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Master of Science HES-SO in Life Sciences

Orientation :
Natural Resources Management

Contribution to status assessment of the African wild dog populations in western Tanzania

Telemetry of an African wild dog in Katavi-Rukwa ecosystem

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Dedicate

In the memory of James Chacha Karomba, my friend and neighbour, who left us too early as another victim of the battles for wildlife. He had recently been promoted to work in the region, far away from his family. James was one of the kindest persons I met during my stay in Tanzania, he was always smiling and kind with everyone. There were two stray dogs staying around our houses, and he was maybe the only person that I saw who would play with them, when they were treated with indifference or aggressivity in general. It may not mean much, but as someone who grew up with dogs and also enjoyed playing with Simba and Mama, it was touching to see this unexpected gentleness. He was also raising many chicken, that he treated with love and care. It was beautiful and inspiring to see someone working with wildlife show this kind of affection to all the animals.

I heard that he was ambushed in in the middle of an operation to evacuate a forest reserve that was going to be upgraded to a game reserve, as there were too many cattle keepers settled inside. When I heard the news, I was sad and angry against the people responsible. But the angriness disappeared quickly, as I cannot judge those people; how could I know if I would not be in a similar situation if I were in their place. If I chose to introduce my thesis with this sad event, it is because it is important for me to put forward one lesser-known aspect of conservation.

There are many kinds of victims in this battle for natural resources, people doing illegal activities, people working to protect the nature, and also domestic and wild animals. Every year, hundreds of people are killed in both sides, and it makes me sad to wonder if all these beautiful animals would still remain without these sacrifices. I do not think there is an easy solution, and I am not saying what is right or wrong, but it is the sad reality.

May each of these souls rest in peace.

Table of Contents

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Abbreviations

ADAP	Association for the Development of Protected Areas
BKZ	Beekeeping Zone
CBNRM	Community Based Natural Resource Management
COSTECH	Tanzania Commission for Science and Technology
DoP	Dilution of Precision
CT	Camera Trap
FR	Forest Reserve
GCA	Game Controlled Area
GLM	Generalized Linear Model
GR	Game Reserve
KAZA-TFCA	Kavango–Zambezi Transfrontier Conservation Area
KDE	Kernel Density Estimator
RSF	Resource Selection Function
SSF	Step Selection Function
TANAPA	Tanzania National Parks
TAWA	Tanzanian Wildlife Authority
TAWIRI	Tanzania Wildlife Research Institute
UASWS	University of Applied Sciences of Western Switzerland
VEO	Village Executive Officer
VGS	Village Game Scout
WMA	Wildlife Management Area

Abstract

The African wild dog is the most endangered carnivore in the continent. In the past decade, research on wild dogs has increased considerably. At first, studies were focused on understanding their complex social behaviour, but recently the interest has shifted on their dispersal. Wild dogs travel distances rarely seen in terrestrial carnivores, and with the advances in telemetric technology, this can be used to determine functional corridors for carnivores. However, most of the studies take place in national parks, but a large and unknown part of the population remains outside these areas. Moreover, because of their high mobility and large home ranges, even the individuals that live within national parks are likely to move in non-protected areas.

This study analyses the data from a female collared in Lake Rukwa GR, used to determine the home range of the pack and its habitat preferences during the rainy season. In parallel to this, all the available wild dog data was regrouped to do a first contribution to a population assessment in the Katavi-Rukwa ecosystem. This includes data from the systematic ecological monitoring by ADAP, direct encounters and camera trapping during the fieldwork, and exchanges with people from TAWA and hunting companies.

A survey was conducted in the eight villages that are participating in community based natural resource management projects with ADAP. The activities include beekeeping, mushroom collection, and a joint forest management. The objective of the survey was to evaluate the perceptions on wildlife of Wasukuma, an agro-pastoralist tribe, who are settled next to forests. They were chosen as the target population as their activities make them prone to conflict.

These findings shall be used to guide local management for wild dog conservation, and human-carnivore conflict reduction in collaboration with ADAP and WCS.

Keywords: African wild dog, Lycaon pictus, wildlife corridor, Katavi – Ruaha, telemetry, genetic pool, endangered species, ecological connectivity, population dynamics, ecology and behaviour, human-carnivore conflict, Wasukuma pastoralists, conflict mitigation strategies, Red List criteria, statistical treatment of telemetry data, GIS, home range, habitat-use, landscape ecology.

Abstract

Le chien sauvage d'Afrique est le carnivore le plus menacé du continent. Au cours de la dernière décennie, la recherche sur les chiens sauvages a considérablement augmenté. Au début, les études étaient axées sur la compréhension de leur comportement social complexe, mais récemment, leur dispersion est au centre des recherches. Les chiens sauvages parcourent des distances rarement observées chez les carnivores terrestres, et avec les progrès de la technologie télémétrique, cela peut être utilisé pour déterminer les corridors fonctionnels des carnivores. Cependant, la plupart des études ont lieu dans les parcs nationaux, mais une partie importante et inconnue de la population reste en dehors de ces zones. De plus, en raison de leur grande mobilité et de leurs vastes domaines vitaux, même les individus qui vivent dans les parcs nationaux sont susceptibles de se déplacer dans des zones non protégées.

Cette étude analyse les données d'une femelle munie d'un collier dans la réserve de chasse du Lac Rukwa, utilisées pour déterminer le domaine vital de la meute et ainsi que ses préférences d'habitat pendant la saison des pluies. En parallèle, toutes les données disponibles sur les chiens sauvages ont été regroupées afin de faire une première contribution à une évaluation de la population dans l'écosystème Katavi-Rukwa. Il s'agit des données issues du suivi écologique systématique d'ADAP, des rencontres directes et du piégeage photo lors du travail de terrain, ainsi que des échanges avec les personnes de TAWA et les sociétés de chasse.

Une enquête a été menée dans les huit villages qui participent à des projets de gestion communautaire des ressources naturelles avec ADAP. Les activités comprennent l'apiculture, la collecte de champignons et une gestion conjointe des forêts. L'objectif de l'enquête était d'évaluer les perceptions de la faune et de la flore des Wasukuma, une tribu agro-pastorale, qui s'installent à proximité des forêts. Ils ont été choisis comme population cible car leurs activités les rendent sujets à des conflits.

Ces résultats seront utilisés pour guider la gestion locale pour la conservation des chiens sauvages, et la réduction des conflits homme-carnivore en collaboration avec ADAP et WCS.

Mots clés: Chien sauvage d'Afrique, Lycaon pictus, corridor biologique, écosystème de Katavi, Katavi - Ruaha, télémétrie, pool génétique, espèces en danger, connectivité écologique, dynamique des populations, écologie et comportement, conflit homme-carnivore, agro-pastoralistes Wasukuma, stratégies d'atténuation des conflits, critères de la liste rouge, traitement statistique des données de télémétrie, SIG, domaine vital, preference d'habitats.

1. Introduction

1.1. Context

The study takes place in the Katavi-Rukwa and Ruaha-Rungwa ecosystems in western Tanzania. The area is attractive because there are several protected areas of different status, with a variety of management and governance strategies. They are all located in a relatively homogenous ecosystem; therefore, they can easily be compared to assess the actual efficiency of conservation strategies. These include national parks (NP), where all kind of resource extraction is prohibited; game reserves (GR), where trophy hunting tourism is allowed; forest reserves (FR) - game controlled areas (GCA) of double status, where logging and hunting is permitted under certain conditions, and there are community-based nature resource management (CBNRM) projects in place; and community-based conservation areas such as the wildlife management area (WMA) in Ipole. All these protected areas prevent human settlement and are dedicated to conservation. Moreover, two of the largest largest NPs in the country are core areas of this large ecosystem, the Ruaha NP (14507 km^2) and Katavi NP (4207 km^2), serving as core areas with the highest degree of protection.

In the western part of Katavi NP, there have been several studies on the dynamics of large mammal populations, the vegetation structure, and bushmeat consumption carried on principally by the University of California (Banda et al., 2006; Mulder et al., 2007; Caro, 2008; Banda et al., 2008; Martin et al., 2012; Mgawe et al., 2012).

On the eastern edge of Katavi NP, the Association pour le Développement des Aires Protégées (ADAP, adap.ch) has been developing community based natural resource management (CBNRM) projects since 2001. The objective is to promote participatory management of the forest that allows sustainable extraction of natural resources, so local communities can retain their rights to use protected areas and obtain revenues from them. In addition to these projects and in collaboration with the University of Applied Sciences and Arts Western Switzerland (UASWS), there has been long-term monitoring of the status and evolution of the surrounding forests, biodiversity as well as socio-political issues, and this research is part of this framework (Hausser et al., 2009; Fischer et al., 2013; Mermod, 2016; Stampfli, 2016; Hausser et al., 2017; Zurkinden, 2017; Bloesch, 2018; Buffard, 2018; Daudet, 2019).

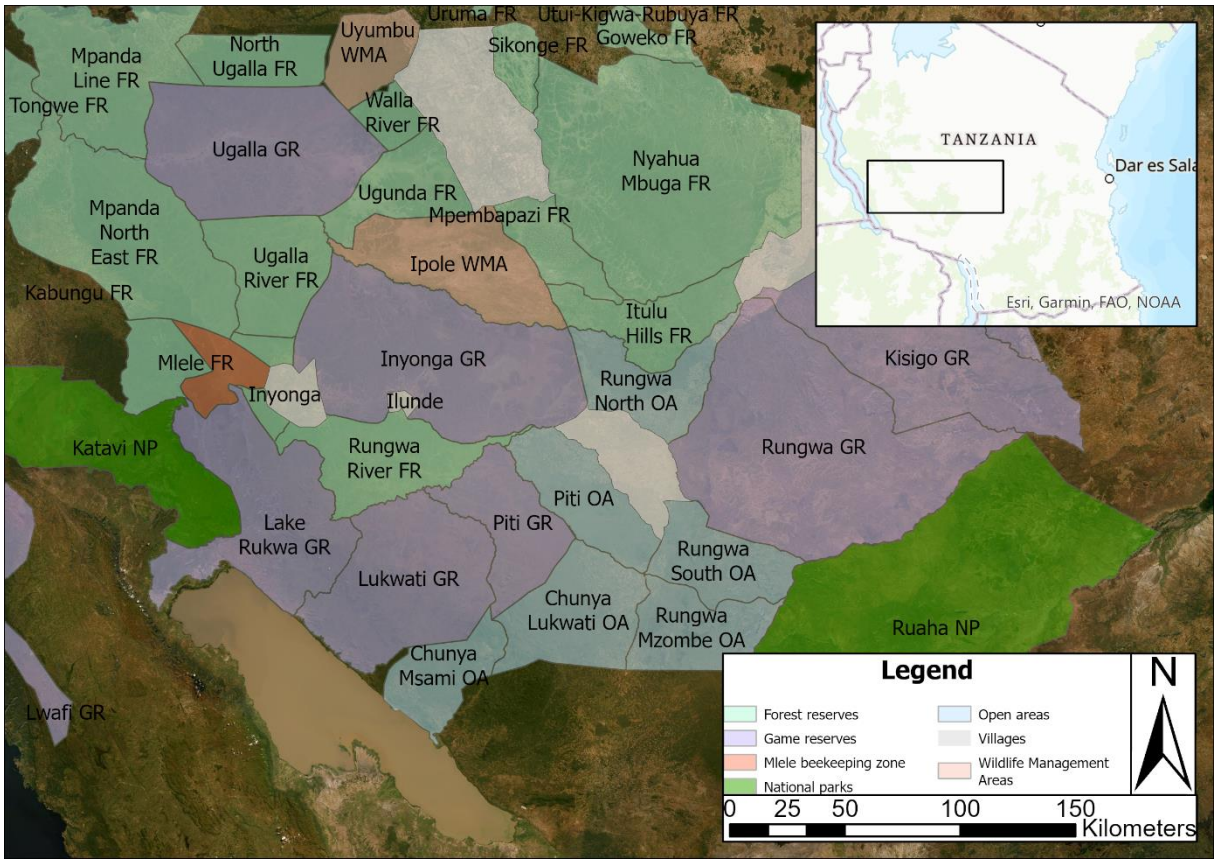

Figure 1: Katavi-Rukwa and Ruaha-Rungwa ecosystems with their protected areas.

The conservation status of the protected areas covering this large ecosystem seems to be influenced by the management effectiveness and the resources available to their management. The success of this management is based on constant conservation efforts, and these can be nullified very quickly, especially with the increasing pressure from agro-pastoralist communities. During the last decade, the large in-migration of Wasukuma agro-pastoralists coming from Simiyu, Mwanza, Shinyanga, Geita, and Tabora regions has led to increasing pressure on the ecosystem. This is reflected in the size and extent of the villages, which have drastically and rapidly changed over the last few years (Hausser, pers. comm.). As shown in a recent study, this pressure has caused the transformation of 1770 km^2 of forest land into agricultural land between 2002 and 2018 (Daudet, 2019). Moreover, Katavi is the region facing the highest rural population growth rate in the country (URT, 2013; Salerno, 2016). According to the last population and housing census in 2012, the population of the Mlele district was estimated to be 34'698 people. Only four years later, the population had doubled: in the VEOs' (Village Executive Officers) report from 2016, the population was estimated to be 69'473 people; this exponential growth was expected to continue, although the infrastructure available is not sufficient to accommodate such a numerous and growing population (Mlele DC, 2016).

When the human pressure becomes too strong and detrimental to the ecosystem, the government can decide to upgrade the protection status of reserves, or on the contrary to degazette them. Due to the increasing pastoralist pressure, multiple reserves in the area had their degree of protection increased this year, such as Inyonga FR, which was upgraded to a GR, and Ugalla GR was transformed into a national park. Even though some of the protected areas have been considerably degraded, large reserves, such as Katavi NP, Lake Rukwa GR, and Mlele FR, remain relatively untouched due to effective management and regular law enforcement patrols. The deforestation levels remain very low, and they harbour healthy wildlife populations, with endangered species of large mammals such as elephants (*Loxodonta Africana*, EN), lions (*Panthera leo*, VU), hippopotamus (*Hippopotamus amphibius*, VU), leopards (*Panthera pardus*, VU) and wild dogs (*Lycaon pictus*, EN) (Hausser et al., 2017; Zurkinden, 2017; Buffard, 2018; TAWIRI & WCS, 2019). The monitoring of Mlele FR has shown that 49 species of medium and large mammals are present in the area, indicating that community-based conservation can effectively preserve biodiversity (Hausser et al., 2017).

Motivated by population growth, the degradation of natural-resource availability, and soil fertility, this inflow of pastoralist migrants has devastating consequences for nature in the places they move to and for the local social dynamics as well (Salerno et al., 2017). Wasukuma agropastoralists started arriving in the region in the 70s, and the flux of immigrants has only increased since (Mulder et al., 2007). Today, large areas bordering the villages, which used to be part of the surrounding forests, have been completely cleared off their trees to create settlements or agricultural land, and encroachment has severely affected wildlife (see Figure 2). Furthermore, these recent settlements are often linked to overgrazing, increasing carnivore kills, and in some cases, people kill each other for land or cattle grazing on farms belonging to others (Salerno et al., 2017). The problems arising from this large-scale migration are not limited to wildlife and deforestation; migrant-resident conflicts are common and make resolving this issue even more complex.

Figure 2: Encroachment of the forest near Majimoto.

The Katavi-Rukwa ecosystem is part of the Central Zambezian miombo woodlands eco-region (Burgess et al., 2004), typically dominated by the genera *Brachystegia*, *Julbernardia*, and *Isoberlinia*, which are rarely found in other types of African forests (Frost, 1996; Banda et al., 2008). Miombo woodlands cover most of the country's forested land (Banda et al., 2006; Lupala et al., 2015), playing an essential role in carbon storage (Shirima et al., 2015; Bloesch, 2018). Fires are part of the functioning of the miombo woodlands (Frost, 1996). In the managed areas, they are artificially started around the beginning of the dry season by the rangers or game scouts. These low-intensity fires help preserve and can even enhance the biomass, as they prevent high-intensity bushfires at the end of the dry season, which are much more destructive (Ryan & Williams, 2011).

Miombo woodlands are characterised by low productivity and soil nutrient deficiency; converting the forests into short-duration croplands without restraint will have significant consequences for the future, and can only provide short-term benefits. Farmers have to move constantly; therefore, the forests tend to be quickly cleared due to the slash-and-burn practices (Mlele DC, 2016; Gumbo et al., 2018). Thanks to its fast regenerative capacities, sustainable use of the miombo is possible, even for charcoal production and slash and burn agricultural practices, if the area is left undisturbed during a recovery period (Gumbo et al., 2018). However, once the forest is too degraded, its resilience is lost, and there are two global consequences. The carbon from the soil and biomass is released into the atmosphere. Considering that the amount of CO2 stored in the miombo is not negligible, this corresponds to an increase of 20% of carbon released from land-use change worldwide (Frost, 1996). The other consequence is a change in energy exchange at the land surface, leading to a decrease in the formation of rain (Frost, 1996).

There is a clear data gap regarding wild dog knowledge in the region. There have been very few studies on large carnivores in the western part of the study area, particularly in the Katavi-Rukwa ecosystem. One of the biggest priorities for conserving the endangered African wild dog is to gather information about the species to propose corresponding management measures. Therefore, research on wild dogs in this ecosystem may be key for their conservation in western Tanzania. Focusing on this species in particular also provides other potential advantages, due to their high ecological needs, management measures for wild dog conservation will also benefit other large carnivores. Furthermore, due to their dispersal behaviour, collared individuals may serve to determine the functionality of corridors linking Katavi-Rukwa to the surrounding core areas. These reasons explain why the wild dog was chosen as a focal species for this study, where one of the objectives is to place six GPS collars on dispersing individuals.

In addition, better understanding the ecology of the species in the miombo woodlands will contribute to their conservation country-wide, as it is the dominant forest in Tanzania and, it also present in several other countries with wild dogs in eastern Africa. Well conserved and diversified miombo forests do not only provide direct benefits to human livelihoods, with their role in the water cycle and as a source of natural resources essential for the subsistence of local communities. But the miombo may also be a very favourable habitat for the conservation of wild dogs, as long as prey availability remains high (Strampelli & Searle, 2021; Goodheart et al., 2021). Lion and hyena densities tend to be lower in miombo woodlands, and this reduced intra-guild competition is beneficial for wild dogs, who will benefit from the poor visibility which reduces klepto-parasitism opportunities (Creel et al., 2001; Cozzi, 2012; Creel, 2013; Swanson et al., 2014; Strampelli & Searle, 2021).

African wild dogs have become the most endangered carnivore in Africa today. Victims of habitat destruction, fragmentation, roadkills, and human-carnivore conflict among others, their numbers have steadily decreased over the past 30 years. Formerly present in the whole continent, their distribution is currently limited to the east and south of Africa, with limited data for the central and western African populations (Woodroffe & Ginsberg, 1997; Jdeidi, 2008; Kingdon, 2014; TAWIRI, 2016; Woodroffe, R. & Sillero-Zubiri, 2020). Based on the last large-scale assessment by the IUCN in 2012 (amended in 2020), Tanzania harbours the largest remaining population with 2042 individuals, representing over 30% of the total population (Woodroffe, R. & Sillero-Zubiri, 2020). Other remaining strongholds are in The Kavango-Zambezi Transfrontier Conservation Area (KAZA-TFCA) and in Kenya, which are also critical areas for the conservation of the species, and the wild dog is recognized as a flagship species (Cozzi et al., 2020; Woodroffe, R. & Sillero-Zubiri, 2020; Hofmann et al., 2021). South Africa also holds a relatively

large population, but it is restricted to fenced reserves, and the metapopulation must be managed artificially to ensure gene flow and its survival in the long term (Mills, 1998; Davies-Mostert et al., 2015).

1.1.1. Conservation in Tanzania

Protected areas are at the base of worldwide conservation strategies, and they have an essential role in maintaining habitats and biodiversity. Today, around 16% of the land in the world is protected (UNEP-WCMC, 2022). Tanzania is one of the countries with the highest biodiversity in Africa and can be considered the most important nation for conservation in the continent (Caro & Davenport, 2016). Almost one third of the country is protected, 38.4% of its total land area (947,253km^2) is composed of protected areas of different statuses, including 17 national parks, 19 game reserves, and 678 forest reserves (UNEP-WCMC, 2022).

From a management perspective and for the case of Tanzania, we consider that PAs can be classified in two groups based on their levels of protection and usage restrictions. The "strict PAs" include national parks, nature reserves, game reserves. Other PAs fall in the "low-status" group, where resource extraction can be allowed and generally associated to traditional resource management systems. In addition to the conservation value of PAs they bring a significative contribution to the country's economy; the bulk of tourism revenues is made in NPs and NCAA, while the major part of hunting revenue stem from GR and GCA, and lower status PAs bring income through forestry and beekeeping, among other regulated extractive sources. In Tanzania, international tourism (photographic and hunting) brought more than $2.5 billion in 2019, accounting for 27.2% of the exports. Trophy hunting is of significant importance as it complements photographic tourism and creates economic incentives in large areas where the latter is not suitable (Lindsey et al., 2007). In general, game reserves are established next to national parks increasing their effectiveness as core areas.

There are indisputable benefits to protected areas; however, they can also be criticised for several reasons. First of all, most natural reserves in Africa were created by colonial authorities in the first half of the 20th century to facilitate hunting, and many of the national parks that exist today were initially game reserves (Caro, 2003). These colonial policies were maintained after the independence, as protected areas continued being upgraded and created by the Tanzanian government. The widespread conservation strategy of extending protected areas and restricting access to the forest and its resources is harmful to the local communities, who often depend on them and had been using them forever (Hausser et al., 2009). Many of these "strict" protected areas' protection enforcement depend entirely on foreign donations and investment (Nelson et al., 2007), posing questions about their sustainability. The COVID-19 pandemic was a great example, travel bans significantly reduced income from tourism, and the global economic losses reduced the amount of money available for foreign investments. Centralized wildlife conservation remains vulnerable to external factors without diversified and locally motivated incentives. Furthermore, several game reserves were upgraded to national parks during the pandemic, which can pose efficiency problems. If tourism does not increase, the costs may exceed the benefits of these changes.

In the end of the 1980s, the government was unable to keep up with the costs of a centralized conservation strategy, therefore they could not efficiently prevent high intensity poaching, like the elephant poaching wave that occurred during this period (Hausser, pers. comm.). The incapacity of funding and managing natural reserves following the country's independence ended up having a negative impact on wildlife, this added to the pressure from international funders helped to shift towards a more inclusive and decentralized conservation strategy. In the mid-1990s, legislations were reformed to promote CBNRM projects (Hausser et al., 2009). Centralized management by the government requires more means. As local communities are excluded, they have no incentives for protecting or sustainably using the resources, and find themselves in a difficult situation, where the means they have historically used to survive become illegal. Furthermore, with no protection, the resources can easily be exploited by outsiders, which will lead to bigger injustices (Mermod, 2016). By accepting that local communities are the most important actors for conservation, working and sharing the benefits with them, they can become the biggest allies of conservation projects, and this also contributes to reducing conflicts with wildlife.

Finally, in addition to the ideological and local empowerment advantages that CBNRM gives, it is also starting to be considered essential for ecological reasons. Conservation priorities are shifting towards concepts that are incompatible localised protection in isolated areas, national parks are showing to be insufficient, and species are disappearing within them (Caro & Scholte, 2007). Even if more than a third of the country has been transformed into protected areas, most of the biodiversity still remains outside, sharing their territory with the local communities (Hausser et al., 2009). Ecosystems are more complex than previously thought, and the focus is shifting towards biological corridors and connectivity.

1.1.2. Importance of the African wild dog in the Katavi and Ruaha ecosystems

At the beginning of the 20th century, wild dogs were persecuted due to the wrongful reputation that they had; they were considered the biggest threat to other game. Because of these beliefs, and until the 1960s, they were shot at sight in many national parks. Their situation today has turned in the complete opposite direction, and they have become one of the prominent faces of African conservation. They have gathered significant interest from the public and the scientific community; from 152 average publications per year from 2001 to 2011, this number more than doubled from 2012 to 2021, averaging 389 publications per year (Web of Science, 2022). Meanwhile, their status on the IUCN Red List has remained stable since 1990, globally listed as an endangered species in their last assessment, with two critically endangered subpopulations (West and North Africa) (Woodroffe, R. & Sillero-Zubiri, 2020).

Using the wild dog as a focal species for conservation studies has many advantages. Similarly to many carnivore species, they can be used as umbrella species in a local scale (Caro, 2003). Their ecological needs, such as prey requirements and habitat quality will serve as bioindicators. Resident populations provide a “gold standard” that shows effective local management of the natural resources (Woodroffe & Ginsberg, 1997). On a larger scale and linked to the context of this study, wild dog dispersal provides critical information about connectivity. With satellite imagery it is possible to identify structural corridors, but to determine whether a corridor is functional or not, other methods such as GPS collars or surveys are necessary (Riggio & Caro, 2017).

In a recent study that combined biological and socio-political factors to determine conservation priorities for the wild dog (Kuiper et al., 2018), Tanzania was scored as the top conservation priority country. This was calculated based on the estimated wild dog numbers in the country (Tanzania having by far the largest), the range of their distribution, as smaller areas have a better return on investments, and the portion of their range in unprotected areas, which requires attention more urgently as they are more threatened (Kuiper et al., 2018). In the conservation likelihood, Tanzania is in fourth place. However, the country-wide context is very different from the local context of the study areas. Tanzania’s governance quality and human pressure obtained relatively low scores. But within the Katavi-Rukwa and Ruaha-Rungwa ecosystems, there are several long-term conservation projects that have proven to have efficient governance and a real impact, which in return also reduce human pressure. Therefore, the conservation likelihood score in this part of the country is probably higher than estimated, and with this the probable effectiveness of wild dog conservation efforts in the area. Moreover, both Katavi-Rukwa and Ruaha-Rungwa subpopulations are in the top six of conservation priorities, and as shown later in this study, the score was likely underestimated for the Katavi subpopulation. Based on the study’s metrics it is clear that the study area is of high importance for wild dog conservation, but the lack of knowledge and information leads to an underestimation of its importance, which may also be the case for other understudied populations. In addition to their importance for wild dogs, the corridors connecting Katavi-Rukwa and Ruaha-Rungwa ecosystems may be among the largest and most important for elephants in East Africa, as they serve to connect the central, southern, and western elephant populations (Jones et al., 2009).

Effective conservation relies on environmental policies and initiatives that depend on observations and information from natural resource management circles (Salerno et al., 2017). Creating favourable conditions for wild dogs or wildlife in general is a long process with many stakeholders at different levels, from the local communities who cohabitate with animals to the people in the field collecting the information that can be used to make decisions at a national level by the policymakers.

In 2016, the national action plan for the conservation of cheetahs and wild dogs in Tanzania was developed to replace the two separate action plans for the species established in 2005 and 2006. As they have similar and demanding ecological requirements, a specific action plan was necessary for these two species. These requirements include massive home ranges, and that these remain effectively connected. For this, conservation policies must be conceived on a large scale, as localised efforts will not be efficient. Moreover, both species face similar threats, including human-carnivore conflict, and habitat loss and fragmentation (TAWIRI, 2016). The present study falls within the framework of the action plan, and should contribute to several of its objectives, which are summarized in Table 1 (the full framework can be found in Appendix I: National action plan logical framework).

Table 1: Shared objectives within the national action plan logical framework.

1.2 Sustainable tools to reduce wild dog and cheetah conflict with livestock keepers developed and disseminated across Tanzania within five years.
1.3 Programmes for local people to derive sustainable economic benefits from cheetah, wild dogs and other wildlife developed and implemented within five years.
1.4 Awareness creation programmes relevant to cheetah and wild dog conservation developed within two years.
2.1 Surveys and monitoring to evaluate presence, trends and threats in key cheetah and wild dog ranges conducted within five years.
2.2 Strategies for disseminating information relevant to cheetah and wild dog conservation to all relevant stakeholders developed and implemented within three years.
5.1. Government officials, local communities and other stakeholders made aware on cheetah and wild dog conservation within three years.
5.2. Land use planning for areas of cheetah and wild dog resident and connecting ranges carried out within five years.
5.3. Identify and priorities corridors, buffer zone and dispersal areas for improved connectivity of cheetah and wild dog ranges within 5 years.

1.2. Hypothesis

According to the reviewed literature and the observations during the fieldwork, which will be detailed in the following chapters, the following hypothesis about the status of wild dogs in the Katavi-Rukwa ecosystem can be stated:

1. Wild dogs are one of the most vulnerable species to human pressure due to their large home ranges and ecological requirements, making them a great target species of high priority (Woodroffe & Ginsberg, 1999; Cozzi et al., 2020; Woodroffe, R. & Sillero-Zubiri, 2020; Hofmann et al., 2021).
2. The miombo woodlands represent a very favourable habitat for the African Wild dog. The closed woodland favours their hunting methods, and in addition competitor carnivores are present in low densities due to their different ecological preferences (Strampelli & Searle, 2021).
3. The populations in the Katavi-Rukwa ecosystem are significantly larger than previously estimated. The last assessment by Woodroffe et al. 2012 shows no wild dogs in Lake Rukwa GR and Mlele FR, where their presence has been confirmed for multiple years.
4. Low intra-guild competition is favourable for wild dogs (Cozzi, 2012); considering the situation in most of the study areas, the results obtained from telemetric data may contrast with previous literature regarding their habitat preferences, as lion presence seems to be relatively low.
5. Wild dogs can establish in lesser protected areas as long as there are no severely destructive human activities such as large-scale poaching and deforestation for cropping or husbandry. If the habitats are kept in a good condition, there will be a large enough prey base, as long as wildlife has not been decimated (Goodheart et al., 2021).
6. Wild dogs in the study area are increasingly threatened by rapid development, particularly by the outstanding expansion of the villages and tarmac paving of the large roads.

1.3. Objectives

The main objective of this study was to assess functional corridors connecting the Katavi-Rukwa ecosystem to neighbouring ecosystems, such as Ruaha-Rungwa towards the west and Ugalla to the north. To obtain this information, six collars shall be placed on potentially dispersing wild dogs to gather telemetric data for a year. This will provide better knowledge and understanding of their distribution, habitat use, and their movements, particularly regarding the use of protected and unprotected land and the way the wild dogs negotiate infrastructures (roads, fields, settlements, etc.). This will be key in determining the viability and long-term survival of the species in western Tanzania. While attempting to collar wild dogs, all the information concerning wild dogs was also documented, such as sighting locations, pictures, and deaths.

In parallel to the wild dog data collection, semi-structured interviews were conducted to assess the degree of conflict in the study area, particularly with agro-pastoralists, who represent the biggest threats to wildlife. This is the first step required to implement strategies that promote the coexistence of carnivores with people and domestic animals, for instance sensitization and improvements of protection methods. The data collected from both of these surveys will be used to design specific and adapted mitigation measures for the conflicts between local people and the wild dogs. It is essential to define clear priorities in conservation, as resources are very limited, they must be allocated efficiently (Brooks et al., 2006; Kuiper et al., 2018).

1.4. Limits

Following the difficulties encountered during the fieldwork and the short time at disposal for the project, the focus had to be changed. At first, the objective was to place collars on six wild dogs to assess functional corridors in western Tanzania; however, only one collar could be placed during the twenty days with the veterinarian despite the intense research efforts. The study's reserves are extensive, and wild dog densities are very low; therefore, their sightings are very rare. Moreover, due to the stochastic nature of wild animals' movement in open areas, the objectives related to corridors could not be attained, as the collared individual did not disperse. Therefore, the data was used to analyse the behaviour of a pack residing between Katavi NP and Lake Rukwa GR. In addition, to complement this information, a parallel task of collecting as much information on wild dogs as possible in the Katavi-Rukwa and Ruaha-Rungwa ecosystems was added. This was accomplished with the team and people from different conservation organisations encountered during the fieldwork. The data will provide a first contribution to the distribution, habitat use and population status for these two ecosystems.

2. State of the art

2.1. African wild dog

African wild dogs are social animals, as canid species tend to be, and they are so dependent on the pack that it makes more sense to consider it over the individual as the basic unit in the population (Woodroffe & Ginsberg, 1999). They live their entire lives in packs of variable sizes, ranging from 2 to 30 adults and yearlings. The average pack size being of 5 to 15 individuals (Creel & Creel, 2002), although there have been exceptional cases with packs of 36 dogs in Botswana and 44 in Tanzania (Kingdon, 2014). Pack size can vary yearly due to mortality, dispersal, and reproductive success. Size is critical for the foraging, breeding, and survival success of the pack. Larger packs tend to be more successful, but there is an upper limit, where the marginal costs of having additional members outweigh the gains (Courchamp & Macdonald, 2001).

Wild dog packs are organized on a social hierarchy where reproduction is mainly limited to the alpha female and male. In general, the dominant female is the oldest one, whereas the status of males shows more variance, as prime-aged males will often take the place of the alpha (Creel & Creel, 2002). Wild dog litters are very large compared to other canids, averaging around 8 pups with a maximum of 21 (Woodroffe & Ginsberg, 1999; Creel & Creel, 2002). This makes them obligatory cooperative breeders, as it is impossible to take care of such large litters alone (Woodroffe & Ginsberg, 1999; Kingdon, 2014). However, this has consequences on the survival of the adults in the pack. As the hunts are not distributed evenly among individuals, larger packs will show a higher reproductive success thanks to increased efficiency during the hunts, but this will lead to lower survival rates in adults (Creel & Creel, 2015).

Female wild dogs tend to have their first litter between 3 to 3.5 years old (Marneweck et al., 2019), and they will whelp in an unoccupied den. The denning period lasts three months, and during this period, they may move to a near den (Creel & Creel, 2002). Studies show that reproduction is seasonal and takes place during the dry season; this may be explained that during the dry season, water becomes scarce, and this will regroup ungulates near permanent water points, making it easier to secure food in a small perimeter. The timing of the reproduction varies with the latitude; in Selous, the denning period goes from June to August (Creel & Creel, 2002; Mcnutt et al., 2019). It is probable that this is also the case in the Katavi ecosystem, as it is located around the same latitude (7°S). The denning period is the best moment to collar wild dogs, as it is the only time where they will remain in a small area (Cozzi, pers. comm.).

Wild dogs have extensive home ranges, going from 150 km^2 to over 2000 km^2, the average size being 606 km^2 (n=50 packs) (Kingdon, 2014). This variance is mostly explained by the vegetation, prey availability and density. The sizes of their home ranges are much larger than expected from their energetic requirements and body size (Woodroffe & Ginsberg, 1999; Kingdon, 2014), therefore there are often areas which are located outside of protected areas.

Cooperative hunting is one of the defining traits of wild dogs and explains that they are one of the most efficient hunters, succeeding in over 80% of their hunt sessions (Fuller & Kat, 1993). Based on Hayward's study (Hayward et al., 2006), wild dogs' preferred prey in the study area should be bushbucks (*Tragelaphus scriptus*, LC), impalas (*Aepyceros melampus*, LC) and greater kudus (*Tragelaphus strepsiceros*, LC). There are very few impalas left outside of the NP and GRs, but direct observations in Mlele confirmed that they can prey on much larger species such as the sable. Since pukus were not present in any of the studies, there is no data to confirm this, but based on their size, density and behaviour, it is probable that they are one of the main prey of the wild dogs around lake Rukwa (Ramoni, pers. comm.). Wild dogs are often called diurnal and crepuscular animals, reflecting their peak activity times (Cozzi, 2012). Their hunts take place between 05:00-09:00 and 17:00-20:00 (Creel & Creel, 2002).

In recent years, African wild dogs have gained increased attention due to their dispersal behaviour, where they can travel distances up to 500 km (Davies-Mostert et al., 2012; Masenga et al., 2016). Adults aged 1-2 years, typically brothers or sisters from the same litter will leave the pack to form a new pack with unrelated dogs of the opposite sex (Behr et al., 2020). This is essential to maintain gene flow between subpopulations (Woodroffe et al., 2020). There were uncertainties about whether there was a sex bias of dispersers, as subordinate females are rarely allowed to reproduce they should be more likely to disperse, but in a recent study large scale study (n= 180 packs), it was shown that dispersing ratios are similar for males and females, although their motivations may differ (Behr et al., 2020). During dispersal, wild dogs will increase their tolerance to suboptimal habitats and take risks that resident animals do not, which increases mortality (Woodroffe et al., 2020). The main factors explaining dispersal seem to be increasing pack size and inbreeding avoidance; when there are few unrelated individuals of the opposite in the same pack, dispersal ratios tend to be higher (Behr et al., 2020).

The main reason for biodiversity loss worldwide, which is also the main threat to wild dogs, is habitat destruction and fragmentation (Woodroffe & Ginsberg, 1997; Brooks et al., 2002; Woodroffe et al., 2005). Wild dogs are very susceptible to these effects due to their large area requirements, where they will often move through unprotected areas. In the current scenario, cultivated land in Tanzania expands by 2% per year (Capitani et al., 2016); it is unavoidable that this growth occurs without the encroachment of the forests. Not only does this have a direct impact on wild dogs, but it also reduces ungulate populations which will also affect wild dog numbers. As humans settle closer or within the forests, the conflicts with carnivores will increase, leading to snaring and shooting. Infectious diseases, such as rabies and canine distemper virus (CDV) are poorly understood causes of mortality of wild dogs, but the effects can be severe (Woodroffe et al., 2005). Finally, there are also some natural factors that reduce wild dog numbers, such as intra-guild competition or predation by other carnivores, but the impact of these are negligible compared to human-caused mortality (Woodroffe & Ginsberg, 1997).

Wild dogs are facing many kinds of threats, which should be addressed by identifying priority areas for wild dog conservation, by doing research in these areas to find the most effective conservation activities. This knowledge should then be used to engage with local managers and regional policy planners to implement wild dog conservation activities (Woodroffe et al., 2005).

2.2. Telemetry

In the past, it was very difficult and time consuming to obtain data on wildlife movements. The earlier studies on habitat selection and home range were based on radio telemetry (Mills & Gorman, 1997) or manually noting GPS locations (Creel & Creel, 2002), which required the presence of the researchers. This was subject to many biases, as it required the presence of the researchers, therefore it was impossible to follow the animals everywhere and get data on a regular schedule.

Technological advances made it possible to acquire data in real time through satellites, which significantly improved the possibilities of animal movement research (Kays et al., 2015). The quantity and precision of the data makes it possible to model animal preferences, home ranges and today it is the most common tool used to determine functional biological corridors, which have become a priority in conservation, particularly for wide-ranging species as the wild dogs or elephants.

The two most commonly used methods for habitat selection are the Minimum Convex Polygon (MCP) and Kernel Density Estimator (KDE). The MCP is a relatively simple technique, which was first used in 1947 as a home-range estimator. It estimates the home-range based on the smallest convex polygon that contains all the point locations (Downs & Horner, 2008). The problems with this technique is that it can contain large areas of unoccupied space and that a single outlier can considerably change the size of the polygon (Downs & Horner, 2008). KDE creates a smooth surface based on the distribution of animal's locations, it has the advantage that the level of extrapolation can be chosen to determine areas with higher utilisation, but it often overestimates the size of the home range (Downs & Horner, 2008).

The primary methods used to determine preferences were Resource Selection Functions (RSF). The method consists of taking each GPS position pixel of an individual and to associate it to the corresponding resource or

predictor value in the same location. The resources can be different types of vegetation, distance to human settlements or water bodies for example (Boyce et al., 2002).

Later on, a new tool was developed, that did not take points as isolated locations, but instead built steps based on these points and compared them with randomly generated steps, the Step Selection Function (SSF). This new offers more accurate estimations, because they consider the potential changes in resource availability as the animal passes through the landscape (Squires et al., 2013; Thurfjell et al., 2014; Zeller et al., 2016).

3. Methods

3.1. General

3.1.1. Study area

The study area covers the Katai-Rukwa and Ruaha-Rungwa ecosystems from west to east. The research permit was accorded to carry out research in two FRs and one GR in the Mlele District from the Katavi region, Mlele FR (2350 km^2), Rungwa River FR (2121 km^2) and Lake Rukwa GR (4339 km^2). In addition, there were two other reserves closer to Ruaha NP, Lukwati GR (3729 km^2) in the Songwe Region and Rungwa North OA (1763 km^2) in the Singida Region. Due to time and logistical limitations, the wild dog research effort was mostly focused on Mlele BKZ (850 km^2) and Lake Rukwa GR, where the conditions were better, but a short evaluation of the current status in Rungwa River FR and Rungwa North OA was nevertheless carried on. This choice was motivated by the fact that the chosen prior areas had daily patrols; therefore, there were multiple reliable sources of information. In addition, the quality of the roads was considerably better, and the reserves were rapidly accessible from Inyonga village, where the team was based, and where the semi-structured interviews would take place, making it easier to use the time out of the bush to advance on other parts of the project.

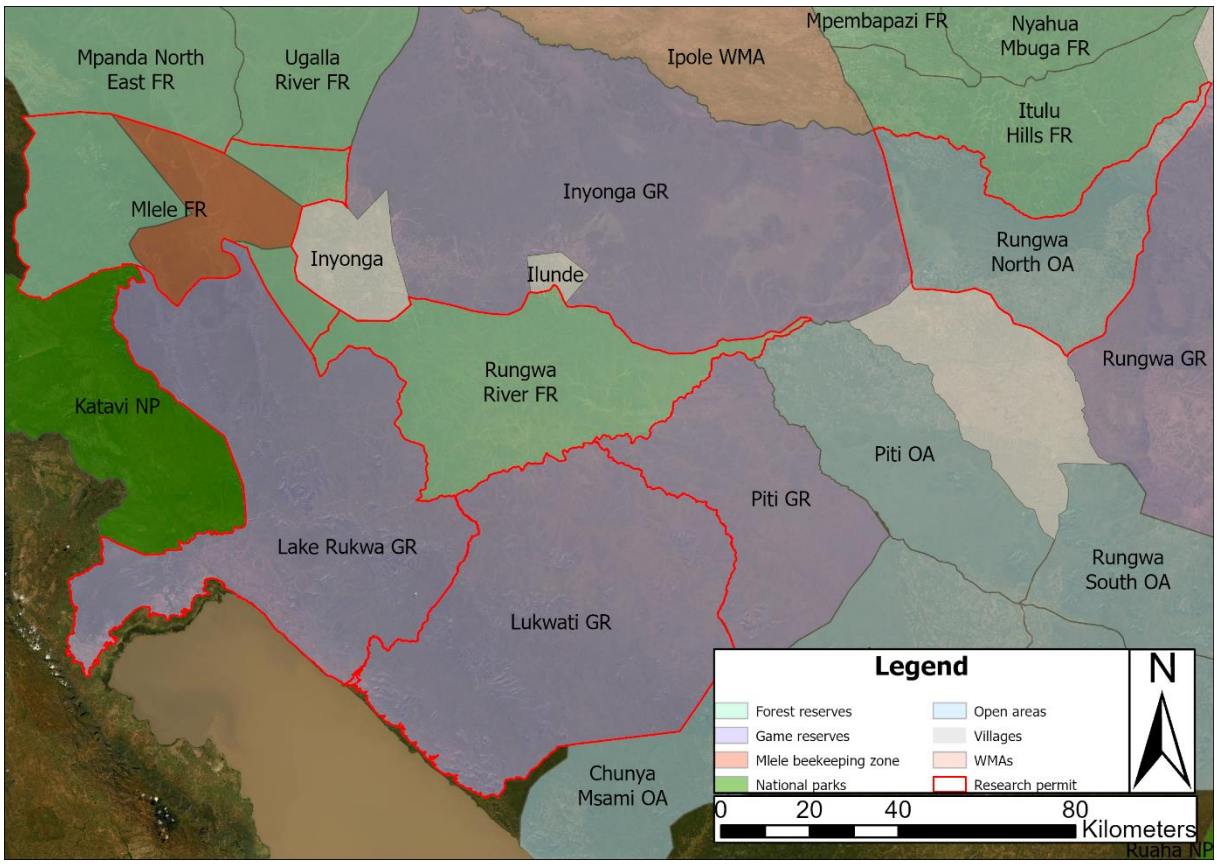

Figure 3: Study area with their protection status and reserves for which the permit was accorded for.

For the questionnaire, seven villages bordering the Mlele BKZ (Kanoge, Kaulolo, Masigo, Mtakuja, Mgombe, Nsenkwa and Wachawaseme) and one village bordering Inyonga GR (Kamsisi) were chosen. The location of the villages and the respondents' households can be seen in Figure 8.

The weather in the Katavi-Rukwa ecosystem is homogenous, with the rainy season going from November to April (600-1200 mm of precipitation per year) and the dry season from May to November, during which the study took place (Banda et al., 2008). These patterns are becoming more and more unstable; for instance, there was so much precipitation during the rainy seasons of 2019 and 2020 that several kilometres of land bordering the lake Rukwa are now below the level of water (Ramoni, pers. comm.). In contrast, the rainy season of 2021 began very late, and the precipitations have been abnormally low, which has impacted agriculture and may also negatively affect the herbivore densities.

The Mlele BKZ is in a rift valley, where there is an escarpment separating an elevated plain with a mean altitude of 1400m from the lower floodplains at 1000m. Although water is scarce in the dry season, a few permanent streams are running down the escarpment (Fischer et al., 2013; Hausser et al., 2017). The vegetation in the area is particularly dominated by fire-tolerant species such as *Diplorhynchus condylocarpon*, *Pseudolachnostylis maprouneifolia*, and *Pterocarpus angolensis*, which can probably be explained due to the high fire frequencies in the reserve (Bloesch, 2018). The most common larger tree species are *Julbernardia globiflora* and *Brachystegia manga/utilis*, characteristic genera from the miombo (Frost, 1996; Bloesch, 2018). The other habitats present are floodplains, mixed bushland, wooded grassland, and riverine forests (Banda et al., 2008; Mermod, 2016). In the beekeeping zone, honey harvesting is the only natural resource extraction currently allowed. Due to its double status, hunting is allowed, but there has been no hunting since 2019 (Hausser, pers. comm.). The beekeeping zone is in great condition compared to the other FRs in the area thanks to the frequent patrols. Gold mining and logging are still allowed in the rest of Mlele FR. This can generate conflicts with the BKZ management since the frontiers between the BKZ and the FR are not always clear, and Tanzania Forest Services Agency (TFS) delivers permits without knowing exactly in which area the trees are located. The BKZ with the tracks taken during the research can be found in appendix II..

Lake Rukwa GR is part of the same eco-region as Mlele FR; therefore, the vegetation and precipitation are very similar. The reserve is split into three different hunting blocks, one in the north, next to Mlele FR, managed by Tanganyika since half 2021, another one next to Rungwa River FR, currently unoccupied and Lake Rukwa block, managed by Tanzania Big Game Safaris (TBGS), bordering the northern part of the lake Rukwa. There were clients on Tanganyika's block, who could be disturbed by the research, and in Rungwa River block, the lack of patrols meant worse conditions for wildlife and a lack of external information sources. Therefore, the wild dog research was focused on Lake Rukwa block. The relations with the current managers are good, so they let us stay in the hunter's camp during the research and offered help for the research. The block is extensive, its surface is larger than 1500km^2 and there are many different kinds of habitats. It has multiple hills and escarpments, which separate the high drier plateau at 1000 - 1100m from the lower one, where the Rungwa River flows into lake Rukwa, at an altitude of around 800m. In the lower plateau, there is a huge floodplain. The only kind of exploitation allowed is the tourist hunting of large mammals during the dry season. The hunting block belongs to category 1, which is the highest quality and most expensive; therefore, the resources allocated to its protection are very high, probably comparable NPs; according to the current managers of the reserve, there are anti-poaching patrols every day of the year. The hunting block with the routes used during the research can be found in Appendix III: Rukwa game reserve and routes taken.

3.1.2. Material

The fieldwork was carried on with research permit no. 2021-456-NA-2021-143 granted by COSTECH. ADAP supplied a Land Cruiser with a driver and one English-speaking village game scout (VGS), which was the team's core. For the work in Mlele FR, two or three armed VGS would join to ensure security and help with the essential tasks in the bush. In the game reserves and areas with less frequent patrols, a TAWA ranger was needed in addition.

For the data analysis, the GPS data was taken with a Garmin GPSMAP 64s (Garmin Ltd.), then transferred and cleaned with Garmin BaseCamp v.4.7.4 (Garmin Ltd.). The maps were created using ArcGis Pro 2.9.1 (Esri Inc.) and the statistical treatment and tables using Microsoft Excel and R version 4.1.2 (R Core Team, 2021) with RStudio.

3.2. Wild dog data

3.2.1. Preparation

The mission was split into two distinct phases considering all the stochastic factors linked to finding wild dogs. The first one was to gather the most information that would help locate wild dogs to determine sections with a higher probability of encounter, this phase corresponded to 25 days in the field. Then, with the veterinarian's arrival, an adaptative strategy was taken based on the previously collected information with the constraints and opportunities appearing in the field to decide where the research efforts should be focused. This second phase with the veterinarian lasted for 19 days, where two days were lost due to problems encountered in the field, and one day was used to pick up the materials needed by the veterinary.

Due to the delays in obtaining permission to enter Lake Rukwa Game Reserve, the first phase was mainly focused on Mlele Forest Reserve. A table of the total research effort per reserve with the distances travelled and the average speed Table 2 (more detailed one with daily information on the activities done and wild dog sightings in Appendix IV: Daily time allocation to the wild dog research).

To assess sections with higher wild dog activity, there were three main sources of information: opportunistic encounters from our team or from other people working in the same areas (ADAP, TAWA, TANAPA, TBGS, TFS and WCS). In addition, camera trap data from the past surveys done by ADAP in addition to the camera traps set up by our team during the fieldwork, which were specifically targeting wild dogs. And finally, every time the soil was favourable, spoors were closely examined.

Table 2: Wild dog research effort by vehicle in each reserve for both phases.

	Reserve	Days	Dist. travelled (km)	Avg. dist./day (km)	Avg. speed(km/h)
PHASE 1	**Mlele FR**	14 (2 not recorded)	1568.4	130.7	21.93
	Rungwa River FR	4 (1 not recorded)	335.9	111.97	22.67
	Rungwa River GR	2	210.9	105.45	17.25
	Lake Rukwa GR	3	450	150	20.3
	Rungwa North OA	2	502	251	35.35
	Total for phase 1	**25 (3 not recorded)**	**3067.2**	**139.42**	**22.60**
PHASE 2	**Mlele FR**	2	247	123.5	19.75
	Lake Rukwa GR	12	2068	172.33	24.03
	Mix of Mlele and LR	2	644	322	43.85
	Total for phase 2	**16**	**2959**	**184.94**	**25.97**
	Total	**41**	**6026.2**	**158.58**	**24.02**

3.2.2. Camera trapping

Two distinct camera trapping methodologies were used for the study. ADAP data was obtained from the systematic camera trapping survey that Claude Fischer elaborated in 2010. For each grid, 36 camera traps are set up in 10 x 10 km grids, separated by 2 km each for 21 days; this number was increased to 28 days thanks to the improvements of batteries and material. The cameras are set up between 60 to 100 cm above the ground, pointing downwards to capture medium-sized and large mammals. The vegetation is then trimmed to avoid having large amounts of pictures without animals. The positions of the five systematic grids in Mlele can be found in appendix VII.

Since the objective was not to do monitoring of all the species present in the area, but to specifically gather information on wild dogs, a non-random camera trap survey was implemented, targeting landscape features that increase the probabilities of capturing wild dogs. They were placed next to roads, trails, and water points, as this methodology is more adapted for rare species occurring at low densities, such as the wild dog (Cusack et al., 2015). The first set of cameras placed in Mlele FR and Rungwa River FR at the beginning of September were placed close

to places where wild dogs had previously been seen, preferably pointed at trails and waterpoints. After recovering these cameras, a slight adaptation was made; considering that the search with the veterinarian would be carried on exclusively by car (unless the position of a den was to be known), the next set of cameras traps was placed on the roads of the study areas. This had two significant advantages; first, the cameras are easier to access, so they could be controlled regularly in the field while simultaneously searching for wild dogs with the veterinarian. Then, even if the preference for roads is not as strong in the dry season, due to the lack of higher vegetation that restraints their movement during the rains, wild dogs and carnivores tend to show a preference for roads (Abrahms et al., 2017; Shumba et al., 2018; O'Neill et al., 2020). The camera sites in Mlele FR can be seen in Figure 4, for the other reserves see Appendix VIII: Camera trap locations in Rungwa River FR and Lake Rukwa GR.

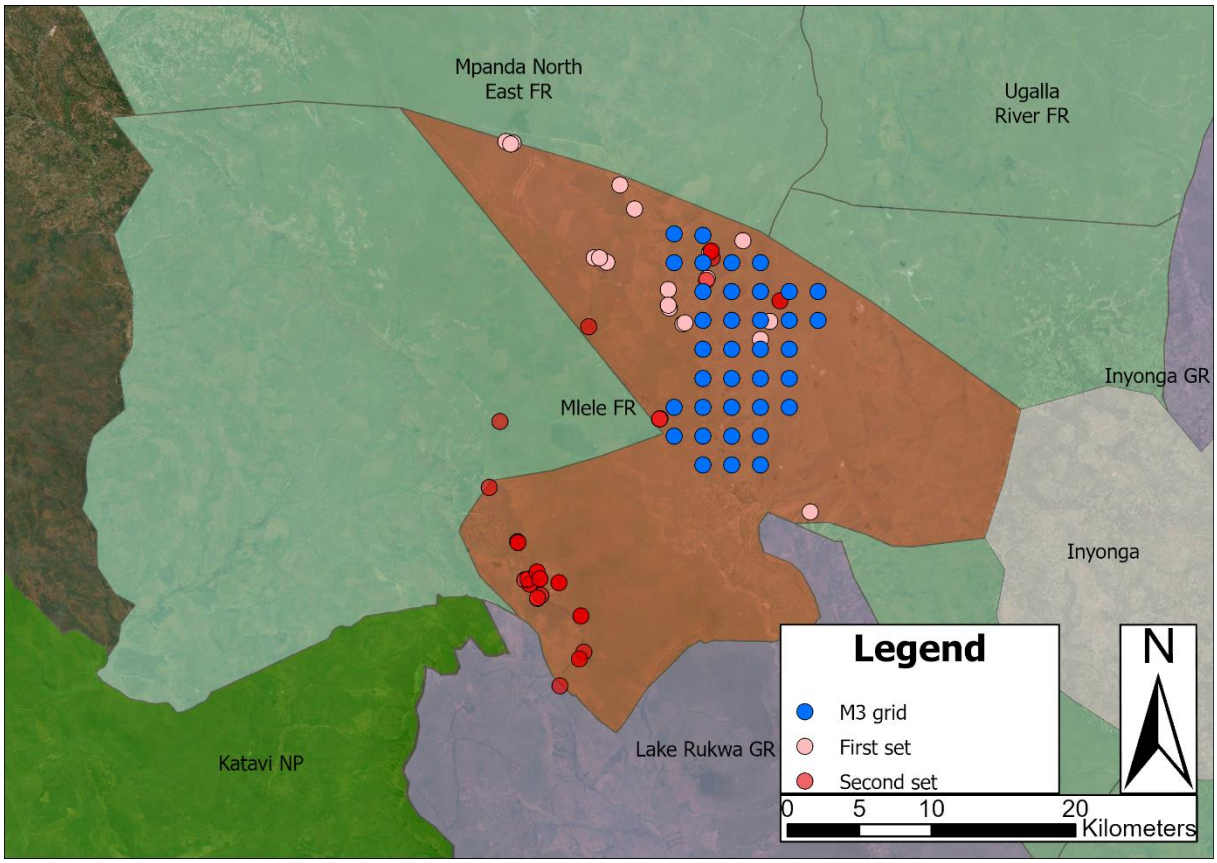

Figure 4: Camera trap sites in Mlele FR.

During the fieldwork, a total of 89 camera traps (Bushnell Trophy Cam HD Aggressor, No-Glow 14 MP) were installed, 68 in Mlele FR, 10 in Rungwa River FR and 11 in Lake Rukwa GR. In addition, five grids were placed by the ADAP teams, one in Mlele (M3) and four in Rungwa River OA (K1 to K4). The research effort, calculated as the number of hours that all the cameras were active was of 1188.8 CT days, see Table 3 for the research effort per reserve (camera trap protocols are in Appendix V: Camera trapping details in Mlele beekeeping zone for Mlele FR and Appendix VI: Camera trapping details in Rungwa River FR and Lake Rukwa GR for Rungwa River FR and Lake Rukwa GR); this does not include the five grids placed by VGS (ADAP) during the same period.

Table 3: Camera effort per reserve.

Reserve	CTs	CT days	Pictures
Mlele FR	68	974.15	94609
Rungwa River FR	10	141.54	7284
Lake Rukwa GR	11	73.11	19119
Total	**89**	**1188.8**	**121012**

3.2.3. Favourable routes

Once areas with higher wild dog presence were established, favourable routes were designed to patrol with the veterinary. The most important factors were to drive in sections of open vegetation, this can be defined as areas with lower tree density, where there are more than two meters between most of the trees, so it is possible to clearly see at 30-40 meters of distance (see Appendix IX: Examples of different types of vegetation for examples of different types of vegetation). This is necessary to allow the veterinarian to get a clean shot to immobilize the wild dogs, and makes it possible to visually follow them to some extent. It is also essential that the quality of the roads permitted to move relatively quickly, the objective being to efficiently cover the longest distance possible daily, at speed ranging from 15 to 25 km/h. In the study areas, there were places where the state of the road was bad enough that it was impossible to travel quickly (max speed <10 km/h), and in some cases, there was even a risk that the car got stuck. The patrols began at 6:00, driving non-stop until 12:00, and then the search restarted from 14:00 to 18:00, which corresponds to times with higher wild dog activity time, during daylight.

Due to the lack of information on wild dogs in Rungwa River FR and Rungwa North OA, and the lower frequency of patrols, these two areas were abandoned for the study's second phase. Mlele FR had weekly patrols by the ADAP team, and there were multiple daily patrols in Lake Rukwa GR carried on by TBGS and TAWA. Being in constant communication with these teams, it was possible to estimate areas where wild dogs were regularly seen, and in some instances, some packs had been seen in the same area for multiple years.

In Mlele FR, two routes were established where the tracks were of good quality and open vegetation. The Kankiningi routes, which takes around three hours to complete starting from the ADAP camp. Their presence was confirmed three times between September-November. The other route was the Kanono-Msima, which takes around three and a half hours to complete from the Katonya small beekeeping camp. They were captured by camera traps twice along this route; furthermore, Kanono road may be where they have been seen most regularly throughout the years. Even if this may be biased because it is also the road with highest passage and the visibility is very good compared to other areas which are mostly composed of closed vegetation, with the limited information available, it was designated as a favourable route.

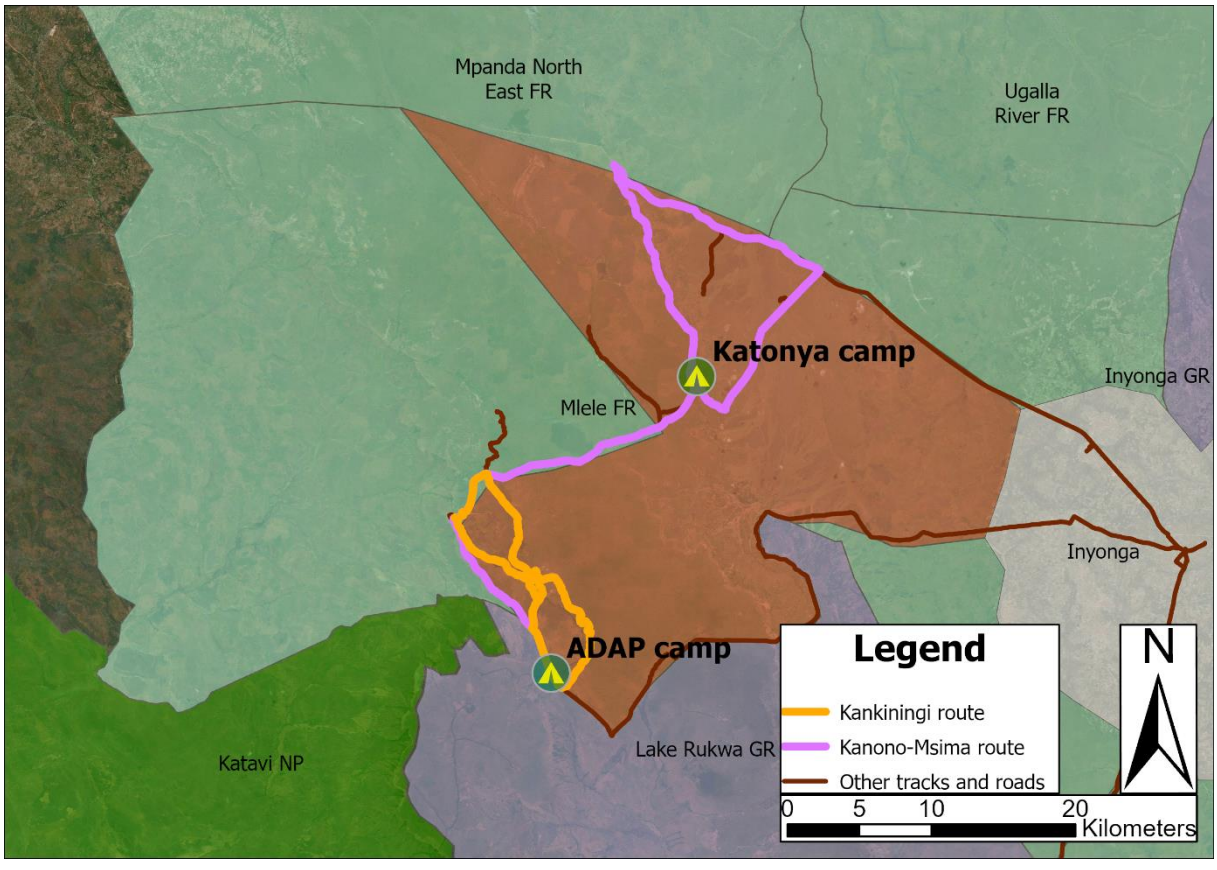

Figure 5: Mlele FR favourable routes.

The people from TBGS and TAWA affirmed that in Lake Rukwa GR, there were three areas where there had been regular wild dog sightings throughout the years. The road to Majimoto, which is biased since it is also the road with the highest frequentation, the road to Dougie's waterhole, and a road near the lake, which was unfortunately under the water after the heavy rains in 2020 and 2021. Considering this information and, after inspecting the whole reserve to assess the sections with favourable road and vegetation conditions, two loops were established. The highest probability section in the whole study area, the road to Majimoto, where a pack of twelve wild dogs is seen multiple times per week, would become our main target for searching with the veterinary. Going from one end to the other takes around two hours and a half. The second route in Lake Rukwa GR is the way to Dougie's waterhole, where a pack of six wild dogs has been seen regularly for the past four years, with its optimal track conditions and very open vegetation all along, going from the hunter's camp to the southern end of the route takes approximately four hours.

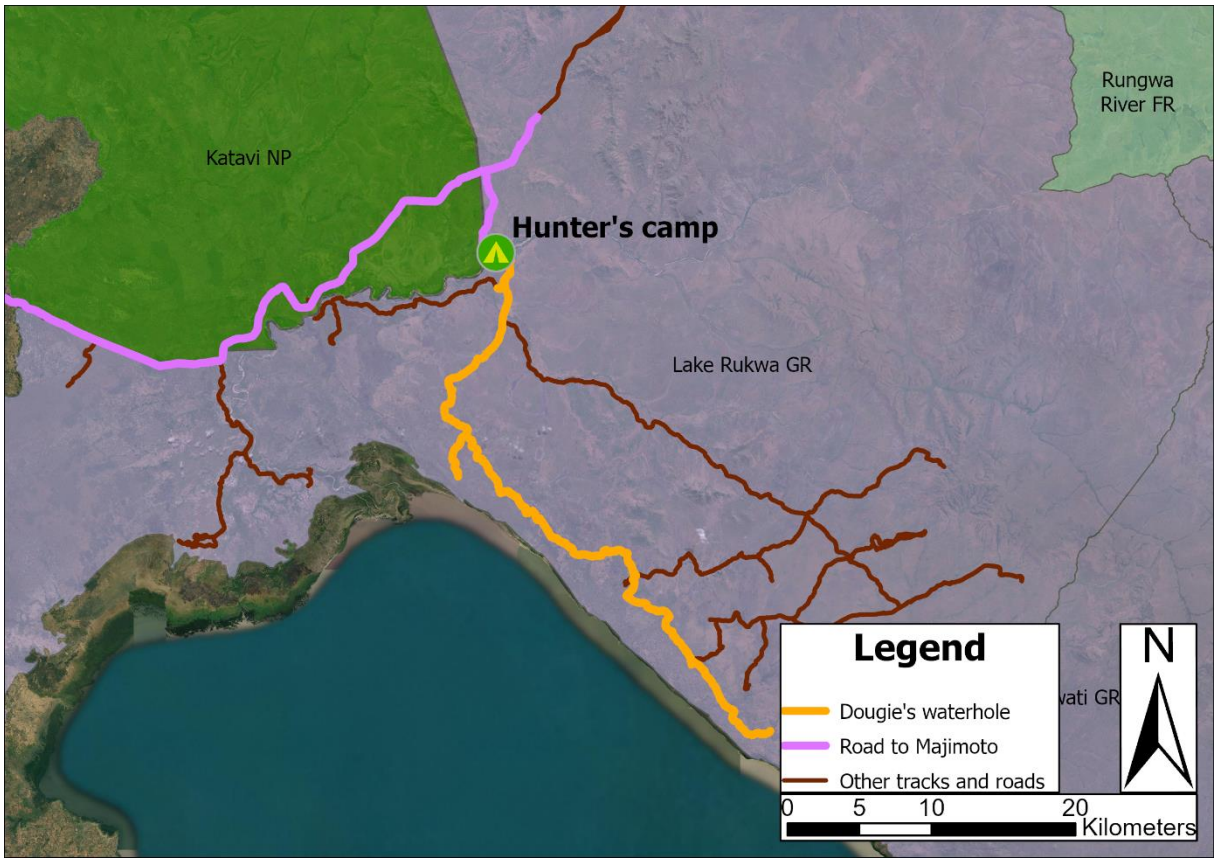

Figure 6: Lake Rukwa GR favourable loops.

3.2.4. Immobilisation and collaring

For the telemetric data, six Iridium-GPS collars (*Vertex Lite, Vectronic Aerospace GmbH, Berlin, Germany*) were taken to the field. Due to the difficulties encountered, only one collar could be placed.

The full immobilisation, collaring and physical handling of animals was done according to the *Tanzania Wildlife Research Institute (Conduct of Wildlife Research) Regulations*, Government Notice No. 628 PART V (TAWIRI, 2020). As specified by the regulations, a professional Tanzanian veterinarian issued by TAWIRI was responsible for the immobilisation and placing the GPS-collar on the wild dog. The individual was immobilised at a distance of 24m using a Pneu-Dart gun (*Pneu-Dart, Inc., Philadelphia, USA*). The dart used was a Pneu-Dart syringe loaded with a combination of tiletamine hydrochloride and zolazepam hydrochloride (Zoletil) with a dosage of 4.5mg/kg body weight, which was injected intramuscularly on shoulder muscles. Since Zoletil has no reversal drug, the wild dog was taken care of by hydrating her and keeping her under shadow to prevent hyperthermia and preserve herself from potential road accidents until she was able to run safely, and the effects from the anaesthesia were completely gone.

Table 4: Collaring detail for Rafi.

Date	Location	GPS coords.	Sex	Age [y]	Distance [m]	Manipulation time [min]	Time until fully recovered [h]
22/10/2021 09:15	Lake Rukwa GR	7.3402°S 31.6677°E	F	2.5-3	24	09:44	03:00

3.2.5. Data analysis

To determine the habitats used by the collared individual, the GPS collar was programmed to record three GPS locations per day, at 6:30, 12:30 and 18:30, then transmitted via iridium satellite system. This pattern was chosen to get two points during the peak activity times and one in between to obtain a 6-hour gap between steps. It is also possible to obtain regular time intervals between steps by removing the point at 12:30 and get two daily points with a 12-hour fix rate. The location at 12:30 was often very close to the location at 18:30. This schedule was chosen to make it possible to relocate the collared individual during the phase with the veterinarian, in case it was necessary to place multiple collars in the same pack. The collar was programmed to three positions per day to increase the collar's longevity and obtain a year of data. For the analysis of the data, it will be supposed that the positions obtained from a single individual represent the behaviour of the whole pack.

Data was collected from the 22nd of October to the 21st of March 2021 for a total of 438 locations in 151 days. Dilution of precision (DoP) indicates the inaccuracy of some points; a value higher than 5 can be considered as inaccurate (O'Neill et al., 2020). None were removed since all the locations had a DoP lower than 3.4. It was assumed that the individual is in a resident-non-denning life stage, the movements being motivated by hunts or resting as the most probable denning period in the area is between June and August, at the end of the rain season (Creel & Creel, 2002; Mcnutt et al., 2019) and by observing at the range of movements of the individual, we can fairly assume that it has not dispersed.

The first step was to estimate the home range based on all the GPS locations. Two methods were used, a minimum convex polygon (MCP) which contains all the points and fixed kernel density estimation (KDE) at 95%, which excludes outliers and gives a more precise estimation of the home range and a KDE at 50% to outline the core areas.

A second-order resource selection function (RSF) model was used to analyse habitat selection. Although step selection functions (SSFs) offer a more precise habitat selection analysis than RSF because they consider the changes in resource availability as the animal passes through the landscape (Squires et al., 2013; Thurfjell et al., 2014; Zeller et al., 2016). In this context, where the animal did not disperse, the results obtained from both functions should give very similar conclusions regarding the preferences of the wild dogs, whether they show a positive or a negative selection towards an environmental variable (O'Neill et al., 2020).

The methodology for the RSF was adapted from O'Neill et al. (2020) et al. First, the centroid of the MCP was calculated to build a circle of 18.3 km to limit the area where the available habitats will be taken from. This radius corresponds to the furthest position to be sure to encompass all the GPS locations leaving a margin to include potential locations in-between of the recorded intervals (see appendix X). Then, 2'000 random locations were generated to compare the used locations to the available locations, the number of points was chosen to keep a similar ratio as in the study, where they used 10'000 random locations for a circle with a radius of 90km.

Raster maps obtained from ADAP, that contained the information on landcover type (discrete variable with five possible values: woodland, grassland, bushland, bare soil, inland water), and three continuous variables representing distance to rivers, distance to roads and distance to the lake were used to attribute the characteristics to each point based on its location (see Figure 7 for landcover and appendix X for the other variables). The choice of these variables was motivated as they are the most common in the concerned literature (Whittington-Jones et al., 2014; Davies et al., 2016; Abrahms et al., 2017; Shumba et al., 2018; O'Neill et al., 2020; Hofmann et al., 2021) and the information was accessible from the available maps. Other variables, such as terrain ruggedness and

slope, which are often included in habitat selection models during the denning period were not used as it is highly unlikely that the pack was denning during the data collection. Distance to human disturbances or a variable linked to human density were not added to the model, because the closest human settlement is 30km away from the centroid and separated by a river, so they were excluded. The most human disturbances could be caused by the high bus traffic on the road separating Katavi NP to Lake Rukwa GR, but the pack seems to be used to vehicles, as they are commonly photographed and filmed in a resting behaviour by the people from TANAPA, TAWA and TBGS.

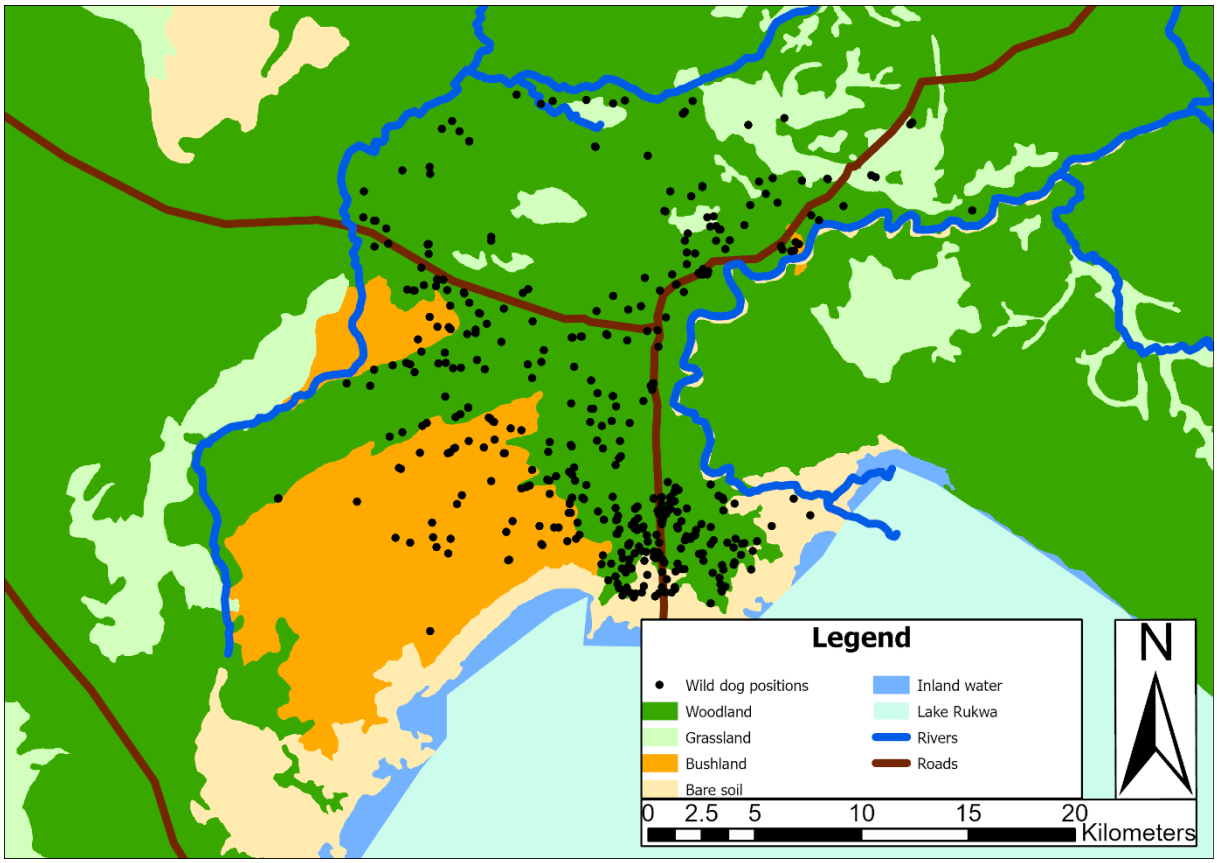

Figure 7: Map with the environmental variables.

The differences between used and available habitats were analysed using a generalised linear model (GLM) with binomial distribution with the basic stats package in R.

Data that was not part of the framework which could not be modelized, such as direct observations in the field (prey types and availability) and long-term information from the managers of the block was also used to give possible explications for the wild dogs' movement patterns and area choices.

3.3. Semi-structured interviews

3.3.1. Designing the SSI

The interview was adapted from *Key determinants of conflict between people and wildlife, particularly large carnivores, around Ruaha National Park, Tanzania* (Dickman, 2008) with minor changes suggested in discussions with WildCRU team and my supervisor, to assess the attitudes of the people living the closest to the forest towards wildlife, with an emphasis on the carnivores present in the study area. Although the study is focused on wild dogs, people's attitudes towards an animal are not only defined by their experiences with this animal, but also influenced by other similar animals and religious beliefs and ethnicity (Dickman et al., 2014). In addition, considering the time and resources spent in doing the interviews, it is better to take the opportunity to gather as much information as possible as some of it may be useful for other research and to get a long-term comparison. The interview follows the guidelines defined in *Essential Ethnographic Methods: Observations, Interviews, and Questionnaires* (Schensul et al., 1999), starting with more general and less sensitive questions, and as the interview advances, more delicate subjects are aborded when the respondent's trust has increased and they feel more comfortable. At the beginning of almost all interviews there was a strong feeling of distrust towards us. Some people even refused to talk to us, and it is possible that some preferred to hide some elements that could have been used against them, so the results are to be interpreted with caution.

The interviews were structured in six parts: (i) socio-economic characteristics of the respondents, which included their sources of income, the number of livestock owned and its evolution in time and how it is kept. (ii) knowledge and feelings towards wildlife: people had to recognise species from pictures and express their feelings towards the species they had issues with. (iii) reports of carnivore attacks and sightings. (iv) actions taken to control carnivore populations and mitigate conflict. (v) benefits obtained from the surrounding wildlife. (vi) statements to further express their feelings towards carnivores, with a focus on lions as they are the best known and most representative of human-carnivore conflict. The full interview can be found in appendix XII.

The Wasukuma were chosen as target population, as their practices and the locations of their households make them most prone to have conflicts with wildlife. However, although we had a specific target population, we never excluded people from other ethnic groups, as their answers could give another perspective which would be interesting to compare. Therefore, the proportions of Wasukuma and other ethnic groups interviewed is also explained by the fact that most of the local people tend to settle in or close to the villages, whereas Wasukuma need larger portions of land to cultivate and for their cattle, so they are very present in the edges of the forests

Personal questions about the level of children's education could not be asked due to the limited time and difficulties that such a question would have arisen. Therefore, there is no recent reliable data concerning the level of education or school attendance. This information could be valuable to determine the commitment of these households in the life of the village and give perspectives of the activities of the future generations. Considering that during the interviews and the displacements, children were always around the households, and none of them were seen with uniforms arriving or going from school, it is likely that they spent more time helping in the field than in school. Even if they were informed of the benefits obtained by having neighbouring protected areas, since farming is the core part of Wasukuma's economic livelihood and identity, indirect benefits that are not linked to farming may not even be perceived as necessary, especially considering the costs of living next to protected forests with wildlife.

3.3.2. Conducting the SSI

The interviews were carried on by a Msukuma teacher of Inyonga primary school accompanied by me. The households were in isolated areas, most often inaccessible by car, so we moved from Inyonga to the villages by bicycle; the locations of the villages and of the respondents' households can be seen in Figure 8.

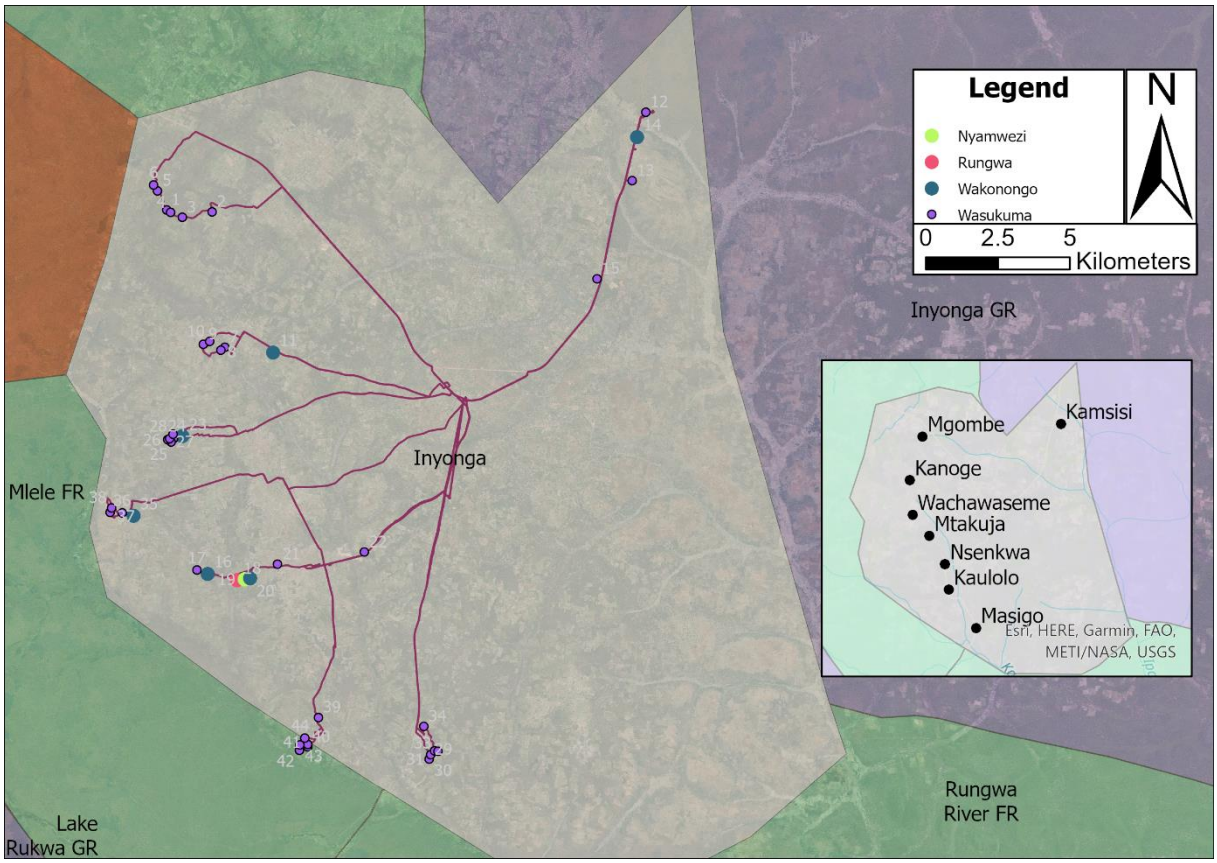

Figure 8: Respondents' household locations.

Arriving to the village, the first step was to visit the VEOs to ask for the authorisation to conduct the survey and explain the purpose of the project, all of them agreed with no problem and were quite happy to cooperate. Then we asked them which direction we should take to find Wasukuma households next to the forest. In Masigo, the chairman even offered to accompany us to guide and introduce us personally. As many interviews as possible were conducted in each village, the number varied depending on the length of the interviews, whether the people were willing to talk or not and on the schedule of the translator.

Arriving to the household, the translator would explain the purpose of our visit, the context and goals of the project, and guarantee them that they would remain anonymous. Our objective being to listen to them, gather information on how to reduce human wildlife conflicts and not to give them any kind of problems by denouncing their activities to anyone. When they accepted, I would ask the questions in English; the translator would then repeat in Kisukuma or Kiswahili and then translate their answers in English to me so I could write them down. At the end of the interviews, the respondents were offered tea and sugar to thank them.

All the answers were transcribed to Excel the same day to ensure that even if there was a transcription error, the interviews were recent enough to remember them with details. In general, the results seem satisfying, but it is possible that there were some simplifications in the translations and that some questions could have been pushed further. Nevertheless, there were not many people who were available and spoke English and Kisukuma fluently, and the time it takes to explain the interview and understand some subtilities was not negligible.

4. Results

4.1. Assessment of the status of protected areas

The total time spent in each reserve can be found in Table 2, and a more detailed timetable in appendix IV. The time spent in each reserve varies significantly, ranging from 2 to 18 days. Although 2 days is not enough to inspect the entirety of reserves as large as the ones in the study area (the smallest one being Rungwa River OA with its 850 km^2, which was formerly 1763 km^2, but its size was reduced due to agro-pastoralist settlements), it is enough to get a general idea of the degree of encroachment and the presence or absence of illegal activities. This time was not sufficient to determine whether there were wild dogs or not, but with lower degrees of protection, the probabilities of them being there are lower. The results concerning wildlife should be interpreted with caution due to the large number of stochastic factors which will determine encounters in the field, but the presence of large carnivores is always a good sign. Furthermore, the most damaging illegal activities, notably those directly destroying habitats like uncontrolled logging and transformation of the forest into agricultural land, leave evidence that remains in place for a long time.

4.1.1. Mlele forest reserve

The beekeeping zone is in excellent condition; there were almost no signs of illegal activities. On the way to the camp from Kanoge village, there was a recently planted rice field, but it was relatively small for the moment. During all the visits, people were found cutting trees inside the BKZ three times; it is not clear whether this was a problem of frontier delimitation between the BKZ and the FR or if people came on purpose to find rarer species inside the BKZ, because they were not present anymore outside. During the 18 days spent looking for wild dogs inside the BKZ, the four larger carnivore species present in the area were directly observed (lion, leopard, hyena, and wild dogs) and captured multiple times in different places with camera traps. Their presence indicates effective conservation of habitats and sufficient prey basis.

Figure 9: Hyena at dawn in Mlele BKZ.

Figure 10: Wild dog in the morning in Mlele BKZ.

Figure 11: Leopard at sunset in Mlele BKZ.

Figure 12: Lion in the morning in Mlele BKZ.

It is harder to precisely assess the situation in the FR (excluding the BKZ), because we only crossed it once, but the passage of large trucks carrying timber is apparent; the roads are larger than in the BKZ and very well maintained, there were also clear marks of larger vehicles on the ground. The vegetation next to the road seemed particularly open, but this may be due to environmental reasons and not intense deforestation. There was a trap set up by poachers and a logging camp close to the frontier with the BKZ. It was unclear whether the trees they were processing had been extracted from the FR or not, as there were no freshly cut tree stumps around. During the four months of fieldwork, the road next to the FR, linking Mpanda to Inyonga was under construction and an electric line was being built across the forest, at the end of the four months the road was fully finished.

Figure 13: Construction of the road linking Mpanda to Inyonga.

Figure 14: Deforestation to create space for the high voltage line.

4.1.2. Rungwa River forest reserve

In comparison to Mlele FR, the situation in Rungwa River was much worse and probably deteriorating quickly if nothing is changed. When entering the forest from Ilunde, there were multiple houses inside the reserve, and in addition, the first six floodplains had been converted to rice fields. Each of the four days we spent in FR, people ran away at the sight of our car, abandoning their bicycles with illegally extracted goods (timber, fish, or honey), which were confiscated. There were no sightings of large groups of herbivores, only isolated individuals. Although the forest seems to be very disturbed and there are many indications of illegal activities, a young lion was seen crossing a road and an elephant crossing the river.

Figure 15: Rice fields inside the forest reserve.

Figure 16: Abandoned items from illegal activities.

4.1.3. Lake Rukwa game reserve

The first block assessed in Lake Rukwa GR was Rungwa river block, the time spent inspecting the block was relatively short and the area was not known, even for the ranger, this reduced the efficiency of the exploration. The last time there was a hunting company in the block was 2 years ago, so there are illegal human activities to be expected from the lack of patrols. On the way to the river, there were three illegal logging camps next to the road, and there was also an illegal settlement with steel weapons. In addition, fresh tracks from vehicles were visible in many places; these were probably from recent illegal activities, as there had been no patrols from TAWA. Several groups of herbivores were present, remarkably a herd of over 50 buffalos, and a group of 8 hippos in the river, where a fresh lion dung was also seen. Even if there were signs of illegal activities, the wildlife populations seem to be faring relatively well.

Figure 17: Illegal settlement burned by the ranger.

Figure 18: Large herd of buffalos.

Out of all the reserves where the research was carried on, Lake Rukwa block, currently managed by TBGS, seemed to have the largest quantity of wildlife by a large margin. This may be biased by the fact that most of the routes pass through places with open vegetation with high visibility, but it is also probably influenced by the intensity of protection and the diversity of habitats. The four large carnivores present in the region and large groups of elephants (more than 30 individuals) were seen multiple times in addition to smaller groups of more common species, which were seen many times per day. However, there were still illegal activities being carried on inside the reserve. In the lower part, next to the lake, there were several settlements of fisherman dating from the last rain season. During the time spent there, the anti-poaching patrols encountered people doing illegal activities in the reserve twice; among them there was a group of more than twenty poachers who were sailing up the river in a small boat. The camera traps placed within the framework of this study captured a picture two poachers with muskets. This shows that even in places with very high protection, some people are still willing to take risks. TBGS lost the management of the place for a few years, during which the area was left unprotected and there was a strong cattle pressure. Luckily enough, the activities were limited to feeding livestock, so there was no deforestation. Nevertheless, there are marks of Wasukuma on the trees, which are used to delimit territory and to show a “safe zone”, namely where lion presence has been controlled (Dr. Iddy, comm. pers.).

Figure 19: Poachers captured by a camera trap.

Figure 20: Territorial mark from Wasukuma.

4.1.4. Rungwa North open area

There was less than a day spent inspecting the situation in Rungwa North OA, but it was enough to see that currently the forest was suffering very high human pressure. In one day, all types of disturbances could be observed; there was land encroachment on the borders of the reserve, hundreds of cattle inside the protected area, people fishing illegally with small nets that catch all the fish, illegal logging camps, and a camp next to the river where there were steel weapons and tools covered with blood. Surprisingly enough, even in a place with so much human pressure, the camera trap grids from 2021 showed higher biodiversity than Mlele FR and wild dogs were captured in three different places. However, other species that tend to be hunted more actively, such as the buffalo was no captured in the area, this may explain the absence of lions (Hausser, pers. comm.).

Figure 21: Illegal settlement inside the forest reserve.

Figure 22: Herd of calf grazing alone inside the FR.

4.2. Wild dog data

4.2.1. Camera trapping

The camera trapping faced some problems; there were four cameras whose data could not be collected, one camera was burned by fire, another one had a defective SD card, and two cameras were stolen. In addition, some of the cameras' batteries ran out, or SD cards got filled before the recovery.

As to be expected due to their low density, there were very few captures of wild dogs, they were only seen in two out of the 89 cameras set up during the fieldwork specifically to capture wild dogs. Both cameras were set up pointing at waterpoints, in the lower part of the BKZ, relatively close to each other (5.7km apart). The same pack, consisting of four wild dogs was captured twice in a 23-day interval.

Figure 23: Three wild dogs in Mlele FR.

Figure 24: Two individuals from the same pack.

Since the beginning of the ecological monitoring with camera traps of higher end in 2013, which had a higher battery lifetime and memory, wild dogs have only been captured 22 times, which can be seen in Table 5.

As to be expected, most of the captures (87.5%, n=21) correspond to the peak wild dog hunting hours (Creel & Creel, 2002; Cozzi et al., 2012; Woodroffe et al., 2017). If 95.8% (n=23) of the captures are between August to November, it is because the ecological monitoring takes place during the dry season.

Table 5: Wild dog camera trap captures.

Place name	Group size	Date and time	Place name	Group size	Date and time
M2_31	1	05/11/2013 07:26	RW4_13	1	29/11/2018 02:03
M2_31	1	05/11/2013 07:46	M3_15	1	15/07/2019 18:56
R2_28	1	23/08/2014 19:53	M3_20	1	18/07/2019 07:33
R2_28	1	24/08/2014 21:32	M3_16	1	23/07/2019 08:58
R3_06	1	04/09/2014 19:17	M3_11	1	30/07/2019 18:41
M5_10	1	30/11/2014 08:45	M3_26	3	18/10/2019 07:11
M1_32	1	20/03/2015 07:53	M3_19	2	23/10/2019 08:54
R1_08	1	29/10/2015 18:51	K2_17	2	11/09/2021 07:12
R3_05	2	04/10/2018 17:51	WD_01	3	28/09/2021 10:21
RW4_24	1	06/11/2018 06:01	WD_02	2	21/10/2021 23:57
RW4_31	1	17/11/2018 17:51	K1_20	1	30/10/2021 06:35
RW4_13	2	18/11/2018 09:18	K1_30	1	03/11/2021 18:04

4.2.2. Direct observations

During the three months of the study, 11 direct observations were documented from different sources. Names were given to identify the packs based on the context of the encounter or specific traits. Unfortunately, the precise time of the encounter was only available when I noted it personally.

As seen in Figure 25: Locations of wild dog sightings during the fieldwork, some of the locations were approximated based on the descriptions from the different sources. Considering the large home ranges of wild dogs, and with the objective of finding areas with high occurrence, having a precise GPS point is not very different from an estimated location, as long as they both show the same area. In the cases where a group is seen multiple times in the same area, mainly if these sightings occur throughout multiple years, certain territoriality can be assumed. Unless a pack is seen multiple times, it is impossible to determine its full size because wild dogs can split into smaller groups to hunt (Creel & Creel, 2002). Therefore, Table 6 shows the number of individuals seen at the time of the encounter, but in two cases (Rafiki and Sita), the packs have been seen enough times to be sure of their composition.

The pictures were only available from the hunters or the professional photographers accompanying them, who have expensive high-resolution cameras. This gives key information to identify the members composing a pack, which can be used to follow a pack's movement through recaptures (either by CTs or photographs) and help estimate the number of packs present in an area.

In addition, due to the very high frequency of patrols (multiple cars patrolling the reserve every day during the hunting season) in the Lake Rukwa hunting block, it was possible to know whether there are packs established in a specific area for several years.

Table 6: Documented direct observations of wild dogs.

Name	Reserve	Date and time	Group size	Pictures	Occurrence	Source
Bahati	Mlele FR (BKZ)	05/09/2021 08:15	8	Yes	-	Self
Bahati (2)	Mlele FR (BKZ)	05/09/2021 09:05	12	Yes	-	Self
Tanga	Lake Rukwa GR	28/09/2021	3	Yes	-	Alan (hunter)
Jangili	Lake Rukwa GR	01/10/2021	20+	Yes	New	Lorne (hunter)
Tanga (?)	Lake Rukwa GR	04/10/2021	7	Yes	-	Alan (hunter)
Sita	Lake Rukwa GR	10/10/2021	6	Yes	Monthly	Dusty (hunter)
Unsure-1	Mlele FR	17/10/2021	20+	No	-	VGS
Rafiki	Lake Rukwa GR	22/10/2021 08:29	12	Yes	Weekly	Self
Tupac	Lake Rukwa GR	27/10/2021 07:11	2	Yes	Multiple	Self
Mpya	Lake Rukwa GR	01/11/2021	10+	Yes	New	Lorne (hunter)
Unsure-2	Mlele FR (BKZ)	06/11/2021	8	No	-	VGS

In Mlele FR, the same pack was probably seen multiple times. The first two encounters occurred beginning of September, very close to each other, within an hour. It is safe to assume that the pack was split into two groups to hunt, as both groups were in an active behavioural state and an individual from the second group had a piece of meat in their mouth. A few weeks later, a pack of more than twenty individuals was seen by the VGS, which corresponds to the probable size of Bahati pack. Finally, in the beginning of November, a group of eight wild dogs was seen less than 2 km away from the first sighting; without pictures it is impossible to say whether it was the same pack, but considering the proximity, it remains plausible. Excluding the two encounters without pictures who might belong to Bahati pack, the minimum population can be estimated to 84 individuals in Mlele BKZ and Lake Rukwa GR, based on direct observations and camera trapping.

In Lake Rukwa most of the information was transmitted by the hunters, they were a reliable source that had the advantage of having long-term information. Four packs were relatively well known. Rafiki is a pack of twelve wild dogs seen multiple times per week on the road from Inyonga to Majimoto; therefore, this became our main target for the collaring. It is important to consider that the frequentation of this road is also the highest, between the hunters, the rangers from TAWA and TANAPA, and the bus drivers. Sita is a pack composed of one male and six females that has been seen in the same area regularly for the past four years in the road to Dougie's waterhole, this became our main target after placing the collar on Rafiki pack. Tupac is a pack of two males that were only directly seen once in the road to Majimoto, but fresh dung and pee were seen every day after that first encounter. It is safe to assume that they were very active on that portion of the road, and this was further confirmed when a team of TAWA told us that they saw two wild dogs running after a roan antelope on the road, unfortunately we did not manage to find them again in better conditions. The last pack that had been constantly observed next to the lake for several years could unfortunately not be relocated, due to the heavy rains of the past two years that increased the lake's level. During the research in the block, the hunters saw two packs that they had probably never observed before. Jangili, a large pack with pups next to the river, so we tried to see if they were still denning, but after inspecting the whole riverside no spoors were seen, so it is very likely that the denning phase was over. And finally, Mpya pack, which also had a litter from the same year, was seen in an area where there had not been a single wild dog sighting for the past 15 years (Ramoni, pers. comm.).

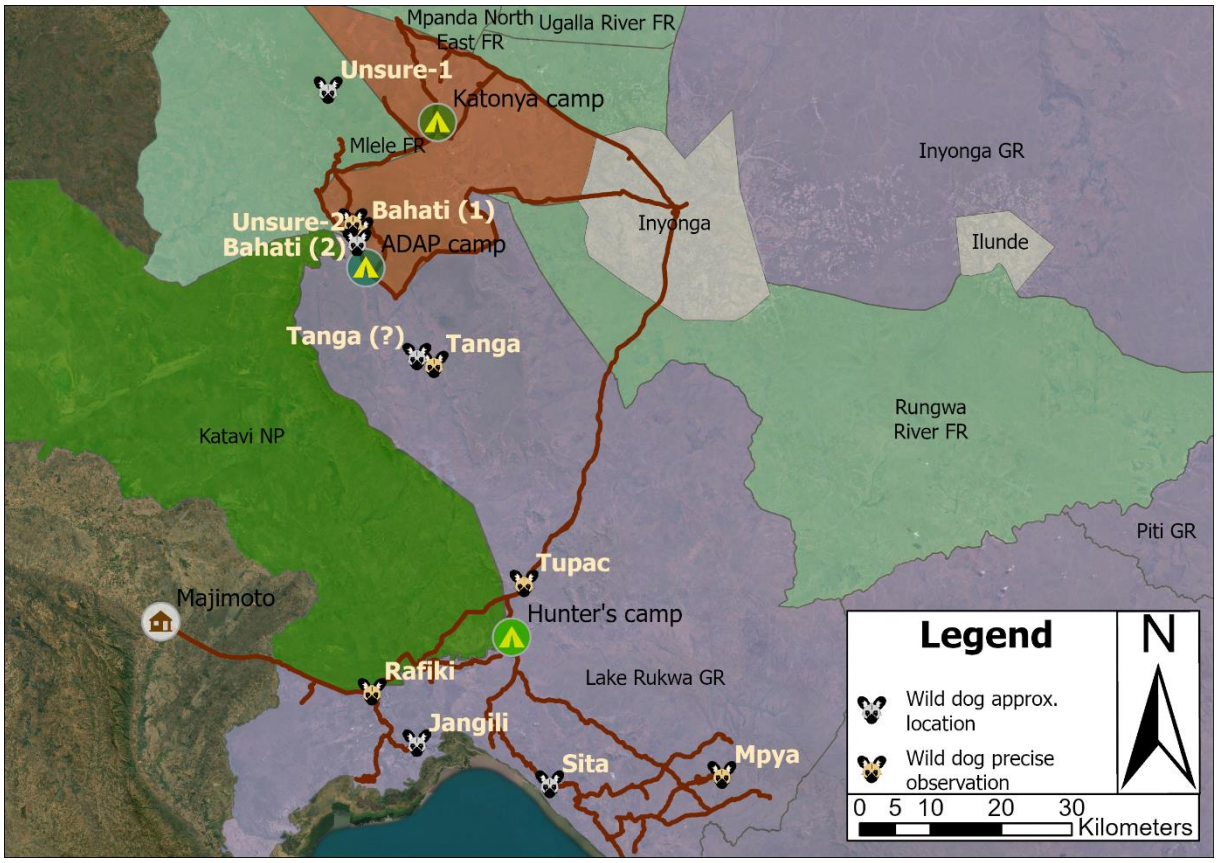

Figure 25: Locations of wild dog sightings during the fieldwork.

During the three months in the field, three roadkills were documented in Katavi-Rukwa ecosystem and there had been one in May 2021 near Rungwa North OA.

Table 7: Details on wild dog roadkills.

ID	Location	Date	Source
1	Rungwa North OA	May-21	ADAP
2	Koga river	01/10/2021	Self
3	Katavi NP	Oct-21	WCS
4	Katavi NP	07/11/2021	Self

Based on personal observations and exchanges with people working on the area (ADAP, TAWA, TBGS), figure 22 was made to show roads with high kill occurrence. There are several animals killed by vehicles every week on the road crossing Katavi NP. During the fieldwork, I had to take the road going from Inyonga to Tabora once (see ID 2), during the route I counted five dead animals, three mammals including one wild dog, one bird and one non-identified animal. People from TAWA confirmed that there was a high frequency of roadkills on this road. ADAP team documented two roadkills (one wild dog and one big reptile in the road bordering Rungwa North OA the same year. There are several sources that have confirmed that roadkills are a common sighting on this road. Finally, when going from Katavi's headquarter to Majimoto, another killed wild dog was seen. Dr. Monty had received another picture from less than three weeks earlier from a roadkill in the same road. Pictures of the carcasses can be found in figures 27 to 30.

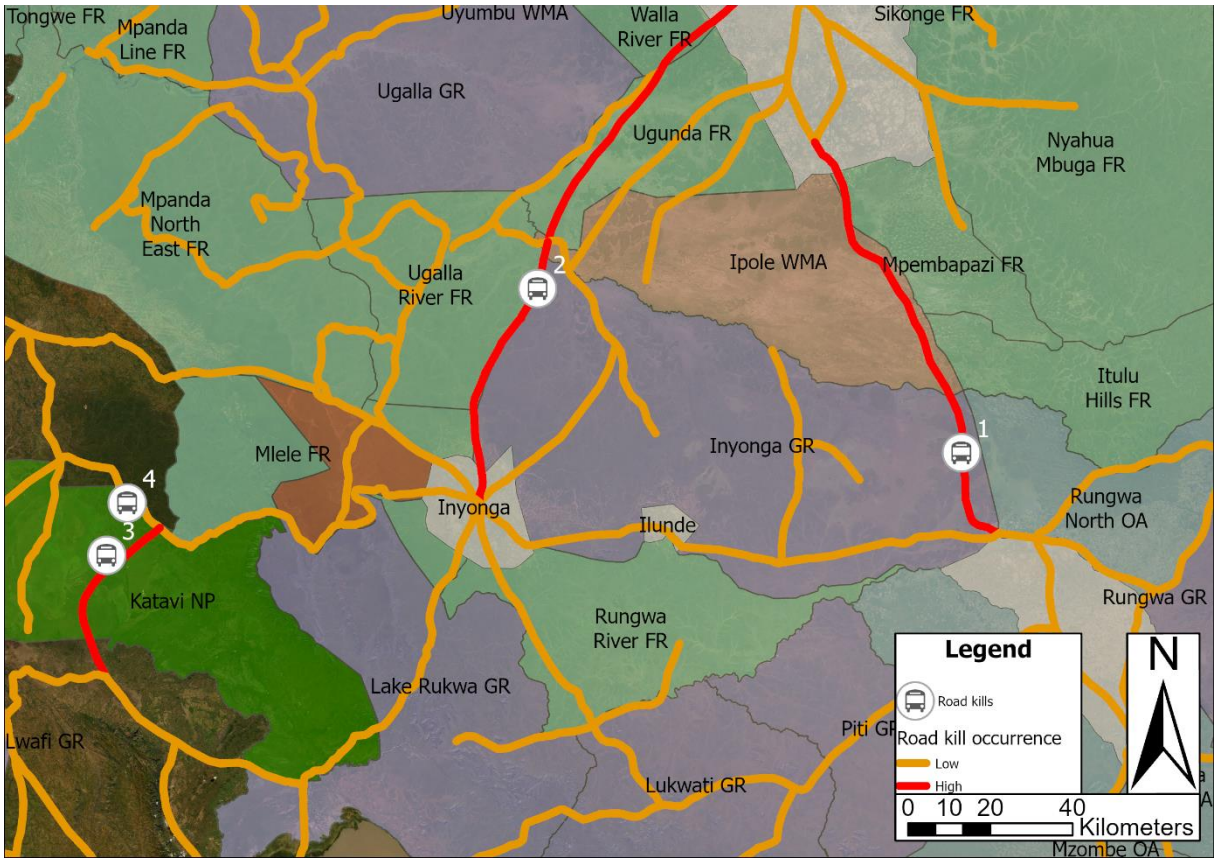

Figure 26: Locations of roadkills with higher mortality roads.

Figure 27: Wild dog roadkill in Rungwa North OA. (ID 1)
Photo by Matana Levi (ADAP).

Figure 28: Roadkill near Koga River. (ID 2)
Photo by Miguel Miguera (TAWA).

Figure 29: Roadkill in Katavi NP. (ID 3)
Photo by Monty Kalyahe (WCS).

Figure 30: Roadkill in Katavi NP. (ID 4)

4.2.3. Telemetric data

The home range of the pack is around 596km^{2,} and it is located in the southern part of Katavi NP and the western part of Lake Rukwa GR. Majimoto is the nearest village to their home range, being located at approximately 16km from the closest point. The KDE at 50% shows two core areas, one in the floodplains and the other in Katavi NP.

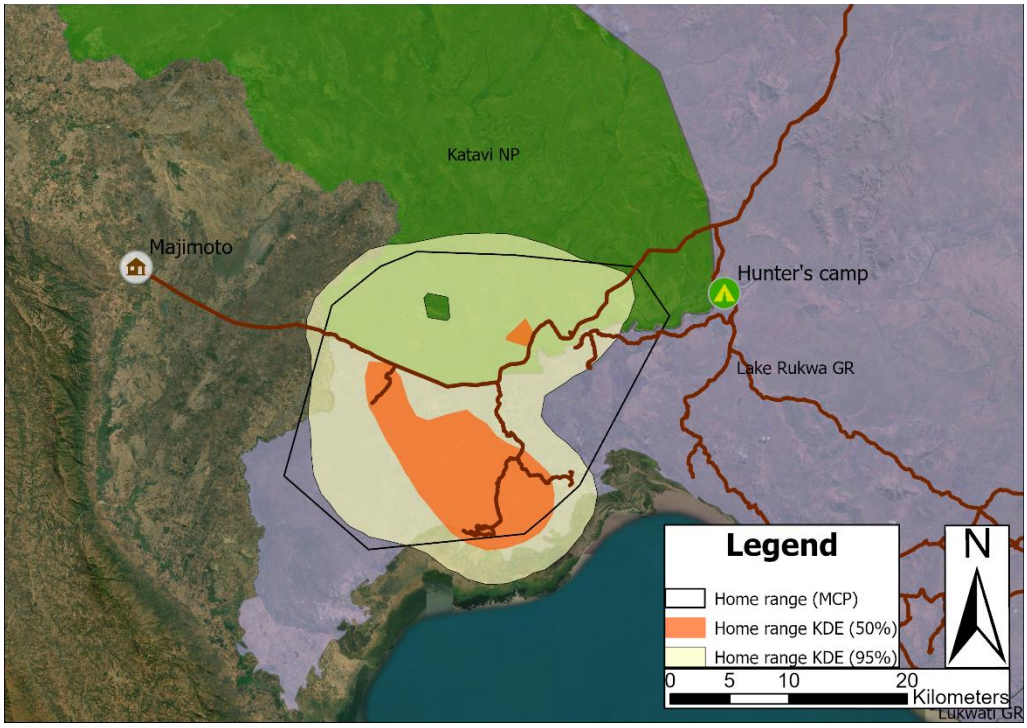

Figure 31: Home range estimations.

Since the date of the collaring, 438 GPS locations were gathered, the total displacements can be seen in Figure 32. The peak of activity in the floodplains bordering Lake Rukwa, where the vegetation is very open and there is a large amount of prey. The local people call this area Kichangani, every time we went there, we could see several large groups of pukus, giraffes, reedbuck, waterbuck, zebras, baboons, bushpigs and warthogs.

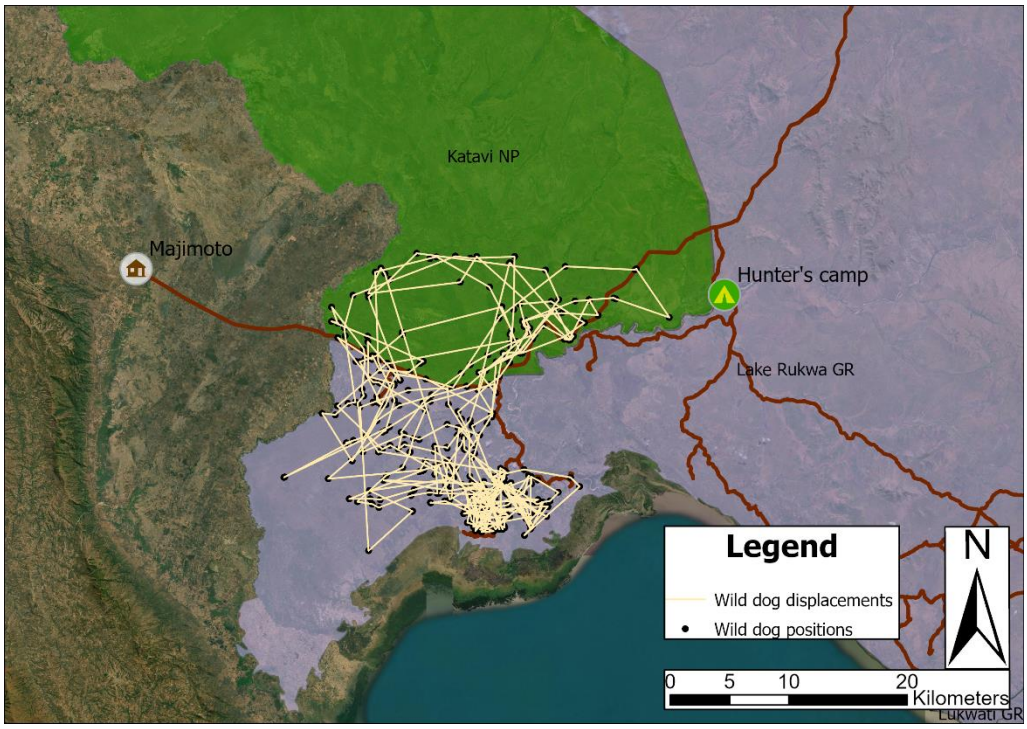

Figure 32: Wild dog displacements from 22/10/2021 to 21/03/2022

The RSF showed that six out of the eight variables tested were significantly different from the randomly generated points at a level of significance of 5% (p-value < 0.05) (see Table 8: 8). The two non-significative variables were inland water, which is expected since there should never be observed points inside the lake. The other one is the distance to the rivers, which does not seem to explain habitat selection for the collared pack. The results show a clear preference for woodland and bushland, and avoidance of bare soil and grassland. The avoidance of bare soil may be biased if the landcover does not correspond to the current situation in the field, where parts of land may be under the water as the level of the lake increased significantly in 2021. Finally, the model also shows a preference for areas close to roads and to the lake.

Table 8: RSF habitat selection model results.

Habitat variable	Estimate	Std. Error	z value	Pr(>|z|)
Woodland	9.24E-01	2.00E-01	4.628	3.69E-06
Grassland	-9.25E-01	2.93E-01	-3.16	0.00158
Bushland	4.53E-01	2.13E-01	2.127	0.03345
Bare soil	-1.33E+00	2.64E-01	-5.024	5.06E-07
Inland water	-1.85E+01	3.94E+02	-0.047	0.96258
Distance to lake (km)	-1.11E-04	1.17E-05	-9.467	< 2e-16
Distance to river (km)	4.93E-05	2.94E-05	1.68	0.0929
Distance to roads (km)	-3.23E-04	2.54E-05	-12.713	< 2e-16

To compare the observed locations with random locations, a simulation was run with 438 points (to correspond the total number of positions collected), shown in Figure 33. The most noticeable differences are that observed variables show a preference for woodland and avoidance of grassland compared to the random ones.

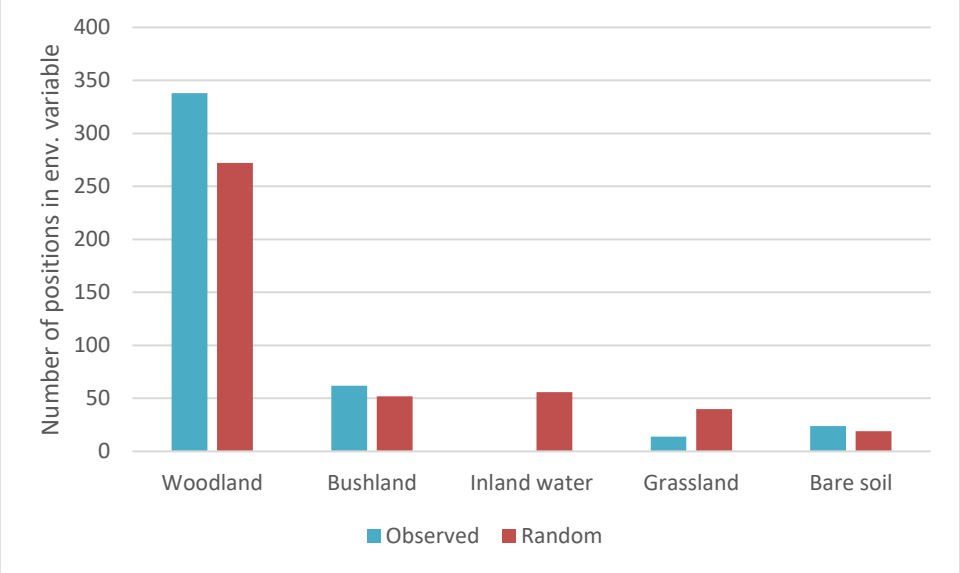

Figure 33: Comparison of observed vs random locations per environmental variable (n=438).

4.3. Semi-structured interviews

4.3.1. Respondents' characteristics

In total, 44 people were interviewed in eight villages bordering the Mlele BKZ. All these villages are working in collaboration with ADAP on multiple community-based natural resource management (CBNRM) long-term projects, such as the community-based forest management project in the Rungwa corridor and the co-management of the Katavi-Ugalla corridor forests. The number of interviews per village varied due to the attitudes of the people met and the circumstances of the encounter. Considering our objective was to interview the people living closest to the forest from each village, it may have been unclear for some people whether their household was within or outside the reserve. Therefore, due to their potential illegal status, many households, particularly those in the villages of Mtakuja and Kaulolo, refused to participate. They were not eager to answer an interview concerning wildlife, fearing repercussions. In the village of Kamsisi, there was a meeting between the Wasukuma families the day the interviews were carried on, so people living within the village were interviewed instead of the ones living within the forest's borders.

Table 9: Number of surveys carried out per village.

Village	No. interviews
Kamsisi	4
Kanoge	5
Kaulolo	6
Masigo	6
Mgombe	6
Mtakuya	4
Nsenkwa	7
Wachawasemi	6
Total	**44**

The target population was the Wasukuma, but if most of respondents (81.8%, n=36) are of Wasukuma origin, it is not because we specifically chose their households. As they are agro-pastoralists, they are the most likely to settle next to the forests to get access to larger parcels of land. Although they originate from the region, there were few Wakonongo (13.6%, n=6); this can be explained by the fact that most of them settle inside the villages. There was one Wanyamwezi and one Rungwa family, these tribes' homeland is within Katavi region, so it is not surprising to find them in the area.

Table 10: Respondents' ethnic group.

Ethnic group	No. interviewed	Percent
Konongo	6	13.6
Nyamwezi	1	2.3
Rungwa	1	2.3
Sukuma	36	81.8
Total	**44**	**100**

The locations of the eight villages and the 44 households interviewed are shown in Figure 3434, with their respective position to the surrounding protected areas.

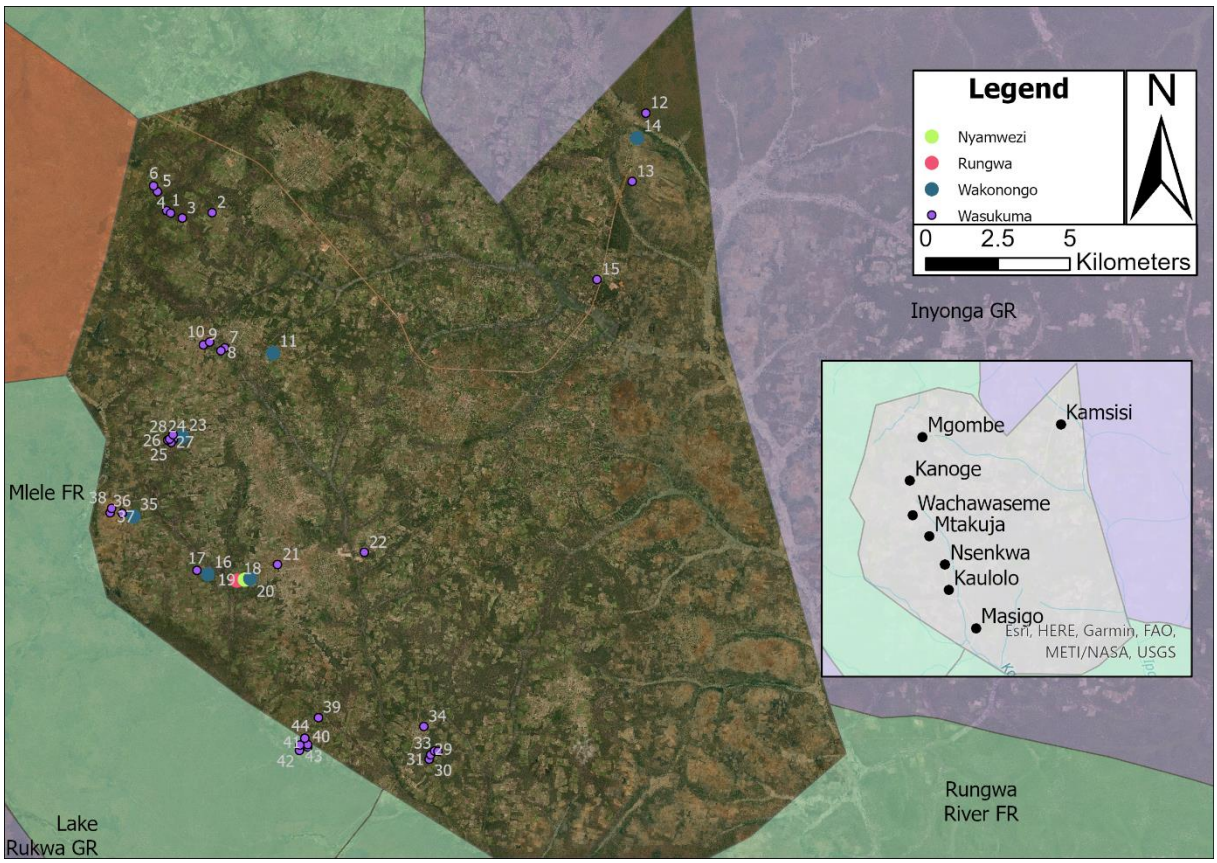

Figure 34: Locations and ethnic groups of interviewed households.

The households were located at an average of 2.34 km (±1.61 km) to the closest protected area. Four households from Kaulolo are within the limits of Mlele Forest Reserve. The furthest household interviewed was in Nsenkwa village, 6.5km away from Mlele FR.

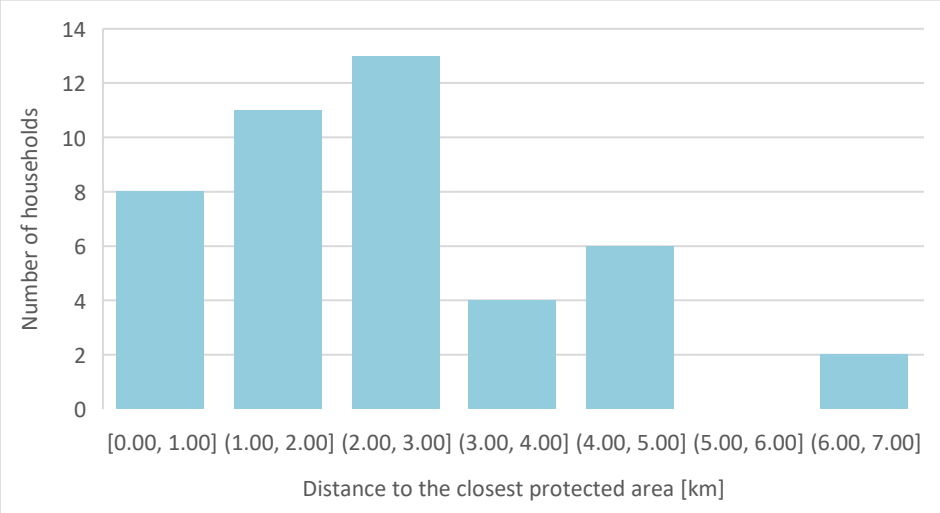

Figure 35: Distance from the respondents' household to the closest protected area.

The majority (66%, n=29) of the respondents recently moved to the area (<6 years); among them 7 households had been living there for less than a year. The average time passed since the arrival is 7.37 years (±10.32 years), and the range is 0 - 47 years.

Figure 36: Respondents' time lived in their current village.

4.3.2. Sources of income

Every household had at least one source of income, and half of the interviewees (n=22) had three different sources of income. When asked for other sources of income that were not listed in the interview, the respondents specified that poultry (chicken, ducks, and pigeons) or milk were sold. Although all the respondents lived less than 7 km away from protected areas (FRs) only one Konongo interviewee reported receiving income related to the forest from beekeeping, otherwise, nobody directly benefited from the presence of protected areas for their revenue, not even in activities linked to timber. Farming was the primary source of income for all the interviewees and livestock mainly was used as a backup source of income or for special occasions.

Table 11: Sources of income of the households per ethnic group.

Source of income	Nyamwezi		Rungwa		Wakonongo		Wasukuma	
	n	%	n	%	n	%	n	%
Livestock only	0	0	0	0	0	0	0	0
Livestock & crops	0	0	0	0	1	16.67	5	13.89
Livestock & crops & other	0	0	1	100	0	0	21	58.33
Crops only	1	100	0	0	0	0	3	8.33
Crops & beekeeping	0	0	0	0	1	16.67	0	0
Crops & other	0	0	0	0	4	66.67	7	19.44
Beekeeping only	0	0	0	0	0	0	0	0
Hunting	0	0	0	0	0	0	0	0
Tourism	0	0	0	0	0	0	0	0

4.3.3. Livestock ownership

63.6% (n=28) of the respondents had owned at least one kind of livestock. Among them the average per household was 20.65 ± 19.89 per household ranging from 1 to 60. This makes a total of 642 heads of cattle, including the ones lost and used. Almost one third (n=16, 36.4%) of the total respondents owned no livestock at the time of the survey, depending entirely on agriculture as a source of income. Being agro-pastoralists, it was expected that most of the Wasukuma had owned at least one type of livestock (n=26, 72%). Wakonongo and Wanyamwezi, on the other hand, are traditionally hunter-gatherers who changed their practices to farming in the last century (Hausser et al., 2009), therefore it not surprising that they do not own livestock, only one Mkonongo had cattle.

Table 12: Livestock ownership by ethnic group.

Type of livestock owned	Nyamwezi		Rungwa		Wakonongo		Wasukuma	
	n	%	n	%	n	%	n	%
Cattle only	0	0	0	0	1	16.67	16	44.44
Cattle & goats	0	0	1	100	0	0	7	13.89
Goats only	0	0	0	0	0	0	3	5.56
None	1	100	0	0	5	83.33	10	36.11

4.3.4. Livestock usage and losses

Out of the 28 households that had owned at least one type of livestock, only 12 (43%) of them had used their livestock. The number of animals used is relatively low compared to the total owned; only 51 (7.9%) animals out of 642 have been sold, slaughtered, or given away.

Table 13: Livestock usage.

	Cattle		Goats	
	No. households	No. of stock	No. households	No. of stock
Sold	11 (44%)	41	1 (4%)	1
Slaughtered	2 (8%)	3	0	0
Given away	1 (4%)	6	0	0

Half of the people that had owned livestock suffered losses (n=14, 50%). Among them four lost cattle to predators and to disease. One household whose losses exceeded the others, had lost six animals to a lion and 20 heads of cattle had been confiscated by the government. The livestock losses are higher than their usage; 93 (14%) of the 642 animals had been lost to predators, disease, or confiscated. For each head of stock used there has been nearly the double (1.82) lost.

Table 14: Livestock losses.

	Cattle		Goats	
	No. households	Total stock	No. households	total stock
Stolen	0	0	0	0
Killed by pred.	8 (32%)	21	2 (8%)	2
Disease	10 (40%)	49	1 (4%)	1
Other	1 (4%)	20	0	0

4.3.5. Species identification

The respondents recognised an average of 12.18 (range 5-16) out of the 18 species. Nobody correctly identified the cheetah, which has been likely extinct in the region for a long time, or the serval that was often taken for the leopard. As seen in Figure 37, 14 species were identified by more than 60% of the respondents. The lesser-known ones were the jackal and the wild dog, which were often confused, and so was the warthog with the bushpig, which was not on the list. Although it is not native to the continent, the tiger was better known than local species, as it was seen on television and on random objects like stickers and clothes, but everyone who identified it correctly knew it was not present in the area. Six species were identified correctly by more than 90% of the respondents and three of them were known by everyone: elephants, lions, and snakes.

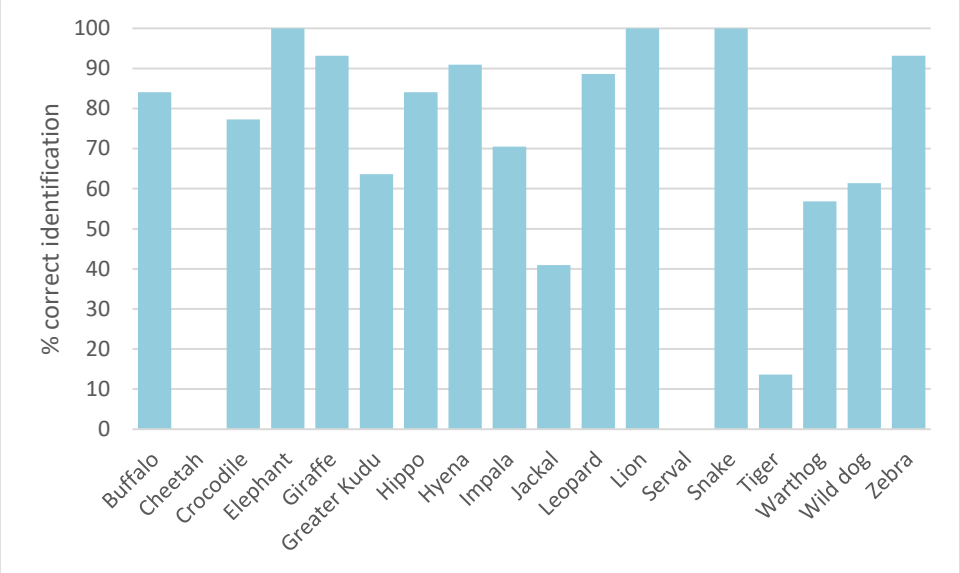

Figure 37: Percent of respondents that

4.3.6. Human-carnivore conflict

General feelings

When asked what they thought about the animals living around their households (Figure 38), 45% (n=20) answered that they were bad and that they did not want to live with them, because they either eat crops or animals. 23% (n=10) did not have an opinion, and 32% (n=14) said it was good to have wild animals around them. However, among the latter group, three of them specified that the herbivores that were eating or destroying their crops (greater kudus and bushpigs) are a big problem.

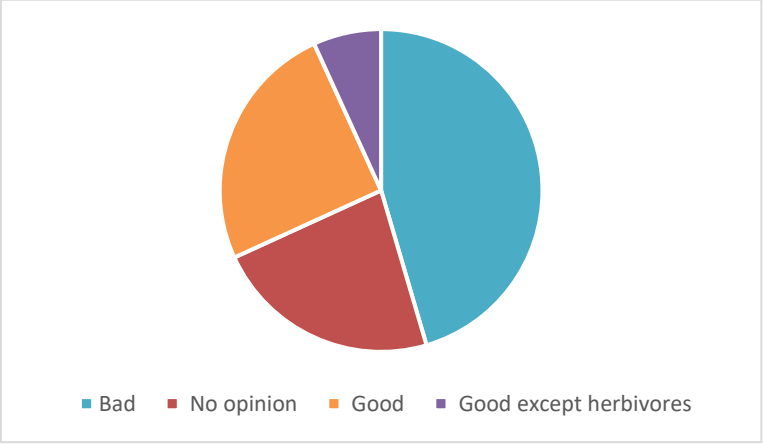

Figure 38: General opinion on the local wildlife.

For the respondents, the most problematic species were the lion (27%, n=12) and the hyena (27%, n=12), feared for their potential to kill people and domestic animals. These were followed by the bushpig and the greater kudu (9.1%, n=4) because of their negative impact on crops. The other animals cited were snakes, monkeys, and wild dogs. Surprisingly, someone mentioned the giraffe because it destroys crops, which is unexpected as they are exclusively browsers.

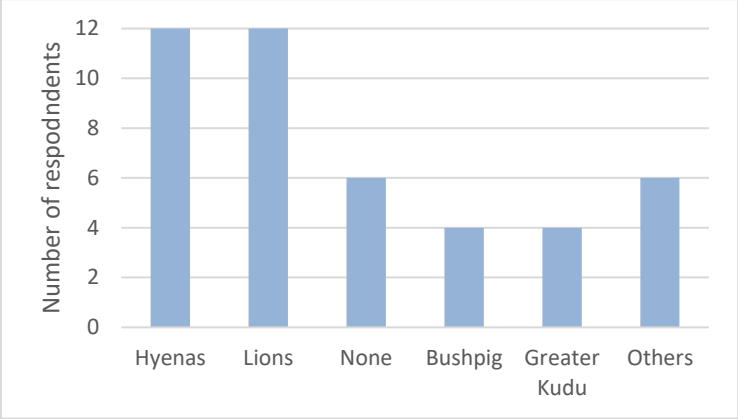

Figure 39: Most problematic species.

To further understand the position of the people, a question was asked to know whether they considered wildlife a danger, to which 61% (n=27) of the respondents answered yes.

Moreover, to allow people to express their feelings, six “statement questions” were asked, focused on lions since they are the most controversial and better-known species. The answers go from 1 (strongly disagree) to 5 (strongly agree), 3 being neutral. Quantifying feelings like this has some flaws, but it can still give an idea of the general attitude.

For the first two questions (see Figure 40), there was a clear antagonism towards lions. Most people clearly said that lions had nothing to do there and that they would be happier if they were gone. Concerning a future without lions, the opinions were more balanced, slightly shifted towards an antagonism (mean of 2.66). For the fourth and fifth questions that were linked to taking actions to reduce lion populations, there is a trend towards not touching the lions, most of the respondents justified this by a fear of the government and by an inability to do so, rather than a willingness to not kill lions. Finally, even with this fear of repercussions, most of the people (mean of 2.41) said that if they killed a lion the village would not be angry, quite the opposite, they would be happy and grateful.

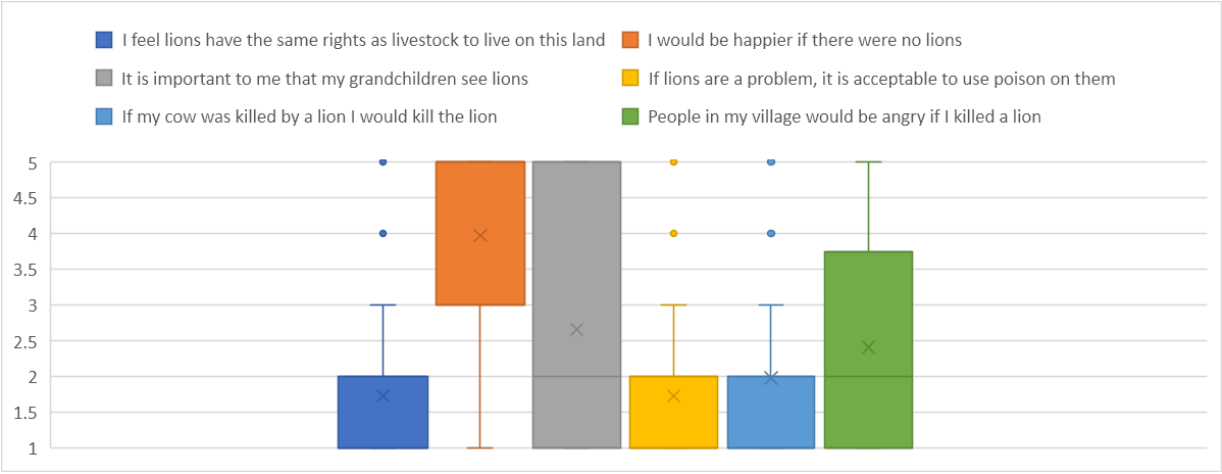

Figure 40: Statements on lions.

Level of conflict

The mean conflict score varies considerably between species, with the hyena and the lion scoring highest, which is consistent with the answers in Figure 39 and Figure 41. The greater kudu is the herbivore with the highest conflict score, and it tied with the leopard for the third place.

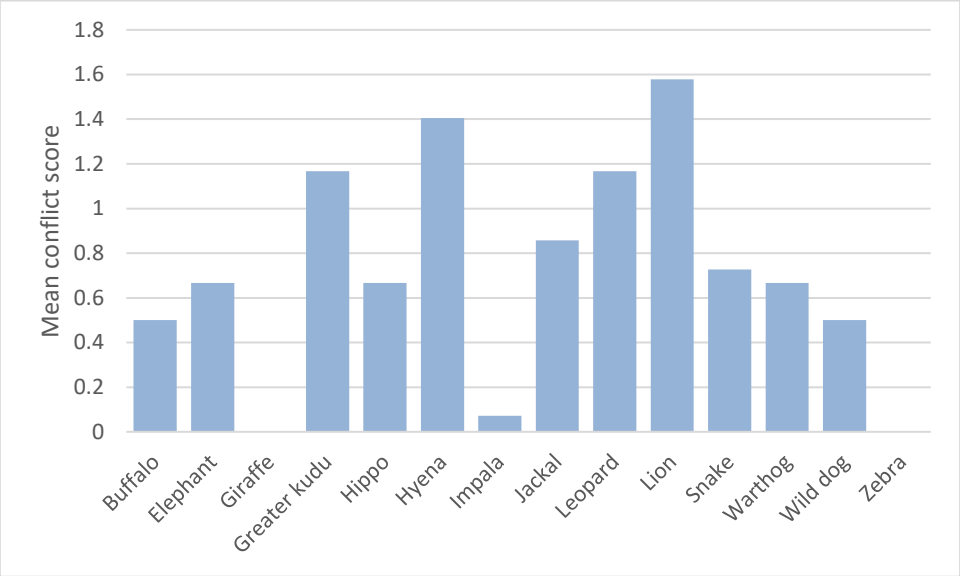

Figure 41: Mean level of conflict per species.

Past and future population trends

With the exception of the hyena, the respondents thought that the number of carnivores present in the area has been reducing since they arrived in the area (which corresponds to a mean time of 7.37 ± 10.32 years). If they believe that hyenas populations are increasing, it may be biased because it is a species that is not only heavily disliked, but it is in found higher densities and can be heard every night, making its presence easier to acknowledge compared to the other three.

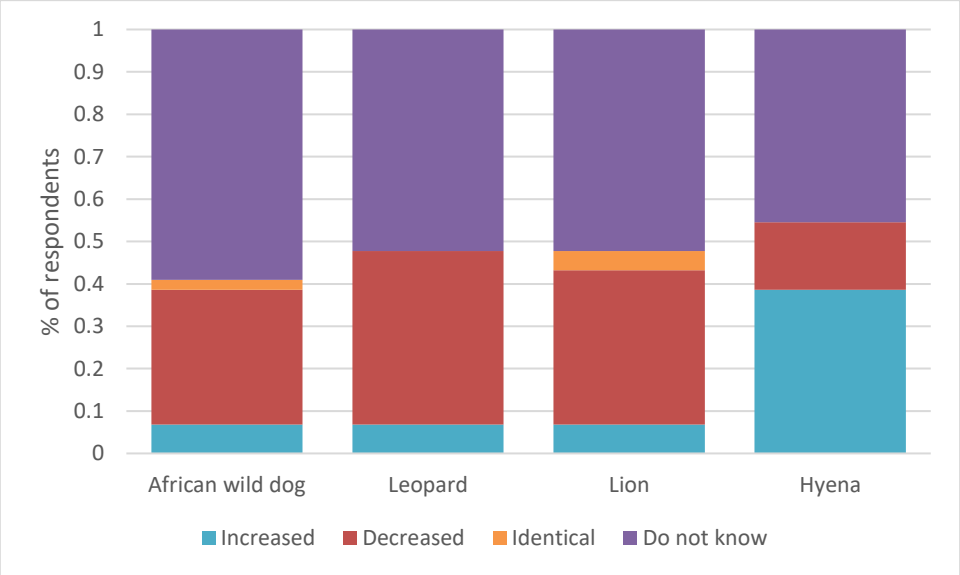

Figure 42: Respondents' thoughts on population variation since arrival in the area.

For the four species, over half of the respondents (61.3% for the wild dog, which was the lowest) expressed a desire to see the carnivores disappear from the area. Some respondents specified that the carnivores had nothing to do outside of the forest, and as long as they stay inside, everything is fine. Most of them justified their choice by explaining that wild dogs, leopards, and hyenas attack domestic dogs and poultry, and lions kill cattle and people.

Comparing the numbers of people that were willing to see the carnivore numbers increase, wild dogs had a much higher acceptability than the other three species with 32% (n=14), which is the double as the leopard and lion.

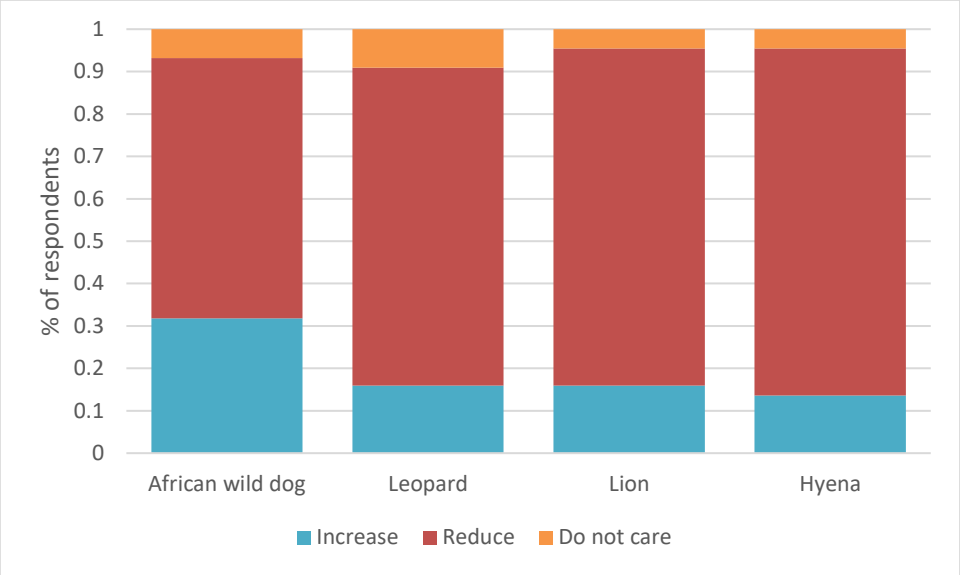

Figure 43: Wishes for future population trends for the large carnivores present in the area.

Risk mitigation techniques used

Every household owning livestock had built a traditional thornbush boma to protect and keep the cattle during the night. The people keeping poultry either had built a small place to keep them or they kept them inside their houses.

Half of the livestock keepers had no dogs (n=14); when asked why most of them answered that it was expensive to keep dogs, as they already struggled to feed their families, it was impossible to also feed dogs. In four households, their dogs had been killed by hyenas.

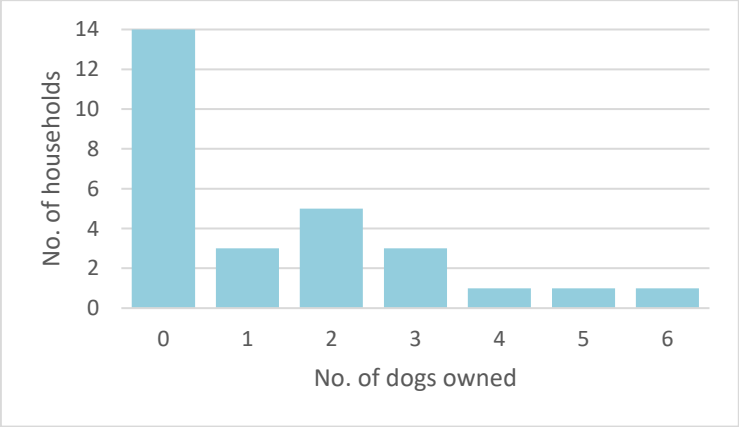

Figure 44: Number of dogs owned per household.

Most effective mitigation techniques

When asked what the most effective way was to protect livestock from predators, the most common answer was that they did not know of any effective methods (n=11, 25%) followed by guarding dogs (n=8, 18%). Some of the respondents answered that supernatural methods, such as praying to God (n=5, 11%) or magical medicines from sorcerers (n=3, 6.8%) can be used to keep the carnivores far from their livestock.

Table 15: Method of protection used by the respondents.

Method of protection	No. of households	
	n	%
Do not know	11	25
Guarding dogs	8	18
Praying to God	5	11
Running away	4	9.1
Building bomas	3	6.8
Magical medicines	3	6.8
Government	2	4.5
Impossible	2	4.5
Staying out of the forest	2	4.5
Fire	1	2.3
Noise	1	2.3
Removing the predators	1	2.3
Torch	1	2.3

Human attacks on carnivores

Only two respondents (4.5%) said that they had placed poison to kill carnivores, and nobody had ever killed a predator else than snakes or even seen someone kill one. However, carnivores are reported to be killed every year in the surroundings of the villages (Hausser, pers. comm.). A lion killed by TAWA rangers in Mapili in 2020, to prevent damage on cattle can be seen in Figure 45: Lion killed to prevent an attack on cattle.. The lion had apparently followed cattle keepers from Lake Rukwa GR to the villages.

Figure 45: Lion killed to prevent an attack on cattle.

Carnivore attacks on human and livestock

Nobody reported any attacks on people. One fourth of the people (n=11) said that they had lost livestock to carnivores, the average loss being 1.91 ± 1.58 heads of cattle. 64% of the attacks were during the rainy season and always at night-time. Lions were responsible for seven attacks, and hyenas for the rest, in addition they killed goats twice. During most of the attacks (55%, n=6), neither a dog nor a person was present.

Table 16: Details on carnivore attacks on livestock.

Animal	Date	Location	Livestock	No. killed	Presence of person/dog
Lion	05.2016 (rain s.)	Forest	Cattle	3	Yes/No
Hyena	2019 rainy season	Boma	Cattle	2	No/No
Hyena	2019 rainy season	Boma	Cattle	1	No/Yes
Lion	01.2020 (rain s.)	Boma	Cattle	3	No/Yes
Lion	03.2020 (rain s.)	Boma	Cattle	1	No/No
Lion	06.2020 (rain s.)	Boma	Cattle	6	No/No
Hyena	07.2020 (dry s.)	Boma	Goat	1	No/No
Lion	2020 dry season	Boma	Cattle	1	No/No
Lion	07.2020 (dry s.)	Boma	Cattle	1	Yes/No
Lion	11.2020 (rain s.)	Boma	Cattle	1	No/Yes
Hyena	12.2020 (dry s.)	Boma	Goat	1	No/No

4.3.7. Conservation costs and benefits

Costs of living with wildlife

Only 7 out of the 44 households have had interactions with people managing the forest. Four of them said that nothing happened, one respondent had 20 cattle heads confiscated by them, and two said they managed to avoid problems by running at their sight.

In an attempt to quantify the respondents' costs of living with wildlife, they were asked how many cows they were willing to give away to never have problems with carnivores again. Ten people answered that they were willing to give away one cow, and the rest said none. It is possible that the question was probably misunderstood sometimes, but even if it was not, asking an economic equivalent for the benefits of never having problems again may not be the best formulation.

Benefits for living with wildlife

People were asked if they felt like they benefitted from the presence of large carnivores in a scale going from no benefits, then small benefits, followed by big benefits and finally very big benefits. 88% (n = 39) of the respondents answered they did not receive any benefits, four said small benefits, and one person said big benefits. They said that the carnivores attract tourists, which brings money to the government, and this money can be reinvested into roads and useful infrastructures such as schools and hospitals. One person said they can profit from carnivore presence by stealing their kills to get meat.

Nobody ever received any kind of compensation for wildlife damage, and the idea seems so far from reality that someone replied: "you cannot take a hyena to the court". This is confirmed by the fact that even considering there are conservation projects in the area, only two persons knew about a project going on because they assisted in the meeting for the Joint Forest Management.

5. Discussion

5.1. Assessment of the state of protected areas

Management effectiveness, such as the frequency of patrols and protection efforts, seems to be a major factor influencing conservation outcomes. Inside Rungwa River FR and Rungwa North OA, where the protection was lowest, there were permanent human settlements, crops, and hundreds of stock heads. Furthermore, even if it is anecdotal evidence, every single day spent patrolling these areas, people doing illegal activities were seen running away when hearing the car's motor. Surprisingly enough, even with all these disturbances, endangered species were still present, which shows the resiliency of these ecosystems. A young lion was seen close to human settlements in Rungwa River FR, and Rungwa North OA camera trap survey from this year showed the largest biodiversity, even though there are no patrols.

Even in TBGS's hunting block, where the protection level was highest, there were still illegal activities. The marks on the trees from the years where the block was not correctly managed, which were very deep into the reserve, show how quickly and deeply cattle keepers can settle when areas become unprotected. Among the places that suddenly had a big arrival of cattle, the floodplains next to the river were strongly impacted; nevertheless, there were many large groups of herbivores present, but there are no more lions in places where they were commonly seen in the past (Ramoni, pers. comm.). This is coherent with the edge effect observed in Katavi NP, lions were already avoiding areas less than 3km away from the borders of the NP in 2009 (Kiffner et al., 2013). If the populations of herbivores seem to be more resilient to human pressure, it may be because of contradictory effects. Even if human pressure should push them away in theory, this same pressure serves as a shield against predators, providing safe places for foraging (Gaynor et al., 2018).

In places where the habitats have remained relatively untouched, the impact of poaching and human pressure can still have long-term effects on wildlife, some adaptations remaining indefinitely. For instance, cattle occupancy is the strongest explanatory variable of lion occupancy (Everatt et al., 2019), and as seen in Lake Rukwa, the avoidance of some areas may remain for years even after the cattle are gone. Elephants, which are also very social animals, have also suffered from long-lasting adaptations due to high-intensity poaching, shifting their activities towards night time (Ihwagi et al., 2018) and in some rare cases even becoming tuskless (Campbell-Staton et al., 2021).

In conclusion, even in highly resilient ecosystems with fast regeneration, such as the miombo woodlands (Gumbo et al., 2018), the impact of human pressure can be much larger and harder to understand than imagined. The disruptions will cause diverse effects and alter the dynamics of the wildlife who will have to adapt their behaviour to cope with the pressure.

5.2. Wild dog status

5.2.1. Camera trapping

As expected, the camera trap survey captured very few wild dogs, even when they were set up using non-random methods to increase the capture chances. In addition, there were no wild dogs in the only grid placed this year in the BKZ. However, there may have been different results if the four grids had been carried out instead of a single one. To put this into context, in the past six years of ecological monitoring, there were only four years with wild dog captures in the area, with an average of two events per year (range 1-5).

During the camera trapping in Mlele FR, a single pack was captured twice in the same area next to the road connecting Mpanda to Inyonga. Construction workers and bus drivers said they had seen a small pack of wild dogs (2-3 individuals) on the road close to these two sites, which probably confirms that they are residing there. Pointing camera traps at waterpoints proved to be most effective, especially considering it was the dry season and water was becoming more and more scarce. Although presence of wild dogs has always been acknowledged in the reserve, these two captures allowed to identify a pack of four individuals, whose markings are clear enough to determine future recaptures in the area.

On the other end of the study area, and completely unexpected based on the situation assessment of Rungwa North OA, there were three different wild dog captures this year. The area with the lowest level of protection, the most human disturbances, and where hundreds of cattle are regularly grazing, was also where the camera trap survey gave the better results. These findings may be too anecdotal evidence to make significant conclusions and should not serve as a basis for conservation measures. Nevertheless, they can arise some questions about the real resiliency of the species and the minimal size required for a reserve to successfully conserve biodiversity, including rare and endangered species. Indeed, smaller reserves are more susceptible to edge effects and represent a greater danger to carnivores due to conflict with humans, but when these reserves are surrounded by well protected areas, they may be sufficient. However, there is not enough information to assess the home range of these wild dogs in Rungwa North OA, or even to know whether they were residing or just crossing the area. But these detections in a small and unprotected reserve, can question some previous estimations on the critical reserve size (Woodroffe & Ginsberg, 1998).

Without a time constraint, carrying on the study during the rainy season would have been preferable to detect wild dogs with camera traps. It offers more favourable conditions when aiming at roads and trails, as carnivores tend to increase their usage to avoid the higher vegetation (Cusack et al., 2015). However, a large part of the study area cannot be accessed during the rainy season.

Finally, a small anecdote during the fieldwork perfectly illustrates the importance of “luck” when targeting such a rare species using camera traps. A camera trap was placed on a tree where the vegetation burned during the night. The following day, we went to inspect if the camera was still functioning after seeing the fires. The fresh ashes kept wild dog tracks where there would otherwise not have been any signs, so we could know for sure that a large pack had passed right behind the tree where the camera was placed a few hours earlier. In addition, this also shows how non-detection does not necessarily mean that the species is absent. Taking this into consideration, two possible adaptations that could have been done to increase success chances. Concentrate the effort in small zone likely to have high activity (characterized by multiple direct and indirect sightings) by placing multiple cameras close to each other, to cover as many passages as possible. Even if the effect is minimal, it is relatively quick to build forced passages with branches, like the poachers do, to create bottlenecks that will reduce the randomness of wildlife movements. Any methods that can increase success chances should be implemented; however small the change may be.

5.2.2. Direct observations

In the latest assessment in 2012, the Katavi sub-population was estimated to have 200 individuals, including adults and younglings (Woodroffe, R. & Sillero-Zubiri, 2020). However, during the three months in the field (September to November 2021) and with limited resources and contacts, the minimum population estimate for Mlele FR and Rukwa GR is of 84 individuals based on the direct observations (see Table 6: Documented direct observations of wild dogs.) and camera trapping. It is very likely that if there was any additional information on populations from Katavi NP, Rungwa River FR, Lukwati GR, Inyonga GR and Ugalla River FR, the sub-population would be larger than 200 individuals. Wild dog presence is confirmed in most of these areas, with past camera trap data from ADAP in Rungwa River FR and numerous packs recorded in Lukwati GR. They have also been seen in Ugalla NP & GR, and in Inyonga GR where roadkills are common. This highlights the importance of gathering information in data-deficient areas, for Katavi the last assessment was an underestimation of the reality, which is good news. But it is not impossible that other areas have been overestimated as well and their populations may be facing a higher risk than assessed.

A small network with Mlele FR and Rukwa GR managers was created to gather and exchange information on wild dogs. People from ADAP, WCS, TAWA, and the two hunting companies currently in Lake Rukwa GR (Tanganyika and TBGS) were constantly communicating any observations that could be useful for this study and in the best cases sharing pictures, that were used to start a wild dog database in the ecosystem.

It is alarming that there were four documented wild dogs roadkills in such a short period of time, considering the little time spent in the large roads connecting villages between reserves, and that two of these happened within a national park. Roadkills present an even bigger threat for an endangered animal living in small densities. The road linking Mpanda to Inyonga was tarmacked during the fieldwork. Before this, buses were already driving very fast (>60 km/h); with this improvement of the road quality, the average speed of all the vehicles will likely increase further. Two studies in Mikumi NP (Newmark et al., 1996; Drews, 2008) have shown the impact of road improvements to wildlife. During these studies, the road that crossed the park was rehabilitated and after this there was a significant increase of the number of roadkills due to the higher average speeds. Based on the warden of the Mikumi NP, the number of large mammals killed on the road exceeded the kills by poachers (Drews, 2008). Fortunately, there has been cases where road upgrades have been halted in favour of conservation, this was the case of two roads bordering and crossing Katavi NP (Caro, 2015). Considering the rapid rural growth of Katavi, improving roads will not only pose problems to wildlife as seen before, but it may further increase the influx of agro-pastoralist migrants and, with this, deforestation, and other destructive practices. The buses and private vehicles travelling from Inyonga to neighbour villages or cities were already driving at excessive speeds (>100 km/h) on dirt roads; upgrading them will further increase this.

The impact of roads on wildlife is very large, not only as roadkills are a major reason of wildlife mortality, their construction requires to cut down all the trees in a range of 40m (Caro, 2015), and the damages caused by them include fragmentation, chemical pollution, noise and the easier access will also incentivise and facilitate further degradation of the environment (Caro et al., 2014).

5.2.3. Telemetric data

Wild dog home ranges vary significantly based on different studies, the average size being around 550-600 km^2. The main factors explaining this variance is the vegetation, prey availability and density (Creel & Creel, 2002; Kingdon, 2014). The home range of Rafiki pack should be comparable to the ones studied in Selous, as the ecosystems are at the same latitude and are both dominated by miombo woodlands. The home ranges in Selous were estimated to average 379 km^2 (range 206-851 km^2) and Rafiki pack is estimated to be around 600km^2. Prey availability and competitor presence may be the two most important factors defining the size of a home range. There has not been a systematic study to determine prey availability and lion densities in the area, but considering the favourable local conditions, Rafiki pack seems to have a surprisingly large home range; even more considering this was estimated with data from five months and not a year like most studies.

Three studies (Abrahms et al., 2017; O'Neill et al., 2020; Hofmann et al., 2021) were chosen to compare the results from the RSF model, as they used similar landscape variables, for a summary see Table 17. As the models used were different, only the direction of the preference (positive or negative) was compared without the values.

Table 17: Habitat preferences of wild dogs.

	Variable	Abrahms (2017)	O'Neill (2020)	Hofmann (2021)	Rafi
	Dominant vegetation	Mopane[1]	Varied[2]	Mopane[1]	Miombo
Human	Distance to roads	+	+	n/a	+
Human	Human influence[3]	n/a	n/a	-	n/a
Human	Human pop density	n/a	-	n/a	n/a
Landcover	Grassland	non sig.	n/a	+	-
Landcover	Low tree cover	n/a	+	+	n/a
Landcover	Woodland	-	n/a	n/a	+
Water	Distance to rivers	n/a	+	n/a	non sig.
Water	Distance to water	n/a	n/a	non sig.	+
Water	Inland water	n/a	n/a	-	non sig.

[1]Mopane covers the largest surface in the study area, but there are four other major habitats (Broekhuis et al., 2013).
[2]There are twelve categories of natural, semi-natural and humanly-created vegetation types (Lane, 2005). O'Neill defined it as a mixed-use, human-dominated landscape.
[3]Composed of human density, farms and roads (Hofmann et al., 2021).

The model shows a clear preference for roads which goes in line with O'Neill's and Abrahms' findings, contrary to Hofmann's which shows an avoidance for roads. This may be linked to the surrounding vegetation, as closed and high vegetation increases the costs of travelling for carnivores, who prefer to travel quickly with less effort and do not need to hide like prey species. This effect is amplified during the rainy season, which is when the data was collected. It is likely that if there was data from the dry season, this preference would be less marked. The difference between travelling in roads or vegetation is smaller in open ecosystems. This may be one of the factors explaining why in Hofmann's study roads were avoided. In the four studies, wild dogs tended to avoid places with higher human presence, this was not calculated in the study as the human settlement was relatively far and cut-off by a large permanent river.

Comparing the actual preferences of vegetation between studies is difficult, as the methods used to define the types of vegetation may be very different. For this study, the high preference for woodlands may be biased by other factors, although it is consistent with other studies in similar ecosystems (Creel & Creel, 2002). As seen in Figure 31 with the KDE 50% home range estimation, the pack's core area is in the floodplains next to lake Rukwa (Kichangani), where the prey availability is very large and mainly composed of pukus, who do not have an anti-predator running reflex (Ramoni, pers. comm.). In addition, lions have not been seen in the area for several years, and other carnivores are very uncommon (Ramoni, pers. comm.). Therefore, Kichangani seems to be the ideal place to maximize hunting success with the lowest effort while avoiding klepto-parasitism at the same time. It is

possible that this explains their presence there more than the type of vegetation, and this could have biased the model towards a strong preference for woodland and closeness to water (in this case, the lake).

The conclusions based on the data collected from the collar should be taken with caution, as several factors limit the robustness of these results. First, there was only one collared individual, so it is impossible to compare the results with other animals in the same area. This would have been useful to determine whether the specific conditions in Kichangani bias the preference for woodland and the lake. It is very likely that the pack has split and regrouped several times during the study period. Without having another collared dog in the same pack, this kind of behaviour cannot be detected, and as no follow-up was possible, nothing guarantees that the pack has the same composition as when the collar was placed. The collar's schedule was chosen to gather data for a long period of time and not to gather a large amount of data for a short period of time (with more fixes per day), which would have been preferred for this study considering the time constraint. The data collected is limited to one rain season, which makes it impossible to determine if movement patterns and preferences change based on the season. Finally, collars with accelerometers could have added interesting data concerning the animal's behavioural state, but it would have significantly increased the costs of the collars.

5.3. Semi-structured interviews

The large in-migration of Wasukuma agropastoralists is reflected in the results of the interviews. The households are located very close to the forest, at an average distance of 2.34km from the closest reserve. This distance is very small; for comparison, the average distance to the forest was 12km in the survey around Ruaha NP (Dickman, 2008). Although it is also possible that since the status of protection is lower, people can settle closer to the forest. Four respondents were settled inside the reserve, which is normally illegal. This can lead to forest encroachment, as in Ipole where several "small villages" were permanently installed inside the forest reserve, next to the rice fields they had planted. Another reflection of this migration was the length of time respondents lived in the area. Two thirds had been living there for less than 6 years, and seven households arrived in 2021, indicating the flux is still ongoing. The sample size was relatively small, but there may be a risk for the forest if this is a generalized tendency, and without legal enforcement to prevent it. Inyonga FR which was the most impacted reserve in the area (Mermod, 2016) had to be upgraded to a game reserve. This is unfortunate for the people that depend on the forest resources for living, as they lost their access and rights of use to the resources. An interesting solution to manage this kind of issues as suggested by Caro and Davenport in 2016, the upgrading or degazetting of reserves could be done based on the abundance of wildlife. GCAs or FRs with abundant wildlife should be upgraded to GR to increase the protection, and on the other side those that have been too degraded can be converted to village land.

The situation concerning the diversity of incomes is decent, as nobody depends solely on one source of income. Diversifying livelihoods is one of the key strategic approaches of local communities to secure their livelihoods, this is a strategy of exposure to risk reduction which is very rationale. Everyone relied on agriculture primarily, followed by poultry and then livestock. This was expected as these are the main Wasukuma practices. For the Wasukuma, livestock is mainly used as a sign of prestige and insurance method (Madulu, 1998; Izumi, 2017). The objective for many is to accumulate as much cattle as possible; with limited resources and space, it is inevitable that some of the livestock ends up inside the reserves, and this may be the biggest threat to conservation in Tanzania. It is not surprising that livestock losses exceed livestock usage (sold or slaughtered), and this is not sustainable in the long term and can fuel antagonism towards carnivores. Some Wasukuma are paid to keep cattle for other people who are generally living in regional cities (Hausser, pers. comm.), it is unclear whether this was the case of the respondents as they were asked how many cattle they had and not specifically if they were the owners or not. Only one person, a Mkonongo, had a more sustainable source of income, he practiced beekeeping in addition to farming. It is difficult as it is a strong part of their identity, but the current practices of Wasukuma have to be adapted or there will be a never-ending cycle of destruction. The only way to maintain the same practices when population growth is coupled with declining soil fertility is to constantly move into new areas. Furthermore, the soils of miombo woodlands can only sustain agricultural production for a very short time. The miombo forests have many resources that can give an income sustainably; moving towards these will not only protect the ecosystem but it will also positively shift attitudes towards wildlife (Sillero & Laurenson, 2001).

Although respondents identified the species relatively well, with an average of 12 correct answers out of the 16 present species, there seems to be a clear lack of knowledge on carnivores. This can be seen in the answers regarding past trends, where around half of the participants said that they did not know what happened to the carnivores in the area. This may be biased by the high number of newcomers and the low density of predators, making it hard to detect their presence except for hyenas' laugh. Explaining that wildlife is disappearing, its consequences, and its importance for the country may increase tolerance towards conflictive species.

Almost half of the respondents had a negative view on the surrounding species, the most troublesome species being the lion and the hyena. In the six "statement questions", they clearly expressed that they do not want to live with lions, and if they did not want to eliminate them, it was only because they do not know how, or by fear of the government. The opinions were more moderate concerning the importance of their grandchildren seeing lions, showing that some people thought they had a patrimonial or other kind of value, even if they did not want or like lions. For the last question regarding the feeling of the village if they killed a lion, although many people say the villagers would be happy, the opinions were more evenly split. There was confusion regarding the real dangerousness of carnivores, as some people said that wild dogs and leopards eat humans, when these are extremely unlikely. In general, the risk of attacks on people can be almost eliminated with correct attitudes, and whether it is consciously or unconsciously, Wasukuma have adopted many strategies, such as large clothing and clearing the vegetation surrounding the households (Woodroffe et al., 2005). Education on wildlife is key to reducing conflict, as people will feel less threatened and more in control of the situation. Many fears that people have are based on beliefs that often exaggerate the reality.

All of the livestock keepers had built traditional bomas, and the cattle were always kept there during the night. However, only half of them had dogs, and even if most of them wished they also did, they could not afford them. Construction of bomas and usage of dogs significantly reduce livestock vulnerability (Woodroffe et al., 2005; Dickman, 2008). Increasing awareness and showing the usefulness of these techniques are effective methods to mitigate the risks of living with carnivores. When asked for the best ways of protection against carnivores, only one fourth cited these techniques. Another fourth of the respondents said they did not know, and others answered questionable methods such as praying to God, magical medicine and running away, which is the worst reaction possible in case of an attack. Here also, there is a clear shortcoming of knowledge. If the resources become available, it would be relevant to invest to promote these protection methods not only for their effectiveness but also because it will give the people bearing the highest costs of living with wildlife some tangible benefits, which will increase their tolerance and acceptance.

Only two of respondents reported using traps and nobody killed a carnivore. This is to be expected since sensitive subjects that concern illegal actions such as usage of snares or poison or ultimately killing animals are unlikely to be reported due to the fear of repercussions (St John et al., 2012; Dickman et al., 2014). Some of the respondents informally specified that if they do not kill animals, it is only by fear of the government or because they are unable to, but that they wished they could. Legal repercussions seem to be an effective method of dissuasion, but this is probably only effective in areas with frequent patrols as the risks of getting caught are much higher.

There are two organisms giving direct benefits from wildlife in Inyonga, ADAP, with its different projects of sustainable use of the forest, where the villagers become actors and beneficiaries of conservation. In a more direct and less participative approach, TBGS and their clients have donated money to improve the local communities' infrastructures. For example, they financed a school, and supplies are regularly donated (Anonymous client, pers. comm.). Since there were no direct exchanges with the other hunting companies in the area, it is unclear whether this is the norm or whether the clients present during the study were an exception. The majority of respondents were Wasukuma living in small communities relatively isolated from the rest of the village, it is possible that they participate less in the activities and meetings within the villages. Considering that only five households declared receiving benefits from the surrounding reserves, they may not know about this kind of actions. This is further confirmed by the general message coming out of the SSI, and the informal discussions following the interviews. There is a clear resentment towards the managers of the surrounding reserves, whose conservation measures directly negatively impact on their livelihood by forbidding their entry to the forests. When asking about their experiences with the managers of the forest reserve, one young man responded: "Look at our cattle! Do you see how thin our cows are? The people of the forest reserve are responsible for the poor conditions of the cattle, they

do not get enough to eat!". This is problematic since they will question the government without thinking about their own actions, and whether it makes sense to continue to accumulate livestock when even they are aware of the lack of resources.

These interviews were conducted to grasp the level of human-wildlife conflict in the area. This information shall be used to determine the key targets for conflict mitigation, where investments will be most efficient. In addition to this, it was probably the first time that most of the participants were included in a conservation project. They could express their feelings, fears, and complaints. Hopefully, this was only the first step, and they will join and benefit from the ongoing and future projects in the area.

There may be some inaccuracies during the translations of the survey. There was an effort to make every question as clear as possible to the translator, but it is probable that there were some small misunderstandings during the first day. There is no way to know how accurate the translations of the answers were, some details may have been lost during the process, but the key information is undoubtedly there.

As specified earlier, even if the respondents are anonymous, all the answers that are linked to illegal activities may not be completely accurate, which is understandable. In addition, the questions concerning livestock losses are susceptible to multiple sources of bias. The losses tend to be attributed to charismatic species and overestimated, as seen in other studies, sometimes giving estimates five to six times higher than the actual losses (Rasmussen, 1999; Dickman, 2008). Potential reasons include a desire for compensation or the lasting impact that attacks can have (Nyhus et al., 2003; Woodroffe et al., 2005; Dickman, 2008). Nevertheless, when working with local actors, it is more important to consider their perceptions over the actual losses, as they reflect other social and biophysical factors linked to their individual vulnerability (Treves et al., 2006).

5.4. Limits and difficulties encountered

Several problems arose during the fieldwork. First of all, the obtention of the research permit was considerably delayed, reducing effective time in the field from 4 to 3 months. Due to the time constraints in the master's, the study had to take place during the dry season, but it would have been preferable to do the field work as soon as the roads became passable after the rainy season. As mentioned earlier, carnivores' preference for tracks is accentuated during the rainy season, so the chances of encounter would have been higher, whether to collar or for the camera traps.

It was the first time I had gone to an African country, and even if I tried to prepare myself as well as possible, there was a considerable difference between the theory and reality. There was a learning process in working with a team in the bush, and the first days' efforts were not as efficient as they could have been. Moreover, most similar studies were in completely different ecosystems; I was naïve to believe that knowledge from other places could easily be translated to the study area. There is indeed relevant information to be taken, but the differences can sometimes be huge, and it is essential to consider this.

In an ideal scenario, and as it is done in other studies (Cozzi, pers. comm.), the veterinarian should constantly be present, as collaring opportunities are rare and it is a pity to miss one, but this requires a considerable budget. Although the veterinarian was present, the conditions of the encounter with Tupac pack were not favourable for collaring, as they were in an "active behaviour" in an area with dense vegetation, inaccessible by car. It would have been possible to attempt to dart them, but I decided not to try as the risks were too high, as it was not guaranteed that we could find the animal if it ran away after getting darted. Animal safety was prioritized. Since only one individual could be collared, the data obtained is less robust, and there are no local comparisons possible. Only data from the rainy season was analysed for this study due to the time constraint imposed by the school, the collar is supposed to remain active for a full year; it would have been interesting to compare if the habitat preferences change based on the season, or hopefully the collared dog may disperse before the collar drops off.

Language limitations may have reduced the precision of the survey, but there were not many people who could speak Kisukuma and English fluently who were readily available in a small village like Inyonga. Many relevant subjects were not approached due to the lack of time; it would have been useful to assess whether the respondents knew the long-term effects of deforestation, and whether they were engaged in the activities inside the village.

Despite all these difficulties, I am satisfied with the data obtained during the fieldwork. We managed to survey 44 different households, providing valuable information on wildlife conflict. And we were lucky enough to place one collar in unfavourable conditions, something experts told me would not be likely (or even impossible). The working conditions were surely not comparable to Switzerland, but this is also what made it more interesting.

5.5. Management recommendations

As the main threat that wild dogs face is habitat destruction and fragmentation, this should be the focal point of the recommendations. The area is suffering from a significant in-migration of Wasukuma, whose practices are very destructive for the environment and wildlife. Furthermore, as shown in section 4.3.7.1, most of them want to have all large carnivores eradicated from the land to settle peacefully with their masses of livestock. Wasukuma traditions include lion killing and increasing their livestock (Izumi, 2017; Salerno et al., 2017); therefore it will be very challenging for them to change this behaviour as it is an intrinsic part of their culture that they take pride in.

The first step, which is relatively low-cost, should be to invite them actively and include them in the conservation projects in the area, as they do not seem to be participating spontaneously. Based on the results in section 4.3.7.2, almost all the respondents were unaware of ADAP's projects, which are numerous and have been going on for more than twenty years. If they can obtain tangible benefits from the surrounding wildlife and forests, this will likely increase their acceptance of them. To go further with the economic benefits of wildlife, meetings should be held with these "small villages" settled next to the forests to discuss the importance of wildlife for Tanzania in general and the critical role that the country has in conserving many species. ADAP's project promote a diversification of economic activities, as Wakonongo are traditional beekeepers, it was not difficult for them to join the beekeeping project. It would be interesting to see whether the Wasukuma living in the region are open to try new activities that are not part of their traditions and it if it possible that the migrant and resident communities can work and live closer together. During the interviews, they gave the impression to be relatively isolated and disconnected from the local communities.

Another element that should be worked on with Wasukuma communities and other livestock keepers settled in the area, which is more time-consuming and shall require some investments, is improving the traditional bomas. Nearly all the attacks happened inside the bomas; therefore, their efficiency in preventing attacks was lacking. Guarding dogs are also an effective way of reducing attacks from carnivores; however, providing expensive specialised breeds may not be the best solution. Giving a dog is the first step, but taking care of them afterwards requires consequent economic investments for the food and medicine, and these breeds usually have higher requirements and may not be adapted to the climate. As one of the respondents said, they wish they could have dogs, but they could not do it because of the economic constraints. Therefore, before providing dogs, these aspects should be studied, and the choice of the breed should be thoroughly thought of.

There is also work to be done concerning the agricultural practices. The soils in the region are not very rich in nutrients, therefore they cannot sustain agricultural practices for extended periods of time. With the current methods, most of plots must be abandoned after a few years. Modernising the agricultural methods and cultivating crops that are more adapted to the ecosystem can increase the sustainability. Tabaco companies promoted themselves in the area, and these are very destructive to the environment, as they require large quantities of water and cause deforestation for the wood required to dry it. Furthermore, they produce soil erosion, reduce fertility and can even be responsible of food shortage (WHO, 2017). This kind of destructive crops should be replaced by sustainable ones, that contribute both economically and to food security.

In a broader scale, the large in-migration brings many issues that should be addressed by the government. Most of the responsibility to manage the migration is on government officials, and there have been cases of corruption where migrants settle in lands that should belong to local people or that should not be used, which are not well perceived by the resident communities (Salerno et al., 2017). Although Tanzania is a country with exceptional ethnic tolerance, with the population growth that the country is facing, these movements will become more and more consequent, so will their impact. If the scale of in-migration becomes too large, it is possible that conflicts will arise mor regularly, not only with the wildlife, but also within the different communities.

Ultimately, it is important to have a follow-up of the evolution of the behaviour if some of these measures are incorporated. Repeating the semi-structured interviews in a regular schedule, every two to four years will show if these recommendations have a real impact.

Roadkills are a danger to wild dogs, as shown in section 4.2.2; in less than six months, there were four documented roadkills, two of them happened within Katavi national park, and there were likely more roadkills that I did not know of. There are roads where killed wild dogs are commonly seen (Majimoto-Sitalike, Inyonga-Tabora, Tabora-Kitunda), and unfortunately, on these roads, they are also seen killed. Surprisingly, on the road linking Inyonga to Majimoto, even though Rafiki pack is regularly seen and the buses drive at an inappropriate speed, no killed wild dogs have been seen in the past twenty years (TAWA rangers & Ramoni, pers. comm.).

Even if conservationists are constantly fighting to limit vehicle speed, actions are rarely ever taken. The issue is that several people from the government own bus or transport companies, and slowing down the traffic means that they lose money. There have been instances where speed bumps had been added, but shortly after, due to governmental pressure, they were removed (Dr. Iddy, pers. comm.). It is not normal that animals are getting killed by vehicles even inside national parks; speed limitations, awareness, and control must be increased to prevent this kind of accident. Currently, the only method used on the road from Mpanda to Inyonga, for example, is one road sign with a greater kudu at each end of the road. The most efficient method to control the speed of passage through reserves would be to install two posts, one at each end of the reserve. They would then communicate with each other whenever a vehicle passes to calculate the speed at which the vehicle crossed the reserve. People driving faster than a reasonable speed limit, somewhere between 60 and 80 km/h, would then receive economic sanctions.

If it is impossible to control the speed of vehicles for the entirety of the road, it would nevertheless be interesting to see whether there are locations where roadkills occur more often; for example, near water points or wildlife trails, and install speed bumps in these critical spots. There is a large panel warning on roads crossing reserves about the dangers of wild animals, but these signs do not inform about the dangers of vehicles for these animals. Unlike the other methods previously proposed, which will forcibly decrease the speed of the vehicles, installing large panels to increase awareness about the risks of roadkills, as they can even be deadly to the people driving, will probably be effective in reducing the number of roadkills. These panels should also invite people to respect road security, such as not using their phones while driving and staying attentive to potential surprises.

Finally, considering the status assessment of wild dog populations in western Tanzania, some key actors were unfortunately not contacted due to the lack of time during the study. TANAPA (managers of national parks), hunters from other reserves in the area (such as Lukwati GR, Piti GR, and Ugalla GR), and the bus drivers have high chances of seeing wild dogs during their work. With the resources available, information should be gathered from every reliable person to increase the precision assessment of the metapopulation present in the Katavi-Rukwa ecosystem; as in this study, there is no data from Katavi NP, where there should be the highest wild dog density in the region theory. Therefore, all of these actors should be contacted in the future so that they can report any wild dog sightings, hopefully with pictures and GPS coordinates.

Further research should be carried in all these areas, now that a base is there for Mlele BKZ and Lake Rukwa GR, pictures of wild dogs in the region may provide additional information, if there are re-captures of the same individuals. In addition, it would be interesting to see whether the wild dogs seen in Rungwa North OA were residents or not. In the case they are, understanding how these wild dogs are sharing their territory with these large numbers of livestock can provide valuable conservation information.

6. Conclusion

The objective of this work was to make a first contribution to the conservation of the endangered African wild dog in the west of Tanzania. Although there have been other studies on carnivores in the area, this is the first one specifically focuses on this endangered species. All of the objectives of this study fall within the framework of the National Action Plan for the conservation of Cheetah and African Wild Dog in Tanzania (TAWIRI, 2016). Moreover, the findings have a real potential to be implemented in the area, as the project is part of a collaboration between two NGOs based in the area, ADAP and WCS. Both of these NGOs follow a CBNRM approach, where wildlife and humans coexist, empowering the local communities to manage and utilise the natural resources and get direct benefits from their conservation.

The African wild dog was chosen as the focal species because of its dispersing potential, possibly giving valuable information to guide the management of the corridors connecting Katavi-Rukwa and Ruaha-Rungwa ecosystems. The obtention of this type of information depended heavily on the dispersal of a collared individual, which unfortunately did not happen. However, even if the study's findings will not directly contribute to guiding the management of the corridor, they may nonetheless have implications for the conservation of the species by arising pertinent questions. The semi-strucutred interviews can be used as a baseline to evaluate the intensity of the conflict between carnivores and agro-pastoralists in the Katavi-Rukwa ecosystem. The semi-structured interview was based on previous work by WildCRU in the Ruaha-Rukwa ecosystem; due to the similarity of the questions, it is possible to easily compare the results in two very similar ecosystems. Moreover WildCRU has also been working with local communities to increase carnivore acceptance. It would be interesting to carry on the survey with a certain regularity to see the evolution of the conflict as new CBNRM projects are implemented in the area. Although Wasukuma are unlikely to be the main beneficiaries of these projects due to their practices and distance from the other people in the village, finding a positive evolution in their views would be very promising. Obtaining tangible benefits may be the most efficient way to reduce negative perceptions of wildlife and reduce deforestation; this highlights the importance of generating income from the forest with sustainable activities.

Considering that habitat destruction and fragmentation are the greatest threats to wild dogs, efforts should be prioritized on reducing their intensity. It is essential to work with the people responsible for these issues to address this. The traditional practices of Wasukuma are, without a doubt, too destructive, and this study shows that most of the ones living in rural areas have little to no tolerance for wildlife. Maasai, on the other hand, who are also agro-pastoralists, manage to cohabitate with carnivores having a similar lifestyle. This shows that coexistence between cattle and wildlife is not impossible. In addition to conflict reduction, modernizing agricultural methods to avoid soil degradation while increasing productivity can also be a way to reduce forest encroachment. In the eastern part of the study area, Lion Landscapes collaborates with the local communities to mitigate the conflicts with carnivores. Their main activities include building modern bomas, training a team to respond to human-carnivore conflict, providing livestock guarding dogs, and explaining about the consequences of poison and snares. Individual communication is essential, but there should also be discussions on a larger scale in the future. During the fieldwork, the Wasukuma living next to Inyonga GR in Kamsisi were holding a meeting. They invited us to join them, but we could not join them due to the limited time; this shows a willingness to exchange, and they were eager to listen to what we had to say. Communication is the first step for collaboration; understanding the Wasukuma social organisation and allowing them to voice their issues is critical to reducing conflict. This can open a dialogue to increase awareness on issues that may not be clear, such as the long-term effects of deforestation and the importance of wildlife to the country.

There is no doubt that strictly protected areas, such as national parks, offer the best theoretical conditions for habitat and wildlife conservation, but this approach has several flaws. Without talking about the ideological issues and the origins of national parks in Africa, from an ecological point of view, most biodiversity is located outside of protected areas, even in a country like Tanzania, where more than a third of its land is protected. ADAP's camera trap surveys and direct observations confirm this. Moreover, even in the largest network of conserved areas, the KAZA-TFCA, there are human landscapes, stressing human-wildlife conflict as a central point in conservation, as large-scale conservation cannot be done excluding humans and will never be successful without addressing these issues. The necessity of having suitable spaces for wildlife out of protected areas becomes more evident with dispersing

species. Their conservation depends on a holistic approach involving different stakeholders, including government officials, agro-pastoralists, and other people prone to wildlife conflict and researchers.

The length of the study was too short to give a precise estimation of wild dogs in the Katavi-Rukwa ecosystem. However, the data collected was enough to show that the numbers from the last assessment were a considerable underestimation. In addition, the presence of wild dogs in Rungwa North OA may indicate that wild dogs are much more resilient than previously thought. This can raise questions concerning the actual status and importance of populations outside of national parks, where most of the research takes place. Some areas may be more important than previously thought, and since

This study is not much more than a drop in the river of research for African wild dog conservation. There is insufficient data to make statistically significant conclusions. Nevertheless, these findings can raise many questions on wild dog research's general focus, priorities, and framework. These are related to the difficulties that I faced when trying to understand wild dogs in a forest reserve dominated by closed vegetation and open to the local communities. What is the point of gathering so much knowledge in areas where African wild dogs face minor threats in enormous guarded national parks, if most of it cannot be translated to the places where wild dogs face the most significant threats? Should not research efforts be focused on lesser-known populations, on understudied areas, where it is more likely that new information appears instead of confirming previous findings?

Genève, April 26, 2022.

Raimundo Pizarro Solar

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Appendices

List of the appendices:

Appendix I: National action plan logical framework

Theme 1. Coexistence			
Objective 1. Develop and implement strategies to promote coexistence of cheetah and wild dogs with people and domestic animals			
Target	**Activity**	**Actors**	**Timeline**
1.1 Programmes to reduce illegal offtake of wild ungulates promoted and implemented in affected areas within three years	1.1.1 Identify areas where wild dogs or cheetah are killed as a consequence of illegal offtake of wild ungulates	TAWIRI (lead), WD, TANAPA, NCAA, LGAs & other stakeholders	1 year and ongoing
	1.1.2 Identify areas where prey loss undermines the viability of wild dog or cheetah populations	TAWIRI (lead), WD, TANAPA, NCAA, LGAs & other stakeholders	3 years and ongoing
	1.1.3 Support the implementation of new and existing measures to prevent illegal offtake of wild ungulates in identified areas	WD (lead), TANAPA, NCAA, other stakeholders	3 years and ongoing
1.2 Sustainable tools to reduce wild dog and cheetah conflict with livestock keepers developed and disseminated across Tanzania within five years	1.2.1 Identify areas where cheetah and wild dog populations are threatened by conflict with livestock keepers	TAWIRI (lead), research and training institutions, NGOs, Ministry of Livestock, scientists, LGAs & other stakeholders	2 years and ongoing
	1.2.2 Identify the circumstances that contribute to cheetah and wild dog conflict with livestock keepers in the identified areas	TAWIRI (lead), researchers, other stakeholders	3 years and ongoing
	1.2.3 Develop effective strategies for collecting and disseminating relevant information on preventing cheetah and wild dog conflict with livestock keepers to relevant parties in Tanzania and in transboundary areas	TAWIRI (lead), researchers, other stakeholders	4 years and ongoing
	1.2.4 Work with communities in affected areas to develop and implement the most effective tools to reduce and prevent cheetah and wild dog conflict with livestock keepers	WD (lead), TANAPA, NCAA, NGOs, LGAs & other stakeholders	5 years
1.3 Programmes for local people to derive sustainable economic benefits from cheetah, wild dogs and other wildlife developed and implemented within five years	1.3.1 Identify areas across Tanzania where tourism could effectively assist cheetah and/or wild dog conservation through sustainable economic benefits for local communities, and hence improve tolerance of both species	WD (lead), TANAPA, NCAA, TAWIRI, TATO, TPHA, researchers, other stakeholders	2 years
	1.3.2 Encourage sustainable tourism programmes in cheetah and wild dog range and benefit sharing among appropriate parties	WD (lead), TANAPA, NCAA, TAWIRI, TATO, TPHA, NGOs,	2 years and ongoing

		civil society, other stakeholders	
	1.3.3 In areas of Tanzania where tourism is unlikely to provide sufficient benefits, investigate alternative options for generating revenue which encourage cheetah and wild dog conservation	TAWIRI (lead), WD/MNRT, TANAPA, NCAA, NGOs, researchers, other stakeholders	5 years
	1.3.4 Develop, disseminate, and promote the implementation of guidelines for tourism in cheetah and wild dog range	MNRT (lead), WD, TAWIRI, TANAPA, NCAA, NGOs, researchers, other stakeholders	3 years
1.4 Awareness creation programmes relevant to cheetah and wild dog conservation developed within two years	1.4.1 Identify target areas and audiences best placed to influence cheetah and wild dog conservation	TAWIRI (lead), WD, TANAPA, NCAA, NGOs, researchers, other stakeholders	1 year
	1.4.2 Investigate local traditions, knowledge and cultural values relevant to cheetah and wild dogs and incorporate into outreach materials	TAWIRI (lead), WD, TANAPA, NCAA, NGOs, researchers, other stakeholders	2 years and ongoing
	1.4.3 Tailor outreach materials for cheetah and wild dog conservation to local conditions and disseminate to target areas and audiences	WD (lead), TANAPA, NCAA, TAWIRI, NGOs, other stakeholders	2 years and ongoing
1.5 Programmes to prevent/reduce deliberate killing of wild dogs and cheetah developed and implemented in affected areas within two years	1.5.1 Identify areas where deliberate killing of wild dogs and cheetah is currently a concern or has high potential to become a concern	TAWIRI (lead), WD, TANAPA, NCAA, NGOs, other stakeholders	2 years and ongoing
	1.5.2 Collect relevant information on the drivers of deliberate killing of wild dogs and cheetah using locally appropriate methods	TAWIRI (lead), WD, TANAPA, NCAA, NGOs, researchers, other stakeholders	2 years and ongoing
	1.5.3 Develop and implement locally appropriate solutions aimed at preventing deliberate killing of wild dogs and cheetah	WD (lead), TANAPA, NCAA, TAWIRI, NGOs, researchers, other stakeholders	2 years and ongoing
	1.5.4 Support existing frameworks aimed at preventing deliberate killing of wild dogs and cheetah	WD (lead), TANAPA, NCAA, TAWIRI, NGOs, other stakeholders	ongoing from now
1.6 Holistic canid disease management strategies	1.6.1 Identify areas where wild dog populations are significantly threatened by infectious disease	TAWIRI (lead), WD, TANAPA, NCAA, Ministry of Livestock,	2 years and ongoing

developed in key areas within three years		NGOs, researchers, other stakeholders	
	1.6.2 Assess and evaluate potential and existing tools for disease management in wild dogs and related species relevant to Tanzania	TAWIRI (lead), TANAPA, NCAA, WD, researchers, NGOs, other stakeholders	2 years and ongoing
	1.6.3 Develop and implement locally appropriate canid disease management strategies in identified areas	TAWIRI (lead), TANAPA, NCAA, WD, researchers, NGOs, other stakeholders	3 years
Theme 2. Surveys and information			
Objective 2 Provide relevant stakeholders and managers with scientific and timely information on the status of and threats to cheetah and wild dog populations			
2.1 Surveys and monitoring to evaluate presence, trends and threats in key cheetah and wild dog ranges conducted within five years	2.1.1 Conduct surveys to determine presence and habitat suitability in areas identified as unknown, possible and connecting ranges in Tanzania within five years	TAWIRI	5 years
	2.1.2 Identify important populations of wild dog and cheetah for long term monitoring and research in Tanzania ensuring adequate eco-region coverage	TAWIRI, Wildlife authorities (DW, NCAA, TANAPA) and higher learning institutions	1 year
	2.1.3 Within select priority sites, initiate and maintain monitoring and research activities to determine population trends, threats and demographic status at each site within three years	TAWIRI and higher learning institutions	3 years
2.2 Strategies for disseminating information relevant to cheetah and wild dog conservation to all relevant stakeholders developed and implemented within three years	2.2.1 Establish a standardised database format to facilitate the collection and sharing of data within one year.	TAWIRI	1 year
	2.2.2 Update the national database within one year	TAWIRI	1 year

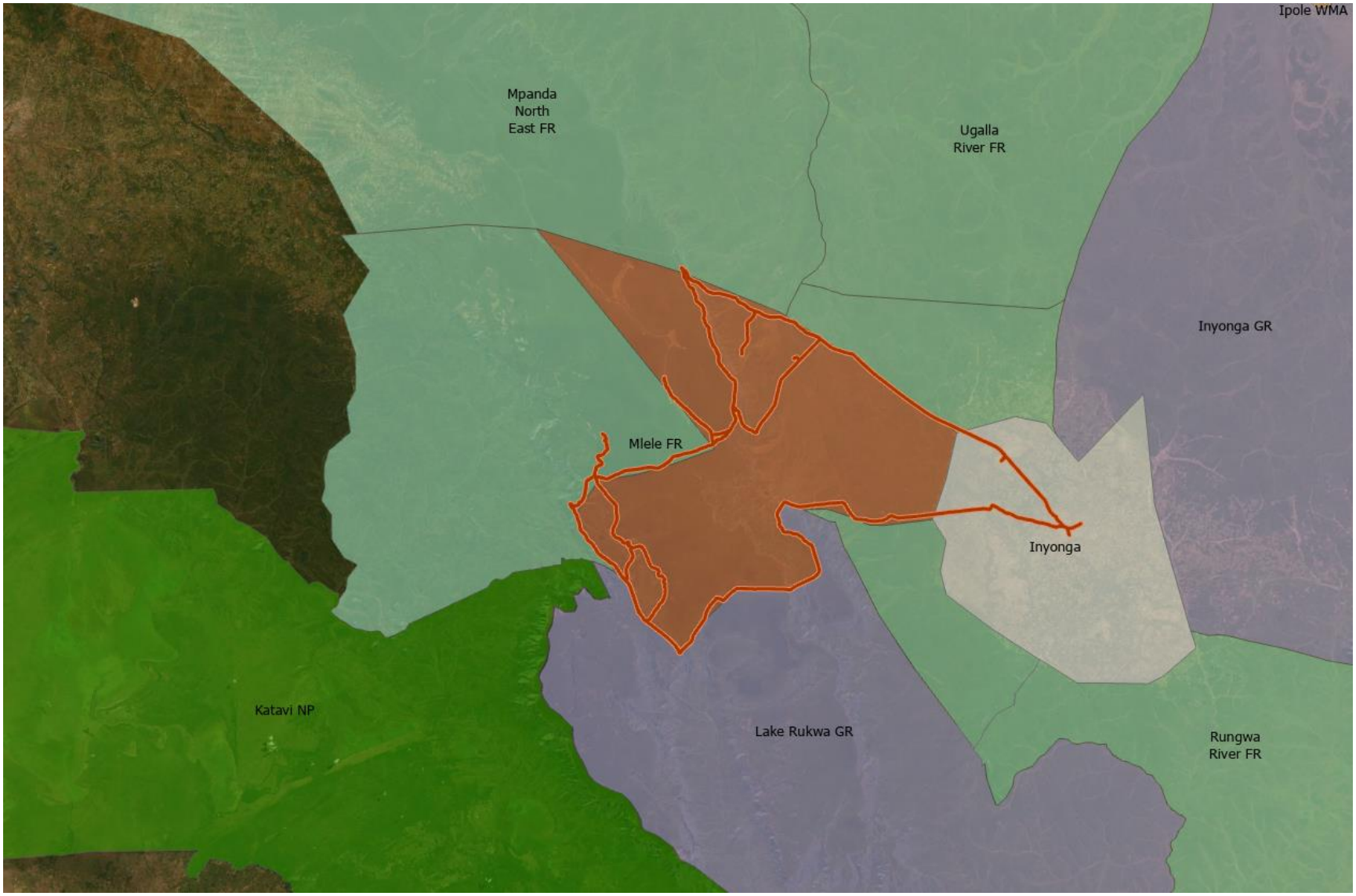
	2.2.3 Use meetings, publications and other media such as radio and television to disseminate information relevant to cheetah and wild dog conservation as a continuous process	TAWIRI, DW, NCAA, TANAPA and Dept of Tourism	Continuous process initiated within one year
Theme 3. Capacity Development			
Objective 3. Strengthen human, financial, information and physical resources for conserving cheetah and wild dogs in collaboration with stakeholders			
3.1 Develop a resource mobilisation plan for the conservation of cheetah and wild dogs in Tanzania within two years	3.1.1 Identify individuals and institutions to produce and disseminate a resource mobilisation plan within two years	WD	2 years
3.2 Have enforcement, extension and monitoring personnel trained and equipped to operate within 50% of the resident range within five years	3.2.1 Complete a Training and Management Resource Needs Assessment for extension, enforcement and monitoring for cheetah and wild dog conservation within one year	TAWIRI, WD, NCAA, TANAPA and higher learning institutions	1 year
	3.2.2 Integrate Finance Plan, Training Needs Assessment and Action Plan within two years	TAWIRI, WD, NCAA, TANAPA and higher learning institutions	2 years
	3.2.3 Train enforcement personnel to address urgent issues affecting cheetah and wild dog conservation, such as trafficking, wherever they are known to occur	WD, NCAA, TANAPA in collaboration with other wildlife stakeholders	Initiated within 1 year
	3.2.4 Recruit and train outreach officers to operate with a target of covering 50% of the cheetah and wild dog resident range within five years	WD, NCAA, TANAPA in collaboration with other wildlife stakeholders	5 years
	3.2.5 Recruit and train monitoring personnel to operate with a target of covering 50% of the cheetah and wild dog resident range within five years	WD, NCAA, TANAPA in collaboration with other wildlife stakeholders	5 years
Theme 4. Policy & legislation			
Objective 4. Review and harmonise relevant policies and legislations; and develop strategies for conservation of cheetah and wild dogs across their range			
4.1. Relevant policies and legislations for conservation of cheetah and wild dogs reviewed and harmonised within three years	4.1.1 Identify gaps in relevant policies and legislations for cheetah and wild dog conservation within one year	WD (lead) TANAPA,TAWIRI, NCAA,NGOs	1 year
	4.1.2 Collating and disseminating information to relevant policy makers on cheetah and wild dog population trends and known threats within cheetah and wild dog ranges within one year	TAWIRI (lead), WD, TANAPA, NCAA, NGOs, RESEARCH Institutions	1 year

	4.1.3 Conduct a stakeholders meeting to establish consensus on review and harmonization of relevant policies and legislation on the conservation of cheetah and wild dogs within two years	WD (lead), TAWIRI, TANAPA, NCAA, NGOs, Ministerial departments and Agencies (MDAs),CBOs, RESEARCH and Training Institutions	2 years
4.2. Develop a framework for implementation of relevant policies and legislations on conservation of cheetah and wild dogs within three years	4.2.1 Produce a review document on national protected species legislations within the country and its implications on cheetah and wild dog conservation within one year	WD (lead), TAWIRI, TANAPA, NCAA, NGOs	1 year
	4.2.2 Conduct stakeholders meeting to develop a framework for implementation of relevant policies and legislations on conservation of cheetah and wild dogs within two years	WD (lead), TAWIRI, TANAPA, NCAA, NGOs, CBOs	2 years
	4.2.3 Develop a timetable for implementation of framework for relevant policies and legislations on conservation of cheetah and wild dogs within two years	WD (lead), TAWIRI, TANAPA, NCAA, NGOs	2 years
4.3. Regional and international collaborations on cheetah and wild dog conservation improved within five years	4.3.1 Identify areas of cooperation on cheetah and wild dog conservation within one year	WD (lead), TAWIRI, TANAPA, NCAA	1 year
	4.3.2 Initiate a process for development of MoU with other member states (with possible reference to CMS) within one year	MEAC (lead), MNRT	1 year
Target	**Activity**		
Theme 5. Land Use Planning			
Objective 5. Mainstream cheetah and wild dog conservation in land use planning and its implementation			
5.1. Government officials, local communities and other stakeholders made aware on cheetah and wild dog conservation within three years	5.1.1 Initiate and implement conservation education visiting programme to local government authorities, CBO's and learning institutions	MNRT (WD - Lead), PMO, RALG, LGAs, universities & funders	3 years
	5.1.2 Prepare and distribute conservation educational materials (posters, flyers and leaflets)	WD (lead), Funders, NCAA, TAWIRI, TANAPA,	2 years

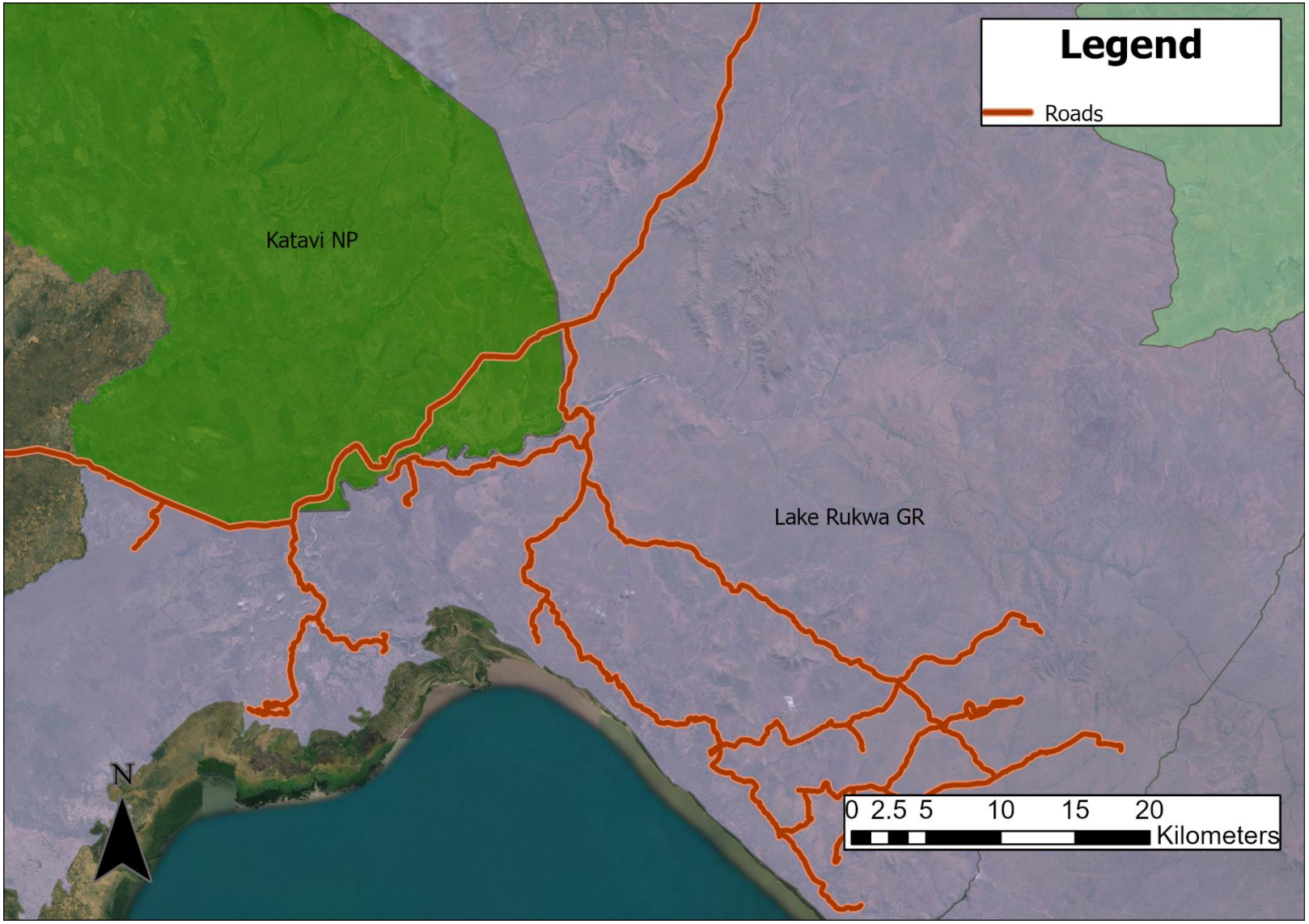
	5.1.3 Convene wildlife ecosystem zones and National meetings to raise awareness of cheetah and wild dog conservation key stakeholders	MNRT (lead), TANAPA, NCAA, TAWIRI, WD, Conservation NGO's	5 years
	5.1.4 Promote presentation of cheetah and wild dog conservation issues in mass media (newspapers, radio, TV)	MNRT (WD - Lead), Funders, TANAPA, NCAA, TAWIRI	5 years
	5.1.5 Develop and maintain cheetah and wild dog information, education and communication material	MNRT (WD - Lead), Funders, TANAPA, NCAA, TAWIRI, Conservation NGO's	5 years
5.2. Land use planning for areas of cheetah and wild dog resident and connecting ranges carried out within five years	5.2.1 Identify cheetah and wild dog conservation priority areas to be incorporated into land use plans	MNRT (WD – lead), Ministry of Lands, Housing and Human Settlements Development (NLUPC), LGAs	2 years
	5.2.2 Prepare village land use plans for priority areas for cheetah and wild dogs	MNRT (WD - Lead), NLUPC, LGAs, Funders, Conservation NGO's	2 years
	5.2.3 Incorporate cheetah and wild dog conservation needs in village(s) land use plans	MNRT (WD - Lead), LGAs, TAWIRI	2 years
5.3. Identify and priorities corridors, buffer zone and dispersal areas for improved connectivity of cheetah and wild dog ranges within 5 years	5.3.1 Determine the spatial extent of corridors and dispersal areas between resident, possible and unknown ranges	MNRT (WD - Lead), NLUPC, LGAs, Funders, TAWIRI	3 years
	5.3.2 Determine threats, habitat quality, and the extent of suitable habitat along corridors and around dispersal areas	MNRT (WD - Lead), LGAs, Funders, TAWIRI	4 years
	5.3.3 Develop and implement legislative and enforcement strategies for protection of corridors and dispersal areas	MNRT (WD - Lead), Funders	2 years
Theme 6. National planning			
Objective 6. Promote the development and implementation of national conservation programmes for cheetah and wild dogs, by government and other stakeholders			
6.1 This national action plan for cheetah and wild dog conservation endorsed and implemented by the appropriate authorities within five-ten years	6.1.1 Identify and collate all the wildlife conservation programme	MNRT (WD - Lead), TANAPA, NCAA, TAWIRI, Funders	1 year
	6.1.2 Incorporate wild dog and cheetah action plan into wildlife conservation programme	MNRT (WD - Lead), TANAPA, NCAA, TAWIRI, Funders	2 years

	6.1.3 Identify a focal person (e.g. a national coordinator) for follow-up endorsement processes	MNRT (WD - Lead), TAWIRI, Funders	1 year

Appendix II: Mlele forest reserve and routes taken



Appendix III: Rukwa game reserve and routes taken



Appendix IV: Daily time allocation to the wild dog research

Date	Reserve	Dist. (km)	Avg. speed	Activity	WD sighting
04/09/2021	Mlele BKZ	-	-	CT placement	No
05/09/2021	Mlele BKZ	-	-	CT placement	Yes
06/09/2021	Rungwa River FR	61.1	26.5	Exploration	No
08/09/2021	Rungwa River FR	95.8	14.9	CT placement	No
09/09/2021	Rungwa River FR	-	-	Return to village	No
19/09/2021	Mlele BKZ	142	30.1	CT removal	No
20/09/2021	Mlele BKZ	230	23.2	CT removal	No
24/09/2021	Rungwa River FR	179	26.6	CT removal	No
25/09/2021	Mlele BKZ	108	30.8	Move to BKZ	No
26/09/2021	Mlele BKZ	87.1	10.8	CT placement	No
27/09/2021	Mlele BKZ	84.7	13.3	CT placement	No
28/09/2021	Mlele BKZ	115	19.3	CT placement	No
29/09/2021	Rungwa River GR	115	17.1	Exploration	No
30/09/2021	Rungwa River GR	95.9	17.4	Exploration	No
07/10/2021	Lake Rukwa GR	147	18.7	CT placement	No
08/10/2021	Lake Rukwa GR	147	21	CT placement	No
09/10/2021	Lake Rukwa GR	156	21.2	Return to village	No
10/10/2021	Rungwa North OA	194	42.4	Exploration	No
11/10/2021	Rungwa North OA	308	28.3	Exploration	No
12/10/2021	Mlele BKZ	85	15.4	CT placement + spoors	No
13/10/2021	Mlele BKZ	62.6	9.6	improve road	No
15/10/2021	Mlele BKZ	103	37.3	CT placement + spoors	No
16/10/2021	Mlele BKZ	152	20.9	CT placement + spoors	No
17/10/2021	Mlele BKZ	214	29.2	Return to Inyonga	No
18/10/2021	Mlele BKZ	185	23.3	CT placement + spoors	No
19/10/2021	Mlele BKZ	101	14.3	Research with veterinary	No
20/10/2021	Mlele BKZ	146	25.2	Research with veterinary	No
21/10/2021	Lost day – Administrative tasks				
22/10/2021	Lake Rukwa GR	197	32.8	Research with veterinary	Yes
23/10/2021	Lake Rukwa GR	125	18.7	Research with veterinary	No
24/10/2021	Lake Rukwa GR	141	21.8	Research with veterinary	No
25/10/2021	Lake Rukwa GR	133	17.8	Research with veterinary	Uncertain
26/10/2021	Lake Rukwa GR	143	26.9	Research with veterinary	No
27/10/2021	Lake Rukwa GR	190	24.6	Research with veterinary	Yes
28/10/2021	Lake Rukwa GR	127	28.3	Research with veterinary	No
29/10/2021	Lost day – Car reparation				
30/10/2021	Lake Rukwa GR	162	18.1	Research with veterinary	No
08/11/2021	Lake Rukwa GR	223	22.3	Research with veterinary	No
09/11/2021	Lake Rukwa GR	164	17.8	Research with veterinary	No
10/11/2021	Lake Rukwa GR	252	35.1	Research with veterinary	No
11/11/2021	Lake Rukwa GR	211	24.1	Research with veterinary	No
12/11/2021	LR GR + BKZ	283	37.6	Research with veterinary	No

Appendix V: Camera trapping details in Mlele beekeeping zone

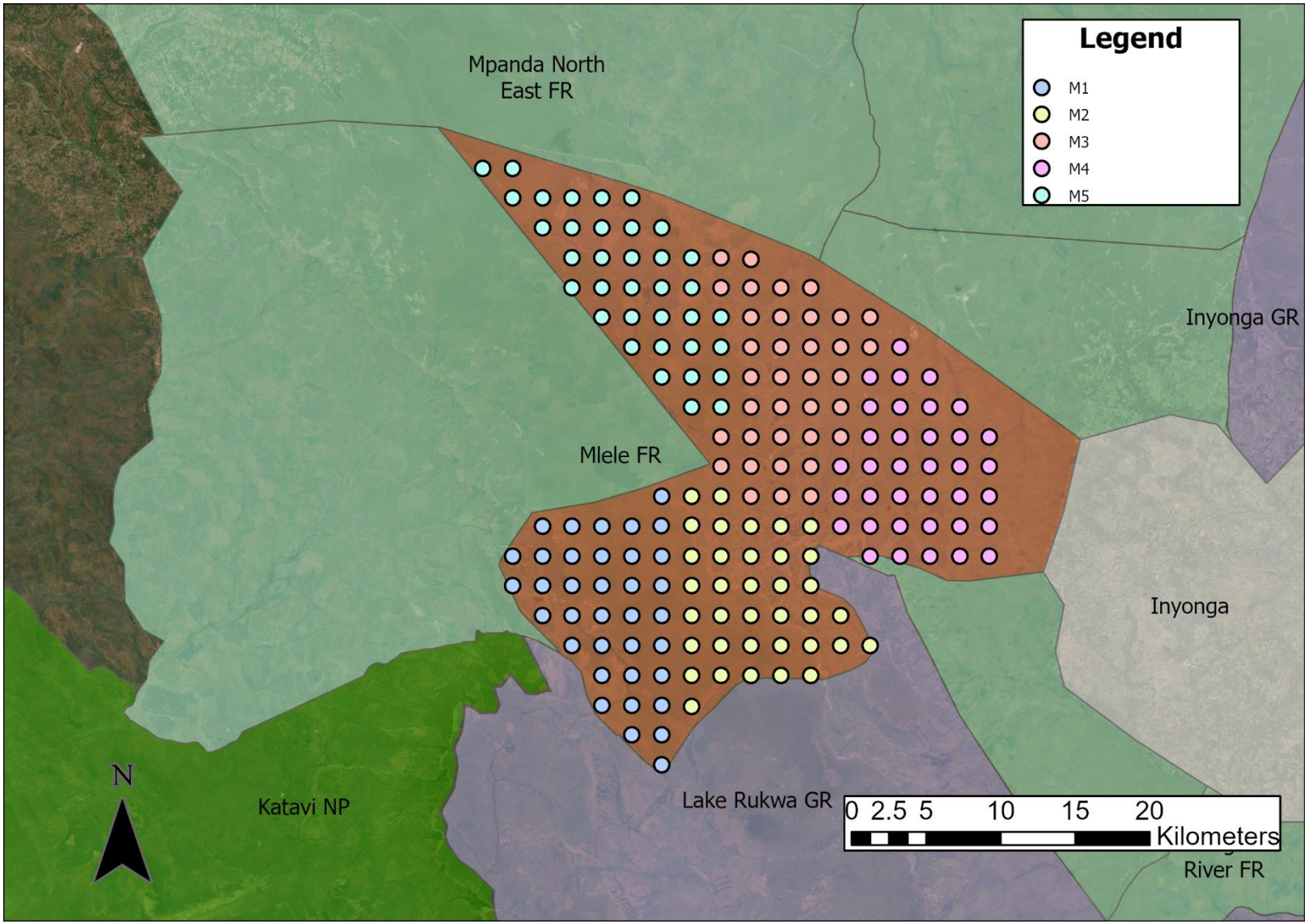
Location	Habitat	ID	Start	End	CT days	Total pics.	Wild dog
Mlele FR	Open woodland	2	03/09/2021 10:12:14	20/09/2021 12:56:20	17.1	114	0
Mlele FR	Miombo	5	03/09/2021 09:46:34	20/09/2021 12:39:18	17.1	237	0
Mlele FR	Mbuga	8	03/09/2021 08:36:51	20/09/2021 11:48:45	17.1	378	0
Mlele FR	Open woodland	12	03/09/2021 14:28:53	19/09/2021 15:35:42	16.0	357	0
Mlele FR	Unused den	13	03/09/2021 12:37:34	05/09/2021 12:32:02	2.0	2470	0
Mlele FR	Mbuga	15	03/09/2021 17:37:23	19/09/2021 06:52:26	15.6	129	0
Mlele FR	Miombo	16	03/09/2021 14:16:56	19/09/2021 15:23:27	16.0	1014	0
Mlele FR	Miombo	18	03/09/2021 10:21:14	20/09/2021 12:18:10	17.1	59	0
Mlele FR	Open woodland	19	03/09/2021 09:30:19	20/09/2021 12:23:16	17.1	102	0
Mlele FR	Miombo	24	03/09/2021 13:19:22	20/09/2021 14:39:41	17.1	25	0
Mlele FR	Open woodland	25	03/09/2021 19:00:18	20/09/2021 12:47:56	16.7	75	0
Mlele FR	Miombo	27	03/09/2021 14:48:48	19/09/2021 15:49:45	16.0	387	0
Mlele FR	Miombo	31	03/09/2021 16:18:40	19/09/2021 14:14:34	15.9	126	0
Mlele FR	Miombo	34	03/09/2021 14:38:02	19/09/2021 03:10:38	15.5	1119	0
Mlele FR	Miombo	43	03/09/2021 10:51:08	19/09/2021 16:29:27	16.2	213	0
Mlele FR	Miombo	46	03/09/2021 13:03:25	20/09/2021 14:29:40	17.1	73	0
Mlele FR	Miombo	7	04/09/2021 10:22:11	20/09/2021 15:22:45	16.2	2319	0
Mlele FR	Miombo	42	04/09/2021 21:12:22	20/09/2021 13:31:32	15.7	114	0
Mlele FR	Miombo	1	05/09/2021 08:36:37	19/09/2021 04:56:44	13.8	59	0
Mlele FR	Mbuga & waterpoint	10	05/09/2021 07:53:26	20/09/2021 08:53:13	15.0	996	0
Mlele FR	Miombo	11	05/09/2021 13:23:43	20/09/2021 16:06:01	15.1	429	0
Mlele FR	Miombo	20	05/09/2021 13:42:04	20/09/2021 15:56:05	15.1	75	0
Mlele FR	Miombo	22	05/09/2021 09:31:44	20/09/2021 09:30:15	15.0	348	0
Mlele FR	Road next to mbuga	23	05/09/2021 08:29:29	20/09/2021 08:30:18	15.0	513	0
Mlele FR	Miombo	32	05/09/2021 16:02:10	20/09/2021 19:47:47	15.2	186	0
Mlele FR	Burned	19	05/09/2021 09:36:00	-	-	-	0
Mlele FR	Road	1.2	26/09/2021 09:52:32	13/10/2021 11:41:36	17.1	1122	0
Mlele FR	Forest edge	3	26/09/2021 18:53:47	12/10/2021 05:08:02	15.4	2919	0
Mlele FR	Forest edge	5.2	26/09/2021 18:55:07	13/10/2021 17:18:26	16.9	2565	0
Mlele FR	Miombo	5.2	26/09/2021 18:55:07	13/10/2021 17:18:26	16.9	2165	0
Mlele FR	Road & trail crossing	7.2	26/09/2021 13:25:22	01/10/2021 21:19:23	5.3	2916	0
Mlele FR	Road next to water	10.2	26/09/2021 11:58:53	05/10/2021 13:43:05	9.1	1523	0
Mlele FR	Road next to river	12.2	26/09/2021 12:28:04	13/10/2021 09:21:59	16.9	10637	0
Mlele FR	Riverside	14	26/09/2021 08:06:10	13/10/2021 13:02:52	17.2	93	0
Mlele FR	Den (mangoose)	19.2	26/09/2021 14:14:25	13/10/2021 18:59:08	17.2	2757	0
Mlele FR	Road next to mbuga	22.2	26/09/2021 12:48:00	01/10/2021 12:16:53	5.0	1391	0
Mlele FR	Waterpoint	23.2	26/09/2021 14:42:15	13/10/2021 16:45:11	17.1	930	0
Mlele FR	Road	27.2	26/09/2021 07:11:06	12/10/2021 18:05:35	16.5	1536	0
Mlele FR	Road next to mbuga	27.3	26/09/2021 14:17:47	30/09/2021 19:56:08	4.2	1395	0
Mlele FR	Riverside	29	26/09/2021 09:02:31	13/10/2021 13:10:06	17.2	453	0

Mlele FR	Trails crossing	32.2	26/09/2021 23:47:14	13/10/2021 17:52:39	16.8	5619	0
Mlele FR	Waterpoint	46.2	26/09/2021 11:24:38	28/09/2021 14:00:13	2.1	2846	0
Mlele FR	Road next to mbuga	8.2	27/09/2021 13:04:16	16/10/2021 16:51:02	19.2	306	0
Mlele FR	Road	24.2	27/09/2021 12:06:58	29/09/2021 11:41:13	2.0	2881	0
Mlele FR	Den (hyena)	11.2	28/09/2021 08:34:07	04/10/2021 01:57:16	5.7	2805	0
Mlele FR	Road next to water	13.2	28/09/2021 08:15:05	16/10/2021 08:52:17	18.0	2601	3
Mlele FR	Waterpoint	15.2	28/09/2021 10:53:32	10/10/2021 13:43:52	12.1	2172	0
Mlele FR	Dry river	43.2	28/09/2021 11:31:49	16/10/2021 13:14:12	18.1	207	0
Mlele FR	Road	1.3	13/10/2021 11:51:36	06/11/2021 16:02:45	24.2	282	0
Mlele FR	Road	16.2	13/10/2021 10:11:13	18/10/2021 09:25:38	5.0	981	0
Mlele FR	Miombo	17	14/10/2021 10:51:40	17/11/2021 09:32:41	33.9	1041	0
Mlele FR	Road next to water	13.3	16/10/2021 10:28:28	31/10/2021 14:12:14	15.2	936	0
Mlele FR	Waterpoint	15.3	16/10/2021 12:45:22	13/11/2021 13:19:12	28.0	3777	2
Mlele FR	Road	24.3	16/10/2021 16:57:31	13/11/2021 13:52:16	27.9	1083	0
Mlele FR	Waterpoint	23.3	17/10/2021 09:21:23	05/11/2021 18:53:06	19.4	930	0
Mlele FR	Waterpoint	43.3	17/10/2021 09:36:16	13/11/2021 17:32:45	27.3	207	0
Mlele FR	Road	16.3	18/10/2021 11:57:26	06/11/2021 15:50:52	19.2	3717	0
Mlele FR	Road next to mbuga	25.2	18/10/2021 17:27:56	06/11/2021 13:38:33	18.8	942	0
Mlele FR	Road & trail crossing	7.3	19/10/2021 13:26:12	26/10/2021 22:20:01	7.4	2850	0
Mlele FR	Road next to mbuga	27.4	19/10/2021 13:43:41	06/11/2021 12:13:24	17.9	11736	0
Mlele FR	Waterpoint	29.2	20/10/2021 07:52:13	13/11/2021 08:21:57	24.0	150	0
Mlele FR	Road next to water	13.4	31/10/2021 14:12:54	13/11/2021 13:33:55	13.0	1324	0
Mlele FR	Road next to water	10.3	06/11/2021 15:44:57	13/11/2021 17:27:39	7.1	360	0
Mlele FR	Road next to mbuga	22.3	06/11/2021 16:56:45	13/11/2021 17:04:05	7.0	183	0
Mlele FR	Waterpoint	46.3	06/11/2021 15:19:12	13/11/2021 17:03:01	7.1	354	0
Mlele FR	Stolen	1.4	-	-	-	-	
Mlele FR	Stolen	16	-	-	-	-	
Mlele FR	Defective sd	3	-	-	-	-	
TOTAL					**967.1**	**94255**	**5**

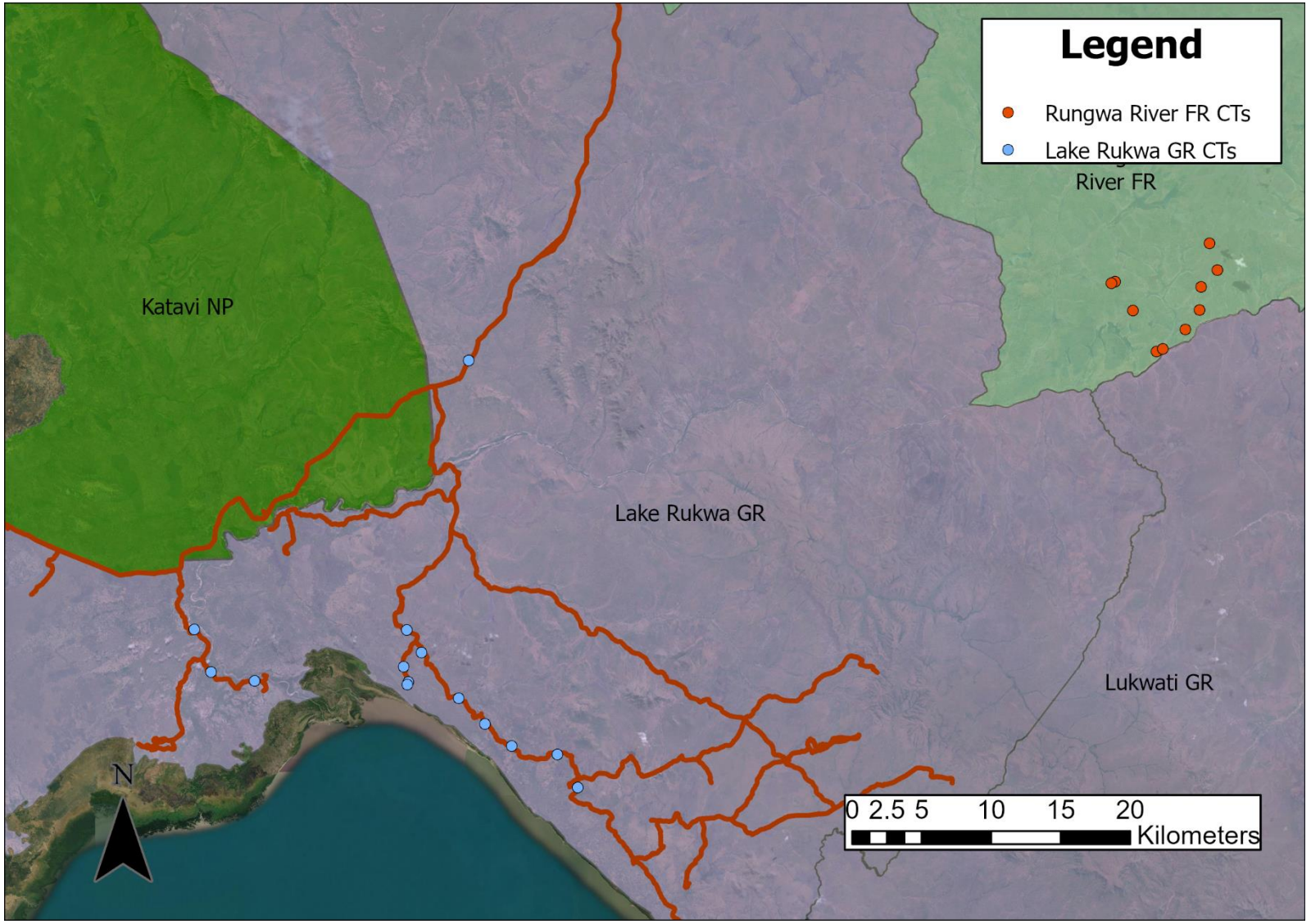
Appendix VI: Camera trapping details in Rungwa River FR and Lake Rukwa GR

Location	Habitat	ID	Start	End	CT days	Total pics.	Wild dogs
Rungwa River FR	Miombo	14	09/09/2021 09:06:22	14/09/2021 06:17:16	4.9	2845	0
Rungwa River FR	Miombo	30	09/09/2021 09:28:42	24/09/2021 17:38:25	15.3	243	0
Rungwa River FR	Miombo	29	09/09/2021 09:49:00	24/09/2021 17:22:36	15.3	43	0
Rungwa River FR	Miombo	27	09/09/2021 10:15:21	24/09/2021 17:00:06	15.3	1719	0
Rungwa River FR	Miombo	17	09/09/2021 10:40:04	24/09/2021 16:45:44	15.3	225	0
Rungwa River FR	Miombo	35	09/09/2021 10:59:00	24/09/2021 16:21:40	15.2	160	0
Rungwa River FR	Miombo	26	09/09/2021 12:33:37	24/09/2021 14:43:04	15.1	1609	0
Rungwa River FR	Miombo	33	09/09/2021 12:51:00	24/09/2021 14:34:18	15.1	19	0
Rungwa River FR	Miombo	10	09/09/2021 13:07:29	24/09/2021 14:19:42	15.1	382	0
Rungwa River FR	Miombo	6	09/09/2021 13:23:18	24/09/2021 14:11:47	15.0	39	0
TOTAL					**141.5**	**7284**	**0**
Lake Rukwa GR	Track next to river	2	08/10/2021 16:05:16	11/10/2021 18:25:16	3.1	2887	0
Lake Rukwa GR	Track	10	08/11/2021 20:25:04	11/11/2021 18:10:37	2.9	42	0
Lake Rukwa GR	Track	12	08/11/2021 17:02:57	11/11/2021 17:30:47	3.0	147	0
Lake Rukwa GR	Track	31	07/10/2021 16:52:04	23/10/2021 16:45:02	16.0	534	0
Lake Rukwa GR	Track	31.2	24/10/2021 11:35:05	27/10/2021 12:19:01	3.0	66	0
Lake Rukwa GR	Track	31.3	08/11/2021 17:44:13	11/11/2021 17:56:36	3.0	1455	0
Lake Rukwa GR	Track	33	27/10/2021 18:04:11	31/10/2021 07:08:19	3.5	153	0
Lake Rukwa GR	Track	34	07/10/2021 18:41:48	09/10/2021 11:18:20	1.7	11316	0
Lake Rukwa GR	Track	34.2	08/11/2021 18:55:04	11/11/2021 18:26:12	3.0	164	0
Lake Rukwa GR	Track	42	07/10/2021 18:57:16	23/10/2021 16:29:52	15.9	1980	0
Lake Rukwa GR	Track	42.2	24/10/2021 11:51:09	11/11/2021 10:15:18	17.9	375	0
TOTAL					**73.1**	**19119**	**0**

Appendix VII: Systematic camera trap grids in Mlele beekeeping zone



Appendix VIII: Camera trap locations in Rungwa River FR and Lake Rukwa GR



Appendix IX: Examples of different types of vegetation

Figure 46: Example of open vegetation.

Figure 47: Example of closed vegetation.

Figure 48: Example of open vegetation.

Figure 49: Example of closed vegetation.

Figure 50: Example of open vegetation.

Figure 51: Example of closed vegetation.

Figure 52: Example of open vegetation.

Figure 53: Example of closed vegetation.

Appendix X: RSF methodology

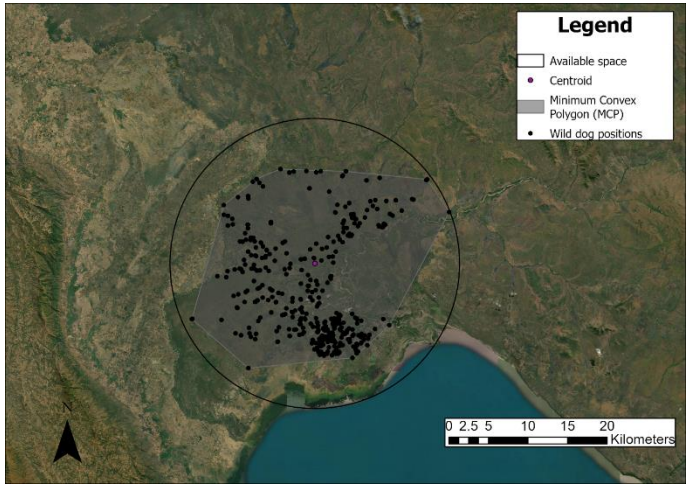


Figure 54: “Available” space with the MCP centroid.

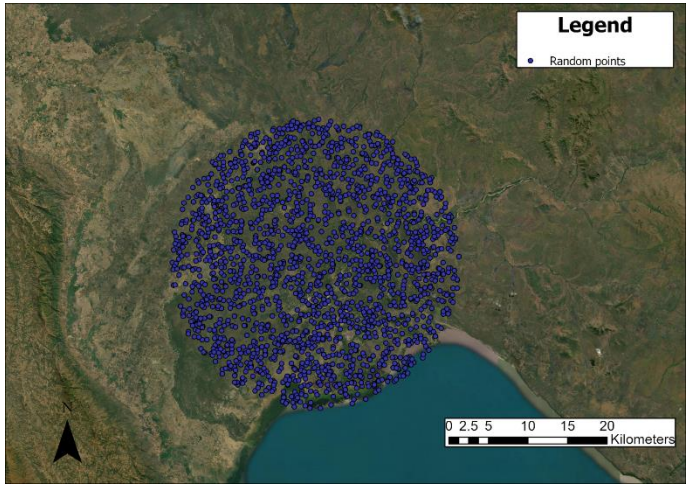


Figure 55: 2'000 randomly generated locations.

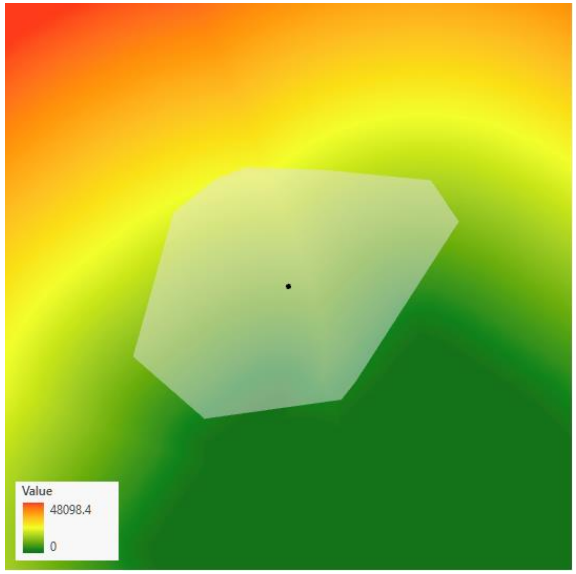


Figure 56: Distance to the lake (m).

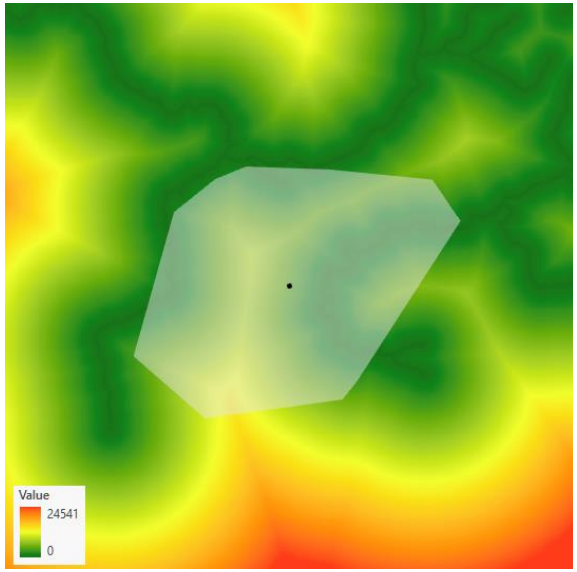


Figure 57: Distance to the rivers (m).

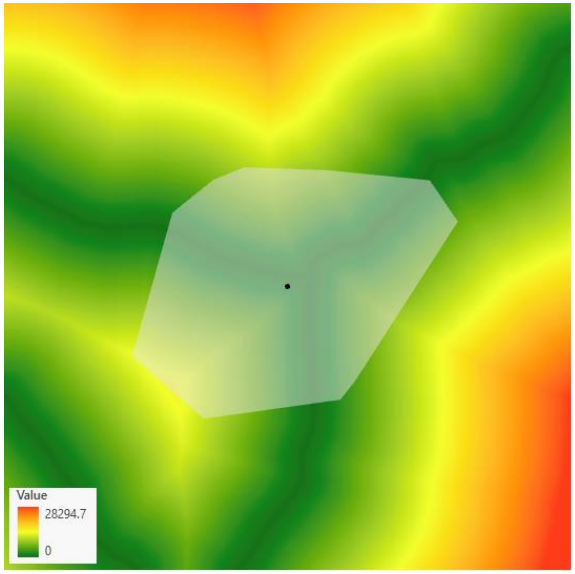


Figure 58: Distance to the roads (m).

Appendix XI: Wild dog database (2021 encounters)

Bahati pack at Mlele BKZ, 05.09.2021 – 6 individuals recognized.

Figure 59: **Nyota** (X), front and tail.

Figure 60: **Nyota** (X), left flank and tail.

Figure 61: **Oro** (M), right flank.

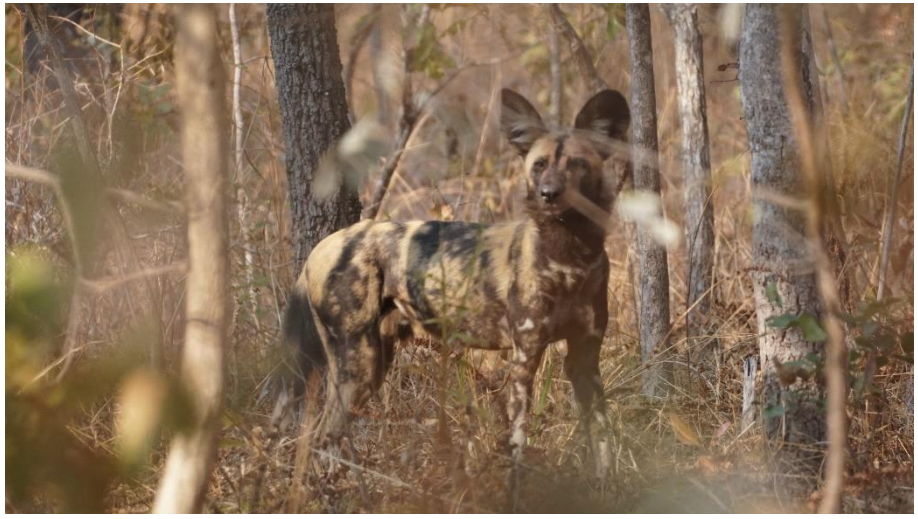


Figure 62: **Oro** (M), right flank and front.

Figure 63: **Baha-1** (X), right flank.

Figure 64:**Llama** (X), front and right flank.

Figure 65: **Llama** (X), front.

Figure 66: **Llama** (X), left flank.

Figure 67: **Baha-2** (X), left flank.

Figure 68: **Panya** (X), left flank.

Maji pack at Mlele BKZ 28.09.2021 and 21.10.2021 – 4 individuals recognized.

Figure 69: **Maji-1** (X), right flank.

Figure 70: **Smile** (X) and **Maha** (X), right flanks.

Figure 71: **Mduara** (M), back and tail.

Figure 72: **Mduara** (M), left flank.

Tanga pack at Lake Rukwa GR (north), 28.09.2021 – 2 individuals recognized. (Credits to Alan Vincent)

Figure 73: **Tanga-1** (X), right flank.

Figure 74: **Tanga-2** (X), left flank.

Tanga pack (unsure) at Lake Rukwa GR (north), 04.10.2021 – 5 individuals recognized. (Credits to Alan Vincent)

Figure 75: **Tanga-3** (X), right flank.

Figure 76: **Tanga-4** (M), left flank.

Figure 77: **Tanga-5** (X), right flank.

Figure 78: **Tanga-6** (X), front and right flank.

Figure 79: **Tanga-7** (X), right flank.

Rafiki pack at Lake Rukwa GR (lake), 22.10.2021

Figure 80: **Rafiki-1** (X), right flank.

Figure 81: **Rafiki-2** (M), right flank.

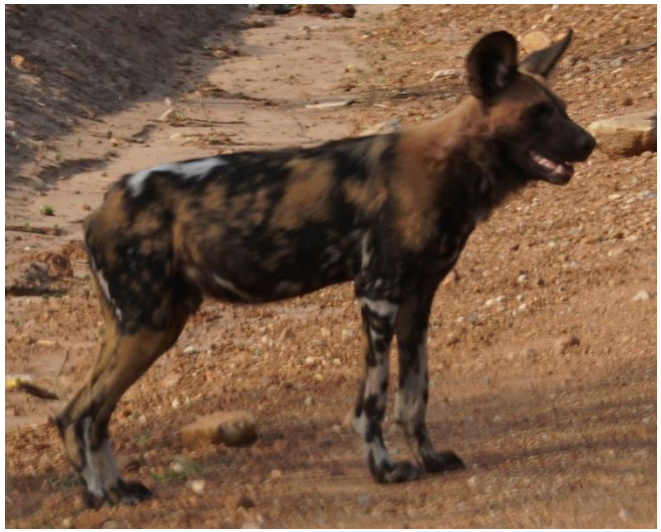


Figure 82: **Rafiki-3** (M), right flank.

Figure 83: **Rafiki-4** (M), right flank.

Figure 84: **Rafi** (F), left flank and tail.

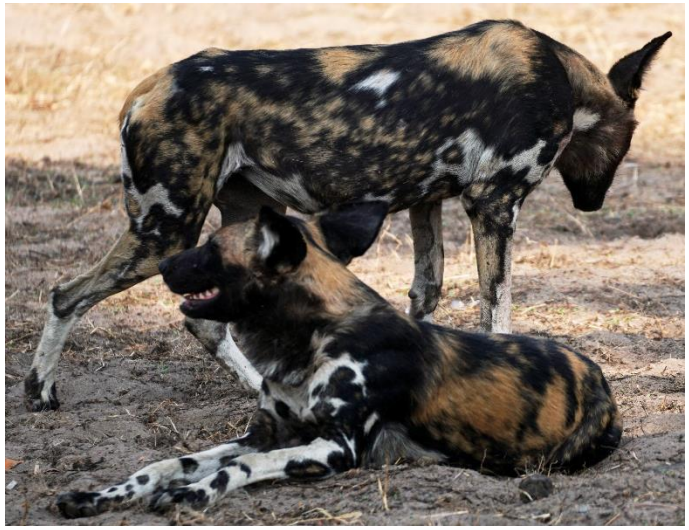


Figure 85: **Rafi** (F), right flank with sister.

Figure 86: **Mpira** (M), left flank and tail.

Figure 87: Unidentified, left flank.

Appendix XII: Semi-structured interview

1. Personal Information

ID	Date	Village	Age	Sex	Function	Ethnic group	Years in area

2. Income

2.1 What are your sources of income?

	Type of Income	Yes	No	Notes (kind of livestock & crop)
1	Livestock (cattle, goats, sheep, other)			
2	Agriculture (crops, vegetables, grain)			
3	Hunting (trophy, bushmeat)			
4	Tourism			
5	Beekeeping			
6	Other (Specify)			

2.2 (If 2.1.1 yes) How do you keep the animals at night?

_____

2.3 (If 2.1.1 yes) Do you use dogs to keep your cattle?

_____

2.4 (If 2.1.1 yes) How many cattle did you have when you arrived here and what happened to them since?

	2.4.1 No. at start	2.4.2 No. sold	2.4.3 No. slaught-ered	2.4.4 No. given away	2.4.5 No. stolen	2.4.6 No. killed by predators (specify spp)	2.4.7 No. dead by disease	2.4.8 Other losses (specify)
Cattle								
Small stock								

3 Knowledge and behaviour towards wildlife

3.1 Please tell me of all the wild animals that live in the area around this household (within 1 day's walk) that you can think of:

1. _____ 7. _____
2. _____ 8. _____
3. _____ 9. _____
4. _____ 10. _____
5. _____ 11. _____
6. _____ 12. _____

3.2 What do you think about wild animals living in the area around this household (within 1 day's walk)?

_____
_____
_____

3.3 Can you sort these pictures into animals that are a big problem, small problem or no problem around this household, and explain why? (show picture cards):

	Animal	Identification		Do not know animal	Does not occur here	Problem			Why is it a problem?
		Right (Y/N)	Conf-used			Big	Small	None	
1	African wild dog								
2	Buffalo								
3	Cheetah								
4	Crocodile								
5	Elephant								
6	Giraffe								
7	Great kudu								
8	Hippo								
9	Impala								
10	Jackal								
11	Leopard								
12	Lion								
13	Serval								
14	Snake								
15	Hyena								
16	Tiger								
17	Warthog								
18	Zebra								

3.4 **Which animal causes the biggest problems in the area around this household (within 1 day's walk)? Why?**

_____

_____
_____

3.5 **Have you had any experiences with the Forest Reserve or with people related to it?**

_____
_____
_____

3.6 What do you think has happened to the numbers of the following animals in this area, since you came to this household?

	Animal	Increased (1)	Reduced (2)	Identical (3)	Do not know (4)
3.6.1	African wild dog				
3.6.2	Leopard				
3.6.3	Lion				
3.6.4	Spotted hyaena				

3.7 What would you like to see happen to the numbers of the following animals in this area, and why?

	Animal	Increase (1)	Reduce (2)	Don't care (3)	Why?
3.7.1	African wild dog				
3.7.2	Leopard				
3.7.3	Lion				
3.7.4	Spotted hyaena				

4. Personal experiences with wildlife (sightings, attacks)

4.1 Have you ever suffered any attacks or damages by wild animals?
[ ] Yes. [ ] No

4.2 If 4.1 yes:

When was the last attack on your livestock by _____?	African wild dog (1)	Leopard (2)	Lion (3)	Spotted hyaena (4)
4.2.1 When (year/month if possible)				
4.2.2 Time of day of attack				
4.2.3 Location of attack				
4.2.4 Livestock type attacked				
4.2.5 No livestock killed in attack				
4.2.6 No. injured but not killed				
4.2.7 Who was with the livestock?				
4.2.8 Was there a dog with the stock at the time of the attack?				
4.2.9 Did anyone see the attack? (If not, find out how it was identified as a predator attack)				
4.2.10 What happened to the predator				

4.3 Last sightings

When was the last time you saw ____ around this household?	African wild dog (1)	Leopard (2)	Lion (3)	Spotted hyaena (4)
4.3.1 Was it the same as attack above?				
If not……				
4.3.2 When (year/month if possible)				
4.3.3 Time of day				
4.3.4 Location of sighting				
4.3.5 How many				
4.3.6 What were they doing				

4.4

Has anyone in this boma been attacked by ___?	African wild dog (1)	Leopard (2)	Lion (3)	Spotted hyaena (4)
4.4.1 Age when attacked (years)				
4.4.2 Location of attack				
4.4.3 When (year/month if possible)				
4.4.5 What was the person doing?				
4.4.6 Was the person injured or killed?				
4.4.7 What happened to the predator				

4.5 Do you feel that the surrounding wildlife represents a danger to you?

_____
_____

4.6 How many cows would you be willing to exchange in order to never have any kind of problems with carnivores again?

_____
_____

5. Actions

5.1

	Yes/No	If yes, how? Poison (1), traps (2)?	If no, why not?
5.1.1 Do people in the area around this boma use poisons or traps to control the numbers of predators here?			
	Yes/No	If yes, what kinds, how many, and when?	
5.1.2 Have you ever killed a predator?			

5.2 What do you think are the most effective ways of protecting yourself, livestock, or crops from wild animals?

_____
_____

5.3 Do you use these methods? If not, why not?

_____
_____

6. Benefits from wildlife

6.1 Do you benefit in any way from the presence of large carnivores?
[0] no benefits [1] small benefits [2] big benefits [3] very big benefits [4] not sure
If yes, how?
_____
_____

6.2 Have you ever received compensations for wildlife damage? If yes, what kind?
_____
_____

6.3 Have you heard of projects that incentivize (give a reason, push) people to protect wildlife?
_____
_____

7. Statements

7.1 Please rank your agreement with the following statements (strongly disagree, disagree, neutral, agree, strongly agree)

7.2 I feel lions have the same rights as livestock to live on this land
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

7.3 I would be happier if there were no lions
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

7.4 It is important to me that my grandchildren see lions
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

7.5 If lions are a problem, it is acceptable to use poison on them
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

7.6 If my cow was killed by a lion I would kill the lion
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

7.7 People in my village would be angry if I killed a lion
Strongly disagree (1) – Disagree (2) – Neutral (3) – Agree (4) – Strongly agree (5)

THANKS + END - Thank you very much for your time and your answers, if you have any questions for us we would be glad to answer to your questions, have a nice day. Would you like some tea and sugar?