someone else)	
Section 9: Killing crocodiles	
9.1) Are crocodiles ever killed in the area?	Yes No Don't know
9.2) Since 2010, has people killing crocodiles:	a) increased b) stayed the same c) decreased d) don't know
9.3) Did you hear about crocodiles that were killed in 2019/2020 (apparently, they found 20 carcasses)	Yes No
9.4) Why were they killed?	
9.5) By whom? (Crocodiles killed by humans)	
9.6) How were they killed?	a) shot b) poisoned c) other
9.7) When did this action take place?	
9.8) Describe the events	
Section 10: Solutions	
10.1) How can life be made safer living with crocodiles?	
10.2) Who do you think should be responsible for making living safer in this area:	a) Government b) MEFT

		c) Conservancy d) Household e) Community f) Traditional authority g) Don't know

Thank you very much for your participation in this survey. We shall return next year to report back on our work at a conservancy meeting. Please contact me at zanleroux@gmail.com if you have any questions.

6.2 Appendix 2: All data gathered during the social survey of the lower Kunene River, open ended questions, as well as questions containing sensitive information are not displayed in this table.

Question posed to respondent	**Number of respondents, respondents who answered question, respondents who abstained, and number of responses.**	**Results**	**Proportion of number of respondents who answered question (%)**
1.1) Questionnaire ID	Sensitive data		
1.2) Name	Sensitive data		
1.3) Date	Open ended question		
1.4) Do you agree to participate in this research?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 155 No = 0	Yes = 100 No = 0
1.5) Signature	Sensitive data		
1.6) Location	Sensitive data		
1.7) Sex	Respondents = 155 Respondents who answered question = 153 Respondents who abstained = 2 Number of responses = 153	Female = 62 Male = 91	Female = 41 Male = 59
1.8) Age	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Mean = 43 Max = 78 Min = 19 SD = 15	
1.9) How many people live in your household?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Mean = 10 Max = 52 Min = 1 SD = 8 Total = 1584	
1.10) Are you a conservancy member?	Respondents = 155 Respondents who answered question = 154	Yes = 66 No = 88	Yes = 43 No = 57

	Respondents who abstained = 1 Number of responses = 154		
2.1) How many adults in your household earned money in the past year (from employment or sales)?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Mean = 1 Max = 5 Min = 0 SD = 1 Total = 199	
2.2) How much money (on average) from wages, sales and government grants comes into your household each month? (N$)	Respondents = 155 Respondents who answered question = 151 Respondents who abstained = 4 Number of responses = 151	Mean = 1678 Max = 25000 Min = 0 SD = 2614 Total = 253350	
2.3) In the past year, did your household produce food?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	a) for your own consumption only = 96 b) for your own consumption and to sell = 46 c) Only to sell it = 1 d) Do not produce any food = 12	a) for your own consumption only = 62 b) for your own consumption and to sell = 30 c) Only to sell it = 1 d) Do not produce any food = 8
2.4) Does anyone in your household fish?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Yes = 74 No = 80	Yes = 48 No = 52
2.5) How important is fish to your household?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	a) Not important = 21 b) Neutral = 0 c) Somewhat important = 68 d) Very important = 65	a) Not important = 14 b) Neutral = 0 c) Somewhat important = 44 d) Very important = 42
2.6) Why (fish)?	Open ended question		
2.7) Who fishes the most?	Respondents = 74 (Only those respondents who answered "Yes" to question 2.4) Respondents who answered question = 73 Respondents who abstained = 1 Number of responses = 83 (some respondents gave multiple answers)	a) men = 37 b) women = 26 c) boys = 14 d) girls = 6	a) men = 51 b) women = 36 c) boys = 19 d) girls = 8
2.8) How often do they fish?	Respondents = 74 (Only those respondents who answered "Yes" to question 2.4) Respondents who answered question = 72 Respondents who abstained = 2 Number of responses = 72	a) Daily = 23 b) More than once a week = 13 c) Once a week = 20 d) Every month = 12 e) Less than once a month = 4	a) Daily = 32 b) More than once a week = 18 c) Once a week = 28 d) Every month = 17 e) Less than once a month = 6
2.9) How do they fish?	Respondents = 74 (Only those respondents who answered "Yes" to question 2.4)	a) lines = 64 b) nets = 13 c) poison = 0 d) fish traps = 4	a) lines = 88 b) nets = 18 c) poison = 0 d) fish traps = 5

	Respondents who answered question = 73 Respondents who abstained = 1 Number of responses = 81 (some respondents gave multiple answers)		
2.10) Where do they fish from most of the time?	Respondents = 74 (Only those respondents who answered "Yes" to question 2.4) Respondents who answered question = 73 Respondents who abstained = 1 Number of responses = 82 (some respondents gave multiple answers)	a) Bank = 65 b) Wading = 11 c) Canoe = 6	a) Bank = 89 b) Wading = 15 c) Canoe = 8
2.11) Does anyone in your household own livestock?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 113 No = 42	Yes = 73 No = 27
2.12) How important is livestock to your household?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	a) Not important = 3 b) Neutral = 0 c) Somewhat important = 25 d) Very important = 126	a) Not important = 2 b) Neutral = 0 c) Somewhat important = 16 d) Very important = 82
2.13) Why (Livestock)?	Open ended question		
2.14) What sort of livestock do you own?	Respondents = 113 (Only those respondents who answered "Yes" to question 2.11) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 157 (some respondents gave multiple answers)	a) Cattle = 44 b) Small stock (goats/sheep) = 113	a) Cattle = 39 b) Small stock (goats/sheep) = 100
2.15) What was the largest number of cattle you had in 2021?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 23 Max = 160 Min = 3 SD = 32 Total = 998	
2.16) Are your cattle?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	a) Herded = 13 b) Alone = 28 c) Bit of both = 3	a) Herded = 30 b) Alone = 64 c) Bit of both = 7
2.17) Do your cattle drink at the river?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14)	Yes = 35 No = 5 Sometimes = 4	Yes = 80 No = 11 Sometimes = 9

	Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44		
2.18) Do your cattle drink with a herder?	Respondents = 39 (Only those respondents who answered "Yes or Sometimes" to question 2.17) Respondents who answered question = 39 Respondents who abstained = 0 Number of responses = 39	Yes = 17 No = 19 Sometimes = 3	Yes = 44 No = 49 Sometimes = 8
2.19) Who herds the cattle most of the time?	Respondents = 20 (Only those respondents who answered "Yes or Sometimes" to question 2.18) Respondents who answered question = 20 Respondents who abstained = 0 Number of responses = 21 (some respondents gave multiple answers)	a) men = 17 b) women = 1 c) boys = 3 d) girls = 0	a) men = 85 b) women = 5 c) boys = 15 d) girls = 0
2.20) How often do your cattle drink from the river?	Respondents = 39 (Only those respondents who answered "Yes or Sometimes" to question 2.17) Respondents who answered question = 39 Respondents who abstained = 0 Number of responses = 39	a) More than once a day = 18 b) Daily = 16 c) More than once a week = 1 d) Weekly = 1 e) Don't know = 3	a) More than once a day = 46 b) Daily = 41 c) More than once a week = 3 d) Weekly = 3 e) Don't know = 8
2.21) Do your cattle drink at certain times?	Respondents = 39 (Only those respondents who answered "Yes or Sometimes" to question 2.17) Respondents who answered question = 39 Respondents who abstained = 0 Number of responses = 71 (some respondents gave multiple answers)	a) Morning = 23 b) Midday = 13 c) Afternoon = 31 d) Don't know = 4	a) Morning = 59 b) Midday = 33 c) Afternoon = 79 d) Don't know = 10
2.22) Do your cattle drink from the same place?	Respondents = 39 (Only those respondents who answered "Yes or Sometimes" to question 2.17) Respondents who answered question = 39 Respondents who abstained = 0 Number of responses = 39	Yes = 15 No = 19 Sometimes = 1 Don't know = 4	Yes = 38 No = 49 Sometimes = 3 Don't know = 10
2.23) What was the largest number of small stock (goats and sheep) you had in the past year?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0	Mean = 77 Max = 400 Min = 5 SD = 86 Total = 8726	

	Number of responses = 113		
2.24) Are your small stock?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	a) Herded = 103 b) Alone = 5 c) Bit of both = 5	a) Herded = 91 b) Alone = 4 c) Bit of both = 4
2.25) Do your small stock drink from the river?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Yes = 89 No = 13 Sometimes = 11	Yes = 79 No = 12 Sometimes = 10
2.26) Do your small stock drink with a herder?	Respondents = 100 (Only those respondents who answered “Yes or Sometimes” to question 2.25) Respondents who answered question = 100 Respondents who abstained = 0 Number of responses = 100	Yes = 85 No = 7 Sometimes = 8	Yes = 85 No = 7 Sometimes = 8
2.27) Who herds the small stock most of the time?	Respondents = 93 (Only those respondents who answered “Yes or Sometimes” to question 2.26) Respondents who answered question = 93 Respondents who abstained = 0 Number of responses = 111 (some respondents gave multiple answers)	a) men = 16 b) women = 3 c) boys = 68 d) girls = 24	a) men = 17 b) women = 3 c) boys = 73 d) girls = 26
2.28) How often do your small stock drink from the river?	Respondents = 100 (Only those respondents who answered “Yes or Sometimes” to question 2.25) Respondents who answered question = 100 Respondents who abstained = 0 Number of responses = 100	a) More than once a day = 34 b) Daily = 62 c) More than once a week = 1 d) Weekly = 1 e) Don’t know = 2	a) More than once a day = 34 b) Daily = 62 c) More than once a week = 1 d) Weekly = 1 e) Don’t know = 2
2.29) Do your small stock drink at certain times?	Respondents = 100 (Only those respondents who answered “Yes or Sometimes” to question 2.25) Respondents who answered question = 100 Respondents who abstained = 0 Number of responses = 129 (some respondents gave multiple answers)	a) Morning = 26 b) Midday = 13 c) Afternoon = 87 d) Don’t know = 3	a) Morning = 26 b) Midday = 13 c) Afternoon = 87 d) Don’t know = 3

2.30) Do your small stock drink from the same place?	Respondents = 100 (Only those respondents who answered "Yes or Sometimes" to question 2.25) Respondents who answered question = 100 Respondents who abstained = 0 Number of responses = 100	Yes = 60 No = 31 Sometimes = 6 Don't know = 3	Yes = 60 No = 31 Sometimes = 6 Don't know = 3
2.31) Does anyone in your household grow crops?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 130 No = 25	Yes = 84 No = 16
2.32) How important is growing crops to your household?	Respondents = 155 Respondents who answered question = 153 Respondents who abstained = 2 Number of responses = 153	a) Not important = 8 b) Neutral = 0 c) Somewhat important = 46 d) Very important = 99	a) Not important = 5 b) Neutral = 0 c) Somewhat important = 30 d) Very important = 65
2.33) Why?	Open ended question		
2.34) Do you water your crops from the river?	Respondents = 130 (Only those respondents who answered "Yes" to question 2.31) Respondents who answered question = 130 Respondents who abstained = 0 Number of responses = 130	Yes = 46 No = 80 Sometimes = 4	Yes = 35 No = 62 Sometimes = 3
2.35) Do you water your crops by hand or with a pump?	Respondents = 50 (Only those respondents who answered "Yes" or "Sometimes" to question 2.34) Respondents who answered question = 50 Respondents who abstained = 0 Number of responses = 50	a) by hand = 22 b) with a pump = 26 c) both = 2	a) by hand = 44 b) with a pump = 52 c) both = 4
2.36) Who fetches water from the river for watering the fields/gardens the most?	Respondents = 24 (Only those respondents who answered "a) by hand" or "c) both" to question 2.35) Respondents who answered question = 23 Respondents who abstained = 1 Number of responses = 29 (some respondents gave multiple answers)	a) men = 13 b) women = 15 c) boys = 0 d) girls = 1	a) men = 57 b) women = 65 c) boys = 0 d) girls = 4
3.1) Where does your household fetch your drinking water?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 157 (some respondents gave multiple answers)	a) River = 116 b) Borehole = 7 c) Well = 0 d) Spring = 10 e) Home = 22 f) Other = 2	a) River = 75 b) Borehole = 5 c) Well = 0 d) Spring = 6 e) Home = 14 f) Other = 1
3.2) Who fetches the water from the river the most?	Respondents = 116 (Only those respondents who answered "a) River" to question 3.1)	a) men = 25 b) women = 88 c) boys = 7	a) men = 22 b) women = 77 c) boys = 6

	Respondents who answered question = 115 Respondents who abstained = 1 Number of responses = 126 (some respondents gave multiple answers)	d) girls = 6	d) girls = 5
3.3) How often do they fetch water from the river?	Respondents = 116 (Only those respondents who answered “a) River” to question 3.1) Respondents who answered question = 115 Respondents who abstained = 1 Number of responses = 115	a) More than once a day = 93 b) Daily = 17 c) More than once a week = 5 d) Weekly = 0 e) Don’t know = 0	a) More than once a day = 81 b) Daily = 15 c) More than once a week = 4 d) Weekly = 0 e) Don’t know = 0
3.4) At what time of day do they fetch water from the river?	Respondents = 116 (Only those respondents who answered “a) River” to question 3.1) Respondents who answered question = 115 Respondents who abstained = 1 Number of responses = 259 (some respondents gave multiple answers)	a) Morning = 112 b) Midday = 51 c) Afternoon = 96 d) Don’t know = 0	a) Morning = 97 b) Midday = 44 c) Afternoon = 83 d) Don’t know = 0
3.5) Do they fetch water from the river at the same place?	Respondents = 116 (Only those respondents who answered “a) River” to question 3.1) Respondents who answered question = 115 Respondents who abstained = 1 Number of responses = 115	Yes = 96 No = 19 Sometimes = 0	Yes = 83 No = 17 Sometimes = 0
3.6) Where does your household fetch your water for washing your clothes??	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 156 (some respondents gave multiple answers)	a) River = 119 b) Borehole = 7 c) Well = 0 d) Spring = 11 e) Home = 19 f) Other = 0	a) River = 77 b) Borehole = 5 c) Well = 0 d) Spring = 7 e) Home = 12 f) Other = 0
3.7) Who fetches water from the river for washing your clothes?	Respondents = 119 (Only those respondents who answered “a) River” to question 3.6) Respondents who answered question = 119 Respondents who abstained = 0 Number of responses = 154 (some respondents gave multiple answers)	a) men = 28 b) women = 99 c) boys = 14 d) girls = 13	a) men = 24 b) women = 83 c) boys = 12 d) girls = 11
3.8) How often do you fetch water from the river to wash clothes?	Respondents = 119 (Only those respondents who answered “a) River” to question 3.6) Respondents who answered question = 119 Respondents who abstained = 0 Number of responses = 119	a) More than once a day = 2 b) Daily = 4 c) More than once a week = 28 d) Weekly = 63 e) Monthly = 22	a) More than once a day = 2 b) Daily = 3 c) More than once a week = 24 d) Weekly = 53 e) Monthly = 18
3.9) At what time of day do they fetch water from	Respondents = 119 (Only those respondents who answered “a) River” to question 3.6)	a) Morning = 78 b) Midday = 3 c) Afternoon = 44	a) Morning = 66 b) Midday = 3 c) Afternoon = 37

the river for washing clothes?	Respondents who answered question = 119 Respondents who abstained = 0 Number of responses = 125 (some respondents gave multiple answers)	d) Don't know = 0	d) Don't know = 0
3.10) Do they fetch water for the washing at the same place at the river?	Respondents = 119 (Only those respondents who answered "a) River" to question 3.6) Respondents who answered question = 119 Respondents who abstained = 0 Number of responses = 119	Yes = 99 No = 20 Sometimes = 0	Yes = 83 No = 17 Sometimes = 0
3.11) Where do you get your water to bathe/swim?	Respondents = 151 Respondents who answered question = 151 Respondents who abstained = 4 Number of responses = 151	a) River = 114 b) Borehole = 5 c) Well = 0 d) Spring = 10 e) Home = 20 f) Other = 2	a) River = 75 b) Borehole = 3 c) Well = 0 d) Spring = 7 e) Home = 13 f) Other = 1
3.12) Who bathes/swims in the river the most?	Respondents = 114 (Only those respondents who answered "a) River" to question 3.11) Respondents who answered question = 114 Respondents who abstained = 0 Number of responses = 140 (some respondents gave multiple answers)	a) men = 55 b) women = 59 c) boys = 15 d) girls = 11	a) men = 48 b) women = 52 c) boys = 13 d) girls = 10
3.13) How often do they bathe/swim in the river?	Respondents = 114 (Only those respondents who answered "a) River" to question 3.11) Respondents who answered question = 114 Respondents who abstained = 0 Number of responses = 114	a) More than once a day = 59 b) Daily = 40 c) More than once a week = 14 d) Weekly = 1 e) Monthly = 0	a) More than once a day = 52 b) Daily = 35 c) More than once a week = 12 d) Weekly = 1 e) Monthly = 0
3.14) At what time of day do they bathe/swim in the river?	Respondents = 114 (Only those respondents who answered "a) River" to question 3.11) Respondents who answered question = 114 Respondents who abstained = 0 Number of responses = 182 (some respondents gave multiple answers)	a) Morning = 64 b) Midday = 20 c) Afternoon = 98 d) Don't know = 0	a) Morning = 56 b) Midday = 18 c) Afternoon = 86 d) Don't know = 0
3.15) Do you bathe/swim at the river at the same place?	Respondents = 114 (Only those respondents who answered "a) River" to question 3.11) Respondents who answered question = 114 Respondents who abstained = 0 Number of responses = 114	Yes = 93 No = 21 Sometimes = 0	Yes = 82 No = 18 Sometimes = 0
3.16) In total, who spends the most time at the river?	Respondents = 155 Respondents who answered question = 147 Respondents who abstained = 8	a) men = 57 b) women = 56 c) boys = 25 d) girls = 9	a) men = 39 b) women = 38 c) boys = 17 d) girls = 6

	Number of responses = 147		
3.17) What is closer, the river or an alternative water source?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	River = 114 Alternative water source = 40	River = 74 Alternative water source = 26
3.18) What do you use more, the river or an alternative water source?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	River = 121 Alternative water source = 33	River = 79 Alternative water source = 21
3.19) How often does your alternative water source break forcing you to use the river?	Respondents = 40 (Only those respondents who answered "Alternative water source" to question 3.17) Respondents who answered question = 38 Respondents who abstained = 2 Number of responses = 38	a) Never = 11 b) Sometimes = 21 c) Often = 6	a) Never = 29 b) Sometimes = 55 c) Often = 16
4.1) Which wildlife does your household benefit from?	Open ended question		
4.2) Why (Wildlife benefits)?	Open ended question		
4.3) Which wildlife does your household not benefit from?	Open ended question		
4.4) Why (wildlife not benefit)?	Open ended question		
4.5) Do you think wildlife should be protected (not allowed to be hunted or killed)?	Respondents = 155 Respondents who answered question = 150 Respondents who abstained = 5 Number of responses = 155	Yes = 114 No = 36	Yes = 76 No = 24
4.6) Are you happy that you live with wildlife?	Respondents = 155 Respondents who answered question = 152 Respondents who abstained = 3 Number of responses = 152	Yes = 118 No = 34	Yes = 78 No = 22
4.7) Does living with wildlife benefit you and your household?	Respondents = 155 Respondents who answered question = 152 Respondents who abstained = 3 Number of responses = 152	a) strongly disagree = 0 b) disagree = 116 c) neutral = 3 d) agree = 33 e) strongly agree = 0	a) strongly disagree = 0 b) disagree = 76 c) neutral = 2 d) agree = 22 e) strongly agree = 0
4.8) Does living in a conservancy benefit you and your household?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	a) strongly disagree = 0 b) disagree = 135 c) neutral = 0 d) agree = 19 e) strongly agree = 0	a) strongly disagree = 0 b) disagree = 88 c) neutral = 0 d) agree = 12 e) strongly agree = 0
4.9) Would you be happier if there was no wildlife in your area?	Respondents = 155 Respondents who answered question = 153	a) strongly disagree = 0 b) disagree = 115 c) neutral = 7	a) strongly disagree = 0 b) disagree = 75

	Respondents who abstained = 2 Number of responses = 153	d) agree = 31 e) strongly agree = 0	c) neutral = 5 d) agree = 20 e) strongly agree = 0
5.1) Are there crocodiles living in the area?	Respondents = 155 Respondents who answered question = 153 Respondents who abstained = 2 Number of responses = 153	Yes = 153 No = 0	Yes = 100 No = 0
5.2) Since 2010, have crocodiles living in the area	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	a) increased = 105 b) stayed the same = 12 c) decreased = 11 d) don't know = 27	a) increased = 68 b) stayed the same = 8 c) decreased = 7 d) don't know = 17
5.3) Why (crocodile population trends)?	Open ended question		
5.4) Do you think crocodiles should be protected (Not allowed to be hunted or killed)?	Respondents = 155 Respondents who answered question = 154 Respondents who abstained = 1 Number of responses = 154	Yes = 68 No = 86	Yes = 44 No = 56
5.5) Are you happy that you live with crocodiles?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 60 No = 95	Yes = 39 No = 61
5.6) Does living with crocodiles benefit you and your household?	Respondents = 155 Respondents who answered question = 152 Respondents who abstained = 3 Number of responses = 152	a) strongly disagree = 0 b) disagree = 131 c) neutral = 2 d) agree = 19 e) strongly agree = 0	a) strongly disagree = 0 b) disagree = 86 c) neutral = 1 d) agree = 13 e) strongly agree = 0
5.7) Can you list some benefits of living with crocodiles for your household?	Open ended question		
5.8) Can you list some problems of living with crocodiles for your household?	Open ended question		
5.9) Are there spiritual/ traditional beliefs on crocodiles in your area?	Respondents = 155 Respondents who answered question = 153 Respondents who abstained = 2 Number of responses = 153	Yes = 12 No = 141	Yes = 8 No = 92
5.10) Describe these beliefs/give an example	Open ended question		
5.11) Are there traditional/spiritual uses for crocodiles or their body parts?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 31 No = 124	Yes = 20 No = 80
5.12) Describe these uses/give an example	Open ended question		

5.13) Would you be happier if there were no crocodiles in your area?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	a) strongly disagree = 0 b) disagree = 46 c) neutral = 2 d) agree = 107 e) strongly agree = 0	a) strongly disagree = 0 b) disagree = 30 c) neutral = 1 d) agree = 69 e) strongly agree = 0
5.14) If there was a way to make money from crocodiles, would you like crocodiles to remain in the area?	Respondents = 155 Respondents who answered question = 131 Respondents who abstained = 24 Number of responses = 131	Yes = 69 No = 56 Don't know = 6	Yes = 53 No = 43 Don't know = 5
5.15) Is it a good thing that crocodiles are on the hunting quota?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 116 No = 34 Don't know = 5	Yes = 75 No = 22 Don't know = 3
5.16) Should more crocodiles be put on the hunting quota?	Respondents = 155 Respondents who answered question = 152 Respondents who abstained = 3 Number of responses = 152	Yes = 93 No = 53 Don't know = 6	Yes = 61 No = 35 Don't know = 4
6.1) Since 2010, has crocodiles attacking livestock?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	a) increased = 116 b) stayed the same = 19 c) decreased = 15 d) don't know = 5	a) increased = 75 b) stayed the same = 12 c) decreased = 10 d) don't know = 3
6.2) Why (Crocodile attack trends)?	Open ended question		
6.3) Did you lose any cattle in 2021?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Yes = 37 No = 7	Yes = 84 No = 16
6.4) How many cattle did you lose to disease?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = <0 Max = 2 Min = 0 SD = <0 Total = 5	
6.5) How many cattle did you lose to drought?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 6 Max = 55 Min = 0 SD = 9 Total = 245	0
6.6) How many cattle did you lose to theft?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0

	Respondents who abstained = 0 Number of responses = 44		
6.7) How many cattle did you lose to wildlife?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 2 Max = 14 Min = 0 SD = 3 Total = 84	0
6.8) How many cattle did you lose to other?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.9) How many cattle did you lose to lion?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.10) How many cattle did you lose to leopard?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = <0 Max = 1 Min = 0 SD = <0 Total = 1	0
6.11) How many cattle did you lose to cheetah?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.12) How many cattle did you lose to spotted hyena?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.13) How many cattle did you lose to wild dog?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.14) How many cattle did you lose to jackal?	Respondents = 44 (Only those respondents who answered "a) Cattle" to question 2.14)	Mean = 0 Max = 0 Min = 0 SD = 0	0

	Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Total = 0	
6.15) How many cattle did you lose to caracal?	Respondents = 44 (Only those respondents who answered “a) Cattle” to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
6.16) How many cattle did you lose to crocodile?	Respondents = 44 (Only those respondents who answered “a) Cattle” to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Mean = 2 Max = 14 Min = 0 SD = 3 Total = 87	0
6.17) Have you ever lost cattle to crocodiles at any time in the past?	Respondents = 44 (Only those respondents who answered “a) Cattle” to question 2.14) Respondents who answered question = 44 Respondents who abstained = 0 Number of responses = 44	Yes = 37 No = 7	Yes = 84 No = 16
6.18) Regarding crocodile attacks on your cattle, which animals are attacked most?	Respondents = 37 (Only those respondents who answered “yes” to question 6.17) Respondents who answered question = 37 Respondents who abstained = 0 Number of responses = 40 (some respondents gave multiple answers)	a) young = 10 b) adults = 30	a) young = 27 b) adults = 81
6.19) Regarding crocodile attacks on your cattle, when were most of the attacks?	Respondents = 37 (Only those respondents who answered “yes” to question 6.17) Respondents who answered question = 37 Respondents who abstained = 0 Number of responses = 41 (some respondents gave multiple answers)	a) Morning = 7 b) Midday = 3 c) Afternoon = 26 d) Evening = 1 e) Don’t know = 4	a) Morning = 19 b) Midday = 8 c) Afternoon = 70 d) Evening = 3 e) Don’t know = 11
6.20) Regarding crocodile attacks on your cattle, at what time of year did most of the attacks happen?	Respondents = 37 (Only those respondents who answered “yes” to question 6.17) Respondents who answered question = 37 Respondents who abstained = 0 Number of responses = 37	a) Summer = 5 b) Winter = 32	a) Summer = 14 b) Winter = 86
6.21) Regarding crocodile attacks on your cattle, what were they doing when they were attacked	Respondents = 37 (Only those respondents who answered “yes” to question 6.17) Respondents who answered question = 37	a) Drinking = 15 b) Grazing = 12 c) Grazing in the river = 5 d) Other = 1 e) Don’t know = 6	a) Drinking = 41 b) Grazing = 32 c) Grazing in the river = 14 d) Other = 3

	Respondents who abstained = 0 Number of responses = 39 (some respondents gave multiple answers)		e) Don't know = 16
6.22) Regarding most of the crocodile attacks on your cattle, was there a herder with them when they were attacked?	Respondents = 37 (Only those respondents who answered "yes" to question 6.17) Respondents who answered question = 37 Respondents who abstained = 0 Number of responses = 37	Yes = 11 No = 26	Yes = 30 No = 70
7.1) Did you lose any small stock (sheep/goats) in 2021?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Yes = 108 No = 5	Yes = 96 No = 4
7.2) How many small stock did you lose to disease?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 2 Max = 30 Min = 0 SD = 5 Total = 210	0
7.3) How many small stock did you lose to drought?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 7 Max = 200 Min = 0 SD = 24 Total = 809	0
7.4) How many small stock did you lose to theft?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = <0 Max = 5 Min = 0 SD = 1 Total = 7	0
7.5) How many small stock did you lose to wildlife?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 10 Max = 60 Min = 0 SD = 10 Total = 1143	0
7.6) How many small stock did you lose to other?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14)	Mean = 0 Max = 0 Min = 0 SD = 0	0

	Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Total = 0	
7.7) How many small stock did you lose to lion?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
7.8) How many small stock did you lose to leopard?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 1 Max = 15 Min = 0 SD = 2 Total = 66	0
7.9) How many small stock did you lose to cheetah?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = <0 Max = 30 Min = 0 SD = 3 Total = 49	0
7.10) How many small stock did you lose to spotted hyena?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
7.11) How many small stock did you lose to wild dog?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 0 Max = 0 Min = 0 SD = 0 Total = 0	0
7.12) How many small stock did you lose to jackal?	Respondents = 113 (Only those respondents who answered “b) Small stock (goats/sheep)” to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 0 Max = 5 Min = 0 SD = 1 Total = 8	0
7.13) How many small stock did you lose to caracal?	Respondents = 113 (Only those respondents who answered “b)	Mean = 1 Max = 15 Min = 0	0

	Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	SD = 2 Total = 103	
7.14) How many small stock did you lose to crocodile?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Mean = 9 Max = 55 Min = 0 SD = 9 Total = 971	0
7.15) Have you ever lost small stock to crocodiles in the past?	Respondents = 113 (Only those respondents who answered "b) Small stock (goats/sheep)" to question 2.14) Respondents who answered question = 113 Respondents who abstained = 0 Number of responses = 113	Yes = 105 No = 8	Yes = 93 No = 7
7.16) Regarding crocodile attacks on your small stock, which animals are attacked most?	Respondents = 105 (Only those respondents who answered "yes" to question 7.15) Respondents who answered question = 105 Respondents who abstained = 0 Number of responses = 109 (some respondents gave multiple answers)	a) young = 17 b) adults = 84	a) young = 20 b) adults = 84
7.17) Regarding crocodile attacks on your small stock, when were most of the attacks?	Respondents = 105 (Only those respondents who answered "yes" to question 7.15) Respondents who answered question = 102 Respondents who abstained = 3 Number of responses = 125 (some respondents gave multiple answers)	a) Morning = 11 b) Midday = 6 c) Afternoon = 92 d) Evening = 16 e) Don't know = 0	a) Morning = 11 b) Midday = 6 c) Afternoon = 90 d) Evening = 16 e) Don't know = 0
7.18) Regarding crocodile attacks on your small stock, at what time of year did most of the attacks happen?	Respondents = 105 (Only those respondents who answered "yes" to question 7.15) Respondents who answered question = 105 Respondents who abstained = 0 Number of responses = 106 (some respondents gave multiple answers)	a) Summer = 7 b) Winter = 99	a) Summer = 7 b) Winter = 94
7.19) Regarding crocodile attacks on your small stock, what were they doing when they were attacked?	Respondents = 105 (Only those respondents who answered "yes" to question 7.15) Respondents who answered question = 102 Respondents who abstained = 3	a) Drinking = 66 b) Grazing = 34 c) Grazing in the river = 4 d) Other = 0 e) Don't know = 0	a) Drinking = 65 b) Grazing = 33 c) Grazing in the river = 4 d) Other = 0 e) Don't know = 0

	Number of responses = 104 (some respondents gave multiple answers)		
7.20) Regarding most crocodile attacks on your small stock, was there a herder with them when they were attacked?	Respondents = 105 (Only those respondents who answered "yes" to question 7.15) Respondents who answered question = 105 Respondents who abstained = 0 Number of responses = 105	Yes = 63 No = 40 Don't know = 2	Yes = 60 No = 38 Don't know = 2
7.21) Do you normally take action against the crocodile/s that attacked your livestock?	Respondents = 113 (Only those respondents who answered "Yes" to question 2.11) Respondents who answered question = 108 Respondents who abstained = 5 Number of responses = 108	Yes = 44 No = 64	Yes = 41 No = 59
7.22) What action do you take?	Open ended question		
7.23) By Whom?	Open ended question		
7.24) Why do you take this action?	Open ended question		
7.25) When last did you take any action following a crocodile attack?	Open ended question		
7.26) Did you receive any offset/compensation for the losses caused by crocodiles?	Respondents = 113 (Only those respondents who answered "Yes" to question 2.11) Respondents who answered question = 101 Respondents who abstained = 12 Number of responses = 102 (some respondents gave multiple answers)	a) No because I did not report the killings = 49 b) No because the deaths could not be confirmed as wildlife related = 2 c) No still waiting = 47 d) Yes, I got offsets for the animal(s) killed = 3 e) Yes, but not for all of the animals killed = 1	a) No because I did not report the killings = 49 b) No because the deaths could not be confirmed as wildlife related = 2 c) No still waiting = 47 d) Yes I got offsets for the animal(s) killed = 3 e) Yes but not for all of the animals killed = 1
7.27) Do you think you will experience more crocodile attacks on your livestock in the future?	Respondents = 113 (Only those respondents who answered "Yes" to question 2.11) Respondents who answered question = 101 Respondents who abstained = 12 Number of responses = 101	Yes = 101 No = 3 Don't know = 2	Yes = 95 No = 3 Don't know = 2
8.1) Since 2010, has crocodiles attacking humans:	Respondents = 155 Respondents who answered question = 148 Respondents who abstained = 7 Number of responses = 148	a) increased = 84 b) stayed the same = 38 c) decreased = 26 e) don't know = 0	a) increased = 57 b) stayed the same = 26 c) decreased = 18 e) don't know = 0

8.2) Why (Human attack trends)?	Open ended question		
8.3) Has anyone in your household been attacked by a crocodile?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 45 No = 110	Yes = 29 No = 71
8.4) How many?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 43 Respondents who abstained = 2 Number of responses = 43	Mean = 1 Max = 2 Min = 1 SD = <0 Total = 48	0
8.5) What was their name?	Sensitive data		
8.6) What was their sex?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 35 Respondents who abstained = 10 Number of responses = 35	a) male = 27 b) female = 8	a) male = 77 b) female = 23
8.7) What was their age?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 32 Respondents who abstained = 13 Number of responses = 32	Mean = 30 Max = 65 Min = 3 SD = 21 Total = 949	0
8.8) Where did the attack take place?	Open ended question		
8.9) When did the attack take place (Date)?	Open ended question		
8.10) What time of the day did the attack take place?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 43 Respondents who abstained = 2 Number of responses = 47 (Some respondents gave multiple answers)	a) Morning = 8 b) Midday = 4 c) Afternoon = 18 d) Evening = 7 e) Don't know = 10	a) Morning = 19 b) Midday = 9 c) Afternoon = 42 d) Evening = 16 e) Don't know = 23
8.11) What were they doing when they were attacked?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 43 Respondents who abstained = 2 Number of responses = 44 (Some respondents gave multiple answers)	a) fetching water = 10 b) washing clothes = 0 c) bathing/swimming = 7 d) fishing = 9 e) herding = 2 f) other = 4 g) don't know = 12	a) fetching water = 23 b) washing clothes = 0 c) bathing/swimming = 16 d) fishing = 21 e) herding = 5 f) other = 9 g) don't know = 28

8.12) Severity of attack	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 43 Respondents who abstained = 2 Number of responses = 43	a) Killed = 16 b) Injured (disability) = 8 c) Injured (minor) = 8 d) No injury = 2 e) Don't know = 9	a) Killed = 37 b) Injured (disability) = 19 c) Injured (minor) = 19 d) No injury = 5 e) Don't know = 21
8.13) Any other details	Open ended question		
8.14) Was the attack reported?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 42 Respondents who abstained = 3 Number of responses = 42	Yes = 21 No = 10 Don't know = 11	Yes = 50 No = 24 Don't know = 26
8.15) Was any action taken?	Respondents = 45 (Only those respondents who answered "Yes" to question 8.3) Respondents who answered question = 43 Respondents who abstained = 2 Number of responses = 43	Yes = 4 No = 16 Don't know = 22	Yes = 10 No = 38 Don't know = 52
8.16) By whom?	Open ended question		
8.17) Describe action taken	Open ended question		
8.18) Do you worry about crocodile attacks when members of your household go to the river?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 148 No = 7	Yes = 95 No = 5
8.19) Do you know of anyone else who was attacked by a crocodile on the Kunene	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 145 No = 10	Yes = 94 No = 6
8.20) What was their name? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.21) What was their sex? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.22) What was their age? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.24) When did the attack take place (Date)? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.25) What time of the day did the attack take place? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding		

	information about other attack victims and how we could obtain more detailed information about the attacks.		
8.26) What were they doing when they were attacked? (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.27) Severity of attack (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
8.28) Any other details (Someone else)	As these questions referred to attacks that occurred outside of the respondent's household, the data was not analysed but rather used as a means of finding information about other attack victims and how we could obtain more detailed information about the attacks.		
9.1) Are crocodiles ever killed in the area?	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	Yes = 24 No = 123 Don't know = 8	Yes = 15 No = 79 Don't know = 5
9.2) Since 2010, has people killing crocodiles:	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 155	a) increased = 6 b) stayed the same = 55 c) decreased = 43 d) don't know = 51	a) increased = 4 b) stayed the same = 35 c) decreased = 28 d) don't know = 33
9.3) Did you hear about crocodiles that were killed in 2019/2020 (apparently, they found 20 carcasses)	Respondents = 155 Respondents who answered question = 152 Respondents who abstained = 3 Number of responses = 152	Yes = 49 No = 103	Yes = 32 No = 68
9.4) Why were they killed?	Open ended question		
9.5) By whom? (crocodiles killed by humans)	Open ended question		
9.6) How were they killed?	Respondents = 155 Respondents who answered question = 37 Respondents who abstained = 118 Number of responses = 45 (some respondents gave multiple answers)	a) shot = 28 b) poisoned = 14 c) other = 3	a) shot = 76 b) poisoned = 38 c) other = 8
9.7) When did this action take place?	Open ended question		
9.8) Describe the events	Open ended question		
10.1) How can life be made safer living with crocodiles?	Open ended question		
10.2) Who do you think should be responsible for making living safer in this area:	Respondents = 155 Respondents who answered question = 155 Respondents who abstained = 0 Number of responses = 212 (some respondents gave multiple answers)	a) Government = 68 b) MEFT = 18 c) Conservancy = 64 d) Household = 11 e) Community = 22 f) Traditional authority = 3 g) Don't know =26	a) Government = 44 b) MEFT = 12 c) Conservancy = 41 d) Household = 7 e) Community = 14 f) Traditional authority = 2 g) Don't know = 17