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MSc. WILDLIFE MANAGEMENT ENGINEERING

MASTER'S THESIS REPORT

PATTERNS OF LARGE CARNIVORE DEPREDATION ON LIVESTOCK AND COMMUNITY TOLERANCE BEHAVIOR AROUND SELOUS-NYERERE ECOSYSTEM; A CASE STUDY OF LIWALE DISTRICT IN SOUTHERN TANZANIA.

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ABSTRACT

Human-Large Carnivore Conflict (HLCC), particularly over livestock depredation is arguably one of the most pressing conservation issues across sub-Saharan Africa, including Tanzania. Despite the country having a large network of protected areas (32.5%), human large-carnivore conflict is still a serious management issue facing wildlife management authorities in the Selous Nyerere Ecosystem (SNE). We conducted a study in the Liwale district in southern Tanzania to assess the impact of co-existence between humans and large carnivores under the constrain of human population growth and changing land use (Introduction of pastoralism) which affects the population through the hard-edge effect and dispersal ecology. We surveyed three (3) pastoralist villages to collect their views and attitudes specifically on sharing their communal land with large carnivores. Furthermore, we surveyed the Magingo wildlife management area, Nyerakipelele and Angai forest reserves for assessing habitat suitability and the rate of large carnivore dispersion in these dispersal areas. The landscape has been highly encroached on and heavily degraded through human activities i.e., illegal livestock keeping, illegal farming and poaching. Human encroachment into dispersal areas makes the habitat unsuitable for large carnivores and led to the competition for resources, which results to human-large carnivore conflicts. From 2019 to 2022, the loss caused by large carnivore depredation on livestock was approximately US dollar 37,573.91, no human injuries/death reported. To mitigate the challenge, local communities discreetly use lethal methods which are cost-effective and kill instantly. We use our interaction with local people to provide conservation education on carnivores and elephants as the species notably cause a lot of damage. We do hope that, this study provides information that will be of high valuable to conservationists to work on fostering coexistence between humans and large carnivores in the Selous-Nyerere ecosystem.

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LIST OF ABBREVIATIONS

CIC	Council for Game and Wildlife Conservation
CO	Commanding Officer
DAS	District Administrative Secretary
DGO	District Game Officer
DLFDO	District Livestock and Fisheries Development Officer
FRs	Forest Reserves
HEC	Human-elephant conflict
HLCC	Human-Large Carnivore Conflict
NRMO	Natural Resources Management Officer
PAC	Problem-animal control unit
PAs	Protected areas
SNE	Selous-Nyerere ecosystem
TANAPA	Tanzania National Parks
TAWA	Tanzania Wildlife Management Authority
TAWIRI	Tanzanian Wildlife Research Institute
TFS	Tanzania Forest Services Agency
VGS	Village game scouts
VLUP	Village land use plans
WMAs	Wildlife Management Areas

1.0   INTRODUCTION

1.1   Background information

The largest terrestrial species in the order of carnivores are wide-ranging and rare because of their positions at the top of food webs. They are some of the world's most admired mammals and ironically, some of the most imperiled (Ripple et al., 2014). Carnivore and human populations are often in proximity to each other, due to carnivore recovery efforts in some areas (e.g., North America and Europe) and ongoing human encroachment into carnivore habitats globally (Expósito-Granados et al., 2019). Multiple-use landscapes composed of cities, highways, and rural communities within a patchwork of remaining natural habitats are now being recolonized by carnivores across the globe (Lamb et al., 2020) i.e., Western Europe (Chapron et al., 2014), East Africa (Woodroffe, 2011), Midwest United States (LaRue et al., 2012) and Southeast Asia (Wikramanayake et al., 2011). These interactions are often viewed through the lens of 'conflict' or 'risk' to human communities, such as livestock depredation, impacts on the abundance of game species, and threats to human safety (Treves & Karanth, 2003; Inskip & Zimmermann, 2009; Dickman, 2010; Miller, 2015; Lozano et al., 2019; van Eeden et al., 2018). Recently, human relationships with large carnivores range from tolerance and co-existence to intolerance and persecution (Boronyak L., Jacobs B. & Wallach A., 2020), which results in the eradication of large carnivores (Graham et al., 2005; Dickman et al., 2011). Unfortunately, most current conservation strategies for large carnivores are focused on protected reserve creation and management, particularly in developing countries (Joppa & Pfaff, 2009; Jenkins & Joppa, 2009). This is problematic because protected reserves in a majority of countries cover only 4-11% of the land area (Venter et al., 2014). Furthermore, the socio-cultural, financial and political challenges that plague the management of large carnivores in human-use areas make it difficult to formulate policies that ensure their conservation while also safeguarding human lives, property, livelihoods and well-being (Chapron & Lopez-Bao, 2014). While the term 'human-carnivore conflict' is widely used to describe negative interactions, it fails to capture the complexity of interactions (Messmer, 2000). Understanding and promoting co-existence between humans and large carnivores would benefit from expanding from a narrow focus on negative interaction alone to a holistic discourse that also recognizes opportunities for positive interaction and mutual benefits (Boronyak L., Jacobs B. & Wallach A., 2020).

1.2 Conservation and management challenge of large carnivores globally

After centuries of the decline of the population of large carnivores due to multiple causes (extermination policies, habitat destruction, reduction in the prey base, etc.), recently, the population progressively regained space, expanded their numbers and recovered much of their former distribution during the last 50 years (Chapron et al., 2014). This happened mainly because of a set of international conventions, which modified their status from that of pest species to conservation priorities, creating the conditions for their legal protection at the national level (Gervasi et al., 2021). For instance, in Europe, the population of brown bears (*Ursus arctos),* lynx (*Lynx lynx),* wolves (*Canis lupus)* and wolverines (*Gulo gulo*) show an increase in number and distribution whereby at present 42 European large carnivore populations can be identified, 34 of which span over two or more (and up to nine) different countries (Chapron et al., 2014). In North America, when the wolf was declared a threatened species in 1974 and the grizzly bear in 1975, the Endangered Species Act provided the impetus to increase the populations of these species. The grizzly bear population in Yellowstone, estimated at 136 at its lowest level, increased to levels approaching 650 by 2007 (Interagency Grizzly Bear Committee, 2012). Despite the recent recovery of large predators, a review of Alaska's predator management history (Regelin, 2002) reported the complexity and difficulty of managing large predators, with implications across the continent. Therefore, Regelin (2002) concluded that it was highly unlikely the Alaska Department of Fish and Game (ADFG) would conduct widespread and continuous wolf control to increase ungulate populations because of high costs and public opposition. The return of large carnivores and the lack of successful predator management caused new human-predator conflicts among farmers, hunters and predators. On one hand, large carnivores often pay a high price for sharing space with humans, as witnessed by the persistently high levels of illegal killing in several countries worldwide (Kaczensky et al., 2012). Although large carnivore attacks on people are extremely rare events (Behdarvand & Kaboli, 2015; Bombieri et al., 2019; Dickman et al., 2014; Gurung et al., 2008; Penteriani et al., 2016), they usually attract a disproportionate amount of public attention and are commonly over-represented by the media (Mohammadi et al., 2021). Fear can influence how people perceive risks (Slovic & Peters, 2006). It is part of the human instinctual response to some species, such as large carnivores, and can affect human willingness to share the landscape with these species (Ambarli, 2016) (Johansson et al., 2016), in turn

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affecting attitudes or behaviors (Johansson et al., 2012). People mainly retaliate against large carnivores for real and perceived threats to property and safety (Marker et el., 2003; Treves & Naughton-Treves, 2005; Woodroffe & Frank, 2005). Globally, more than 75% of the 31 large carnivore species have a declining population (Wolf & Ripple, 2016) and 17 species now occupy less than half of their former historic ranges in the last 500 years (Wolf & Ripple, 2017), largely due to human threats in competition for space and resources (Ripple et al., 2014). The strength of these threats varies substantially by region with Southeast Asia, southern and East Africa and the Amazon being among areas in which multiple large carnivore species are declining. In sub-Saharan Africa, human population growth, loss of natural habitat and associated declines in herbivore populations have significantly reduced large carnivore populations (Mills & Hofer 1998). Over the last century, Africa's large carnivores have undergone a massive decline due to anthropogenic activity (Ripple et al., 2014), and on average lost 68.16% of their historical range (Wolf & Ripple 2017); Lions lost 75% (Riggio et al., 2013), cheetahs lost 91% (Durant et al., 2016) and leopards lost 63%-75% (Jacobson et al., 2016). However, most African large carnivores are now restricted to protected areas (PAs) and areas of low human density, large carnivores that often have large home ranges do not recognize artificial boundaries (Woodroffe et al., 2005) and once outside the protected areas, these species can cause considerable economic damage mainly due to livestock depredation and also sometimes harm people (Jackson et al., 2010) which led to the retaliatory killing.

1.3   Human-large carnivore conflict (HLCC) in Tanzania

Human-Large Carnivore Conflict, particularly over livestock depredation is arguably one of the most pressing conservation issues across sub-Saharan Africa, including Tanzania (Woodroffe et al., 2005; Kissui, 2008; Thorn et al., 2013; Hemson et al., 2009). Despite the country having a large network of protected areas, HLCC is a serious management issue facing wildlife management authorities today. Human-carnivore conflict in Tanzania is determined by both human and carnivore behavior. The general ecology of carnivores, such as social status, habitat use, and hunting strategies, may influence their predisposition to livestock depredation (Elliot et al., 2014; Loveridge et al., 2017). On the other hand, human behaviors such as livestock husbandry, which can be deconstructed into herding practices, the structure of livestock enclosures (bomas), and the use of deterrents such as dogs (*Canis*

familiaris), can determine the likelihood of livestock depredation (Ogada et al., 2003). Large carnivore attacks have become more common it is estimated that more than 563 people were killed and 308 injured between 1990 and 2004 (Packer et al., 2005). For instance, Ikanda and Packer (2008) found that lion killing in the Ngorongoro Crater is directly proportional to the amount of cattle depredation, and Kissui (2008) found that in the Maasai steppe, 100% of lion attacks resulted in retaliation for livestock predation. A study in villages outside the Serengeti National Park showed that economic losses due to livestock predation by carnivores amounted to $12,846 per year (Holmern et al., 2007). Livestock depredation by large carnivores affects the quality of people's livelihoods (Barlow et al., 2010; Kissui et al., 2019), at the same time, people i.e., farmers, pastoralists and even local government authorities under problem-animal control (PAC) activity (Ikanda & Packer 2008) normally react against carnivores perceived to be responsible for the losses (Kissui, 2008) thus, threatening the persistence of large carnivore populations (Patterson et al., 2004). While lions are typically the focus of retaliatory killings, leopards, spotted hyaenas, wild dogs and cheetahs are also commonly killed, driving multiple species declines (Inskip & Zimmermann, 2009). Mitigating these conflicts is an essential carnivore conservation goal, particularly in human-dominated landscapes to promote human-carnivore coexistence (Kissui et al., 2019).

1.4   Rationale of the study

The carnivore population in the Selous-Nyerere ecosystem (SNE) is unfenced and surrounded by semi-protected areas such as Open Areas (OAs), Wildlife Management Areas (WMAs), Forest Reserves (FRs) and extensive open wilderness village lands that are primarily used by the nominal population for dispersal. But human population growth and changing land use (Introduction of pastoralism) constrain large carnivore dispersal ecology, potentially affecting the population through the hard-edge effect. The main question was on the present suitability of the open areas, wildlife management areas and forest reserves for carnivore dispersal ecology under ongoing population pressures and changing land use in the ecosystem. It was hypnotized that both human population increase and land-use change had negatively affected carnivore dispersal by aggravating human-carnivore conflicts in time and space. Given that the shared landscapes often represent a vital part of their remaining geographic distribution (Di Minin et al., 2016), the eradication of large carnivore species

from the area may threaten their conservation. Despite this, the need for the conservation of large carnivores in proximity to human populations often generates intense debate, with a critical point of contention being whether, and to what degree, the negative impacts humans and large carnivores have on each other can be sufficiently minimized (Carter & Linnel, 2016). This study, therefore, presents information on (i) Understanding the social and economic impacts of human-carnivore conflicts in the study area (ii) Identifying human and landscape factors that influence human-carnivore conflicts (iii) Determining local community behavior in response to human-carnivore conflicts in the study area, and (iv) Identifying areas with high human-carnivore conflict incidences for suggesting proper and practical mitigation measures.

1.5 Research objective and activities
1.5.1 General objective and hypothesis of the study

This study provides considerable information on patterns of large carnivore depredation on livestock and assesses community behavior regarding human-carnivore conflicts in the Selous-Nyerere ecosystem (SNE). The study hypothesized that there would be more human-carnivore conflicts (HCC) and depredation events in villages and grazing fields which are close (≤ 8 Km) to protected area boundaries. Additionally, the study predicted that lions and spotted hyenas would be more responsible for the highest percentage of livestock loss (Ogada et al., 2003; Kolowski & Holekamp, 2006; Mponzi et al., 2014).

1.5.2 Key activities
To accomplish the main objective, the study had four (4) main activities

  i. To show the current dispersal rate of large carnivores and evaluate the differences among wildlife management areas, open areas and forest reserves.

  ii. To collect evidence about large carnivores' livestock depredation from the local communities adjacent to protected areas (Pictures, observations and carcasses remain).

  iii. To assess human attitudes and responses towards the effect of large carnivores' dispersal in time and space.

  iv. To provide conservation education to the local communities specifically on the importance and behavioral ecology of large carnivores.

2.0   LITERATURE REVIEW

2.1   Behavioral ecology of African large carnivores

2.1.1   Spotted Hyena (*Crocuta crocuta*)

Spotted hyenas are among the large terrestrial predators (45-80kg) occurring throughout sub-Saharan Africa (Holekamp et al., 2007). Crocuta lives in permanent complex social groups called clans that range in size from 6 to 90 individuals. All members of a clan recognize each other, cooperatively defend a common territory, and rear their cubs together at a communal den (Kruuk, 1972; Henschel & Skinner, 1991). Hyena shows evidence of much behavior that set them apart from other large carnivores, making them a fascinating model organism for the study of animal behavior (Smith & Holekamp, 2010). They can adapt to habitats with a dense human population (Woodroffe, 2001) eating almost any organic matter, even putrid carrion, and anthrax-infected carcasses (Johnson, 2006). Hyenas have been recorded to eat almost any mammal, bird, fish or reptile but they also feed on garbage, cooked porridge and dung (Mills & Hofer, 1998). Although hyenas scavenge opportunistically, they are efficient hunters and kill 60-95% of the food they eat in their natural habitats (Smith & Holekamp, 2010). Hyenas hunt alone or in groups, an adult hyena can bring down a prey animal weighing up to four times its body mass (Mills & Hofer, 1998). They can eat and digest all parts of their prey except hair and hooves (Smith & Holekamp, 2010). Bones are digested so completely that only the inorganic components are excreted in the hyena's droppings (Smith & Holekamp, 2010). In 2014 the spotted hyena was listed as Least Concerned on the IUCN Red List. The population estimate in Africa is between 27,000 and 47,000 individuals (Bohm & Höner, 2015).

2.1.2   Cheetah (*Acinonyx jubatus*)

Cheetahs (40-75Kg) are one of the smaller populations of large carnivores present remain in the wild with a population estimated at 7100 globally, where the African continent remains a stronghold with an estimated 5000 individuals (Durant et al., 2022); it is listed as Vulnerable on the IUCN Red List. They have slender body shapes built for speed and are estimated to be capable of running at 80 to 128 km/h over a short distance (300-400m). The fastest land animal on earth (Durant, 2000a). They are solitary mammals, except for some adult males who form coalitions of normally two or three siblings, and mothers with dependent offspring (Caro & Collins, 1987). Cheetahs potentially inhabit any area with the prey of the preferred size being 23 to 56 kg (Hayward et al., 2006), and vegetation open

enough to allow high-speed pursuit, although they seem to prefer habitat with some cover for approaching prey undetected (Buk & Marnewick, 2016).

2.1.3   Leopard (*Panthera pardus*)

The leopard (50-90Kg) is a solitary, reclusive species of big cat. It is also the most widespread felid, extending across much of Africa and Asia from the Middle East to the Pacific Ocean (Nowell & Jackson, 1996; Sunquist & Sunquist, 2002). The leopard has the broadest diet of larger obligate carnivores (Hayward et al., 2006). Their behavioral plasticity allows them to persist in areas where other big cats have been extirpated or severely isolated (Athreya et al., 2013; Athreya et al., 2014). IUCN has classified Panthera pardus as a vulnerable species, with the number of leopards worldwide estimated at several hundred thousand individuals (Britannica, 2022). In sub-Saharan Africa, leopards are classified as a vulnerable species by IUCN in 2015 (Britannica, 2022), though, regional populations are increasingly threatened by habitat loss, exploitation and conflict with humans (Nowell & Jackson, 1996).

2.1.4   African Wild Dog (*Lycaon pictus*)

African wild dogs are medium-sized (18-28 kg) canids living in highly cohesive packs holding 2 to 28 adults (Creel & Creel, 2002). The African wild dog's coat patterns are unique to each individual and can be used to identify individuals (Woodroffe et al., 2004). The relative strength of social bonds between individuals and thus the degree of social integration of a newly formed wild dog pack is reflected in the patterning of spatial relationships and social interactions (McCreery, 2000). Wild dogs can take huge prey weighing up to 120% of their body weight because cooperative hunting allows packs to kill animals that would be too large for a single wild dog to subdue (Creel & Creel, 1995). The population of African wild dogs is estimated at fewer than 2000 and is still declining (Woodroffe & Sillero-Zubiri, 2020). In 2012 the species was listed as globally endangered by the IUCN red list and is therefore considered to be facing a very high risk of extinction in the wild shortly (IUCN, 2012).

2.1.5   Lion (*Panthera leo*)

Lions (150-200Kg) are the most gregarious of all felids forming 'fission-fusion' social units known as a pride that typically comprise 4-6 related females, their dependent offspring and a temporary unrelated coalition of typically two adult males (Bertram, 1975; Packer & Pusey, 1982; Mosser & Packer, 2009). Pride rarely moves collectively, encounters in the field are usually with subunits that we refer to as groups. Several factors influence lion grouping

patterns, such as cub defence, group territoriality, defence of kills against scavengers, synchronized female breeding patterns and communal raising of offspring (Mosser & Packer, 2009; Packer et al., 1990; Funston et al., 2001). Globally, the population of African lions is estimated at 23,000-39,000 individuals and listed as Vulnerable on the IUCN Red List in 2014 (Bauer et al., 2016).

2.2   Ecological role of large carnivores in the ecosystem

Large carnivores are a diverse group and top predators that play important roles in structuring ecosystems and regulating ecosystem function (Ripple et al., 2014). These roles, moreover, may not be redundant among carnivore species, because the strength and nature of their impacts are influenced by factors such as the carnivore's size, metabolic demands, density, sociality and hunting tactics (Ripple et al., 2014). Through hunting, carnivores help to reduce disease prevalence in ungulate prey populations (Packer et al., 2003), and also maintain herbivore populations at a healthy level, preventing an overabundance of herbivores and thereby protecting vegetation from being too heavily grazed or browsed (Fleming, 2019). That, in turn, protects other plant and animal species that depend on a healthy vegetation assemblage for food or shelter (The Carnivore Conservancy, 2021). Large carnivores may enhance scavenger diversity (Beschta & Ripple, 2012), thereby contributing to nutrient cycling and myriad other documented cascading and ramifying pathways (Schmitz et al., 2010). augmented, Therefore, ecologically large carnivores are crucial not only in predicting cascading effects but also in establishing successful conservation initiatives that guarantee the persistence of predator and prey populations, with reduced risks of predator starvation or over-predation (Wolf & Ripple, 2018), as well as to minimize conflicts with humans (Packer et al.,2005; Acharya et al., 2016; Nyhus PJ, 2016). Given the delicate and interdependent nature of the food chain and the laws of trophic cascades, predators cannot be eliminated without risking the larger ecosystem (Waage, 2011).

2.3   Social and economic benefits of large carnivores in the community

People appreciate large carnivores for the cultural, aesthetic, existence, economic, and other values they represent (Kellert, 1996). The beauty and symbolic nature of large carnivores inspire many people. A historical or other human-centered perspective leads to strong personal, religious, symbolic and historical values for many people and society (Shepard, 1978; Kellert, 1996). To these people, such intrinsic "existence values" are

important and influential (Rolston, 1981; Brown & Gonzalez, 2001; Stevens et al., 1999), such that, they can donate substantial sums of money to ensure the conservation of large carnivores and often vote to further their protection. For some, these species are important to themselves and want to ensure their children or grandchildren can see them in the wild (Reading et al., 2010). On the other side, large carnivores are associated with important economic benefits due to their role as one of the primary species that people want to see through wildlife viewing tourism (Lindsey et al., 2007). When people engage in wildlife-based recreation, they often expend great effort in trying to catch a glimpse of large carnivores in their natural locations (Dieren & Hummelinck, 1979), thus, as a result of the satisfaction many people obtain from direct experiences with large carnivores, they spend money travelling to several destinations to view them (Kellert, 1996). For instance, the economic impact of wolf restoration to Yellowstone National Park generates an additional $35 million per year in revenue for the region surrounding the park, and because those dollars turn over to the local communities, the wolves have created an overall impact of $70 million per year to the local economy (Duffield et al., 2008), thus, make tourism to be very crucial, especially in the developing world where it is a significant or growing component of the Gross Domestic Product (Ashley et al., 2000).

2.4   Conservation and management approach of large carnivores in Tanzania

Tanzania's mainland has a wildlife-protected area network that covers 32.5% of the total land surface (URT, 2021), and the country is home to more than 35 species of carnivores including the large carnivores, notably the African lion, cheetah, leopard, African wild dog and spotted hyena (SFS, 2016; TAWIRI, 2006; TAWIRI, 2007a; TAWIRI, 2007b; TAWIRI, 2007c). As such, Tanzania is a global hotspot for carnivores, particularly for species vulnerable to extinction (Mills et al., 2001), and is a priority for carnivore research and conservation (Nowell & Jackson, 1996; Woodroffe et al., 1997). To ensure the effective conservation and management of large carnivores within the country there are several action plans and ongoing projects carried out by the government and non-government organizations for the conservation and monitoring of the population of large carnivores. For instance, the Serengeti Wild Dog Conservation Project, which was established in 2018 and run by the Tanzanian Wildlife Research Institute (TAWIRI) aims to re-introduce wild dogs within the greater Serengeti ecosystem (Grumet fund, 2018). The Ruaha Carnivore Project

(RCP), established in 2009 aims at successful coexistence between humans and carnivores through empowering local communities and developing effective strategies for carnivore conservation in the Ruaha landscape (RCP, 2022). From 2019 to 2021, African People & Wildlife (APW) conducted a project aimed at conserving the population of large carnivores in northern Tanzania via capacity building and environmental education targeting the local communities of the Tarangire/Manyara ecosystem (APW, 2022). Furthermore, in 2020 the Lion landscape began to conduct a large-scale assessment of large carnivores in the Selous-Nyerere ecosystem to understand their population in the landscape (Lion Landscapes, 2020). All these ongoing projects imply that humans still pose a major threat to the conservation of large carnivores within the country. Therefore, community-led projects on human-carnivore conflicts are inevitable to protect these species from extinction within the country. Several studies show that community involvement in conservation projects resulted in a positive impact on wildlife conservation. Therefore, this study is a vital step toward serving the population of large carnivores by involving the local communities in raising conservation awareness through education programs.

2.5   Co-existence between livestock and large carnivores in Tanzania

It has long been recognized that pastoralists with their livestock and large carnivores live alongside one another in many parts of Tanzania's ecosystems, where they exhibit a high degree of spatial overlap or co-existence (Sitters et al., 2009; Du Toit, 2011). Pastoralist livestock and carnivores utilize foraging strategies based on high mobility to access resources (i.e., Water, pastures, prey) in an unpredictable physical environment (Homewood & Rodgers, 1991). In the country, livestock husbandry is commonly practiced with mixed species herds of cattle, goats, and sheep and a few farmers also keep donkeys and pigs (Holmern et al., 2006). Grazing usually takes place on a piece of land "grazing land" set aside purposely by the village government or administrative authority in a specific area. However, pastoralists tend to encroach on protected areas with their livestock in villages bordering protected areas, leading to serious destruction of wildlife habitat and biodiversity. Identifying key factors influencing interactions between livestock and carnivores is therefore critical for land use planning and other management tools where livestock production co-exists with carnivores' conservation (Zengeya et al., 2015). Shortcomings of conservation strategies in Tanzania have been

exposed in the last decade with the realization that most protected areas (PAs) do not meet the needs of these mobile species adapted to coping with strong spatial and temporal variability in resources (Harris et al., 2019; Craigie et al., 2010; Fynn & Bonyongo, 2011). Minimizing contact between large carnivores and livestock to reduce these risks remains a key challenge for biodiversity conservation, livestock production and the health of socio-ecological systems (Lamarque et al., 2019). Sometimes, complex interactions involving humans, domestic animals, and carnivores create environments favorable to the emergence of new diseases (Palmer, 2007). Wild animals are susceptible to infection with many of the same disease agents that afflict domestic animals and transmission between domestic animals and wildlife can occur in both directions (Palmer, 2007). Conserving large carnivores in human-occupied landscapes requires management intervention that is guided by a mechanistic understanding of how anthropogenic factors influence large-scale ecological processes (Georgiadis et al., 2007).

3.0   METHODOLOGY

3.1   Study area

The study was conducted in the Liwale district located at 9^0 48'17.44'' S, 37^0 55'52.46'' E of the Lindi region in south-eastern Tanzania (Fig. 01). The district has a total area of 3,780,000 Ha out of which 58% is covered by the Selous Game Reserve (Dondeyne et al., 1998) which supports the conservation of Africa's largest population of both lion and the endangered African wild dog, as well as the important population of leopard and spotted hyena (Lion Landscapes, 2020). The vegetation is mainly covered by miombo, dominated by Pterocarpus angolensis, Afzelia quanzensis, Dalbergia melanoxylon, Euphorbia candelabrum, and Brachystegia spiciformis species (Dondeyne et al., 1998; Dondeyne et al., 2004). The climate is characterized by two yearly rain periods: a short period from late November to January and a longer period from March to May. Annual precipitation ranges from 600-1000 mm (Næsset et al., 2020). The main dry season is from July to October and the average temperature is about 25°C. Liwale district has the largest river in Tanzania and East Africa, the Rufiji River which together with the great Ruaha river creates vital habitat for the important population of many species including endangered African elephants, buffalo, crocodiles, hippos, Lesser Kudu, sable antelope and Impala (TAWA, 2016). Importantly, the district comprises two (2) core protected areas the Selous game reserve and one of the

sectors of the Nyerere national park. Selous game reserve (1,802,000 Ha) is the largest game reserve in Tanzania and is often seen as one of Africa's last true wilderness areas (Brilliant Africa, 2022) with undisturbed nature where relatives of dinosaurs walked over 160 million years ago (TAWA, 2016). It was established by the Germans in 1896 and was declared a UNESCO World Heritage Site in 1982 (TAWA, 2016). The reserve was named after Frederick Selous Courtney, a great hunter and explorer who died in 1917 (Mandiringana & Stapleton, 1998). The Selous game reserve has the largest concentration of African elephants in Tanzania and about 430 bird species birds such as vultures, eagles, kingfishers, kites and hornbills whose livelihood is the mighty Rufiji River (TAWA, 2016). The south-eastern sector of the Nyerere national park (200,000 Ha) is among the 6 sectors that form the largest national park in Africa, the Nyerere national park which has a total area of 3,089,300 Ha. The Park was established in 2019 by upgrading nearly two-thirds of the Selous game reserve to a national park. The Nyerere national park hosts one of the world's largest concentrations of wildlife including the famous ''Big Five'' and some rare species of antelopes like Roan Antelope, Brindled Gnu, Lichtenstein hartebeest, roan, and sable antelopes (TANAPA, 2020). Other protected areas found in the district include the Magingo wildlife management area (451,500 Ha), Nyera-kipelele (98,420 Ha) and Angai (140,000 Ha) forest reserves as well as open areas. The area is an important biological link for wildlife migrating between the core and dispersal areas.
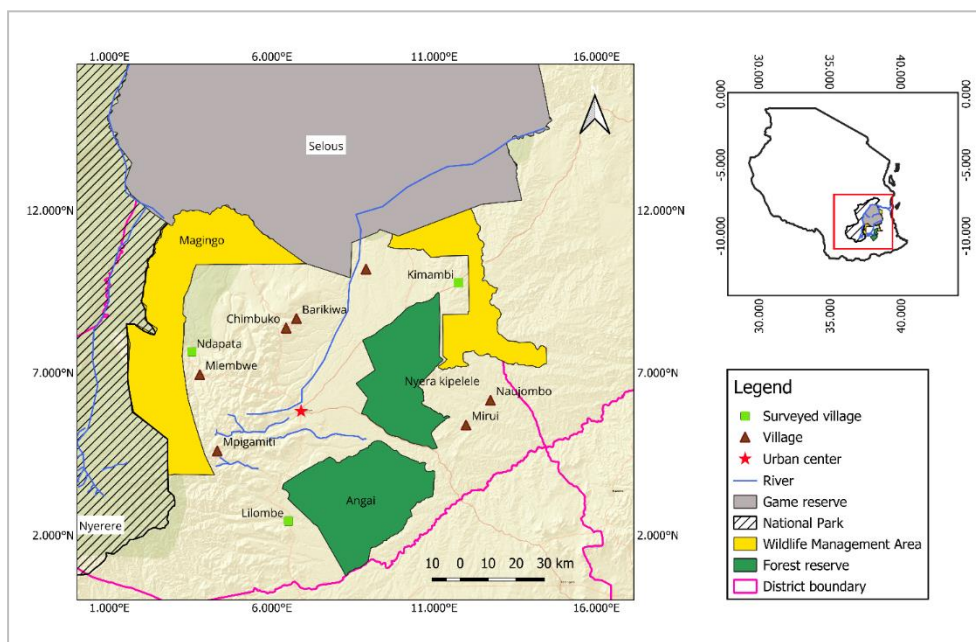
Figure 01: A map of the study area showing villages adjacent to protected areas

3.2 Human-large carnivore conflicts in the Selous-Nyerere Ecosystem (SNE)

The study area is predominantly the Ngido ethnic group. Other small ethnic groups include Mwera, Makonde, Yao, Makua, Sukuma and Mang'ati (LDC, 2018). The recent national population census shows that, in 2022, the district had 136,505 inhabitants (NBS, 2023) and the main economic activities include agriculture, livestock keeping and tourism (Hunting tourism). The Selous-Nyerere Ecosystem (SNE) hosts the largest population of large carnivores in the world specifically lions, with the ecosystem serving as a core habitat for an estimated 3000 - 4000 lions (Crosmary et al., 2018). In the course of the past decades, the expansion of agricultural activities and the introduction of hundreds of livestock under a traditional pastoralist husbandry regime in marginal village areas have fragmented protected wildlife habitats and restricted large carnivores to areas of high potential. Furthermore, the proliferation of livestock herds among large carnivores has likely led to conflict and aggravated the killings of large carnivores. Therefore, the study area is crucial for providing information on human-large carnivore conflicts and suggesting adaptive mitigation measures to combat the challenge.

3.3 Research design

The research used primary and secondary data to collect social and ecological data for the past 5 years (2018 - 2023). Data were collected from January 2023 to April 2023 using a combination of different approaches; - Questionnaires, key informant interviews, sign surveys, sighting reports and damage reports. Before the commencement of the study, we clarified the purpose of the study to the District Administrative Secretary (DAS) together with the government and non-government institutions that protect wildlife and their habitat in the study area. We conducted a brief survey to identify villages that are vulnerable to human-carnivore conflicts based on incidences reported by local communities to TAWA, TANAPA, TFS and DGO.

3.4 Data collection
3.4.1 Sighting reports

After a keen consultation with conservation scientists and experts from TAWA, TANAPA, TFS, Magingo WMA and hunting companies, we recognized a total of 20 carnivore sighted sites for ground surveillance (10 sites in WMA, 6 sites in forest reserves and 4 sites in open areas). Sites recognized were georeferenced using QGIS V3.30 software and then, surveyed

for 1 month. Sites survey was very crucial for designing transects for the sign survey approach.

3.4.2 Sign surveys

The sign surveys approach was used to identify a range of potential sites for carnivore species across wildlife management areas, open areas, and forest reserves (Thorn et al., 2010). A total of ten (10) transects (Grids with 225 Km^2) were designed following the site surveys conducted earlier. Sites selection was based on Habitat suitability (Vegetation cover, water availability and herbivores presence), geographical location, distance from human settlements and accessibility of the area (Kendall et al., 1992). The survey was conducted both by foot and from a vehicle (Toyota Landcruiser) travelling at 10–15 km/h with 4 trained observers who were searching for signs. Where necessary field guidebooks were used for assistance (Burgener & Gusset, 2003; Dunstone, 2005). If a species was recorded on the sub-transect, it was marked as one (1), if it was not recorded it was marked as zero (Foley et el., 2018).

3.4.3 Questionnaire survey and interviews

The understanding attitude of local communities is becoming increasingly important in wildlife as it can help provide better-predicted support for local communities for wildlife conservation (Browne-Nuñez & Jonker, 2008). Household surveys were held in three (3) villages, namely Kimambi, Lilombe and Ndapata, and a total of 131 respondents successfully participated in the survey (Table 01). On the other hand, nine (9) key informants were interviewed to provide their vital insights regarding the situation of human-carnivore conflicts in the Liwale district (Appendix 4).

3.4.4 Damage reports

In the three (3) villages, two (2) village game scouts (VGS) were trained on how to collect data on livestock depredation when the incident occurs. The selected VGS were provided with a data collection kit with pencils, data sheets, a camera, an identification manual and a GPS device for recording location if an incident happens.

3.4.5 Focus group discussion

A group of 5-15 people, which included both males and females aged 18 and above was allowed to participate in a discussion regarded for provision of conservation education specifically about the ecological behavior of large carnivores. We held group discussions with local people together with their leaders in each surveyed village. 80% of the participants declare that human-carnivore conflict incidences are getting worse as compared to the last 2 years. The majority of them responded that they don't know the correct path to follow when the incident happens.

3.5 Data analysis and evaluation

3.5.1 Regression modelling

Data for structured questionnaires and damage reports were categorized into themes and sub-themes, each of which will be assigned an identification code for easy analysis (Masenga et al., 2019). Descriptive analyses were employed in the Statistical Package for Social Sciences for Windows (SPSS 16). Other results are summarized in tables and graphs.

3.5.2 Occupancy modelling

Primary and secondary data on large carnivore distribution were analyzed using occupancy modelling (MacKenzie et al., 2002; MacKenzie and Bailey, 2004; MacKenzie et al., 2006) to estimate both site occurrence (ψ; the probability that the species occurred at a site) and detectability (P; the probability that the species was detected if present). The R (R Development Core Team, 2018) package unmarked (Fiske and Chandler, 2015) includes the occ function, which fits the occupancy model from MacKenzie et al., (2002).

4.0   RESULTS

4.1   Socio-demographic characteristics of respondents

4.1.1   Surveyed villages

Table 01: Surveyed villages during household questionnaire survey.

Name of village	No. of household	Frequency	Percent (%)	Cumulative Percent (%)
Kimambi	512	54	41.2	41.2
Lilombe	454	55	42	83.2
Ndapata	173	22	16.8	100
Total	1139	131	100	

For the past 5 years (2018-2022), the three villages have been reported to have seriously human-carnivore conflict incidences compared to other villages bordering protected areas in the Liwale district. Kimambi and Lilombe had an average of 42% of the total respondents as compared to Ndapata's 16.8% due to several reasons; - (i) The number of households in the village (ii) The total area reserved for livestock keeping (iii) Accessibility of the area/Dispersion and, (iv) Respondent willingness to cooperate/Fear factor.

4.1.2   Socio-economic characteristics of respondents

Table 02: Local community's socio-economic characteristics regarding response to human-carnivore conflicts.

Variable name	Variable category	Frequency	Percent (%)
Sex	Female	52	39.7
	Male	79	60.3
Age	18-28	38	29
	29-39	48	36.6
	40-49	34	26
	50 and above	11	8.4
Family size	01-05	64	48.9
	06-10	44	33.6
	11-15	18	13.7
	16 and above	5	3.8

Variable name	Variable category	Frequency	Percent (%)
Education level	Informal	98	74.8
	Primary level	32	24.4
	Vocational training	1	0.8
Occupation	Agriculture	4	3.1
	Livestock keeping	43	32.8
	Agriculture and Livestock keeping	84	64.1
Total number of livestock	Below 50	58	44.3
	51-200	51	38.9
	201-350	17	13
	Above 351	5	3.8
Residential status	Native	0	0
	Immigrant	131	100
Years spent in the area/village	0-5	71	54.2
	06-10	45	34.4
	11 and above	15	11.4

Communities living adjacent to protected areas are highly dependent on agriculture and livestock keeping as a source of food and income. 64.1% of respondents practice both agricultural and livestock-keeping activities, while 43% only depend on livestock-keeping. In the past 6 years (2018-2023), the influx of pastoral societies (Mainly the Sukuma and Mang'ati) in the Liwale district became very high 54.2% as compared to 11 years back 11.5%. The majority declared they moved into the area to find good pastures and space for their livestock. During the questionnaire surveys, 60.3% and 39.7% of males and females consecutively participated in the survey. The culture and traditions of the Sukuma and Mang'ati tribes show that females rely on males/husbands for decision-making, leading to the number of females being small compared to males. The survey involved respondents who were 18 years and above. The age group of 29-39 years was prominent with 36.6% followed by 29% of the 18-28 years age group. The age groups mentioned implying that the survey comprised respondents who were within the age defined as active and economically productive population (Ogunniyi et al., 2011). Also, Mwamnyange (2008) points out that the respondent's age may determine individual maturity and ability to make rational decisions. 48.9% of the household surveyed fall under the family size category of 1-5 people followed

by 33.6% of the 6-10 category. Family size is very important in determining the number of livestock a household can keep. 44.3% of households had a total number of livestock below 50, while households with a total number above 351 only 3.8%. On the education level, 24.4% of the respondents have primary education while 0.8% have vocational training. Despite 74.8% of the respondents possessing formal/indigenous knowledge, the knowledge is useful in predicting weather conditions because the majority of pastoralists are nomads.

4.2 Livestock keeping and management system in the Liwale district.

Table 03: Area reserved for livestock keeping in Liwale district.

Village	Area for livestock keeping (Ha)	Carrying capacity	Type of livestock				Livestock #/ village	%
			Cattle	Donkey	Goat	Sheep		
Ndapata	5,456.47	2,728	939	0	212	131	1,282	4.81
Kimambi	42,022.76	21,011	15,355	33	1,558	499	17,445	65.44
Lilombe	19,920	16,833	6,736	13	1,025	156	7,930	29.75
Total	**67,399**		**23,030**	**46**	**2,795**	**786**	**26,657**	

Source: District Livestock and Fisheries Development Officer (DLFDO), 2023.

In the Liwale district out of 3,780,000 Ha, the total area reserved for livestock keeping is only 67,399 Ha which is claimed not to be enough by local communities due to the ongoing increase of informal pastoralists and arbitrary livestock keeping which sometimes leads to controversy among conservationists, farmers and pastoralists specifically to those who are already officiated by the district council. The area reserved depends on the total size/area of the village land and the village land use plans (VLUP). VLUP may include designated areas for human settlement, agriculture, forest land, water catchment areas, area for social services, economic zones and no-use zones. VLUP is usually reviewed after every 10 years by a team of surveyors together with the village government to promote more desirable social and environmental outcomes and more efficient use of resources and prevent land use conflicts. According to DLFDO, all the pastoralists from Ndapata village will soon be translocated to Kimambi and Lilombe villages with enough space for animal husbandry. In the Liwale district, livestock keeping is still traditional whereby more than 60% of pastoralists depend on weather seasons (Wet/Dry) to migrate with their livestock searching for food and water. Also, they are using traditional bomas/enclosures to protect their livestock against predators.

4.3   Human-large carnivore conflicts in the Liwale district

4.3.1 Dispersal rate of large carnivores in wildlife management areas, open areas and forest reserves
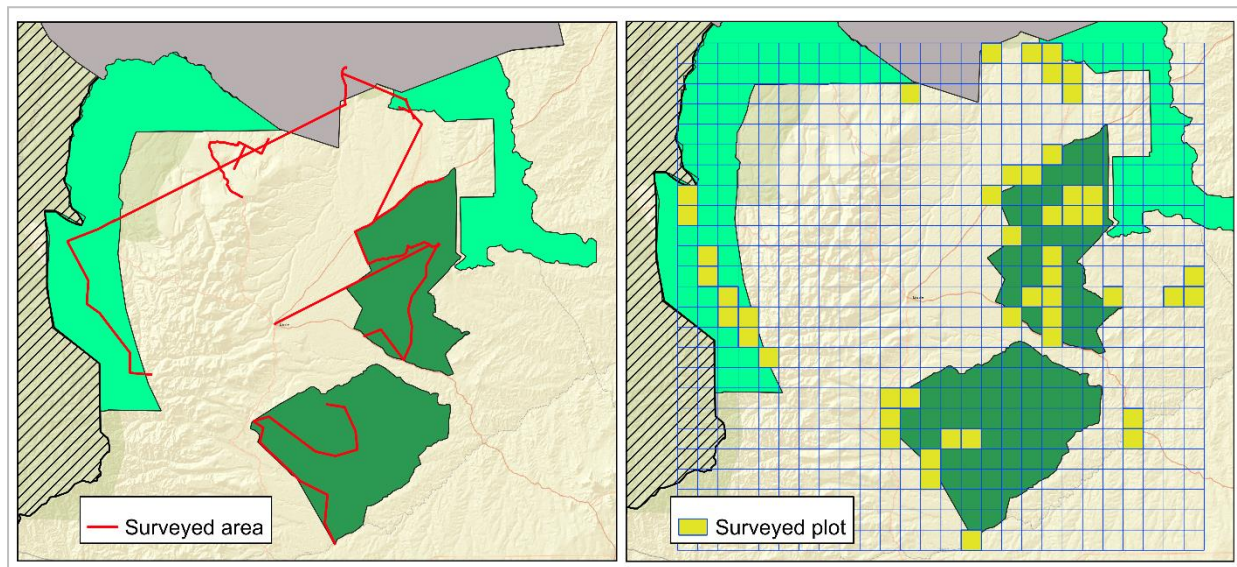

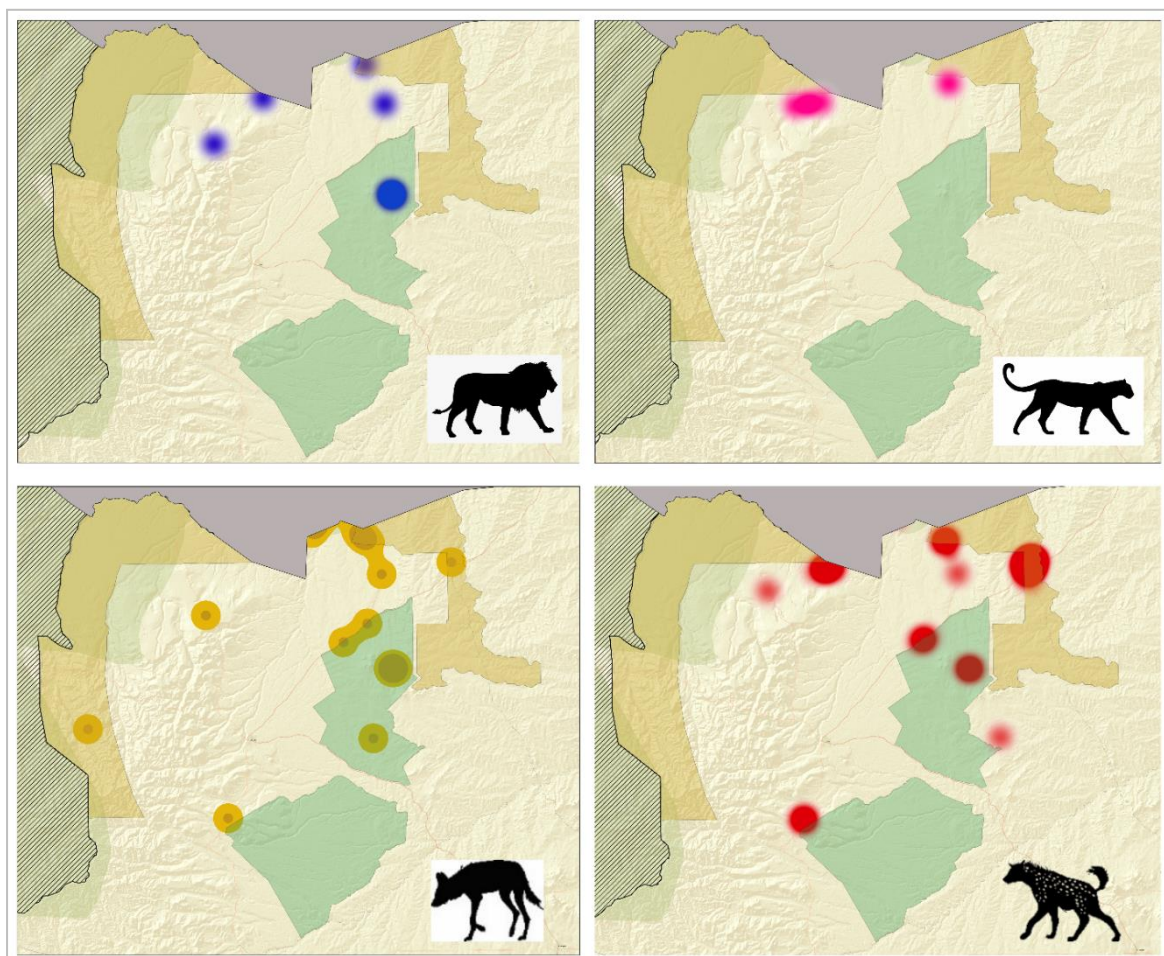Figure 02: Surveyed area and plots in the Selous-Nyerere ecosystem

Figure 03: The rate of large carnivore dispersion in the protected areas

The dispersion of large carnivores is high in pastoralist village land than in agricultural land. The high overlapping between endangered wild dogs and spotted hyenas was due to similarities in their hunting strategies. Spotted hyenas and wild dogs are both predators that hunt in groups. For example, both species use cooperative hunting techniques to take down prey that is much larger than themselves. They also both have a high success rate when hunting in groups. However, there are also some differences between the two species. For example, wild dogs are more agile and can run faster than hyenas. They also tend to hunt during the day while hyenas are more active at night. However, hyenas are larger and stronger than wild dogs and can sometimes overpower them. In addition, hyenas have been known to steal food from wild dogs.

4.3.2   Hot spot areas with high incidences of human-carnivore conflicts
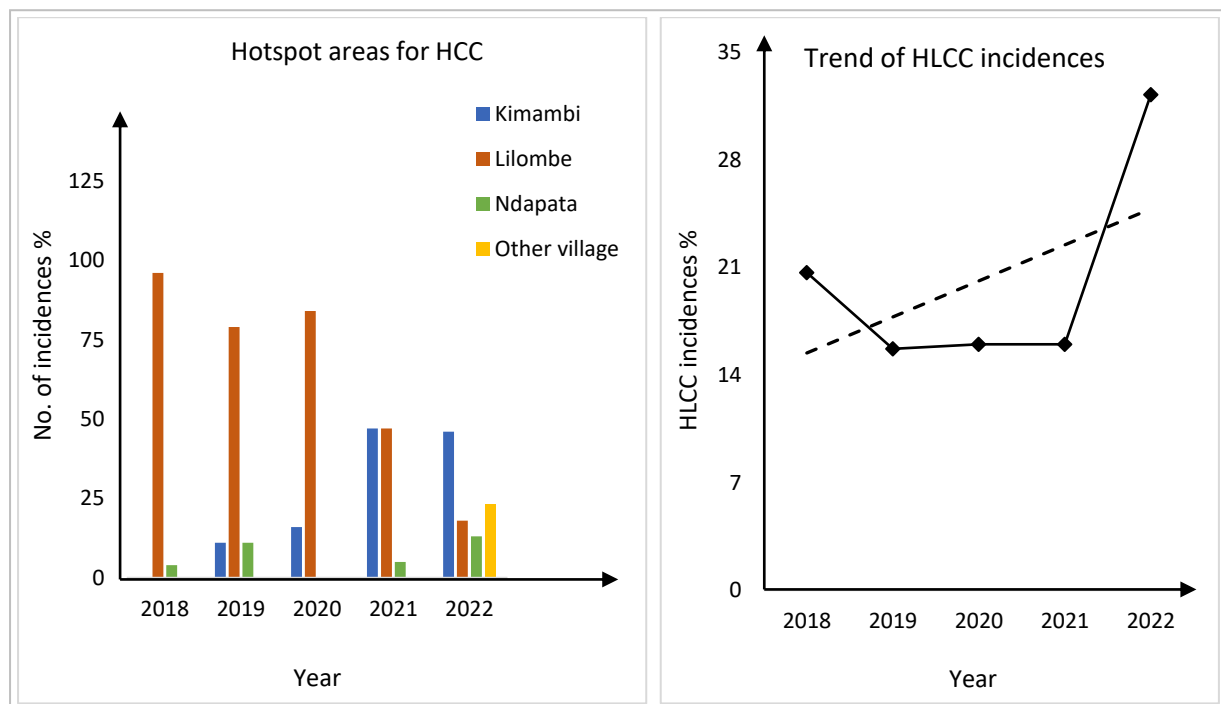
Figure 04: Human-large carnivore conflict incidences between 2018-2022

In the Liwale district, the first carnivore attack on livestock was reported in 2014 in Ndapata village. Later on, in 2018, the situation became too serious and started to evolve in other villages bordered by the protected areas. From 2018-2022, a total of 121 HLCC incidences were recorded which marks an average of 24.2 incidences yearly. For the past 5 years, Kimambi and Lilombe villages had a total of 32 and 71 incidences which is equal to 26.44% and 58.68% consecutively. Ndapata and other villages equally had a total of 9 incidences

20

which marked 7.44% each. Yearly, 39 incidences were recorded in 2022, the highest number of incidences reported in the past 5 years. Between 2018 and 2021, an average of 21 incidences were recorded yearly. Village executive officers of both surveyed villages declared that currently, carnivore attacks on livestock became severe due to improper livestock husbandry and livestock incursion into protected areas.

4.3.3   Trend of large carnivore attack incidences in the Liwale district
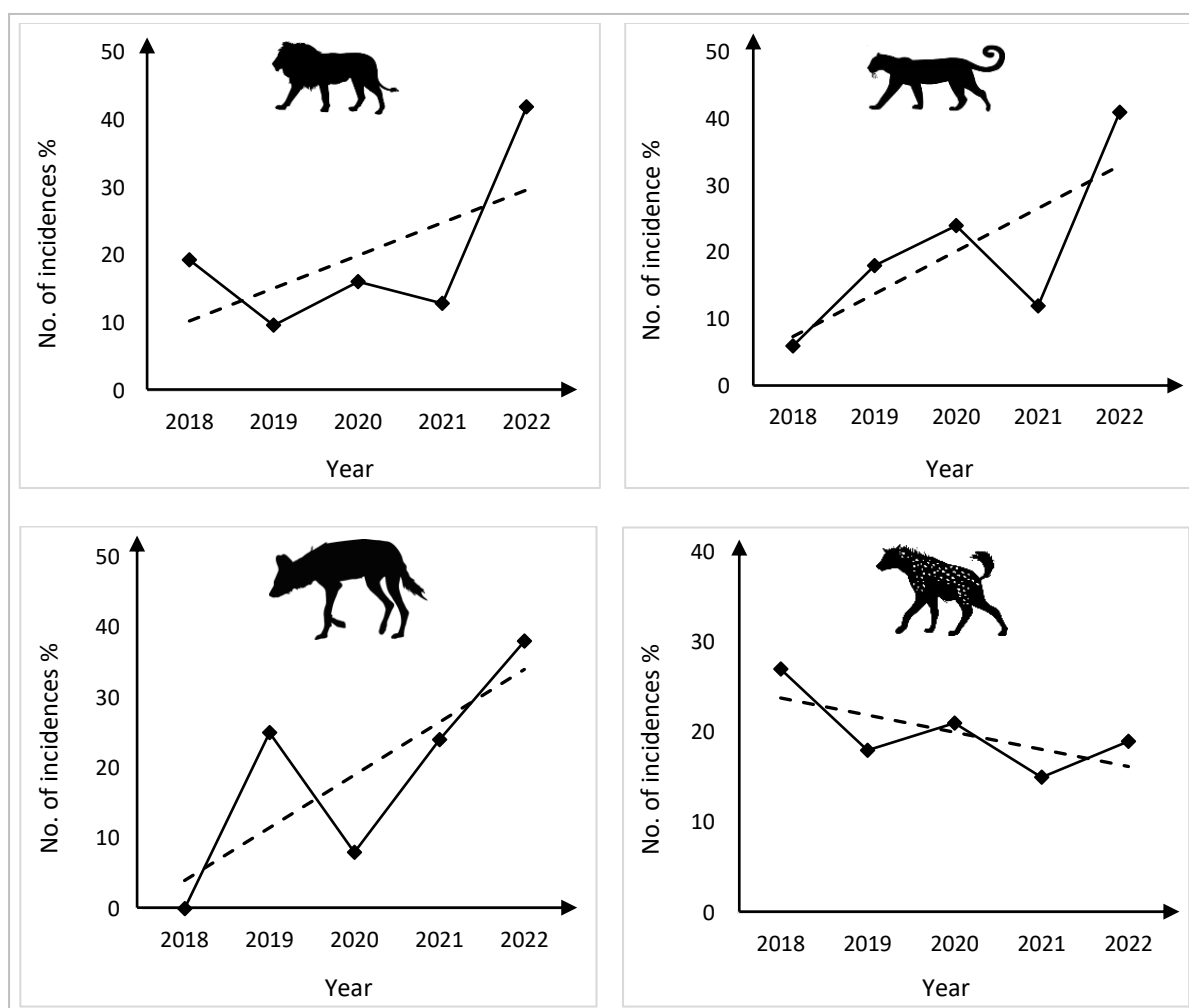
Figure 05: Trend of large carnivore attack incidences between 2018-2022

In the period of 2018-2019, large carnivores were involved in 150 attacks specifically on livestock, with no human death/injuries recorded during that time. In total, hyenas had the highest number of attacks 52% followed by lions 20.67%, wild dogs 16% and leopards 11.33%. Due to retaliation killing by local people, currently, the trend of hyena attacks on livestock tends to decrease compared to other carnivores. However, for the past 5 years,

hyenas were more responsible for the highest percentage of livestock loss due to their hunting strategies and they can live closer to human settlements with less fear. Local people declared that killing a hyena is much easier than other carnivores. They consider other carnivores are more aggressive and dangerous, therefore killing a lion or leopard could cost their life, especially human death/injury.

4.3.4   Nature and frequency of large carnivore attacks on livestock
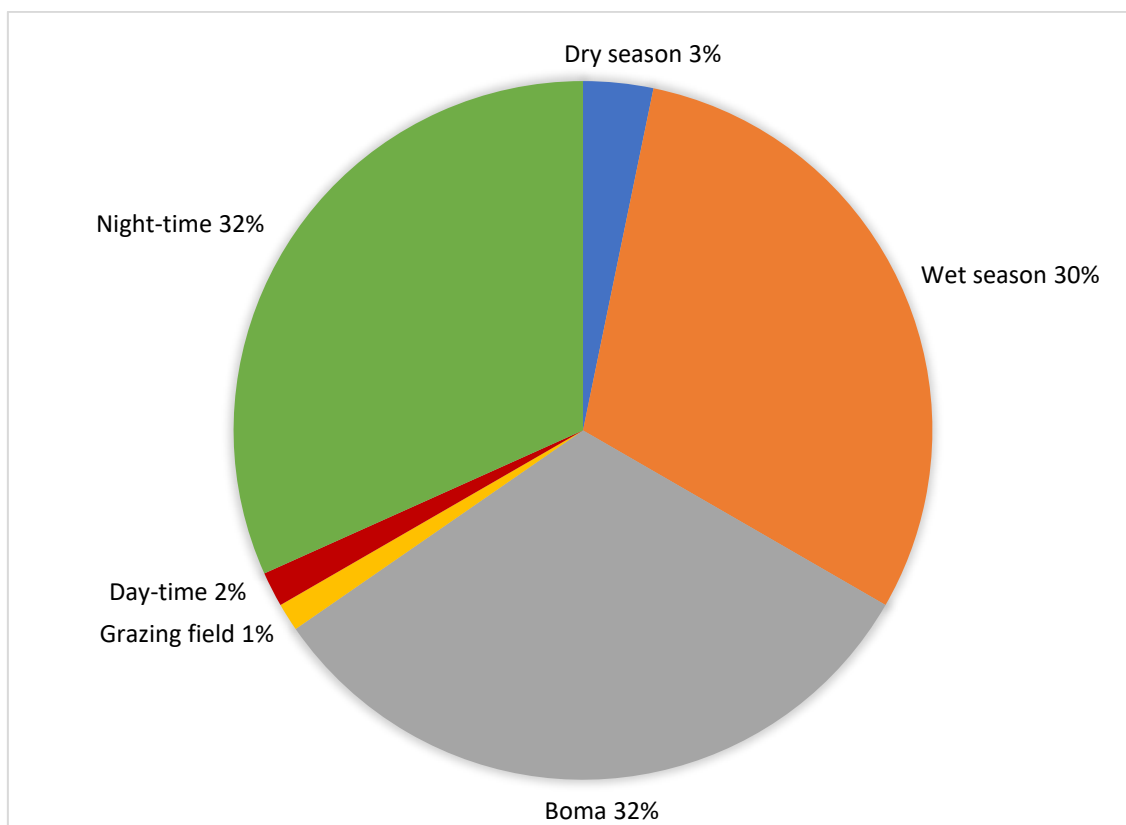
Figure 06: Trend of large carnivore attack incidences between 2018-2022
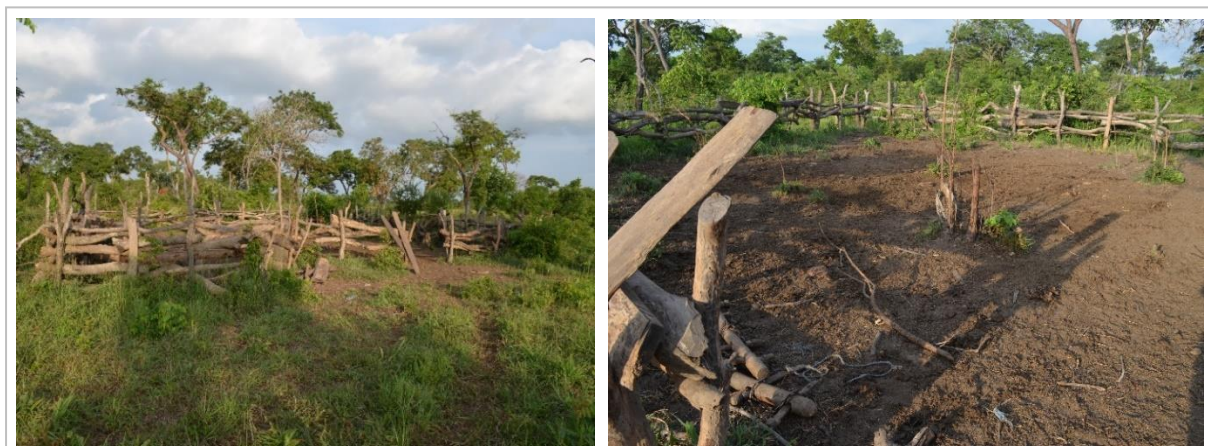
Figure 07: A structure of a traditional livestock enclosure/Boma

Depredation events were highly dependent on the season of the year, the structure of livestock enclosure/bomas and the time of the attack. Carnivore attacks were high during the night-time 32% than day-time 2% because most carnivores are nocturnal hunters, the darkness provides a favorable condition to hunt and during the time livestock are less alert and more vulnerable. Livestock attacks were high in livestock enclosure/bomas 32% while were very low in grazing fields 1%. Traditional bomas are often made of weak materials such as sticks and bushes which are not strong enough to keep out lions, hyenas and leopards. In grazing fields, carnivores are hard to hunt due to the daylight, presence of watchmen and guarding dogs which might prevent the attacks. Pastoralists are highly dependent on the season of the year to settle with their livestock. During the wet seasons, pastoralists can settle in one place for a long period this scenario attracts carnivores due to the availability of easy food. In dry seasons pastoralists migrate with their livestock searching for water and green pastures hence escape attacks.

4.4   Effect of large carnivores on the local community living adjacent to protected areas
4.4.1   Livestock loss caused by large carnivores in the Liwale district
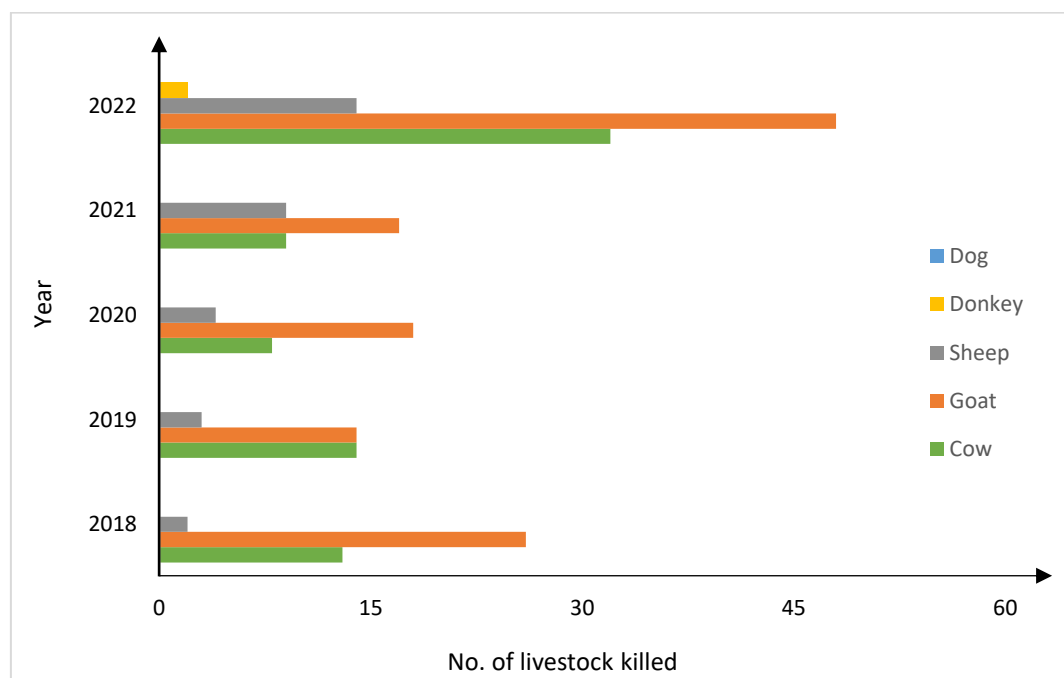
Figure 08: Number of livestock killed by large carnivores between 2018-2022

From 2018 to 2022, a total of 233 livestock were killed by large carnivores with the highest percentage of goats 52.8% followed by 32.6% of cows, 13.7% of sheep and 0.9% of donkeys. The number of goats attacked is high while there was no death recorded in dogs because usually carnivores prefer preys that are easier to catch with less effort to reduce energy and maximize their intake. In 2022 livestock killed by carnivores was 41.2% which was the highest value compared to 17.6% in 2018, 13.3% in 2019, 12.9% in 2020 and 15% in 2021. The total amount lost due to livestock depredation by large carnivores was about US dollar 37,573.91, such amounts could be useful in improving the standard of living since the communities living adjacent to the protected areas are poor and live below basic needs and food poverty lines.

4.4.2 Fear of human death/injury due to the high distribution of carnivores in communal lands

Figure 09: A pack of wild dogs sighted near Kimambi village

The high dispersion of large carnivores in communal lands led to the impeding and worsening of social and economic activities in villages surrounding the protected areas. People fear going to farms and schools in dawn hours and returning to their premises in the late evening for fear of encountering carnivores. In all surveyed villages, spotted hyenas and wild dogs were highly sighted near the village's land by local communities. This human-domestic-wild animal interface had much impact on domestic animals, no information had been reported on pathogen transmission due to the co-existence.

4.5   Human and landscape factors that influence human-carnivore conflicts

4.5.1   Livestock invasion in the protected areas
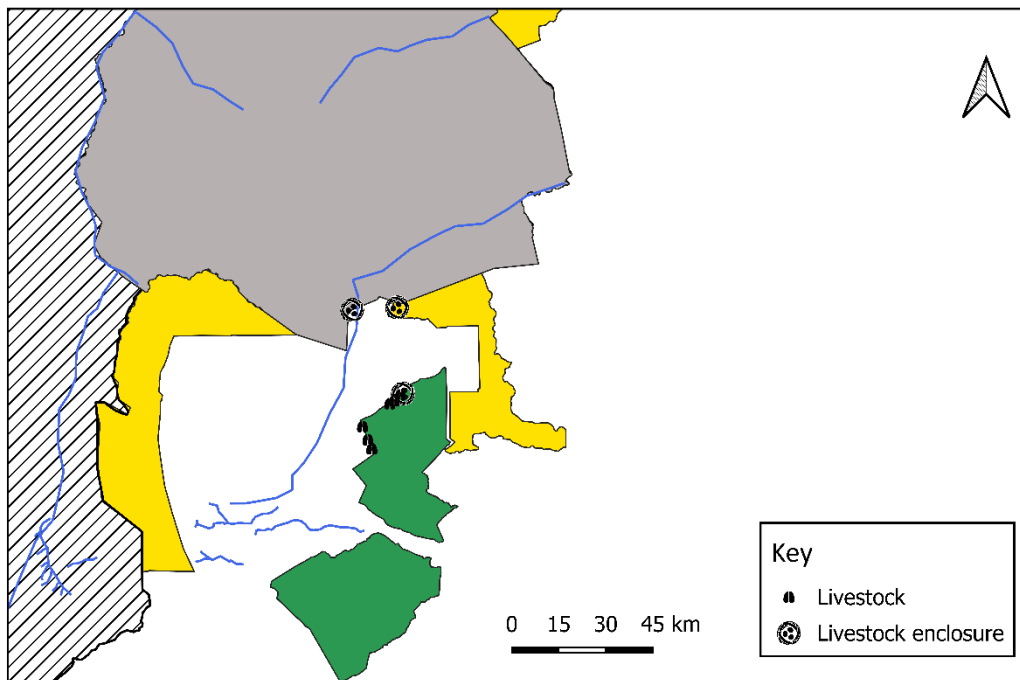
Figure 10: A map shows livestock invasion in the protected areas

Figure 11: Livestock and livestock enclosure encountered within the protected areas

Figure 12: A sign banner shows a boundary of the Nyerakipelele forest reserve

Livestock invasion in protected areas leads to habitat fragmentation which results in the competition of resources i.e., water and space between carnivores and domesticated mammals. Habitat fragmentation leads to prey base decline since herbivores shift from unsuitable to suitable places. Also, the interactions could lead to the transfer of zoonotic diseases from wild animals to domesticated animals. During the survey, we encountered several groups of cattle and temporary livestock enclosures/Bomas within the Nyerakipelele forest reserve while, within Magingo WMA, we only encountered temporary livestock enclosures. These temporary livestock enclosures are mostly built and used during the seasonal movements of herds of cattle. Despite the clear demarcation of the Nyerakipelele forest reserve livestock incursion was very high compared to the Angai forest reserve and Magingo WMA. The invasion of livestock in protected areas is higher in dry seasons than wet seasons because during wet seasons water and pastures became available in most places. In all surveyed villages, VEOs were complaining that current village land use plans are old and have not been reviewed for more than 5 years to match the current situation of human population growth. The situation has contributed to livestock invasion into protected areas due to limited spaces available.

4.5.2 Farming activities in the protected areas
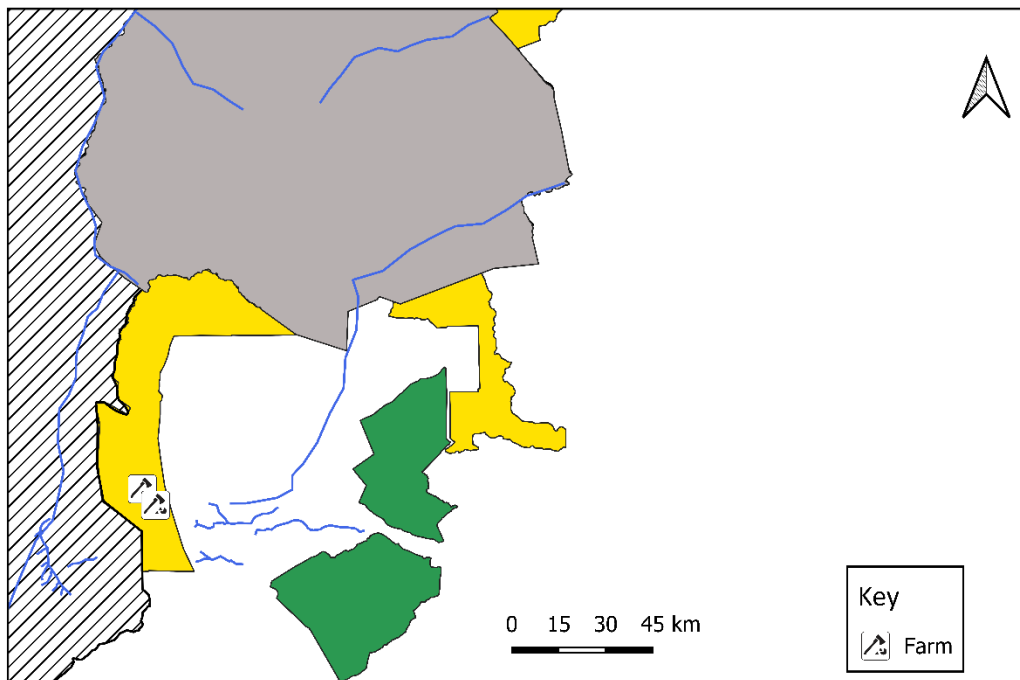
Figure 13: A map shows farming activities inside the protected area

Figure 14: Aerial picture shows illegal farming activities within Magingo WMA

We encountered several farms and small temporary houses for settlements within the Magingo WMA. People caught inside claimed that they don't know the official demarcation of the WMA, it's a coincidence. VEO of the Ndapata village admitted that after the official upgrading of two-thirds of the Selous game reserve to Nyerere national park, the challenge arose. However, the district government has a plan to reallocate all pastoralists to Kimambi village for easy management and control of the livestock-keeping system, still, the process

would be too expensive in terms of money and manpower and most likely it will take too long to be implemented.

4.5.3 Decline of prey base due to poaching
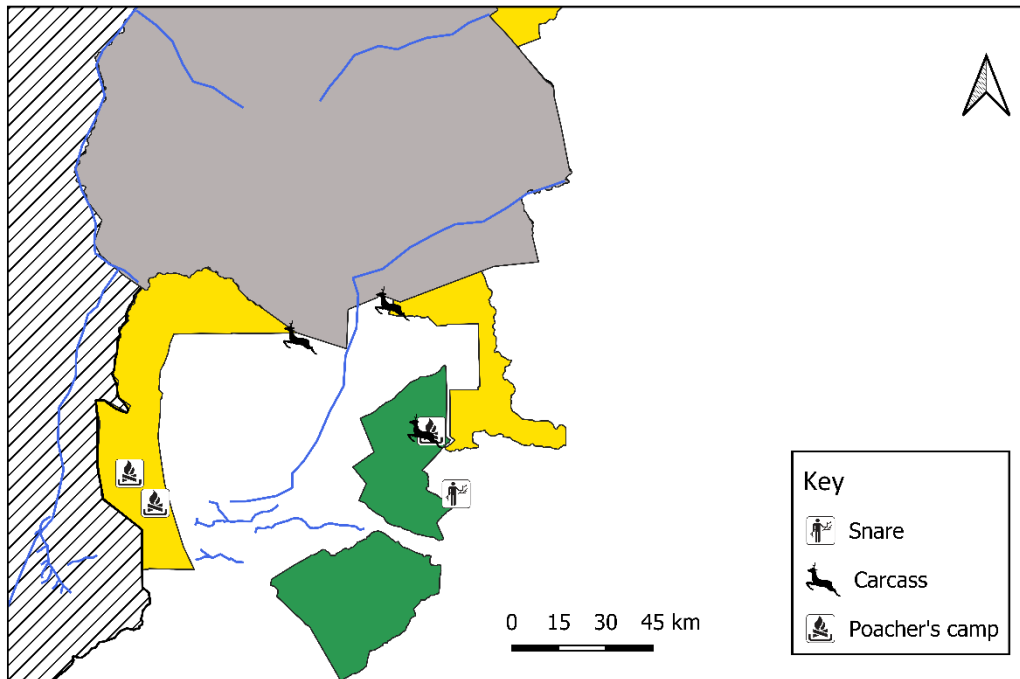
Figure 15: A map shows poaching incidences that are encountered within protected areas

Figure 16: Poaching incidences that are encountered within the protected areas

Figure 17: Snares used to trap wild animals in the protected areas
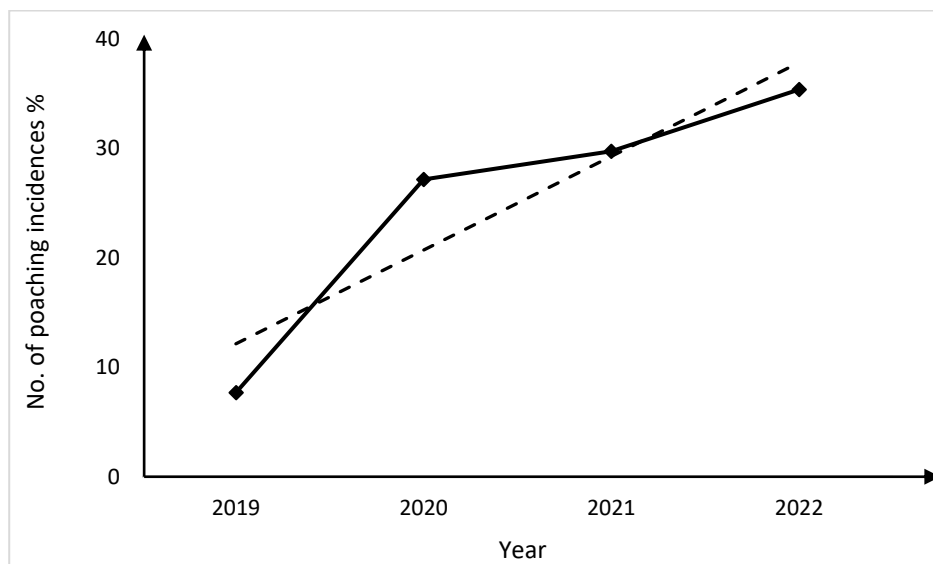
Figure 18: The trend of poaching incidences from 2019 to 2022

In the Liwale district, the communities living adjacent to protected areas are poor and live below basic needs and food poverty lines (SEAP,2016). These people are easily manipulated by wealthy people to facilitate the killing of wild animals for food and commercial purpose. Poaching was among the key determinants for human-large carnivore conflicts due to the decline of the prey base. From 2019 to 2022 the trend of poaching has increased in dispersal areas due to the high demand for bush meats and the use of a new and growing method of wire snares on bush meat poaching. The method is widespread because it is cost-effective, easy to adopt and hard to be detected by wild animals (Gray et al., 2018). Snares frequently catch a large number of both targeted and non-targeted species within a short period.

Despite international conventions and the country's laws modified and restricting the illegal use of firearms, in another way it accelerates the evolution of wire snares in poaching in the ecosystem (Gervasi et al., 2021).

4.5.4 Distance of villages from protected areas boundaries
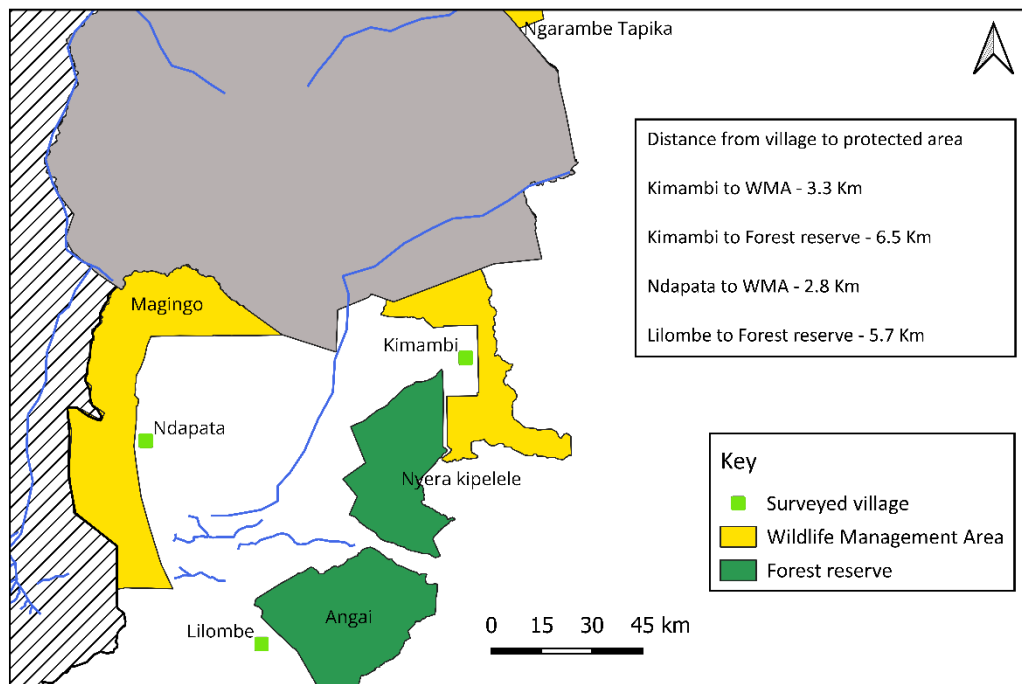
Figure 19: A map shows the distance from the village to the protected area boundaries

Villages that are set aside for livestock keeping are very near to the protected area boundaries and hence are more vulnerable to carnivore attacks, and this has also led to incidents of indiscriminate raids and human activities within the protected areas. Livestock raids in the Nyerakipelele forest reserve have been widespread in Kimambi village due to having a large number of livestock than in Lilombe and Ndapata villages. People living near the protected areas may benefit from the long-term conservation of wild resources through tourism activities. Currently, 3 hunting companies operate in Magingo WMA and villages that form the WMA receive annual allocations from the central government for community development and conservation activities.

4.6   Local community attitudes towards human-carnivore conflicts
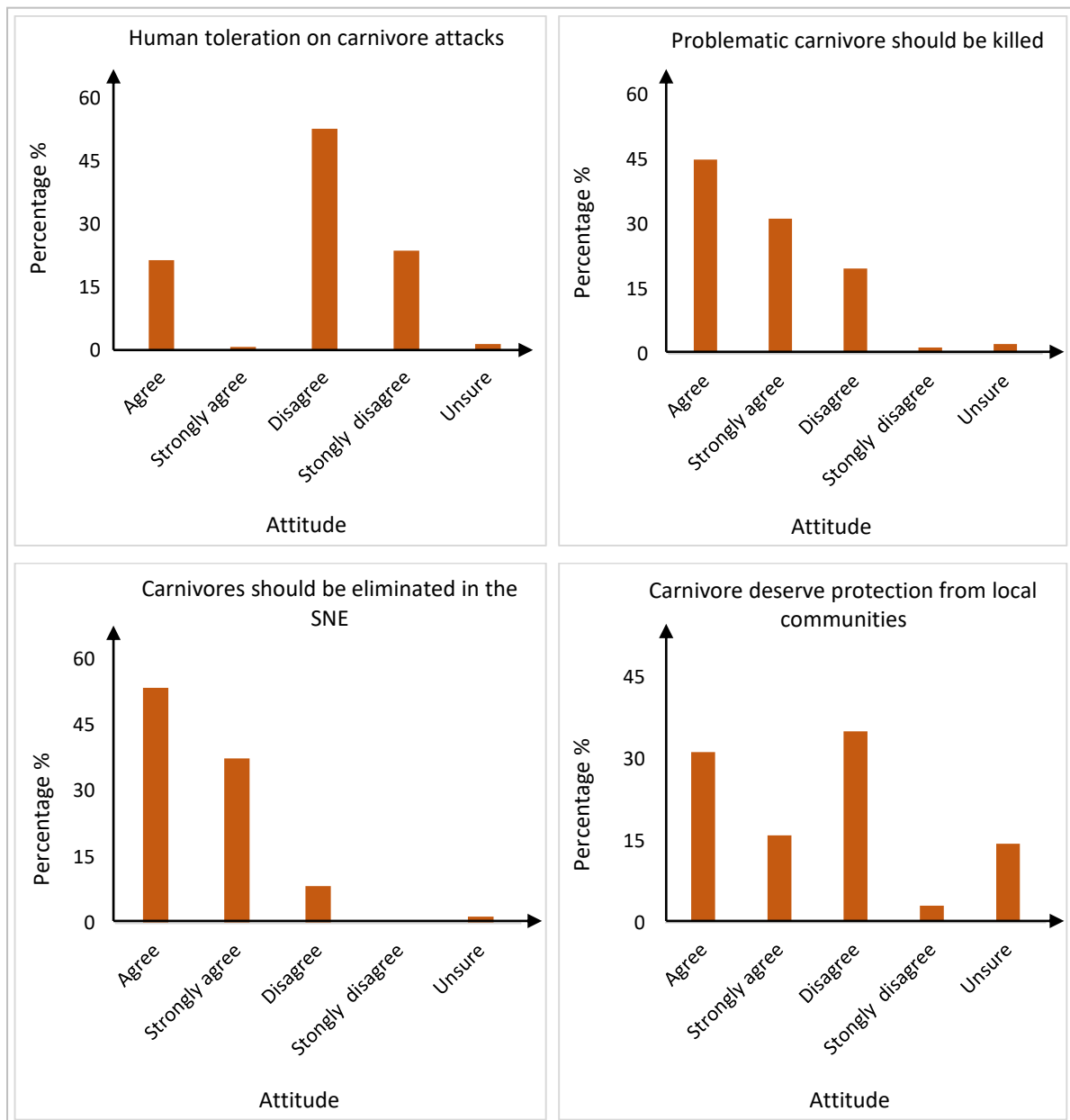
Figure 20: Local community attitudes towards human-carnivore conflicts

In response to questions asked about the local community's attitude toward large carnivore conservation efforts, the majority respond negatively. The level of negativity (Disagree/Strongly disagree) among people was highly dependent on the level of damage a person has faced. The situation reflects how much effort needed to be invested to secure the promising future of the carnivore population in the ecosystem, otherwise, the population could face a serious decline.

4.7   Local community's behavior response in mitigating problematic carnivores

Figure 21: Carnivore killed by the local community in mitigating HLCC

Local communities tend to use lethal methods to mitigate problematic carnivores and regularly use poison and cheaper equipment available i.e., bows and arrows, spears and snares. According to pastoralists If someone/people have killed a problematic carnivore the herdsmen union gives cattle to the parties as a reward. Sometimes, the PAC unit from wildlife authorities helps to mitigate the challenge by killing problematic carnivores. Retaliation killing of large carnivores is usually conducted in utmost secrecy without wildlife authorities and village leaders being aware because local people know it's illegal and not allowed.

5.0   DISCUSSION

During the study, we also discovered other forms of human-wildlife conflicts (HWCs), which was a human-elephant conflict (HEC). Farmers have been heavily affected by the presence of large groups of elephants roaming in their village land. Several times, local communities have reported carnivore attack incidences to their village leaders i.e., VEO and VWO but it appears that it's not a serious issue as compared to elephant attacks. Much effort has been put to mitigate elephants than carnivores because farmers don't have any other option rather than reporting the problem to wildlife authorities since elephants are too big to compete with and usually cause human injuries and death when disturbed. This is a different situation for large carnivores, where pastoralists may sometime use lethal methods to control the problem. Because of the ongoing expansion of livestock-keeping activities, currently, the situation is getting worse, and when an incident happens, local communities usually don't report it to the responsible authorities. They are afraid of being harassed and reallocated to other places by the district government because most of the pastoralists are not natives in the district and are considered a stubborn community. Records show that pastoralism in the Liwale district became more effective over the period of 5-7 years back when a large number of pastoralists were shifted from other districts i.e., Kilwa and Nachingwea to Liwale district. The current increase in pastoralist pressure accompanied by climate change and variability is amplifying stresses to large carnivores due to habitat shrinkage that tends to limit access to key resources for living including water and prey (Daszak et al., 2001; Olff & Grant, 2008). Also, the grazing patterns involving mobility (nomadism), the restriction of grazing to specific areas at certain times of the year and heard splitting create many problems for carnivores and farmers. However, meeting with the local community in the study area was very important because not only the team explained a lot about carnivore behavioral ecology and conservation initiative, but also, local people had a great opportunity to interact with the team and see a better way forward on solving human-carnivore conflicts. In the past 2 years, the government built more than 2 ranger posts to combat the challenge of human-wildlife conflicts which has been a problem for pastoralists and farmers for several years. It is my opinion that when the local communities have a chance to be involved in several projects may change their attitude toward problematic animals.

6.0   CONCLUSION AND RECOMMENDATION

The management of conservation conflicts to mitigate negative outcomes for biodiversity and well-being is becoming increasingly important (Sargent, 2022). Also, identifying solutions for managing human-carnivore conflict is a priority for people and wildlife in the Selous Nyerere ecosystem, as elsewhere. But conservation advocates tend to assert their interests through legislation and enforcement which renders lethal retaliation illegal and/or socially unacceptable (Carter et al., 2017; Redpath et al., 2017). To reduce human-carnivore conflicts, technical interventions often have to be implemented including using wildlife management authorities such as TAWA and TANAPA (Lesilau et al., 2018; Miller et al., 2016). Also, providing consolation for the loss of livestock caused by large carnivores would be an additional strategy to encourage human-carnivore coexistence in the ecosystem (Dickman et al., 2011). To foster the coexistence between humans and large carnivores, therefore, recommend the followings; -

i.   To enhance law enforcement and habitat suitability in dispersal areas specifically in Magingo WMA and Nyerakipelele forest reserve to foster human-carnivore coexistence.

ii.   To minimize livestock depredation by large carnivores' pastoralists should modernize their traditional livestock enclosures and use cost-effective mitigation methods like flashing lights.

iii. Wildlife authorities should enhance consolation/compensation schemes for the loss of livestock caused by large carnivores.

iv.   Wildlife authorities should enhance community conservation awareness through tourism benefit-sharing schemes and education programs.

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9.0 APPENDICES

Appendix 01:   Household questionnaire survey form for the data collection on human attitudes
toward large carnivores.

QUESTIONNAIRE SURVEY FORM   (*This form will be translated into the Swahili language*).

Patterns of large carnivore depredation on livestock and community tolerance behavior around Selous-Nyerere ecosystem; A case study of Liwale district in southern Tanzania.

Form No: ⎯⎯⎯⎯ **Village** ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ **District** ⎯⎯⎯⎯⎯⎯⎯⎯

GPS Coordinates: X ⎯⎯⎯⎯⎯⎯⎯ **Y** ⎯⎯⎯⎯⎯⎯⎯ **Date** ⎯⎯⎯⎯⎯⎯⎯⎯

Background

1. Sex of the respondent   Female ☐   Male ☐
2. Age of the respondent   18 - 28 ☐   29 - 39 ☐   40 - 49 ☐   50 and above ☐
3. Ethnic group of the respondent   Ngindo ☐   Sukuma ☐   Mang'ati ☐   Other ⎯⎯⎯⎯
4. Family size of the household   1 - 5 ☐   6 - 10 ☐   11 - 15 ☐   16 and above ☐
5. Education level of the respondent
   Informal ☐   Primary ☐   Secondary ☐   College/University ☐   Vocational training ☐
6. Main economic activity of the respondent   Livestock keeping ☐   Agriculture ☐
7. How did the respondent get into the area he/she lives presently   By birth ☐   Immigrant ☐
8. Length of time (Years) lived in the area/village   0 - 5 ☐   6 - 10 ☐   11 and above ☐

Livestock keeping

9. Type of livestock the respondent possesses
   Cattle ☐   Goat ☐   Sheep ☐   Donkey ☐   Dog ☐   Pig ☐
10. Total number of livestock the respondent possesses
   ≤ 50 ☐   51 - 200 ☐   201 - 350 ☐   ≥351 ☐
11. Number of livestock now compared to 5 years ago
   Same ☐   Fewer ☐   More ☐
12. Are the livestock guarded in any way?   Yes ☐   No ☐. If the answer is **YES.**
   a) How? Dog ☐   Bomas ☐   Fencing ☐   People/Watchman ☐   Other ⎯⎯⎯⎯⎯
   b) They guarded livestock against what
      Thieves ☐   Predators ☐   Elephant ☐   Both ☐   Other ⎯⎯⎯⎯⎯
   c) When have they guarded   Day-time ☐   Night-time ☐   Always ☐

Large carnivore attacks

13. Which large carnivore have you experienced in your area/village land for the past 5 years

   Lion ☐   Leopard ☐   Spotted Hyena ☐   Wild dog ☐   Other _____

14. Which large carnivore is more threatening and destructive in your area/village land
   Lion ☐   Leopard ☐   Spotted Hyena ☐   Wild dog ☐   Other _____

15. Level of threats and destruction caused by large carnivores mentioned in 14 above
   Human injury ☐   Human death ☐   Crop raiding ☐   Livestock depredation ☐

16. Have any livestock losses been caused by carnivores in your household?   Yes ☐   No ☐

   If **NO** please go to question 17. If **YES** please continue to sections (a), (b), (c) and (d).

   (a) Approximately how many livestock have you lost to carnivores for the past 5 years

Sn.	Domestic animal	2019				2020				2021				2022				2023			
		Li	Le	Wd	Sh	Li	Le	Wd	Sh	Li	Le	Wd	Sh	Li	Le	Wd	Sh	Li	Le	Wd	Sh
1	Cattle																				
2	Goat																				
3	Sheep																				
4	Donkey																				
5	Pig																				
6	Other																				

Note

Li   -   Lion
Le   -   Leopard
Wd   -   Wild dog
Sh   -   Spotted Hyena

   (b) Frequency of sightings and attacks

Attack on livestock by large carnivores?	Lion	Leopard	Spotted Hyena	Wild dog
Season of attack (dry/wet)				
Location of attack (At/around the boma or grazing field?)				
Time of day of the attack (Day/Night)				
Livestock type attacked				
What happened to the carnivore after an attack				
Attack on humans by large carnivores?				
Date (year and month if possible)				
Location of attack (Boma/Grazing field)				
What was the person doing				
Was the person injured or /killed?				
What happened to the predator?				

(c) What do you think about these incidences of human-carnivore conflicts around your area/village?

Village close to PA ☐   Traditional bomas ☐   Encroachment to PA ☐   Nomadism ☐

(d) Do the number of large carnivore attacks appear to be more or less than 5 years ago

More ☐   Less ☐   Same ☐   Don't know ☐

Local community attitudes

17. Are Large carnivores more threatening to humans than livestock?
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

18. Are Large carnivores more threatening to livestock than humans?
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

19. Can you tolerate when a large carnivore kills your livestock or cause any human injury/death in your household?
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

20. A large carnivore led to any loss of livestock or cause human injury/death needs to be found and killed?
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

21. Would you be happier if no large carnivores were around your villages?
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

22. Large carnivores deserve protection from the local community
Agree ☐   Strongly agree ☐   Disagree ☐   Strongly disagree ☐   Unsure ☐

23. What is your opinion of the carnivores that cause problems to humans and livestock in the village?
Problem animal control ☐   Shoot to kill ☐   Poisoning ☐   Spearing ☐   Snaring ☐

24. What happens when a loss caused by a large carnivore occurs (Human injury/death/livestock killing)
Compensation ☐   Carnivore killed by PAC units ☐   Carnivore killed by local people ☐
No action ☐   I don't know ☐

25. Do you know the official demarcation/boundary of the protected areas in your area?
Selous game reserve ☐   Nyerere national park ☐   Magingo WMA ☐
Nyerakipelele forest reserve ☐   Angai forest reserve ☐

Appendix 02: Guiding questions for the key informant interview.

GUIDING QUESTIONS FOR INTERVIEW (*This form will be translated into the Swahili language*).

Patterns of large carnivore depredation on livestock and community tolerance behavior around Selous-Nyerere ecosystem; A case study of Liwale district in southern Tanzania.

Form No: ⎯⎯⎯⎯ **Village** ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ **Name** ⎯⎯⎯⎯⎯⎯⎯⎯⎯

Rank ⎯⎯⎯⎯⎯⎯⎯⎯⎯ **Date** ⎯⎯⎯⎯⎯⎯⎯

1. What is the historical profile of your village?

2. What are the major socio-economic activities performed within the village?

3. Does the village have a land use plan? If yes, is the land use plan followed? and if not followed what are the causes?

4. Can you tell me the total number of livestock in your village?

5. Is there any conflict existing between the people and large carnivores in your village? If yes, what are the causes?

6. What kind of intervention mechanisms have people been using to mitigate the conflicts between humans and carnivores?

7. What do you think should be done as intervention measures for the problem?

Appendix 03: A list of key informants interviewed during the study.

Sn	Name	Rank	Institution
1	Philipo Benard Orio	Commanding Officer (CO) - Selous Game Reserve Liwale station.	Tanzania Wildlife Management Authority - TAWA.
2	Richard Baltazar Tarimo	Commanding Officer (CO).	Tanzania Forestry Services Agency - TFS.
3	Damasi M. Mumwi	District Natural Resources Management Officer (NRMO).	Liwale District Council.
4	Patrick Senga	District Game Officer (DGO).	Liwale District Council.
5	Bernard Kivamba	District Livestock and Fisheries Development Officer	Liwale District Council.
6	Mbaraka Adinani Mapande	Secretary	Magingo Wildlife Management Area - WMA.
7	Shabani Mohamedi Luwongo	Village Executive Officer - VEO.	Kimambi village.
8	Shaibu Seifu Mnaliwa	Village Executive Officer - VEO.	Lilombe village.
9	Juma Abdalla Amani	Village Executive Officer - VEO.	Ndapata village.

Appendix 04: Community's identification card for large carnivores.

(A)

(B)

(C)

(D)

Appendix 05: Declaration on authenticity and intellectual property management.

DECLARATION

on authenticity and public assess of final ~~essay/thesis/~~mater's thesis~~/portfolio~~[1]

Student's name: KATWANA DEOGRATIAS GERVAS

Student's Neptun ID: B8Y5QR

Title of the document: MASTER'S THESIS

Year of publication: 2023

Department: WILDLIFE BIOLOGY AND MANAGEMENT

I declare that the submitted final ~~essay/thesis/~~master's thesis~~/portfolio~~[2] is my own, original individual creation. Any parts taken from an another author's work are clearly marked, and listed in the table of contents.

If the statements above are not true, I acknowledge that the Final examination board excludes me from participation in the final exam, and I am only allowed to take final exam if I submit another final essay/thesis/master's thesis/portfolio.

Viewing and printing my submitted work in a PDF format is permitted. However, the modification of my submitted work shall not be permitted.

I acknowledge that the rules on Intellectual Property Management of Hungarian University of Agriculture and Life Sciences shall apply to my work as an intellectulal property.

I acknowledge that the electric version of my work is uploaded to the repository sytem of the Hungarian University of Agriculture and Life Sciences.

Place and date: 2023 year 05 month 02 day

Student's signature

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[1]Please select the one that applies, and delete the other types.
[2]Please select the one that applies, and delete the other types.

Appendix 01: Statement on consultation practices

STATEMENT ON CONSULTATION PRACTICES

As a supervisor of **Katwana Deogratias Gervas** (Student's NEPTUN ID: B8Y5QR), I here declare that the final master's thesis has been reviewed by me, the student was informed about the requirements of literary sources management and its legal and ethical rules.

I recommend the final master's thesis to be defended in a final exam.

The document contains state secrets or professional secrets: yes   <u>no</u>*[1]

Gödöllő, 2023 April 26

Internal supervisor
Prof. Dr. Miklós Heltai

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[1] Please underline applicable.